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Achieving the Sustainable Development Goals Through Sustainable Food Systems

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ISBN 978-3-030-23968-8 ISBN 978-3-030-23969-5 (eBook)
https://doi.org/10.1007/978-3-030-23969-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

To present and future generations.
Everyone can contribute to build a more sustainable world.

Foreword

The food system stands today at crossroads.

It is an integral component of the biological, social, economic, cultural, and environmental systems in which we live and operate but is currently faced with major challenges that include climate change, depletion of water, soil degradation, biodiversity loss, deforestation, ecosystem stress, as well as nutrition challenges in terms of hunger, micronutrient deficiencies, and obesity.

The environmental crisis is destabilizing the food systems, while agriculture, in turn, contributes to environmental degradation. This is a vicious circle that needs to be broken in order to implement *sustainable development* by ending poverty and achieving economic prosperity, social justice, and environmental sustainability.

The 2030 Agenda for Sustainable Development adopted at the United Nations Sustainable Development Summit on 25 September 2015 critically depends on the transformation of agriculture and the food system. We need a food system that produces healthy foods for all, that protects rather than degrades the planet, and that is resilient to the environmental stresses, especially climate-related stresses that lie ahead. Sustainable agri-food systems are critical to achieving all dimensions of sustainable development.

Real solutions and good practices exist at all governance levels—local, national, and international—as well as across the many stakeholders of the agri-food system, including local smallholder farm communities, major food traders, and world's large food and agricultural companies responsible for a remarkable share of the global trade and preparation of foods for commercial sale. We need an agri-food system that is sustainable across the supply chains from the upstream producers to the downstream consumers of food, that is, all of humanity!

This is at the core of the United Nations Sustainable Development Solutions Network and the Barilla Center for Food & Nutrition Foundation collaboration to champion the development of a *roadmap* that prompts the world leaders and food businesses to chart a decisive course to the implementation of the 2030 Agenda for Sustainable Development.

Against this context, this book is a compelling journey across the multifaceted agri-food system challenges, opportunities, and risks that present generations need to address and tackle in order to build a future of well-being, peace, and prosperity for all people in the world.

The analyses offered here are primarily directed toward researchers, technical practitioners, and business operators in the food, agriculture, and nutrition areas. They also target public institutions and decision-makers who are responsible for integrating the goals and the targets of the 2030 Agenda for Sustainable Development into national planning, policies, and programs. The studies provide up-to-date, cutting-edge, and comprehensive syntheses of the many challenges facing all aspects of the global agri-food system. We are deeply grateful to the authors and editors for such stellar and in-depth contributions.

Above all, this book is a call for greater multi-stakeholder commitment, collaboration, and partnerships, between public and private entities, on one of the great challenges of our time. This global cooperation, based on rigorous science and shared moral values, will be vital to achieving the 2030 Agenda, the 17 Sustainable Development Goals, and the Paris Climate Agreement and thereby creating "the future we want."

United Nations Sustainable Development Solutions Network and Columbia University, New York — Jeffrey Sachs
Sustainable Development Solutions Network Mediterranean University of Siena, Siena, Italy — Angelo Riccaboni

Preface

The food system is becoming a central nexus with our future, encompassing a broad range of societal challenges, from food security, nutrition, and social and economic inequalities to climate change, biodiversity, and land and ocean ecosystem services. In order to guarantee the future of human kind, food systems have to meet the needs of a growing and increasingly urbanized population while avoiding harm on the environment. At present, food production is falling short of meeting nutritional requirements and guaranteeing long-term health for almost one third of people worldwide. Agriculture and food production account for a very substantial share of climate-altering emissions and are intensely consuming water and land.

The 17 SDGs of the 2030 Agenda for Sustainable Development (SDGs) adopted by the world leaders in September 2015 at the UN Sustainable Development Summit have food at their very core. This is a first major argument made in this book aimed to reach researchers, policy-makers, businessmen, and practitioners in all sectors crosscut by food. The SDGs provide a framework to mobilize efforts toward sustainable development, reducing poverty and inequalities, fostering economic growth, and at the same time addressing climate change issues and environmental conservation. This implies urgent and far-reaching changes in the way we produce and consume food.

The COP21, held in Paris in 2015, became the first conference to establish a concrete, long-term plan to reduce greenhouse gas emissions and to involve not only the most advanced countries but also the developing countries. For the first time in 20 years of negotiations in the United Nations, a legally binding, universal agreement on the climate was signed, with the ambitious goal of keeping global warming below 2°C and, in longer term, below 1.5°. The IPCC report released in October 2018 clearly showed that we need to stay well below 1.5°C for dramatic impacts on ecosystems, health, and economic growth associated with this rise in temperature to be avoided.

The SDGs and the Paris Agreement call for responsibility by all the actors in the food system, from farm to fork. The construction of sustainable food systems requires the prompt engagement of all stakeholders: from the citizens, called upon to choose a healthy and sustainable diet, to the farmers, who can combine ancient traditions and technological innovation to reduce the impact of agriculture; from the private sector, to invest in the development of a truly sustainable food offers, to scientists, called to fill in data gaps, to institutions and policy-makers, who can place the protection of natural resources and environment at the top of their agenda, also through incentives. Public-private partnerships become capitalize on the relative strengths and address the sustainability issue, which can be achieved through cooperation.

We can see a number of initiatives and project that have the potential to put forward the transformation of food systems. For example, a growing number of national food-based dietary guidelines are advocating environmentally friendly diets. The Netherlands recommends limiting the servings of meat to twice per week, the United States includes a vegetarian diet as one of their three recommended dietary patterns, while China advocates cutting meat consumption by 50%. Canada has released the most updated food guide in 2019, underlining that food choices can have an impact on the environment and recommending choosing protein foods that come from plants more often. Cities are taking the lead in catalyzing climate action, as the experience of the Milan Urban Food Policy Pact, gathering 199 cities over the world to mobilize change in urban food systems.

The engagement of individuals is fundamental to achieve this kind of change. This happens only if the individual citizen internalizes what a sustainable food system can look like. Education thus is fundamental in building "sustainability literacy" defined as the knowledge, skills, and mind-sets that allow individuals to become deeply committed in building a sustainable future and assisting in making informed and effective decisions to this end. This education has to put forward a new mind-set, from linear to circular.

The book makes the effort of compassing the immensity of challenges and changes that the global food system of the twenty-first century will have to undergo, going from the involvement of youth to the role of artificial intelligence and from climate change mitigation and agroecology to the role of advocacy and activism, investments, and migration policies. We do not have the pretension of exhaustiveness, but we can argue that there is enough data today to compel us to take action.

The book is divided in two parts: the first summarizes the key issues regarding food systems; the second identifies a new collaborative approach for solutions that can re-establish the balance between human health and the planet. Sustainability, especially when it concerns food, is trans-disciplinary. It intersects disciplines such as ecology, geography, nutrition, medicine, economics, philosophy, and behavioral sciences, and this book is the result of the different perspectives over the issues faced by the food system in the hope to inspire new visions to progress in a sustainable development pathway.

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Acknowledgments

This book has been possible with the support and encouragement of special people we would like to thank: Anna Ruggerini and the Barilla Center for Food & Nutrition for strongly believing in the project, Professor Stefano Zamagni for the valuable inputs during the review process, Dr. Pin-Jane Nora Chen for the priceless patience and professionality to assemble this volume, and Logos for their assistance.

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Part I
Current Issues

Understanding the Global Food System

Francesca Allievi, Marta Antonelli, Katarzyna Dembska, and Ludovica Principato

1 Introduction

Current food systems are in need of profound changes as they still fail to provide basic food requirements for a large share the world's population while being responsible for an unsustainable burden on the environment. The world population is expected to reach ten billion by 2050, with a projected increase in food demand by 50% compared to 2013, also driven by the dietary transition that especially low- and middle-income countries are experiencing (FAO 2017). Unless we radically transform food systems, additional food demands will drive, in the future, an

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_1

increase in GHG (Greenhouse Gas) emissions, land and water use, as well as trigger conflicts, social unrest and migrations (FAO 2017).

The number of hungry people, for the second year in a row, has continued to increase up to over 820 million (FAO 2018a, b, c), while two billion people are overweight or obese (World Health Organization (WHO) 2018b). Nearly one third of food production is lost or wasted, respectively before reaching the market or at the end-user level (Gustavsson et al. 2011). The food sector also operates—and depends on—a natural environment profoundly under stress and faces increasing competition for natural resources between different sectors. Crop production is the largest freshwater user (about 70% of withdrawal on a global average), accounts for about 12% of the globe's land surface (arable land and land under permanent crops), and is responsible for land degradation, biodiversity loss and pollution of terrestrial and aquatic ecosystems (FAO AQUASTAT 2019; Alexandratos and Bruisma 2012). Climate change is both impacted by food systems and has an impact on food systems. A large share of GHG emissions, ranging from 18% and 51%, has been linked to food supply chains (Steinfeld 2006; Goodland and Anhang 2009). At the same time, climate change may decrease food availability by jeopardizing crop and livestock production, fish stocks and fisheries, while increasing food price volatility (FAO 2017, 2018a). These changes will affect disproportionately developing countries and the poorest populations.

Acting as a multiplier of the already existing competition over land and water resources, biodiversity loss and ecosystem degradation, food crises and malnutrition, population displacement and migrations, conflicts and social unrest, climate change is considered "the defining issue of our time".[1] Since 2011, climate-related risks such as water crises, flooding, biodiversity loss, greenhouse gas emissions, are placed among the top 5 global risks both in terms of likelihood and impact by the World Economic Forum (2019). The Intergovernmental Panel on Climate Change (IPCC 2018) has emphasized that climate change will impact *all* aspects of food security and that "rapid, fair-reaching and unprecedented changes in all aspects of society" are necessary to keep global warming below 1.5 °C, relative to pre-industrial levels. The Paris Agreement, although not mentioning explicitly agriculture, has the potential to unlock opportunities for transforming food and farming systems, to safeguard food security, address vulnerabilities of food supply chains, guarantee human rights and the health of ecosystems and biodiversity.

Sustainable food systems are at the core of the 2030 Agenda for Sustainable Development defined by the United Nations and signed by 193 countries in September 2015, to build peace, prosperity and inclusiveness in the world, and enable "socially inclusive and environmentally sustainable economic growth" (Sachs 2015, p. 3). While the Sustainable Development Goal (SDG) 2 pledges to eradicate hunger and malnutrition, food and food systems are directly or indirectly

[1] United Nations Secretary-General. Remarks at High-level Event on Climate Change, 26 September 2018. Retrieved on December 18, 2018: https://www.un.org/sg/en/content/sg/speeches/2018-09-26/remarks-high-level-event-climate-change.

connected to all 17 SDGs (FAO 2018b), as key enabling factors or as main targets to be achieved.

Against this context, the present chapter outlines the main challenges that the global food system currently faces in terms of nutrition challenges (Sect. 2), environmental challenges (Sect. 3), food loss and waste (Sect. 4). Each of these dimensions will be put into relation with the relevant SDGs. Finally, the chapter provides a few recommendations on how to bring about a transformational change towards sustainable and healthy food systems with the contribution and cooperation of all stakeholders—from policy-makers, to business, citizens and civil society organizations.

2 Nutrition Challenges

Food systems today are posed with the unprecedented challenge of feeding an increasingly growing and urbanized population and are currently falling short in meeting nutritional requirements and guaranteeing long term health for almost half of people worldwide (Global Nutrition Report 2017).

At the beginning of the nineteenth century, the total world population crossed the threshold of one billion for the first time in the history of the *homo sapiens sapiens*. Since then, growth rates have been increasing exponentially, reaching remarkably high peaks in the twentieth century, when the total world population reached seven billion just after 2010 (Van Bavel 2013) and is expected to count ten billion by 2050 (FAO 2017). This growth goes hand in hand with global urbanization: in 1950, 30% of the world's population was urban, and by 2050, 66% of the world's population is projected to be urban (UN 2014). It is widely upheld that urbanization affects nutrition patterns, as changing environment and preferences is a driver of a change in diet. City dwellers generally consume more animal-source foods, sugar, fats and oils, refined grains, and processed foods, with urban food systems currently accelerating the nutrition transition. On the one hand, urban environments facilitate access to unhealthy diets (i.e. greater availability of fats and sugars), on the other they can improve access to nutritious foods for the wealthier segments of population (Hawkes et al. 2017). For this reason, national policies addressing food environments are particularly relevant to municipalities.

Despite the significant gains in improving the global nutritional status, still there is almost no country immune from a significant nutrition challenge, with many countries facing a double, if not triple burden of malnutrition, where undernutrition coexists with overweight and obesity within the same country, the same community and even the same household (WHO 2016).

In 2017, the number of undernourished people rose to 821 million people, up from 804 million in 2016, with Instability in conflict-ridden regions, adverse climate events and economic slowdowns explaining this deteriorating situation (FAO 2018a, b, c). Globally in 2017, 151 million children under the age of 5 were stunted, i.e. too short for their age, and 51 million children under the age of 5 were wasted, i.e. too light for their height. Stunting is the result of chronic malnutrition and affects mainly children living in Asia-Pacific and Africa regions (WHO 2018a). At the same time, two billion people lack key micronutrients (Global Nutrition Report 2017) with iron, iodine, folate, vitamin A, and zinc deficiencies being the most widespread micronutrient deficiencies (MNDs) (Bailey et al. 2015). Low- and middle-income countries have the highest burden of MNDs as the main cause of undernutrition is poverty. However, underestimated MNDs, so-called "hidden hunger", pose health risks in developed economy settings as well. In this alarming scenario, some countries, such as Brazil, are taking action. Stunting prevalence among children younger than 5 years in the country decreased from 37% in 1974–1975 to 7% in 2006–2007 thanks to rapid advances in economic development and healthcare, and interventions outside the health sector, including a conditional cash transfer program and improvements in water and sanitation (Keefe 2016; Victora et al. 2011).

Meanwhile, worldwide obesity has nearly tripled since 1975. In 2016, almost two billion adults are overweight, and 650 millions of these were obese. On a global level, this translates into 39% of adults aged 18 years and over being overweight in 2016, and 13% obese (WHO 2018a). In parallel, the world has seen a more than tenfold increase in the number of obese children and adolescents aged 5–19 years in the past four decades, rising from just 11 million in 1975 to 124 million in 2016. An additional 213 million were overweight in 2016 but fell below the threshold for obesity. Taken together this means that in 2016 almost 340 million children and adolescents aged 5–19 years, that is almost one in every five (18.4%) were overweight or obese globally (Global Nutrition Report 2017). The data confirms the alarming prevalence of overweight and obesity, both among adults and children, in a number of countries. In Saudi Arabia, for example, 69.7% of adults have a BMI over 25. A similar trend applies to Jordan (69.6% of overweight and obese adults), the United States and Lebanon (67.9%) (WHO 2016).

Overweight and obesity cannot be considered as a mere result from the subtraction "ingested foods - caloric expenditure" but are rather very complex conditions. Certainly, individual choices such as poor diets, physical inactivity and sedentary behavior play their part, but interact with multiple social, economic and environmental factors. Scientific evidence brings out the significant role of the "obesogenic environment", defined as 'the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations' (Swinburn and Egger 2002). According to the Global Nutrition Report published in 2017, "No country has been able to stop the rise in obesity", and countries with burgeoning prevalence should start early to avoid some of the mistakes of high-income neighbors.

Furthermore, the double burden of malnutrition is a growing global challenge and is characterized by the coexistence of undernutrition along with overweight, obesity or diet-related NCDs, on different levels: individual, household and population, and across the life-course (WHO 2016). The simultaneous increases in obesity in almost all countries seem to be driven mainly by changes in the global food system, which is producing more processed, affordable, and effectively marketed food than ever before (Swinburn et al. 2011). The double burden of malnutrition is strictly related to the nutrition transition, the shift in dietary patterns, consumption and energy expenditure associated with economic development over time, often in the context of globalization and urbanization (WHO 2016).

The past decades have seen a decline in adherence to the so-called ‘healthy diets’ such as the ‘Mediterranean diet’ (da Silva et al. 2009). The analysis on diet composition developed in the Food Sustainability Index (FSI 2018) draws the attention to the high intake of nutrients associated with the development of health conditions. For example, sugar in diets expressed as percentage over total calories, goes up to 16% in the United States and Malta, 15% in Mexico, Argentina, Slovakia, Jordan and Sudan (FAO 2013a, b). Meat consumption levels, analyzed as the difference in meat supply quantity from recommended intake, are of 228 g/capita/day in Australia, 225 in the United States, 203 in Argentina and 180 in Luxembourg (FAO 2013a, b; McMichael et al. 2007).[2]

For food system researchers, obesity is the result of people responding normally to the obesogenic environments they find themselves in (Lake and Townshed 2006). Supporting individual choices will continue to be important, but it is here argued that the priority should be for policies addressing specific contexts that might lead to the excessive consumption of energy and nutrients. Policymakers and governments are among the first stakeholders responsible for tackling the issues through education and facilitating access to healthier foods, such as the “Let’s Move” campaign in the United States, as well as through measures to discourage consumption of certain foodstuffs, such as the sugar-sweetened beverage (SSB) tax introduced in Mexico in 2013. Although effective in discouraging the consumption of certain foods and moderately leading to improvement in the population’s health, fiscal measures have not come without economic and social downside, which reminds us that none of the interventions can be adopted as a sole solution but must be part of an extensive strategy in public health nutrition. According to a recent review, school-based interventions show promising results to reduce SSB consumption among adolescents (Vézina-Im et al. 2017).

2.1 Nutritional Challenges in the SDGs

A number of SDGs are linked to the global nutritional challenges, besides the SDG number 2 “End hunger”.

- **SDG #1. No poverty**
  Today millions of people are struggling to satisfy their most basic needs. Poverty and other social inequities are associated with poor nutrition in low, middle and high-income countries, also among certain population subgroups within coun-

[2] In the first case, sugar is calculated as the actual consumption, while in the second, meat consumption is based on the market availability to consumers, specific of a food system in a country.

tries. Addressing poverty will improve nutritional outcomes, just as improving nutrition is essential in the fight against poverty (Perez-Escamilla et al. 2018; Global Nutrition report 2017).

- **SDG #2. Zero Hunger**
  "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" underlines the importance of hunger as a barrier to sustainable development and creating a trap from which people cannot easily escape. A world with zero hunger can positively impact our economies, health, education, equality and social development and is a prerequisite to achieving the other sustainable development goals such as education, health and gender equality (UN 2015).
- **SDG #3. Good Health and Well-Being**
  "Ensure healthy lives and promote wellbeing for all at all ages" addresses all major health priorities, including communicable and non-communicable diseases (NCDs) (UN 2015). Overnutrition is among the major risk factors driving the rise NCDs, including heart disease, stroke, cancer and diabetes and chronic lung disease, collectively responsible for almost 70% of all deaths worldwide (WHO 2018c). NCDs not only threaten development but are also a cause and consequence of poverty, and tackling the NCDs needs to squarely address social inequity (UN 2011). However, due to the very large number of targets and indicators in SDG 3 specifically and the SDGs generally, the NCDs agenda is at real risk of becoming invisible and not being addressed (Ordunez and Campbell 2016).
- **SDG #4. Quality Education**
  Education is associated with improved nutritional outcomes. Mothers who have had quality secondary school education are likely to have significantly better nourished children. Also, improved nutrition means better outcomes in education, employment and female empowerment, as well as reduced poverty and inequality (Global Nutrition Report 2017).
- **SDG #5. Gender Equality**
  Guaranteeing equal access to and control over assets raises agricultural output, increases investment in child education and raises household food security. Women's empowerment within the food-system, from food production to food preparation is a fundamental prerequisite for social and economic development of communities, yet efforts in this direction are hampered by malnutrition (Oniang'o and Mukudi 2002).
- **SDG #6. Clean Water and Sanitation**
  Billions of people do not have access to safe drinking water and lack adequate hygiene and sanitation services, living at risk of avoidable infections and disease that negatively impact nutritional status and health. Irrigation, the single most important recipient of freshwater withdrawals with potential to influence nutritional outcomes in several ways, has not been given enough attention. Addressing water variability, scarcity and competing uses is beneficial for food security and nutrition (Ringler et al. 2018)
- **SDG #10. Reduced Inequalities**

Powerful synergies exist between social protection and food security. Effective social assistance programs can alleviate chronic food insecurity, while demand-driven or scalable social insurance and safety net programs can address transitory food insecurity caused by seasonality or vulnerability to livelihood shocks (HLPE 2012).

- **SDG #12. Responsible Consumption and Production**
  "Ensure sustainable consumption and production patterns" implies that meeting the nutritional needs of a rising population requires consumers to choose, and food systems to provide, a nutritious and safe diet, with a lower environmental footprint. SDG 12 offers clear opportunities to reduce the NCDs burden and to create a sustainable and healthy global scenario.
- **SDG #13. Life on Land**
  The declining diversity of agricultural production and food supplies worldwide may have important implications for global diets. Agricultural diversification may contribute to diversified diets through both subsistence- and income-generating pathways and may be an important strategy for improving diets and nutrition outcomes in low- and middle-income countries. Additional research is also needed to understand the potential impacts of agricultural diversification on overweight and obesity (Jones 2017).
- **SDG#14. Life Below Water**
  Healthy water-related ecosystems provide a series of ecosystem services, many of which in turn support nutrition and health outcomes (Ringler et al. 2018)
- **SDG #16. Peace, Justice and Strong Institutions**
  Food security and nutrition can contribute to conflict prevention and mitigation by building and enhancing social cohesion, addressing root causes or drivers of conflict, and by contributing to the legitimacy of, and trust in, governments. Food security can support peace-building efforts and peace-building can reinforce food security (FAO 2016).
- **SDG#17. Partnerships for the Goals**
  The complexity and the relations between all of the SDGs call require a paradigm shift, calling for all stakeholders of the food system to engage and share knowledge in supporting communities and countries in achieving the SDGs.

3 Food and the Environment

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, as well as the outcomes of these activities; namely nutrition and health status, socio-economic growth and equity and environmental sustainability (Mehta et al. 2014). When it comes to agriculture, there exists a paradox concerning the allocation of land and resources for human and animal consumption as well as the production of biofuels: only 55% of the total crop calories produced in the world are eaten by people, as a vast share of the total is used for animal feed (36%) and another 9% goes into biofuels production (Cassidy et al. 2013).

Among all the economic sectors, food production is the one with the highest burden on the environment, with animal products being the most relevant (Steinfeld et al. 2006). The amount of greenhouse gas (GHG) emissions which can be linked directly with the production of food is very large, with the quotas found most often in literature ranging between 18% and 51% (Steinfeld 2006; Goodland and Anhang 2009). Moreover, it should be noted that the GHGs emissions from the agricultural sector are constituted mainly by CH4 (52%) and N2O (44%) (Baumert et al. 2005; van Beek et al. 2011): these gases are far more heat absorptive than CO2, respectively 21 and 310 times more.

Food production also affects global water use: on average, as much as 92% of daily personal water footprint can be linked to food (Hoekstra and Mekonnen 2012). This figure accounts for 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. A number of countries also externalize their water footprints related to food through trade, a phenomenon that has been referred to as virtual water trade (Allan and Allan 2002). In the EU, for instance, the water-stressed Italy and Spain are major exporters of blue water (Antonelli et al. 2017). Another very important environmental impact is the one related to land. This has many forms, from direct pollution of arable areas with, for example fertilizers and antibiotics, or through an excessive discharge of animal waste, to changes in land use after the deforestation of the Amazon rainforest. 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). 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); nearly one-third of global arable land is used for feed production, while of the total share of ice-free Earth's surface, 26% is dedicated to grazing (FAO 2018c). Moreover, only about 0.002% of global GDP is invested to reverse biodiversity loss (Sumaila et al. 2017).

The environmental impacts of food production, coupled with an increasing demand for animal products worldwide, highlight the importance of the adoption of sustainable diets. This is due mainly to two reasons: firstly, population is projected to continue increasing in the future and so will the need for food (Dubois 2011), and secondly, the average income per capita is expected to rise globally, a factor which traditionally has been linked with a shift towards the consumption of foods with higher environmental impacts (such as animal products—Grigg 1995). The combination of these factors highlights how crucial is the issue of transforming food production and consumption to both ensure the preservation of natural ecosystems, while improving nutritional outcomes. The Mediterranean diet, for instance, is explicitly cited by FAO as an exemplary Sustainable Diet (FAO 2010), besides a diet with well-documented healthy benefits (Sofi et al. 2010; Dernini et al. 2017). In this context, a number of models have been developed to provide quality guidance for sustainable diets, including the Double Pyramid, showing the relationship between a healthy diet and one with a lower environmental impact (BCFN 2016; Ruini et al. 2015), as well as the One Planet Food programme by WWF-UK, aiming to reduce the environmental and social impacts of food consumption in the UK.

In assessing the progress towards a more sustainable food system worldwide (and therefore also the achievement of SDGs), it becomes particularly useful to use monitoring systems that can account for the complexity of the food system and look simultaneously into different dimensions. The FSI (2018) highlights that, some countries perform better than others when it comes to reducing the impact on the environment of their agricultural systems. For example, when it comes to the share of agricultural land under organic farming, Austria, Finland and Estonia lead the way, while South Africa, Zambia and Zimbabwe fall on the other end of the scale (FAO 2015a, b). Similarly, the highest levels of average carbon content of soil are found in Finland, Rwanda and Estonia, while UAE, Zimbabwe and Egypt lag behind (FAO 2008). However, when looking at other indicators, such as those related to the age of farmers, the countries which perform best are Senegal, Cameroon and Rwanda, while problems might arise in the future in Japan, Portugal and South Korea, where the farmers' age is much higher (FSI 2018). A more sustainable agricultural system can be achieved with a mix of strategies, harnessing both traditional and new techniques and knowledge. Precision farming, including the use of algorithms to predict which microbes will be most beneficial to the growth of a certain plant, needs to go hand in hand with practices such as cover cropping or agroecology, which improve soil quality and preserve biodiversity. A significant contribution will also come from the cooperation of multiple stakeholders, from NGOs to governments and business. Last, but not least, sustainable food systems need integrated frameworks that align health, nutrition and environmental outcomes (Recanati et al. 2018).

There is a growing consensus regarding how the current food system 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). From all the points raised so far, it becomes evident how food is also a central issue for the achievement of the 17 SDGs (UN 2015). In fact, 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). 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, directly or indirectly, an integral component of all the SDGs (SRC 2016). Moreover, six SDGs state clearly how food is crucial for goals such as ending poverty and hunger; guaranteeing health and wellbeing; responding to climate change and preserving life on land or under water; fostering innovation and education; assuring the inclusion of women and youth and more responsible production and consumption patterns.

3.1 Food and the Environment in the SDGs

A number of SDGs are related to the environment, besides the SDGs number 13 “Climate action”, number 14 “Life below water” and number 15 “Life on Land”. As described below, environmental protection is crucial also for other SDGs.

- **SDG #1. No poverty**
  Most of the world’s poor people get the highest share of their income through agriculture: supporting sustainable small-scale farming and a diversity in agricultural models is a fundamental step towards poverty reduction (OECD 2011).
- **SDG #2. Zero Hunger**
  Ensuring access to nutritious food is a pre-requisite for a reduction in environmental degradation. When faced with desperate hunger, people are led to desperate strategies for survival, making the conservation of natural resources less relevant to them (IFPRI 1995). In turn, supporting education and training for an adequate management of natural resources has benefits for hunger reduction.
- **SDG #3. Good health and well-being**
  A clean environment, without pollution, is essential for well-being and positive effects on health. Specifically, environmental protection and sustainable agricultural production, fosters the achievement of target 3.9 “Reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination”.
- **SDG #5. Gender equity**
  Women represent 43% of the total agricultural labor force worldwide (FAO 2011a), with shares close to 50% in some regions of Asia and in Sub-Saharan Africa. This makes women an essential contribution to agriculture and rural enterprises in the developing world. Promoting policies and supporting programmes that are targeted at increasing women’s knowledge on sustainable agricultural practices would in turn also provide them with the tools to foster a fairer recognition of their role in society.
- **SDG #6. Clean water and sanitation**
  As much as 80% of wastewater from municipalities is discharged untreated into water bodies worldwide (WWAP 2017). Agriculture accounts for 70% of water use globally, making it a major player in water pollution, as farms also discharge agrochemicals, drug residues, sediments etc. into water bodies. The pollution resulting from this process affects aquatic ecosystems, human health and productive activities (UNEP 2016). Less polluting agricultural practices can have significant benefits for a higher level of cleanliness in water resources worldwide.
- **SDG #11. Sustainable cities and communities**
  By 2025, more than half of the world’s population will be urban. The sustainable urban and peri-urban horticulture will play a crucial role in making cities more sustainable (FAO 2011b).
- **SDG #12. Responsible consumption and production**
  The production of food globally creates the largest pressure on Earth, with effects on water, land use and greenhouse gas emissions which threaten local ecosys-

tems (Willett et al. 2019). A more sustainable food system and more sustainable dietary habits would be crucial to achieve this goal.

- **SDG #13. Climate Action**
  Food production, and animal products in particular, is responsible for a significant share of GHG emissions, up to 51% according to Goodland and Anhang (2009). The transition to a more plant-based diet has been indicated as the single most significant action towards a reduction of the impact on Earth, including GHG emissions (Poore and Nemecek 2018).
- **SDG #14. Life below water**
  Industrial agriculture and farming can be linked also with ocean pollution, as in the case of "ocean dead zones": these are the result of large scale animal farming, often referred to as Concentrated Automated Feeding Operations—CAFOs (Imhoff 2010) and are formed by untreated animal waste, which creates runoff, reaches the water streams and then collects in the ocean. The animal waste is in such a high concentration that it depletes the oxygen available in the pre-existing ocean ecosystem. Changing such agricultural structures to alternatives which prevent runoff, and reducing other types of water pollution from agriculture can have a significant effect on improving the quality of life in the oceans.
- **SDG #15. Life on land**
  More sustainable agricultural practices can play a big role in halting the ongoing massive degradation of biodiversity and ecosystem services (Ceballos et al. 2017). Ensuring that higher levels of biodiversity are preserved in the agricultural systems, for example with the use of agroecology, allows for processes such as nutrients recycling and microclimate regulation, which are essential for all life on land.
- **SDG #17. Partnerships for the goals**
  Given the central role of food in the achievement of SDGs, partnerships which are developed specifically to increase the sustainability of the food sector and to include perspectives of all stakeholders can play a positive role. This is the case of multi-stakeholder partnerships (MSPs), 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). Examples in the context of food and agriculture include the Water Footprint Network, the Roundtable on Sustainable Palm Oil and the Global Roundtable for Sustainable Beef (GRSB).

4 Food Loss and Waste

Every year, a third of the world's food production along the entire supply chain is wasted (Gustavsson et al. 2011). Food production encompasses land, water usage as well as all the GHG associated to agriculture (FAO 2015b; BCFN 2012). And the waste of these natural resources due to the phenomenon of food losses and waste

(FLW) ultimately has repercussions on income, on the economic growth, on nutrition and on individuals' hunger (FAO 2015b). Due to its importance, the reduction of FLW have been integrated in the 17 Sustainable Development Goals (SDGs). Specifically, the SDG number 12 "Ensure sustainable consumption and production patterns" encompasses the issue in its third target: "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (SDG 12.3, UN 2015). That is why it is fundamental that institutions, government, scientific communities, media, and individuals deeply understand the phenomenon and try to put forward whatever they can do to reduce it.

According to FAO (Gustavsson et al. 2011), food losses refer to avoidable edible waste that occur at the agricultural, post-harvest, and processing phases of the food supply chain, and are mainly due to poor infrastructure and investments. While food waste specifically happens in the last phases of the food supply chain, that is at retail and consumption level and are specifically due to behavioral issues (Parfitt et al. 2010; Principato 2018). Concerning the amount, although industrialized and developing countries almost discard the same amount of food (respectively 670 and 630 million tons every year), in the developing countries 40% of losses happen at post-harvest and processing phases, while in industrialized countries more than 40% of waste occur at retail and consumer ones (Gustavsson et al. 2011). Considering the type of food, globally every year 30% of cereals, 40–50% of root crops, fruits and vegetables, 20% for oil seeds, meat and dairy, and about 35% of fish get lost or wasted (Gustavsson et al. 2011). Food waste causes an exploitation of natural resources: land, water and related carbon emissions due to the production of food that ultimately ends up in the trash. FAO (2013a, b) highlighted that if food waste could be a country, it would be the third top greenhouse gas emitters after China and USA. The global economic cost of FLW, that encompasses not only the financial aspect, but also the social and environmental impacts, is estimated to almost 2.6 trillion of US Dollars (FAO 2014). The social impacts of FLW are related to the issue of food security and food access. To make an example, food waste, that occurs in the rich countries (222 million tons) represents the net food production of Sub-Saharan Africa (222 million tons) (Gustavsson et al. 2011).

FLW represents a multi-faceted problem that should be addressed with the commitment of all the actors involved, starting from governments and policy makers. According to the FSI (2018), some countries are already at a good well under way, while some others needs some important changes. France, Argentina, and Luxemburg, for instance, have an excellence policy involvement against FLW. In France, it is noteworthy the proactive legislation of 2016 that prohibits big supermarkets to waste unsold food, requiring them to sell at a smaller price or to donate to people in need. This result in an annual food waste per capita of 67 kg, a good achievement if we consider, for instance, that countries like United States wastes 95 kg per capita (the highest amount in the FSI ranking). Another practice that is necessary is setting reduction or prevention quantitative targets on FLW, this is important, not only to align to the SDGs targets, but also to measure how policies and initiatives against FLW are effective. Indeed, all the top three countries of the ranking (France, Argentina and Luxembourg), aligning to the majority of high-income ones, encompass specific food waste reduction targets. Among the high-income countries that still do not have reduction targets there are Canada and Italy. Relevant good practices happen also in the southern part of the world. In Egypt, for instance, it has been introduced a smartcard system to limit the daily amount of subsidized bread for each family to reduce the demand for bread consequent food waste. In Lebanon civil-society organizations, like Food Establishments Recycling Nutrients and the Lebanese Food Bank, have taken the lead in tackling the problem of food waste by promoting no-waste campaigns and distributing surplus food. In Australia food donations are fully tax deductible, and in Saudi Arabia there are voluntary agreements in place to deal with reducing food waste. For example, the General Sports Authority has signed an agreement with the Saudi Food Bank that aims to promote the reduction of food loss, for example through the launch of a food conservation prize targeting hotels and restaurants (FSI 2018).

The UAE, Malta and Turkey are instead performing the worst result among the 67 countries considered (FSI 2018). In particular, UAE has the highest percentage of food losses, that is 59% of total food production is discarded during the first stages of the food supply chain (FAO 2013a, b) and has no policy response and a national plan to tackle food losses and waste. Similarly, Turkey has a high percentage of food losses (9% of total food production) and at the moment, no policy response is put forward against it. Malta has a high rate of food losses (9% of total food production), but contrary to the others two countries attempts to have a food loss strategy, that is the National Agricultural Policy for the Maltese Islands 2018–2028. This policy considers, among its economic objectives, reducing product loss in order to increase value addition and to identify new export markets. Malta has also a high number of food waste per capita, 52 kg per year, but there is almost no policy response to this issue.

FLW is a complex issue that involves a number of stakeholders at the different stages of the FSC. In particular farmers, food producers, and distributors for the first stages of the FSC, and retailers and individuals during the last stages. Considering the first stages of the FSC, the main recommendation would be to develop supply chain agreements between farmers, producers, and distributors for more appropriate planning of food supply, along with investing in better road infrastructure and storage facilities in order to transport and preserve food correctly. At the individual's level, since it has been acknowledged that FLW mainly happens for behavioral issues (Parfitt et al. 2010; Principato 2018), it is fundamental to increase consumer awareness about waste and on how to better plan, purchase, preserve, prepare, and ultimately redistribute, and dispose food. Along with this, it is necessary to have the involvement of policy makers both at international, national, and local level in order to implement FLW policies and set targets for improvement. Academia and third sector/private initiatives also play a role: the former should continue to analyze the phenomenon and set a clearer methodology to define and quantify it; the second one is fundamental in creating a bridge between food companies/retailers and food banks/charities in order to redistribute food to people in need.

4.1 Food Loss and Waste in the SDGs

A number of SDGs are related to FLW, besides the SDG number 12 "Ensure sustainable consumption and production patterns". As analyzed below, addressing FLW is essential in the accomplishment of a number of other SDGs.

- **SDG #1. No poverty**
  Food waste is a waste of money: the social cost related to it amounts to $940 billion per year (FAO 2014). Reducing it can save Countries budget and household money, thus relieving poverty.
- **SDG #2. Zero Hunger**
  It has been estimated that 45% of all fruit and vegetables, and about 20% of meat gets wasted, as highlighted in the BCFN third paradox, this is not a comforting fact in a growing population that is still suffering hunger (Gustavsson et al. 2011).
- **SDG #9. Industry Innovation and Infrastructure**
  Thanks to the rising of sharing economy and digital technology, food sharing models are emerging. It has been seen that they could represent an innovative way to share excess food, thus avoiding waste, while fostering innovations and sustainable development (Michelini et al. 2018).
- **SDG #10. Reduce inequalities**
  It has been shown that reducing food losses in the Developing Countries could lead to less inequality within and among countries, due to the money saved from food losses reduction (Gustavsson et al. 2011).
- **SDG #11. Sustainable cities and communities**
  Food waste reduction at consumer and retail level, the promotion of sorting practices at community level (like policies to increase composting), and the use of food sharing platforms, could lead to more sustainable cities and societies (Michelini et al. 2018; Secondi et al. 2015).
- **SDG #12. Responsible consumption and production**
  From the consumer perspective, it is worth noting that individuals that are more aware of food waste impacts tend to waste less (Principato et al. 2015). From the retailer perspective, initiatives like "buy one, get the second free later" that propose the 2X1 marketing offer but with the option of getting the second one when necessary, represent a valuable production initiative (Mondéjar-Jiménez et al. 2016). From the food company perspective, we should mention the report of Champions 12.3 that highlighted that companies that invest $1 in the reduction of food losses and waste along their food supply chain, can pursue a return of investment of up to $14 (Champions 12.3, 2017).
- **SDG #13. Climate Action**
  FLW produces about 8% of global greenhouse gas emissions (CAIT 2015). It has been demonstrated that reducing FLW would limit emissions of planet-warming gases, lessening some of the impacts of climate change, such as more extreme weather conditions and rising seas (Hiç et al. 2016).

- **SDG #14. Life below water**
  Food that is produced but not eaten produce a volume of water comparable to the annual flow of Russia's Volga River (FAO 2013a, b).
- **SDG #15. Life on land**
  FLW reduction could save 30% of arable land, which is yearly used to cultivate, or farm wasted food (FAO 2013a, b).
- **SDG #17. Partnerships for the goals**
  Food waste can be tackled only with the involvement of all the stakeholders (institutions, individuals, companies, NGOs and academia) and the creation of inclusive partnerships.

5 The Pathway Towards Sustainable and Healthy Food Systems

This chapter has attempted to highlight some of the issues that global food systems are currently facing. A few recommendations can be drawn on how to progress towards the establishment of sustainable and healthy food systems that pave the way to sustainable development, both "a way of understanding the world and a method for solving global problems" (Sachs 2015, p. 1).

In the current food system, for every US$1 spent on food, US$2 is incurred in economic, societal, and environmental societal costs, (totaling USD 5.7 trillion/year) due to both food production and to the consequences of consumption (Ellen MacArthur Foundation 2019). A number of interventions can be put forward to accelerate the transition to a healthier and more sustainable food systems. These measures, at the public level, include use regulations or financial incentives, applying taxes or charges for certain types of foodstuff, running mass information campaigns, providing food-related education in schools (Willett et al. 2019). Policy can play a crucial role in enabling transformative change by removing barriers while providing incentives to influence stakeholders' behaviors; ensure transparency and accountability of operators; mobilize public and private resources for addressing priority areas; ensuring coherent and integrated policies, beyond the agricultural sector, as food fundamentally cross-cuts a number of sectors (Rawe et al. 2019). At the city level, policies for food system transformation can address local challenges, encourage citizens engagement (Rawe et al. 2019). A number of umbrella organizations and initiatives, such as the C40 Food Systems Network and the Milan Urban Food Policy Act, have shown that urban food policies have the potential for both scaling up and out good practices. Business interventions range from sustainable farming initiatives and reshape of supply chains, to product reformulation and prioritization of sustainable and healthy products in marketing (Willett et al. 2019). Given the scope of the challenge, there is an increasing urgency to develop a society-wide response to food system challenges, that encompasses people's mindset and behavior. Consumers can orient business practices by modifying their behavior to support environmental objectives through sustainable purchasing choices, therefore increasing public understanding and awareness is crucial for its potential to shape decisions, consumption, and lifestyles (Bartels et al. 2013).

Education, new technologies and bottom-up solutions-based approaches are also important ingredients for a food system transition. As we strive to reach the SDGs, it is important to reimagine how to educate the future generations of leaders in the policy, business and civil society domains. Obtaining a quality education, as prescribed in SDG 4, is a major driver of sustainable development and the foundation to creating sustainable food systems. As such, education is linked to all the areas analyzed in this chapter, from improving the nutritional quality of diets to prevent end-user food waste. Management education will also require a fundamental overhaul, by considering the SDGs as targets to be achieved, thus going beyond the concept of shareholder value maximization (Davis 2018). New and traditional knowledge will need to go together towards the same direction in order to ensure that food production becomes more sustainable. Agroecology principles can offer a wide range of low-impact techniques that assist not only a more ecologically friendly food production and higher levels of biodiversity, but also water conservation and soil fertility improvements; for these reasons, also the FAO has recently launched an initiative to scale-up agroecology and favor the achievement of SDGs. Also new digital tools can bring benefits, for example in increasing efficiency, sparing environmental resources and reducing the use of chemicals thanks to a greater real-time data availability. For example, in Italy a project is being implemented by CREA and the Italian Ministry of Agriculture to develop sustainable biotechnologies. Enabling the scale up and out of bottom-up solutions is increasingly recognized as potentially transformative of food systems globally, as witnessed by initiatives such as the Global Opportunity Explorer from the United Nations Global Compact.

An integrated framework establishing a safe operating space for global food systems to feed a population of ten billion people with a healthy and sustainable diet has been defined by the EAT-Lancet Commission report, calling for a “Great Food Transformation” (Willett et al. 2019). The pathway envisioned includes major transformation in diets (the healthy diet consists mainly of vegetable, fruits, whole grains, legumes, nuts and unsaturated oils) so to stay within planetary boundaries in terms of climate change, land-use systems, water use, biodiversity loss etc.

Sustainable development is a universal challenge and a shared responsibility of all countries (which are increasingly interdependent) and actors in society, and requires a fundamental overhaul in the way we produce and consume food with a holistic approach that considers both the socio-economic and ecological dimensions. Any transformational change can only be achieved by means of integrated, multisector and multilevel action and the collaboration of all stakeholders, involved or touched upon by food systems.

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Climate Change, Sustainable Agriculture and Food Systems: The World After the Paris Agreement

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1 Introduction

1.1 Climate Change and Agriculture

According to the fifth assessment report of the IPCC (2014), the concentrations of greenhouse gases (GHG) in the atmosphere are at the highest they have been in the past 800 thousand years. Current levels of CO_2 have increased by 30% from 280 ppm in pre-industrial times to 407 ppm today (2019), and they continue to rise. Present CH_4 concentrations of 2000 ppb are nearly triple their pre-industrial value of 700 ppm. N_2O levels reached 328 ppb in 2019 compared with the 280 ppb of pre-industrial time. Only in the past 50 years we have doubled human population (from 4 to 7 billion), increased GHG emissions by 2.5 times, doubled freshwater

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_2

withdrawal, halved the agricultural land per capita (from 1. 4 to 0.7 ha) by agriculture intensification. This is an unprecedented velocity of transformation that our Planet and human society had never experienced.

Today, the agro-food sector alone accounts for some 80% of the world freshwater use, 30% of world energy demand, and more than 12% of man-made greenhouse gas emissions worldwide, including indirect emissions such as those of deforestation (Foley et al. 2011). Moreover, according to the Food and Agriculture Organization (FAO) of the United Nations, croplands and pastures occupy about 38% of Earth's terrestrial surface, the largest use of land on the planet (Foley et al. 2011). With global food production expected to increase 70% by 2050, and considering the meat dietary changes, the sector is facing unprecedented resource pressures and strong perturbations to the climate systems. By 2050 more than nine billion of people will be in search of food and most of them (68%) will be living in mega-cities (UN DESA 2018). Under these circumstances, a substantial redefinition of the actual food supply chain is essential. Meanwhile, many rural-communities, which strongly depends on domestic-subsistence agriculture, will be exposed to food scarcity and accessibility. Indeed, in some regions of the world (i.e. tropics and part of temperate regions) increasing of climate extremes will produce adverse effects on agriculture, forestry and fisheries sectors with yield reduction of 35% in African countries and 2% globally per decade, despite the increasing food demand (Barros et al. 2014). It is time to reflect on the global agro-food systems, its paradoxes, inequalities and capacities to support future generations. On the other side global warming can also expand the land suitability for some crops, like wheat at high latitudes (Di Paola et al. 2018). Humanity needs to act urgently and fast, pushing the high-level governmental agenda (SDGs, Climate Paris agreement) as well as industry sector and citizens in the most difficult and challenging transformation of our society to feed the new two billion of people expected by 2050 and, at same time, stabilize climate below 2.0° (possibly 1.5°) and reducing the pressures on natural resources.

1.2 The Paris Agreement: Implications for the Agriculture Sector

The significant role that agriculture can play in climate change was relatively under-represented in the previous discussions and decisions under the frame of the United Nations Framework Convention on Climate Change (UNFCCC), before the Paris Agreement (PA) was adopted by the 21st Conference of the Parties (COP21) of the UNFCCC on the 12th of December 2015.

Food security and food production are explicitly mentioned in the PA: in its preamble the Parties recognize "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change", and the Article 2 highlights the importance of "increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production". Moreover, the role of agriculture in the PA is also linked to the capacity to be a possible sink and reservoir of GHG in soils and vegetation biomass: in the Article 5 Parties are invited to "take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases". This opened to agriculture as a key sector, not only impacted by climate change but also with a great potential for mitigation.

In fact, more in general, the PA has the ambition to keep "the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change". In order to achieve this long-term temperature goal, parties are therefore committed to achieve a balance between anthropogenic emissions by sources and removals by sinks in the second half of this century. Different options are feasible and the agriculture sector can play an active role, in particular by contributing to the net emissions reduction, while guaranteeing food security. Besides, under the UNFCCC process a specific programme on agriculture was launched (the "Koronivia Joint Work on Agriculture", see Box below) that provides space and opportunities for Parties to fully engage on climate related discussions in the agriculture sector in order to foster actions related to adaptation and mitigation taking into consideration the sectors vulnerabilities.

Box: The Koronivia Joint Work on Agriculture

The agriculture negotiations under the UNFCCC were incorporated as a specific agenda item under the Subsidiary Body for Scientific and Technological Advise (SBSTA) in 2011 with decision 2/CP.17 (paragraphs 75–77). The COP requested SBSTA to consider issues related to agriculture, with the aim of exchanging views. The discussions that followed for the next 7 years led to a historic milestone in Bonn at COP23, when Parties adopted decision 4/CP.23 on the "Koronivia Joint Work on Agriculture" (KJWA) (UNFCCC 2017).

The decision recognizes the fundamental importance of agriculture in responding to climate change while ensuring food security, and calls for joint work between SBSTA and the Subsidiary Body of Implementation (SBI) on specific elements, including through workshops and expert meetings. As mandated by the decision, the KJWA should take into consideration the vulnerabilities of agriculture to climate change and approaches to address food security.

The paragraph 2 of the KJWA decision provides a list of initial elements on which Parties were invited to submit their views by 31 March 2018:

(a) Modalities for implementation of the outcomes of the five in-session workshops on issues related to agriculture and other future topics that may arise from this work;

(b) Methods and approaches for assessing adaptation, adaptation co-benefits and resilience;
(c) Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management;
(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems;
(e) Improved livestock management systems;
(f) Socioeconomic and food security dimensions of climate change in the agricultural sector.

The submissions provided by Parties and observers were considered at the 48th session of the Subsidiary Bodies (SB48) of the Convention, in Bonn (30 April–10 May 2018), where a 3-year road map of the KJWA was defined. The road map includes a schedule of workshops, submissions and reports related to each topic (from 2(a) to 2(f)). However, many Parties have already declared in their submissions that the 3-year period currently foreseen for the KJWA may not signify the end date of the KJWA, but that the SBs may define further work after 2020, pending a further COP decision. The Subsidiary Bodies are expected to report on progress and outcomes of the KJWA to the COP at its 26 session in November 2020.

In pathways limiting global warming to 1.5 °C with limited or no overshoot, Agriculture, Forestry and Other Land-Use (AFOLU) related carbon dioxide removal measures are projected to remove 0–5, 1–11, and 1–5 $GtCO_2$ $year^{-1}$ in 2030, 2050, and 2100 respectively (IPCC 2018). Due to this key potential role plaid by the agriculture, the 80% of the Nationally Determined Contributions (NDCs) submitted by countries committed to actions on agricultural mitigation, and 90% of NDCs selected agriculture as a priority sector for action on adaptation (CCAFS 2016; FAO 2016).

Despite the inclusion of agriculture and the land sector in general in most NDC, this is still not enough to achieve the 2 °C goal and additional reduction targets are needed (Fujimori et al. 2016). According to the Fujimori et al. (2016) modelling exercise, large-scale negative CO_2 emissions and land-based CO_2 emissions-reduction measures are required and the bioenergy crops need to be an important component in addition to agriculture, with an area of cropland used for bioenergy to be 24–36% of the total cropland. Indeed, the deployment of such a large-scale land-related measures, like afforestation and bioenergy supply, can compete with food production raising not only food security concerns (IPCC 2018) but also increasing the environmental footprint, due to the increased use of natural resource (e.g. water and nitrogen for bioenergy crops) and environmental impacts (e.g. loss of biodiversity and increasing pollution from fertilizers).

Furthermore, climate-related risks on food security are projected to increase under global warming, with projected net reductions in maize, rice, wheat and, potentially, other cereal yields in many regions of the world (IPCC 2018).

Studies based on multi-model inter-comparisons (Schleussner et al. 2016) foresee a general crop yield reduction, particularly in tropics, for maize and wheat under increasing temperature scenarios, with more significant reductions projected at 2 °C than 1.5 °C. On the other side, local rice and soy yields are projected to increase in the tropics, as the positive effect of CO_2 fertilization counterbalances the detrimental impacts of climate change in the model projections (Schleussner et al. 2016). However, additional gains for warming above 1.5 °C resulted not significant, and yield reductions are expected for all the four widespread global crops.

In the light of these evidences, trade-offs between mitigation and adaptation, as well as economic and environmental benefits, need to be addressed when balancing the need of land for bioenergy crops, reforestation or afforestation, versus the land needed for agricultural adaptation under a changing climate, not undermining food security, livelihoods, ecosystem functions and services and other aspects of sustainable development.

2 A Paradigm Shift in Agriculture: From Carbon Source to Sink

The AFOLU sector (including agriculture, forestry and changes in land use) produces 21% of global greenhouse gas emissions, making them the second largest emitter after the energy sector (Smith et al. 2014). The agricultural sector, in particular, is the largest contributor to global anthropogenic non-CO_2 GHGs, accounting for 56% of emissions in 2005 (IPCC 2007). At the same time agriculture has great potential for mitigation: among the most cost-effective mitigation options are cropland management, grazing land management, and restoration of organic soils (Smith et al. 2014). The balance between the emissions and the mitigation potential is further challenged by the increasing global demand for food due to the projected increase of global population to 9.7 billion people by 2050 (FAO 2017).Therefore, to fully address all the challenges raised by the PA and contribute to the target of limiting the temperature increase to less than 1.5–2.0 °C something more than mitigation supply-side options (e.g. changes in land management, etc.) would be needed, starting from the drivers of our unsustainable food systems, and considering a shift of the consumers' behavior and perception of environmental impacts of climate change. As showed by Smith et al. (2013) demand-side mitigation measures (e.g., lifestyle changes, reducing losses and wastes of food, changes in human diet, etc.) offer greater potential in reducing GHG emissions while meeting food security than do supply-side measures.

2.1 Demand-Side Drivers of a Sustainable Food System

Food production and the systems needed along the whole food supply chain can be significantly modified by a number of demand-side drivers that can be managed through virtuous actions in order to shift the agriculture sector from source to sink of carbon, while guaranteeing food security and protecting the environment. Here below we propose a list of main drivers of the food demand mainly taken from the Barilla "Climate@risk&Food@risk" chart, published in 2016, Barilla Foundation. https://www.barillacfn.com/en/research/public_consultation/climate_at_risk_and_food_at_risk/.

- Costs. Food prices are among the main drivers to food choice. In most cases they do not reflect true costs in terms of positive and negative externalities.
- Policy. Governments and supra-national bodies play a key role in promoting the shifting towards a truly sustainable food system, through international treaties, national laws, incentives, informative campaigns, etc.
- Global trade. Reforming global trade policies, including eliminating price-distorting subsidies and tariffs, will facilitate the adoption of long-term virtual strategies.
- Compensation to farmers. Fair compensation for farmers would promote the transition to climate smart agriculture.
- Knowledge, innovation and technology. These three elements can bring a positive transformation to the agro-food system and increase its resilience.
- Ecology. Environmental sustainability of food can be an important factor influencing consumers' dietary patterns.
- Food loss and waste. Changes in supply chain and consumption behaviors can significantly reduce food loss and waste.
- Urbanization and agriculture. Connecting urbanization to agriculture create big opportunities for less impacting food production systems.
- Business. Business should be accountable for the impacts of their activities on the environment and society. The implementation of environmental and social sustainability standards for business should be promoted.
- Circular economy. Full transition to circular economy in the agro-food system would be required.
- Life-style. Changes in consumers behavior (including diets), can lead to changes in food choice and adoption of a less impacting life-style.

2.2 Solutions and Tools

Agriculture was too often deplored as a cause of climate change, rather than recognized for its potential as a solution in climate change mitigation and adaptation. Leveraging on the above drivers in the right way will facilitate the transition from conventional agriculture to agro-ecology that would ensure food security while reducing GHG emissions and other impacts on the environment. This transition can be promoted by an ecological approach to food production, aiming above all to increase the resilience of the ecosystem rather than yields only. To this end, the agro-ecology adopts strategies such as the implementation of multi-cropping systems and/or crop mixtures, the use of landraces (which are more resistant to climate variability, pest and disease), habitat diversification, natural pest control and the minimization of external inputs (including fuel). These strategies can enhance also food security, nutrition, health, environmental protection and many socio-economic challenges associated with the food system as a whole. Therefore, the agro-ecology should be promoted by all the main actors playing along the food supply chain: farmers, consumers, policy makers, business sector, consumers.

Food systems must be sustainable also in terms of prevention, recycling and up-cycling of waste and losses from the agricultural sector. Supply chains are still inefficient with regard to food loss and waste which globally are equivalent to some 40% of total food production (Foley et al. 2011).

Positive externalities, such as carbon sequestration, can convey financial rewards. True costs need to be taken into account in business models, based on local food cultures, availability and sustainable use of natural resources. Progress can be made using the RIO + 20 agreement on natural capital value.

The foundational concept is that the carbon stored in agricultural soil is an important value which should be reflected in monetary and non-monetary values. Protection and conservation of carbon stocks is even more important than carbon emissions. This implies reduction of tropical deforestation and improving agriculture productivity per land area. As climate change can adversely impact agriculture and forestry sectors, adaptation is required to make the whole agro-food system more resilient. Developments of the PA should emphasize the agro-food system as a priority element, both its protection against and as a solution to climate change. This should be seen in the context of a wider vision to connect global ecology with global economics by developing macroeconomic policies based on carbon and its storage and value as stocks rather than its use as flows—that can be referred to as moving onto a carbon-based standard of economic valuation.

Also the relationship between agriculture and the urban areas must be seen as an opportunity for developing more sustainable food systems. Urbanization is a big challenge not yet adequately considered by the agro-food sector. From one side there is an urgent need to reverse the rural-urban migration pattern in most countries by providing more jobs in and out of agriculture and the food system and by investing in rural areas. From the other side farm production on urban and peri-urban areas should be enhanced. This includes protecting space for agriculture in urban areas and promoting self-productions and 0 km food.

More in general, action is needed at all levels including a more conscious consumption behavior, diversify food transformation along different lifestyles, change packaging to reduce waste and pollution, ensure access to proper food and nutrition for the poor and preserve cultural importance of traditional foods.

The following solutions (defined as organizational and technological changes) and tools (defined as methodologies or operational specific instruments), are feasible options to implement the required paradigm shift, acting both on the demand-side drivers and land management.

Solutions:

– Policy and legislative framework. The right to healthy and nutritious food is a basic human right that governments and public institutions have to provide to their citizens. In particular for demand-side measures, given the difficulties in their implementation and lag in their effectiveness, policy should be introduced quickly, and should aim to co-deliver to other policy agenda, such as improving environmental quality or improving dietary health (Smith et al. 2013). Many policies address lot of critical issues but only partially, whilst other critical issues are not considered at all. A first assessment of the agricultural sector status at the national level will allow to select the best policies and call for an effective implementation of the existing legislative frameworks, and in turns, to achieve the established, agreed targets, or to formulate new policies if needed, in line with the SDGs and COP21.

– Incentives. The use of incentives must be encouraged, pushing the move from the current paradigm toward a more conscious and sustainable one. These incentives can include investment in public research and science-based solutions as well as investments in rural communities (for instance through fair income for farmers). Governments could likewise overhaul subsidies in agro-food to ensure they support businesses and farmers who put sustainability at the core of their operations. Finally, government funding could be used to finance large-scale food security and food loss/waste projects from industry and farmers.
– Consumer education. If food security is approached from the angle of production only, half of the problem is overlooked, as well as half of the solution. As dietary patterns dramatically influence food production, consumption behaviors need to be addressed and consumers must be involved in knowledge sharing and awareness raising. Guidelines for nutritious eating must become guidelines for nutritious and sustainable eating by sharing information on the environmental impact of various foods. Nutrition education must be part of school curricula to begin shaping new standards of consumer behavior in terms of dietary habits from early childhood. Education on these topics in schools, cooking classes, advertisements and news have the capacity to influence the consumers' behavior toward a more sustainable food production.
– Focus on the right scale. Many solutions have been developed and proven effective at pilot scale, but very few have been taken to any significant scale. Taking a solution to large scale requires solving many issues that are trivial—or even overseen—in the pilot phase, but critical in the large-scale implementation.

Tools:

– Big data analytics. A measurement framework that assesses the effectiveness, resilience and sustainability of entire food systems is required. Current indices focus on single dimensions of food systems, but lack an overall view on the whole system. The measurement framework needs to be fed with reliable data. Without reliable data, the scale and urgency of the problems cannot be properly assessed. There is a need to develop indicators that can be compared and coordinated across geographies, scales and communities. A first analysis can start from using the existing databases, aligning information to bring them together. Open data transparency will be important to make progress in this regard.
– Innovation. Digital and technological innovation can both assist farming in becoming more efficient and more sustainable. Farm equipment is getting

"smart" and is increasingly powered by renewable sources. Satellites can take images of land, analyze crop conditions and predict harvests. Internet connection in rural areas can increase dialogue and access to information among farmers, leading to a better quality of life. More in general, knowledge, innovation and technology bring a positive transformation to the agro-food system and increase its resilience, by improving the efficiency along the whole food supply chain.

– Best practice exchange. This transition to a more sustainable food production system is already ongoing. Many progresses have been done and significant advancements are expected, thanks to the work of all the actors in agriculture, business and civil society. To widen the impacts of these positive aspects, a concrete exchange of best practices, including smart and precision agriculture, agroecology and new business models, need to be realized to share these throughout the world so that other parties may implement them and replicate their success. The provision of capacity development and information, in particular to women and the youth is also essential for this transformation.

3 Conclusions

Humanity needs to act urgently and fast, pushing the high-level governmental agenda (SDGs, Paris Agreement) as well as industry sector and citizens in the most difficult and challenging transformation of our society to feed the new 2 billion of people expected by 2050 and, at same time, stabilize climate below 2.0° (possibly 1.5°) while reducing the pressures on natural resources. Current climate change scenarios, both at 2 °C and in particular 1.5 °C, require large scale mitigation in the land sector, both in the form of carbon sequestration in soil and biomass and the reduction of agriculture GHG emissions. Likely this large effort will interplay with food security, water resources, biodiversity and the need of additional land transformation. These goals cannot be achieved without a parallel reduction of fossil fuel emissions in other sectors, i.e. energy and transport, and without a comprehensive approach to the whole food system. In this respect, without a strong inversion of the human demand-side drivers, the goals of the Paris Agreement, and more in general, the paradoxes, inequalities, and capacities of the global agro-food system to support future generations cannot be achieved.

Leveraging on the above drivers in the right way will facilitate the transition from conventional agriculture to the agroecology, ensuring food security while reducing GHG emissions and other environmental footprints.

Moreover, introducing the global ecology concept within the global economy, by developing macroeconomic policies based carbon neutrality and recognizing the conservation of carbon stocks (e.g. by introducing positive externalities as a true cost in business models), can result in financial rewards, giving rise to the actual benefits from the protection and conservation of carbon stocks and reduce the agricultural expansion at the expense of forested areas, and in an effective contribution, making agriculture a critical sector acting as a solution to climate change while responding to the challenge of feeding the future world.

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Drivers of Migration in the Trans-Mediterranean Region: The Likely Role of Climate Change and Resource Security in the Geopolitical Context

Luca Caporaso, Monia Santini, Sergio Noce, Alberto de Sanctis, Lucio Caracciolo, and Marta Antonelli

1 Introduction

Today, 258 million people in the world live outside their country of birth, a figure that is expected to grow in the next period as a result of demographic growth, global connectivity, rising inequality and unemployment (UNDESA 2017). Human migration is defined by the International Organization for Migration as "*the movement of a person or a group of persons, either across an international border, or within a State […] encompassing any kind of movement of people, whatever its length, composition and causes; it includes migration of refugees, displaced persons, economic migrants, and persons moving for other purposes, including family reunification*". As such it includes people choosing to move not just because of a direct danger of persecution or death, but also to improve their lives through better work, education, health or other reasons, as well as people whole livelihoods are directly threatened due to human or environmental conditions. It is a structural phenomenon in the world we live and it will be even more in the future to come. Against this context, the "Global Compact for Safe, Orderly and Regular Migration", adopted in December 2018 by the majority of UN Member States (https://www.iom.int/

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_3

global-compact-migration), represents the first global agreement in history that seeks to address migration with a common (although non-legally binding) approach based on 23 Principles.

This is especially of interest for the Trans-Mediterranean migration region, i.e. the one encompassing departure, transit and destination countries from Sub-Saharan Africa and Middle East to Europe. This region recently deserved attention at global level for the variety of migration routes as well as for a variety of institutional, social, cultural and economic issues affecting not only single countries internally but also international relationships and cooperation. The region faces significant environmental-related challenges due to the combination of climate change vulnerability, water scarcity, land degradation, coupled with increasingly urbanized populations that require environmentally-intensive food products as they experience a nutritional transition. For these reasons, more in-depth knowledge on how interacting geopolitics and environmental change interact and have an impact on the food system, in the present as well as in the future, can shed light on the extent to which these expected changes will act as drivers of human migration in the Trans-Mediterranean region.

The aim of this chapter is to investigate the potential *nexus* among climate, geopolitics and migration across the Trans-Mediterranean region. Such nexus is here analyzed focusing on countries of origin, transit and destination of Trans-Mediterranean migrations' routes. Several key environmental (esp. climate change and its impacts) factors that influence resource (food and water) and socio-economic security, and thus the movement of individuals and populations, will be analyzed. A comprehensive spatially- and temporally-explicit analysis has been conducted about the exposure of the Trans-Mediterranean regions to climate hazards, namely atmospheric conditions, crop yield and water availability (proxies of food and water security, respectively) as observed along the historical period and expected for the future.

The chapter builds on the analyses conducted in the Report "*Food and migration: Understanding the geopolitical nexus in the Euro-Mediterranean*" (https://www.foodandmigration.com/) to deepen and consolidate the understanding on the above-mentioned nexus with a multidisciplinary approach that builds on environmental and social sciences.

In the following paragraphs, the background and rationale for the study is described, followed by the geographical domain, data and methods of analysis. The following section presents and discusses the results of the analysis, to finally draw key conclusions and recommendations.

2 Climate Change Assessments: An Overview

Many studies now recognize the link between climate change and human migration, due to the decline of ecosystem services, increasing constraints on natural resources, and associated socio-economic and geopolitical pressures under threatened environmental conditions (Piguet 2010). At the 21st Conference of Parties (COP 21) under the United Nations Framework Convention on Climate Change (UNFCCC), the Executive Committee requested the formation of a task force to develop recommendations on "*integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change*".

Shortly before this important acknowledgement, the Intergovernmental Panel on Climate Change (IPCC), in its reports on "*Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*" (IPCC 2012) and "*Climate Change Impacts, Adaptation and Vulnerability*" (IPCC 2014), stated that the vulnerability to climate change, including extreme events, is expected to become more and more heterogeneous across the globe in the future. The urgent need to tackle climate change with "rapid, far-reaching and unprecedented changes in all aspects of society" to limit global warming to 1.5 °C was also stressed in the Special Report on Global Warming of 1.5 °C released in October 2018 (IPCC 2018).

Many initiatives and projects attempted to quantify, based on available observational datasets, ensembles of climate to impact models, and synthesis statistics, the current to future vulnerability under climate change for the different countries and regions of the world.

As noteworthy example, the Notre Dame-Global Adaptation Index (ND-GAIN)[1] is a combination of over 74 variables into 45 core indicators to measure *vulnerability* and *readiness* for more than 180 UN countries from 1995 to the present. *Vulnerability* is intended as combination of exposure, sensitivity and adaptive capacity[2] with respect to climate change. More specifically, the exposure is the component associated to climate-related hazards and their physical impacts (among others, changes in cereals' crop yield, water availability and variability). The *readiness* instead regards countries' social, governance and economic ability to leverage investments for implementing climate adaptation actions.[3]

[1] https://gain.nd.edu/our-work/

[2] **Exposure**: The extent to which human society and its supporting sectors are stressed by the future changing climate conditions. Exposure captures the physical factors external to the system that contribute to vulnerability.

Sensitivity: The degree to which people and the sectors they depend upon are affected by climate related perturbations. The factors increasing sensitivity include the degree of dependency on sectors that are climate-sensitive and proportion of populations sensitive to climate hazard due to factors such as topography and demography.

Adaptive capacity: The ability of society and its supporting sectors to adjust to reduce potential damage and to respond to the negative consequences of climate events. Adaptive capacity indicators seek to capture a collection of means, readily deployable to deal with sector-specific climate change impacts.

[3] **Economic Readiness**: The investment capability that facilitates mobilizing capitals from private sector.

Governance Readiness: The stability of the society and institutional arrangements that contribute to the investment risks. In a stable country with high governance capacity investors are assured that the invested capitals could grow under the help of responsive public services and without significant interruption.

Social readiness: Social conditions that help society to make efficient and equitable use of investment and yield more benefit from the investment.

Similarly, the joint World Food Programme and MetOffice initiative “Food Insecurity & Climate Change” (http://www.metoffice.gov.uk/food-insecurity-index/) focused on the Least Developed and Developing Countries of the World to investigate their vulnerability to suffer from climate change impacts in terms of food security, under current conditions and in the future. Based on the Hunger and Climate Vulnerability Index (HCVI) from Krishnamurthy et al. (2014), *vulnerability* was again calculated as combination of exposure (to climate-related hazards), sensitivity (of national agricultural production to climate-related hazards) and adaptive capacity (to cope with climate-related food shocks). The Food Insecurity was also projected for the medium-term (2050) and long-term (2080) time horizons in both cases revealing that, even under high adaptation and low emissions’ scenarios, food security is at risk of worsening in many countries of the world.

Food security depends on climate through impacts on water resources and agricultural production (via crop yield). It has been assessed that climate variability accounts for up to 60% of yield variability in many parts of the world (Ray et al. 2015) and it is thus a crucial factor for food stability. As example, meteorological droughts (lack of rain) often lead to hydrological and agricultural droughts (lack of water in surface to underground water bodies, and of moisture in the soil), so that the fulfillment of crop water requirement is at risk from both the rainfed and irrigation side (Ronco et al. 2017).

Climate change and its impacts thus are key determinant of present and future vulnerability to food insecurity in the countries of origin, transit and destination of migrants. In the context of increasing climate change vulnerability, especially in terms of resources—food, water and land—availability (Vörösmarty et al. 2000), the migration of individuals and communities from the most vulnerable areas becomes an important option, often the last chance, to adapt. The link between climate change and migration (both internal—e.g. from rural areas to cities—and international—from one country to another) was explored by Barrios et al. (2006), Marchiori et al. (2011), and Cai et al. (2016) looking at both rainfall and temperature variability. While one soon realizes that people tend to move from areas most exposed to climate shocks to less climate-vulnerable areas, as also shown by Grecequet et al. (2017), climate anomalies seem however driving migration more from middle income countries, while populations locked in deep and persistent poverty (low income countries) are constrained (“trapped”) by lack of economic resources to migrate (Cattaneo and Peri 2016; Grecequet et al. 2017) (see e.g. Fig. 1).

Moreover, it is necessary to differentiate between migration caused by slow-onset climate-related events, such as droughts and land degradation, and those caused by fast-onset events, such as floods, storms, tsunamis or fires. While the former is usually voluntary, economically motivated, gradual and almost definitive; the latter is involuntary, rapid and tends to be temporary and reversible (Brzoska and Fröhlich 2016).

Additionally, as the latest World Food Programme report clearly shows, there is a particularly strong link between migrations, food and conflicts: refugee outflows per 1000 population increase by 0.4% for each additional year of conflict, and by

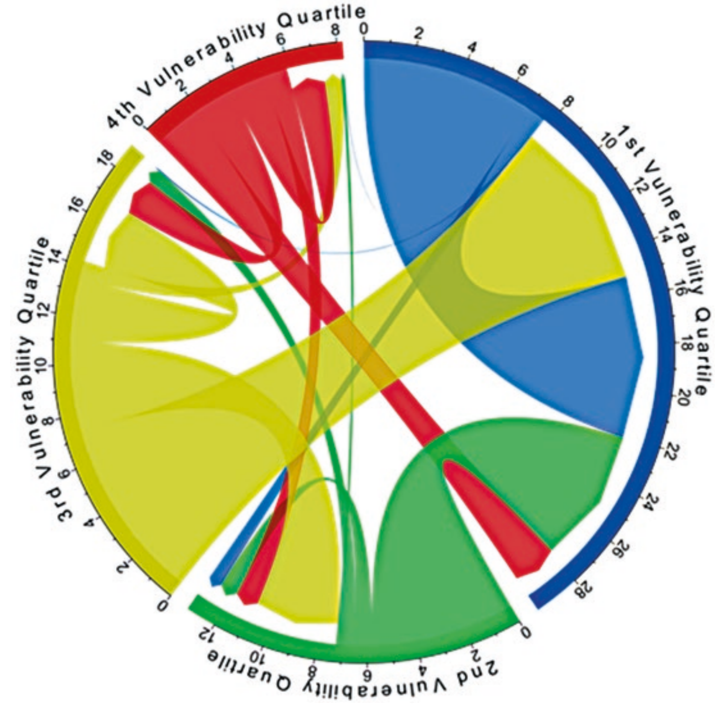


Fig. 1 Bilateral migration flows between and within climate vulnerability quartiles: 2010–2015. Quartiles from first to fourth represent increasing vulnerability to climate change. Numbers and tick marks on periphery are counts of out- and in-migrants in units of millions. Migration flows and directions are represented by arrowed cords. (Source: Fig. 6. Grecequet et al. 2017; http://www.mdpi.com/sustainability/sustainability-09-00720/article_deploy/html/images/sustainability-09-00720-g006.png; caption modified)

1.9% for each percentage increase of food insecurity, while "*higher levels of undernourishment contribute to the occurrence and intensity of armed conflict*" (World Food Programme 2017).

However, the clear relationships between climate trends, or their extremes, and conflicts driven by scarcity of essential resources, which are supposed to induce migrations, are still uncertain (Brzoska and Fröhlich 2016). Conflicts are not only direct drivers of climate-related migrations because of resources scarcity, but they can be also a consequence of climate vulnerability and increased competition for natural resources (Hsiang et al. 2013). Extreme climate events, such as recurrent floods but especially prolonged droughts and irreversible land degradation, may intensify the process of displacements and out-migration to a point that fast and large waves of migrants are not smoothly absorbed in destination countries, and this can ultimately produce security risks and make conflicts more likely in those receiving regions with a lack of stable structures and institutions to prevent or mitigate migration-induced resource scarcity. This condition can be exacerbated by ethnic tensions, distrust and demolition of social capital (Reuveny 2007). Further, Ghimire et al. (2015) found for example that displacement of people due to floods is not a cause of new conflicts but rather contributes to prolong existing conflicts all around the World. This is even truer when the high vulnerability to climate change coincides with other drivers, such as ethnic polarization, weak political structures and low levels of economic development (Brzoska and Fröhlich 2016).

3 The Trans-Mediterranean Migration Routes

To seize the importance of the challenge linked to migration, resources and climate, one should never dismiss the geopolitical context that conditions it. From this perspective, in fact, the Trans-Mediterranean region represents a critical juncture of two neighboring worlds defined as much by current asymmetries, as well as by their long-standing economic, political and socio-cultural linkages.

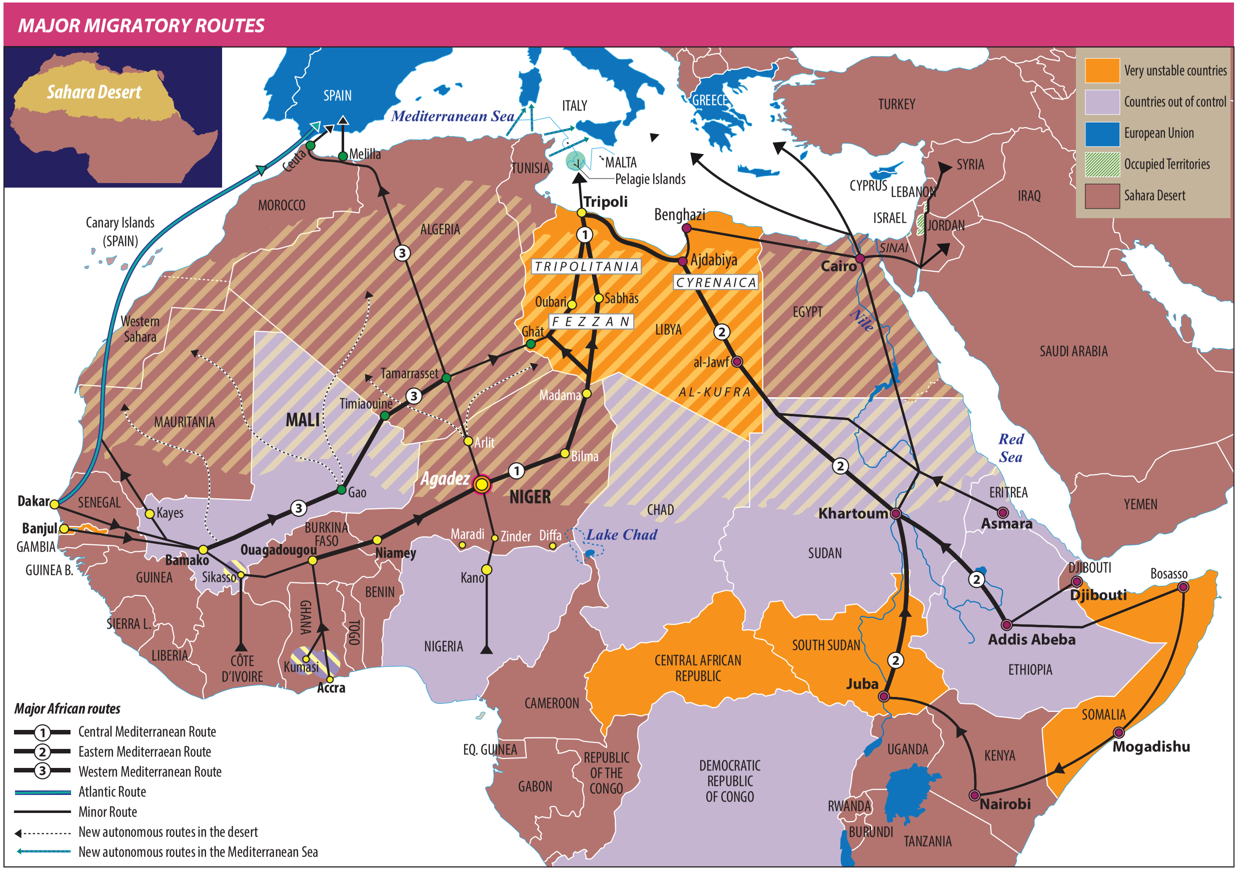
For what concerns Europe, frictions, potential conflicts and persistent migratory flows are having a significant impact on its culture and identity. This pattern is set to endure especially if the Old Continent will continue to highlight a visible lack of trust in its institutions and even in the possibility of a common approach to common challenges. In the meantime, Africa and the South-East Mediterranean countries are struggling with the greatest instability factors of our times, such as wars, terrorism, widespread poverty and the consequences of climate change on agriculture and food, which undermines their chances of economic and social development.

Within this picture, migration flows have become factors of interdependence between the two shores of the Mediterranean (Fig. 2). As recent experience shows, they can be sealed for some time but not forever, as they are capable of reacting promptly to political and economic shifts occurring in the countries of origin, transit and destination.

Paradigmatic, in this sense, the resumption of the migration route from Morocco to Spain in 2018, which has surpassed the Central Mediterranean route as the principal transit corridor for African migrants eager to reach Europe.

In the early 2000s, the prominent role of Spain as one of the main entry points of migrants to Europe contributed to consolidating the so-called West Mediterranean and the Atlantic routes. The popularity of this route peaked in 2006, when approximately 32,000 migrants landed in Spain, most notably from West Africa. However, the entry into force of bilateral agreements between the governments of Spain, Senegal and Mauritania contributed to considerably reducing these flows. In 2016, 10,631 attempts of illegal border crossing were detected between Spain and Morocco (mainly through the Spanish enclaves of Ceuta and Melilla in Africa), while entries via the Atlantic route were just 671.

Meanwhile, the popularity of the Central Mediterranean Route began to grow considerably, until it skyrocketed following the collapse of the Ghaddafi regime in Libya (2011) and the failure of the subsequent state-building process. With its branches drawing deeply into sub-Saharan Africa, this route prompted an unprecedented



Sources: Frontex, Europol, Icmpd, Unhcr, Unodc and authors' elaboration

Fig. 2 Major migration routes over the Trans-Mediterranean region. Source: Report "Food and migration: Understanding the geopolitical nexus in the Euro-Mediterranean" (https://www.foodandmigration.com/)

upsurge of arrivals by sea in Italy: from about 43,000 in 2013, to 170,100 in 2014, 153,842 in 2015, 181,436 in 2016, and 119,369 in 2017 (UNHCR Italy data portal[4]). Nigeria and Eritrea were the most represented countries of origin. It was the natural consequence of the absence of any unitary authority in Libya, which greatly favored the role of the North-African country as a transit corridor for the flows directed towards Europe, whose push factors were the most disparate. From the presence of authoritarian regimes and systematic human rights abuses in countries of origin such as Eritrea and Gambia, to the state collapse and widespread insecurity in Somalia or the impact of the economic crisis in Nigeria.

The picture has started to change once again since mid-summer 2017, when volumes of migration through the Central Mediterranean shrank abruptly. This was widely seen as the result of the co-option of Libyan militias into anti-smuggling efforts prompted by the Italian and other European Union (EU) governments, the first interception of migrants at sea by the revamped Coast Guard of Tripoli and the agreements reached with other transit countries, such as Niger. The same mechanism had already been adopted with Syrian, Afghan and Iraqi refugees who had entered Europe from Turkey until March 2016. Still, ongoing-armed clashes in key transit nodes in the Sahel region and the presence of consolidated smuggling networks suggest that also this scheme might be much more volatile than it appears, with new transit-Mediterranean routes being carved out promptly, including from Tunisia, Algeria and Egypt.

During the first 10 months of 2018, for instance, migrants landed on the Italian coast were only 21,935 (Italian Ministry of Interior, Department for civil liberties and immigration[5]), while in the same period Spain experienced the arrival of 43,519 migrants by sea, up from the 28,349 landed altogether last year (UNHCR Spain data portal[6]). The resumption of the Western Mediterranean route is therefore remaking Spain the first European country by number of migrant arrivals almost 20 years after the establishment of the Western route, with Madrid dealing with a very mixed humanity made of people from sub-Saharan Africa (Guinea, Mali, Ivory Coast), the Maghreb (Morocco, Algeria), and even the Middle East (Syria, Iraq).

Overall, the current management of migratory flows amounts to a veritable time bomb (Raineri 2018). Current trends suggest that sub-Saharan Africa is trapped in a Malthusian vicious circle, where poverty nourishes hunger, malnutrition and high infant mortality which, coupled with high fertility, imply a high rate of growth that generates even more poverty (Livi Bacci 2018). The high number of variables at play makes it hard to come out with reliable forecasts, and obliges one to draw on existing trends and likely scenarios. Within this context, climate change remains an important factor to assess the vulnerability of countries of origin, transit and destination of migrants.

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[4] https://data2.unhcr.org/en/situations/mediterranean/location/5205

[5] http://www.interno.gov.it/it/sala-stampa/dati-e-statistiche/sbarchi-e-accoglienza-dei-migranti-tutti-i-dati

[6] https://data2.unhcr.org/en/situations/mediterranean/location/5226

Because the climate-geopolitics-migration *nexus* is both complex and spatially heterogeneous across the Trans-Mediterranean region, and it depends profoundly on the differential vulnerability of places and populations, it becomes essential improving the knowledge about the likely association between the resources' exposure and (eco)systems' sensitivity to climate change hazards, which potentially contributes to worsening migrations and/or conflicts in all the interested countries (origin, transit, destination).

4 Data and Methods

4.1 Geographical Context

The analyses developed in this chapter are concentrated on the Trans-Mediterranean region of migrations, encompassing the Mediterranean basin and part of its bordering continents (Central to South Europe, South-West Asia and Africa). As described above, this area recently deserved particular attention due to the people involved and issues triggered: institutional incapacity and divergences, human rights, cultural diversities, social instabilities and conflicts, employment conducts, poverty and health problems. Moreover, also the spatio-temporal variability of routes makes this region particularly interesting: African migratory routes, which often follow the ancient transit roads used for trade of every kind, starting with food and the other natural products, evolve constantly due to the changing intensity of push and pull factors, as well as the enforcement policies of local governments, which are effectively subsidized by some European countries.

The spatial domain of the analysis has been set to cover five regions, each comprising several countries, in some cases grouped for the successive discussion so to consistently address changes and re-arrangements of boundaries occurred over time (e.g. Sudan,[7] Former Yugoslav Republic). The regions and countries analyzed are (in alphabetical order)[8] (Fig. 3):

- *Central Europe (CE)*: Austria, Belgium, Luxembourg, **France**, **Germany**, Netherlands, Switzerland.
- *Mediterranean Europe (MedE)*: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Greece, **Italy**, Kosovo, Macedonia, Malta, Montenegro, Portugal, Romania, Serbia, Slovenia, **Spain**.
- *Middle East (ME)*: Armenia, Azerbaijan, Bahrain, Georgia, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, **Turkey**, United Arab Emirates, Yemen.

[7] South Sudan was comprised because country level data are available for the former Sudan according to the time period analysed.

[8] Excluded: Liechtenstein, Andorra, Gibraltar, San Marino, Vatican City because of their limited surface area.

Fig. 3 Map of the domain, regions and countries

- *North Africa (NA)*: **Algeria**, **Egypt**, Libya, **Morocco**, South Sudan, Sudan, Tunisia, Western Sahara.
- *West Africa (WA)*: Benin, **Burkina Faso**, Gambia, Ghana, Guinea, Guinea-Bissau, **Ivory Coast**, Liberia, **Mali**, Mauritania, **Niger**, **Nigeria**, Senegal, Sierra Leone, Togo.

On the agricultural side, the analysis from the regional level was also focused to the 13 major players above reported in bold.

From a quick scan of the domain considering the ND-GAIN approach mentioned in Sect. 2, it seems that combining *vulnerability* to climate change hazards and other global challenges (such as, food, water, health, ecosystem services, human habitat and infrastructure) with the *readiness* to build climate change resilience, the average index is greater (worse) for the Trans-Mediterranean region than for the globe (50 vs. 48). Looking at Fig. 4, referring to the year 2016, more than 30% of the countries in the domain fall in the category "high vulnerability and low readiness" (red triangles; mostly Africa and Middle East countries), while another 13% have or high vulnerability (blue rhombus) or low readiness (yellow squares) but they are counterbalanced by their high readiness or low vulnerability, respectively. The northernmost countries of the domain in general have low vulnerability and high readiness (green circles).

Based on the previously mentioned "Food Insecurity & Climate Change" initiative, the Table 1 reports the percent changes (positive = increase; negative = decrease) of food insecurity expected for those countries matching with our study domain. Among the different combination among emission level (low, intermediate, high) and adaptation degree (high, low, none) and time frames (2050 and 2080), we selected the two extremes. A general increase in food insecurity is expected, especially in the long-term scenario with high emissions and low adaptation.

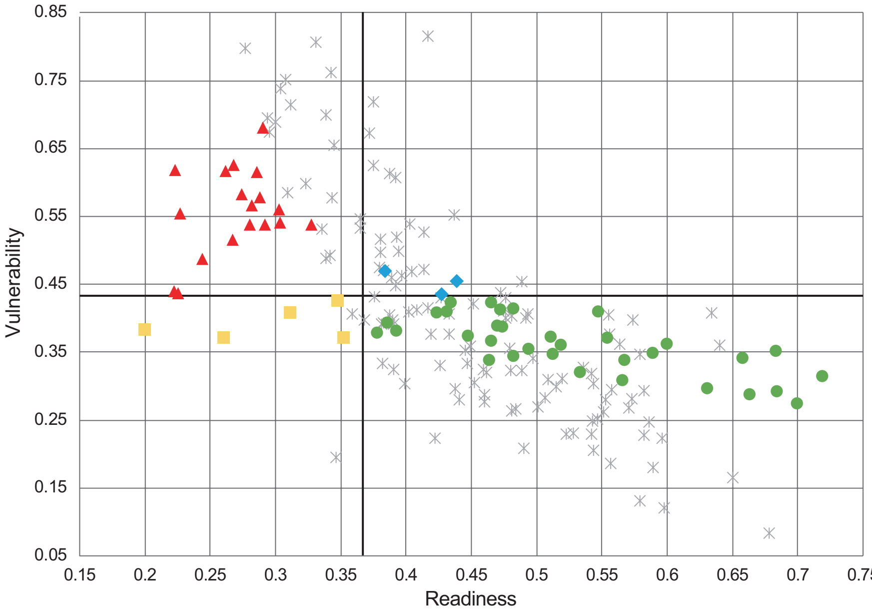

Fig. 4 Classification of Vulnerability and Readiness of countries according to the ND-GAIN approach. Colored symbols represent different degrees (low vs. high) of vulnerability (ordinate) and readiness (abscissa), within quadrants distinguished in function of the median values of Vulnerability and Readiness calculated across all the years (black horizontal and vertical line, respectively). Grey symbols are all other world's countries not considered in the study. (Elaborated from http://gain.nd.edu/our-work/country-index/matrix/)

4.2 Methods and Data for the Historical and Future Analysis

For a comprehensive analysis of the climate-water-food vulnerability across the Trans-Mediterranean region, first average (observed and projected) trends of precipitation and temperature are analyzed. Then, water resources are addressed in terms of average trends of the superficial water cycle component (runoff) and food security is analyzed by looking at agricultural yield variability for selected crops.

4.2.1 Climate

Concerning the historical climate analysis, the most consolidated and freely accessible data were considered about two atmospheric variables: precipitation and 2-m air temperature (simply "temperature" hereafter). Spatially interpolated (gridded) observational time series on these variables were available through the Climate Research Unit (CRU) dataset TS v4.0, at 0.5° × 0.5° resolution (ca. 50 km × 50 km) and with a monthly time step from 1901 to 2015 (https://crudata.uea.ac.uk/cru/data/hrg/; Harris et al. 2014). While the spatial resolution is largely valuable for global to sub-continental scale studies, the monthly resolution speed-up the investigation of intra-annual and inter-annual trends.

Table 1 Percent changes in food insecurity vulnerability

Region	Country	2050Low emissionsHigh adaptation	2050High emissionsNo adaptation
Mediterranean Europe	Serbia	2	36
	Bosnia and Herzegovina	1	33
	Montenegro	1	38
	Albania	2	48
	Macedonia	4	47
North Africa	Morocco	18	90
	Algeria	10	76
	Egypt	18	85
	Sudan	5	24
	South Sudan	−2	25
West Africa	Mauritania	2	60
	Senegal	10	91
	Gambia	11	79
	Guinea Bissau	11	82
	Guinea	1	91
	Sierra Leone	2	52
	Liberia	1	44
	Cote d'Ivoire	−2	25
	Mali	−1	79
	Burkina Faso	−5	20
	Ghana	−1	21
	Togo	−5	18
	Niger	−8	12
	Benin	−2	23
	Nigeria	−5	24
Middle East	Azerbaijan	1	42
	Iraq	9	83
	Syria	6	58
	Lebanon	7	82
	Jordan	8	102
	Yemen	10	58
	Palestina	8	102

Own elaboration based on data extracted from "Food Insecurity & Climate Change" initiative maps (https://www.metoffice.gov.uk/food-insecurity-index/). N.B. The 'low emissions' scenario represents a rapid and sustained reduction in future global greenhouse gas emissions resulting in an increase in global average temperature of around 2 °C above pre-industrial levels by the end of the twenty-first century; this scenario is also known as RCP2.6. The 'high emissions' scenario represents considerable future increases in global greenhouse gas emissions resulting in a rise in global average temperature of 4 °C or more above pre-industrial levels by the end of the twenty-first century; this scenario is also known as RCP8.5. Concerning adaptation, the 'high adaptation' scenario corresponds to an increase (or decrease) of approximately 10–15% in the adaptation (sensitivity) for 2050s compared to the present-day, and a further increase (decrease) of approximately 10–15% in the adaptation (sensitivity) for 2080s compared to the 2050s. The 'no adaptation' scenario maintains the sensitivity and adaptive capacity components of the index at the present-day level

Concerning the future climate analysis, the model experiments from the phase 5 of the Coupled Model Intercomparison Project (CMIP5) (Taylor et al. 2012) were first considered. However, impact studies rarely use climate model outputs directly because they exhibit systematic error (i.e. bias) resulting from sub-grid scale parameterizations, simplified physics and/or incomplete knowledge of climate system processes (Cannon 2016; Sippel et al. 2016). Hence, the data obtained after applying a bias-correction method (Hempel et al. 2013) developed within the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP Fast-Track) were used. For 5 out of 6 Earth System Models (ESMs) considered here, data are available publicly and were downloaded via the ESGF server (https://esg.pik-potsdam.de/search/isimip-ft/); while in case of the CMCC-ESM,[9] the above-mentioned bias-correction method was implemented over raw data. A multi-model ensemble approach was then adopted, relying on the fact that multi-model average often outperforms any individual model compared to observations. To isolate the impact of different socio-economic scenarios on climate, two different Representative Concentration Pathways (RCPs) were selected: the RCP 4.5 and RCP 8.5 (Van Vuuren et al. 2011). The RCP 4.5 stabilizes radiative forcing at 4.5 Wm^{-2} in the year 2100 without ever exceeding that value, while the RCP 8.5 predicts a rising of the radiative forcing pathway leading to 8.5 Wm^{-2} top-of-atmosphere forcing by 2100.

Two main climate indicators were calculated from observed and projected monthly series, the Annual Mean Temperature (MAT, °C) and the Annual Precipitation Amount (APA, mm/year). For the historical period, they were computed for each year from 1951 to 2015. From them, trends of MAT (°C/year) and APA (mm/year) were also calculated and averaged at macro-regional and country level for the periods 1951–2015, 1971–1990 and 1995–2014. Finally, anomalies were quantified and again averaged at macro-regional and country level for the future periods 2016–2035 (centered on 2025) and 2041–2060 (centered on 2050) vs. the recent period 1996–2015 (centered on 2005).

4.2.2 Water Resources

Globally, water resources are highly shared among different human and natural sectors and systems. First of all, water is used by agriculture to cover Crop Water Requirements (CWRs). Even if such water needs are satisfied thanks to precipitation, especially in case of rainfed agriculture, many cultivations need additional water if and when rainfall is not enough to cover CWRs; thus, water is withdrawn for irrigation from superficial and underground sources. Under global changes, an increase of irrigation is largely projected with impacts on the whole water resource sector (Mancosu et al. 2015). Further, as meteorological droughts often lead to hydrological and agricultural droughts (lack of water in superficial to underground water bodies, and of moisture in the soil), the fulfillment of CWR is at risk from both the rainfed and irrigation side (Ronco et al. 2017).

[9] https://www.cmcc.it/models/cmcc-esm-earth-system-model

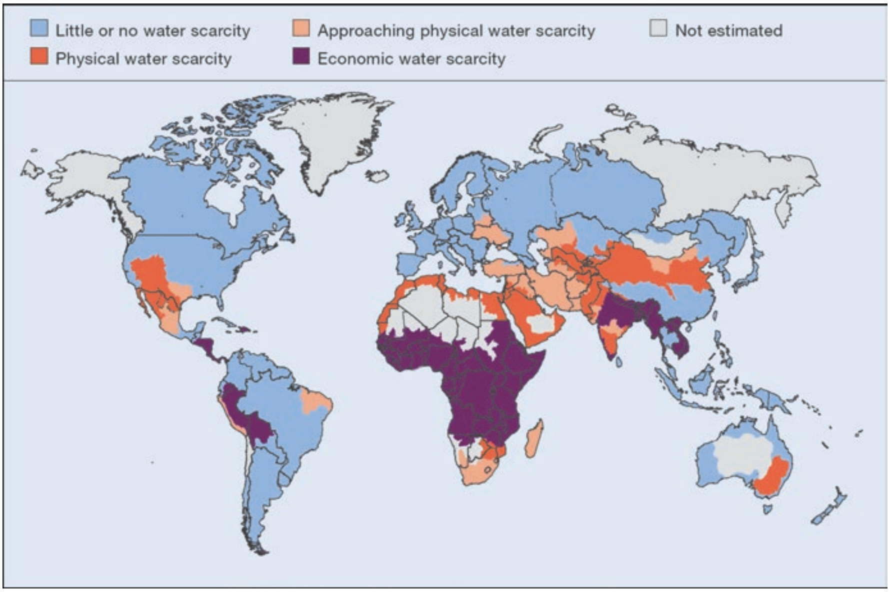

Fig. 5 Water scarcity levels in 2007. "Little or no water scarcity" means that less than 25% of water are withdrawn from rivers for human purposes. "Physical water scarcity" indicates that more than 75% of river flows are withdrawn for human uses (agriculture, industry, energy, domestic purposes). "Approaching physical water scarcity" means that more than 60% of river flows are withdrawn and thus these basins will experience physical water scarcity in the near future. "Economic water scarcity" indicates that, although less than 25% of water from rivers withdrawn for human purposes, malnutrition exists. (Source: figure as modified in Mancosu et al. (2015) from IWMI 2007)

As a comprehensive view, Fig. 5 shows the levels and types of water scarcity at the basin level assessed in 2007, showing that the dimensions of water resource scarcity are not only physical but also economic (thus relating to the capacity to deploy the water resource available locally due to socio-economic-institutional constraints).

This is why attention was given, in this chapter, also to the observed and projected changes in water availability, as proxy of water security in the Trans-Mediterranean region. In this sense, reanalysis datasets are valuable to provide runoff data at daily scale to assess likely changes on surface water availability, which is then drained along the river network. Reanalyses are observationally constrained model outputs, i.e. meteorological station measured variables are directly assimilated in the global circulation models, so that gridded products can be assumed representative of real conditions even in areas not covered by stations. Given the importance of the land component in the hydrological cycle, mainly in terms of topographic characteristics, the reanalysis dataset offering the finest spatial resolution (0.75° lat × 0.75° lon) at the time of the analysis (ERA-Interim; https://www.ecmwf.int/en/research/climate-reanalysis/era-interim) was selected for this study, with data available from 1979 to 2015.

For the future, changes in water availability will depend on changes in the volume, variability and seasonality of runoff (IPCC 2013). To this aim, runoff projections from four hydrological models participating to the ISI-MIP Fast-Track experiment (MPI-HM, WaterGAP, H08 and PCR-GLOBWB; https://www.isimip.org/impactmodels/), forced with five bias-corrected ESMs data under the RCPs 4.5 and 8.5, have been analyzed.

Moreover, to take into consideration the impact of human activities, projections derived from naturalized streamflow characterized by absence of water use vs. simulations used to quantify anthropogenic pressures on water resources under current socio-economic conditions were considered.

As indicator, the mean annual runoff (MAR) was first computed for each year from 1979 to 2015. After creating an ensemble by averaging across both ESMs and hydrological models, historical trends of MAR (mm/year) were calculated and averaged at macro-regional and country level for the whole period. Then, also the anomalies in MAR (mm/year) were calculated and averaged at macro-regional and country level for the future time frames considered (2016–2025 and 2041–2060) vs. the reference period 1996–2015.

4.2.3 Agriculture

Agriculture is arguably the sector most affected by climate change (Rosenzweig et al. 2014): changes in temperature, atmospheric carbon dioxide (CO_2), and the frequency and intensity of extreme weather could have significant impacts on crop yields. Dealing with drought episodes could become a challenge in areas where rising summer temperatures cause soils to become drier. Although increased irrigation might be possible in some places, in other places water supplies may also be reduced, leaving less water available for irrigation when more is needed (Evans and Sadler 2008).

For that concerning the analysis in agricultural production, as proxy of food security, the extensive and continuously updated FAOSTAT database (http://www.fao.org/faostat/en/#home) allows accessing data on several agriculture-related topics like primary crop production and yield (production over harvested area). Yield data for all the countries considered[10] for four crops, of which three cereal (maize, rice, wheat) and one leguminous/oil (soybean) crops. These crops were selected as a good compromise among several considerations:

- They account for a significant share of the world's agricultural production as well as in the study domain, within the macro-categories of cereals and leguminous/oil crops;

[10] No data for Bahrain is available in FAOSTAT.

– They are important in covering both energy (maize, wheat) and protein (rice, soybean) supply from a nutritional point of view;
– They play a role in the food-feed-energy debate as they are used to feed livestock (Di Paola et al. 2017) and for biofuel production.
– There are available scientifically sound experiments and comprehensive datasets on future projections of yields for these crops.

According to the temporal coverage of crop production data, first the trends of yields were assessed from 1961 to 2014 and then for two 20-years periods 1971–1990 and 1995–2014, trying to identify a sort of variability in yield that could be related to shorter term (e.g. annual) climate variability, in particular looking at the occurrence of drought episodes, as established from literature and with focus on those countries designated as major players.

Impacts of future climate change on crop productivity were then calculated using global yield projections for the four above crops building on the results from the pDSSAT and the LPJmL crop models participating to the ISI-MIP Fast-Track initiative, driven by the same five ESMs and under both the RCP 4.5 and 8.5 used for the analysis on water resources. For each crop, both a full irrigation scenario ("irr") and a no-irrigation scenario ("no irr") were considered.

Results are provided in terms of crop yield anomalies aggregated at country and macro-regional levels for the future time frames considered (2016–2025 and 2041–2060) vs. the reference period 1996–2015.

5 Results

The main outcomes of the analysis suggest that, during recent decades, while warming appears rather homogeneous, wetting and drying trends are more fluctuating although finally leading to a clear decrease of water availability in the Trans-Mediterranean region, contrasting with the global increase. In this context, even if agricultural production showed consistent yield increase on the longer term for the four crops analyzed (wheat, maize, soybean, rice), such increasing trends are lost, or however lose significance, if considering shorter time frames: this suggests a rising influence on crop yields of inter-annual climate variability.

Concerning the future, besides a temperature anomaly predicted to increase homogeneously (up to 1.44 ÷ 2.14 °C in the period 2041–2060) and in line with global trends, a slight increasing or even decreasing trend of rainfall (ranging from +0.5% to −1%) is predicted according to the different emission scenarios and periods considered. This is opposite to the increase by ~1% and ~4% that is expected in the near future (2016–2035) and far future (2041–2060), respectively, at the global level. Results about precipitation anomaly are well reflected in the hydrological cycle, suggesting that the study region will face a general decrease of water availability, with an expected drying from 2 to 7% in terms of drop in mean annual runoff generation.

In case of both rainfed and irrigated agriculture, the yields of the key energy and protein crops considered are threatened by the combination of new climate and water resources' regimes, with the increase in irrigation needs that will pose additional competition on the share of water resources among different sectors as well as impact on water availability in adjacent countries.

In the following paragraphs the main results concerning the climate dynamics and the likely impacts on water resources and agriculture are described more in detail.

5.1 Climate

The trend in Mean Annual Temperature (MAT) from 1951 to 2015 was 0.022 °C/year on average across the full domain (in line with the global tendency) and rather homogeneous across the region. Looking at the shorter 20-year periods, the warming trend was higher (0.040 °C/year, even higher than the global trend of 0.033 °C/year) during 1971–1990 in the south-westernmost side of the domain. Along the 1995–2014 period, the warming trend in the region was around 0.029 °C/year, slightly higher than the global trend of 0.026 °C/year, and more accentuated in the eastern side of the domain.

The trend of changes in Annual Precipitation Amount (APA) along 1951–2015 was −0.55 mm/year on average across the full domain, and +0.16 mm/year as global average, reflecting not only an opposite direction but also a stronger magnitude of modifications in the study region. Looking at the shorter time horizons, the drying trend in the area was stronger along 1971–1990 (−1.27 mm/year, even higher than the global trend of −1.03 mm/year), while during 1995–2014, a wetting trend dominated for around 0.36 mm/year, however lower than the global trend of 0.48 mm/year.

Figure 6 shows the spatial variability, among countries, in MAT and APA trends along 1951–2015.

By processing the CMIP5 bias-corrected simulations, results for the future period suggest across the Trans-Mediterranean region a spatially homogeneous warming. A substantial warming (by 0.61 ÷ 0.77 °C according to the different emission scenarios considered) might affect the region in the short-term period 2016–2035 compared to the reference period 1996–2015. The temperature is predicted to increase homogeneously (by 1.44 ÷ 2.14 °C) in the farthest period considered 2041–2060, with a warming peak in the Middle East sub-region (+2.32 °C).

The annual rainfall at global level is predicted to increase by ~1% (~9 mm) in the near future (2016–2035) and by ~4% (~30 mm) in the far future (2041–2060) while a weaker wetting up to a drying (ranging from +0.5% to −1%) is predicted in the Trans-Mediterranean region, function of the different emission scenarios and periods considered. At the sub-regional level, the Mediterranean Europe and the Middle East are expected to experience the strongest rainfall decrease (~7.1% corresponding to 57 mm and ~7.4% corresponding to 18 mm, respectively) according to the

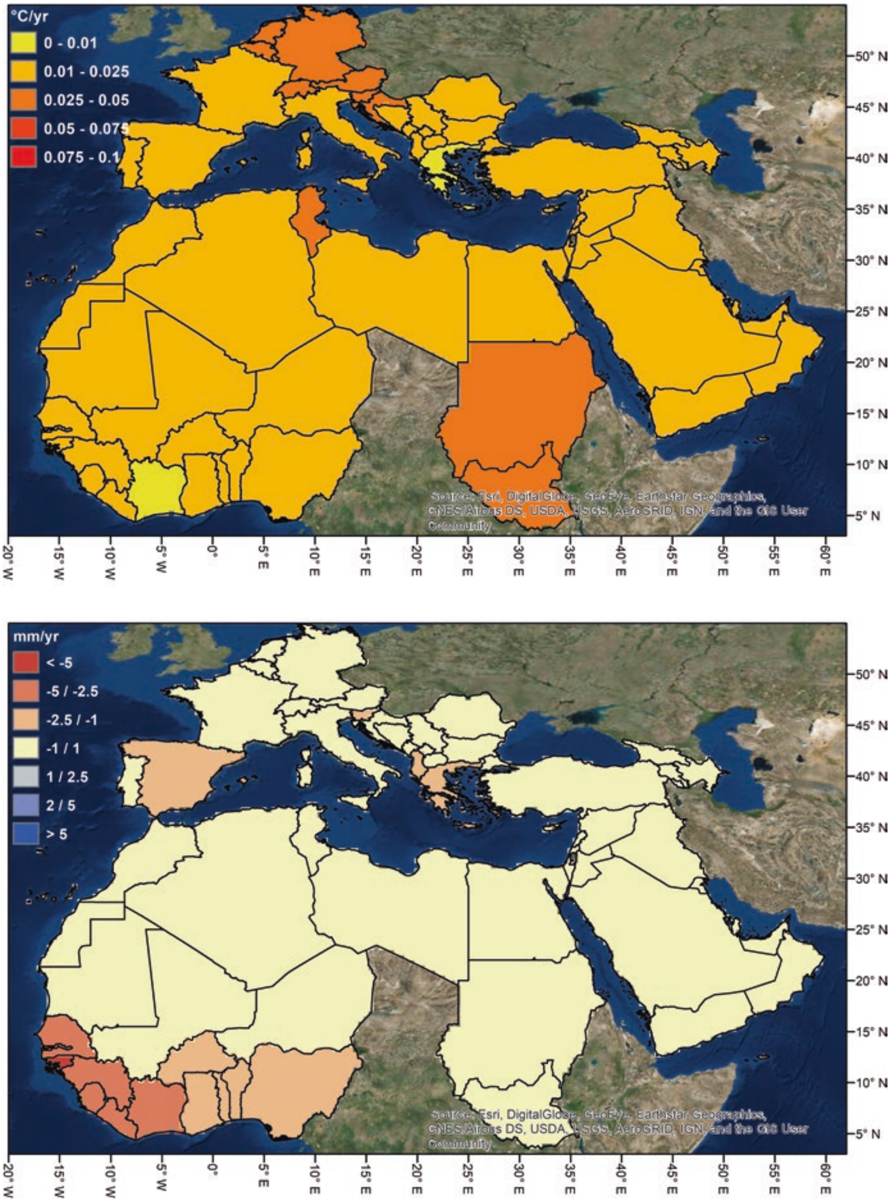

Fig. 6 Trends in MAT (°C/year) (top) and APA (mm/year) (bottom) for the period 1951–2015

Table 2 Anomalies in MAT (°C) and APA (%) for the periods 2016–2035 (2025, near future) and 2041–2060 (2050, far future) vs. the reference period 1996–2015 (2005), and for the two RCPs examined

	MAT (°C)				APA (%)			
	RCP 4.5		RCP 8.5		RCP 4.5		RCP 8.5	
Anomaly vs. 2005	2025	2050	2025	2050	2025	2050	2025	2050
Global	0.83	1.85	0.90	2.57	1.26	4.37	1.11	3.79
Regional	0.61	1.44	0.77	2.14	−0.79	0.42	0.50	−1.38
Central Europe	0.75	1.51	0.81	1.94	1.68	−3.19	−0.39	−1.68
Mediterranean Europe	0.66	1.50	0.75	2.09	−3.78	−5.08	−1.33	−7.13
Middle East	0.65	1.57	0.83	2.32	−1.69	−4.12	−0.45	−7.40
North Africa	0.57	1.38	0.76	2.15	−0.99	−0.38	−0.72	−2.28
West Africa	0.58	1.38	0.72	2.06	1.51	5.74	2.38	4.52

RCP 8.5 scenario for the far future period 2041–2060. In contrast, the annual precipitation over West Africa is predicted to increase for about 1.5 ÷ 2.4% (equal to a gain of ~10 ÷ 16 mm) in the near future, and this wetting is confirmed when analyzing the far future with an average (between RCPs) precipitation gain of more than 5% on average between RCPs. Table 2 reports the expected future anomalies (per RCP scenario and time frame) at global, regional and macro-regional level.

5.2 *Water Resources*

Across the globe, an overall increasing trend of the mean annual runoff (MAR) was observed, around 0.6 mm/year, while in the Trans-Mediterranean region a much higher decrease (2 mm/year) was registered. This reflects what observed for precipitation (APA) on the longest period analyzed (1951–2015). Figure 7 shows the country average of MAR trends, with Sub-Saharan Africa and almost half of non-African Countries suffering from a decrease in runoff larger than 1 mm/year (red tones).

The analysis on future projections (Table 3) show that the Trans-Mediterranean region is expected to dry in terms of mean annual runoff (MAR) generation over land. Such drying is more marked in the Mediterranean Europe, Middle East and North Africa with a decrease ranging from 14 to 18% in 2041–2060 vs. 1996–2015, under the RCP 8.5. Again, the globe and the whole study domain have an opposite behavior, wetting the former and drying the latter (results not shown).

5.3 *Agriculture*

Annual trends in yield changes, and related significance, for the four crops selected (wheat, maize, rice, soybean) are shown in Table 4 for “major player” countries.

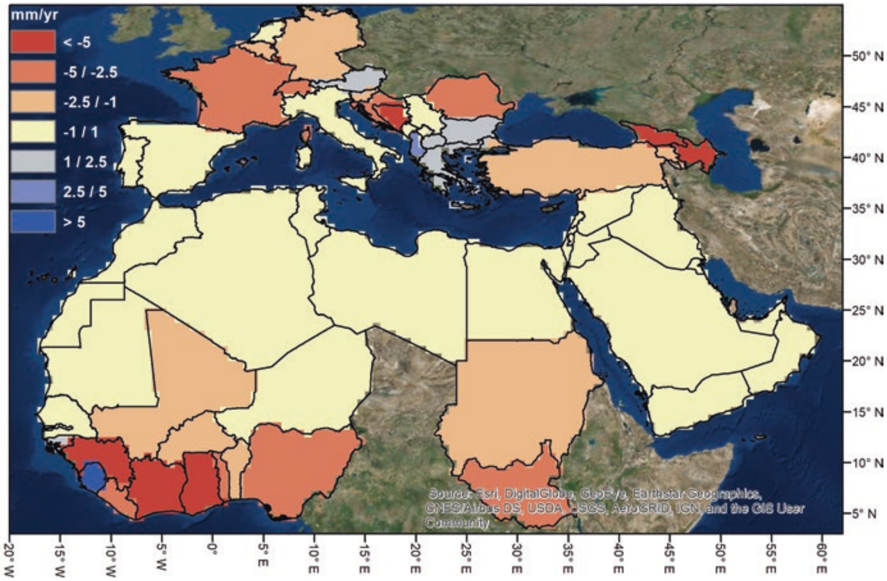

Fig. 7 Country average of trends in MAR (mm/year) along the period 1979–2015

Table 3 Anomalies of MAR (%) for the periods 2016–2035 (2025, near future) and 2041–2060 (2050, far future) vs. the reference period 1996–2015 (2005), and for the two RCPs examined

	MAR (%)			
	RCP 4.5		RCP 8.5	
Anomaly vs. 2005	2025	2050	2025	2050
Central Europe	−6.12	−7.81	−3.10	−8.88
Mediterranean Europe	−8.51	−13.09	−2.83	−13.74
Middle East	−2.61	−7.71	−3.47	−14.18
North Africa	−5.86	−13.83	−9.20	−18.12
West Africa	1.03	3.63	−0.30	1.00

On the shorter to inter-annual time frame, a long-lasting positive impact of technological development (positive trends) can leave the floor to the influence of climate variability (negative trends). This was confirmed by comparing the peaks of yield losses with the occurrence of isolated episodes or prolonged periods of drought as reported in literature (Spinoni et al. 2015; De Pauw 2005; Masih et al. 2014). For example, in Spain, peaks of negative wheat yield anomaly match with droughts conditions in 1981, 1995, 2005 and 2012. For Italy, a long period of negative wheat yield anomaly occurred from 1997 to 2003, classified as a long and severe drought period. From 2000 to 2012, in general, higher drought frequency and duration were found in France and Italy, and FAOSTAT data revealed along this period half and two-thirds of years with negative yield anomalies of maize for France and Italy, respectively, and also of soybean for Italy. Concerning Germany, losses in wheat and maize yield occurred around 1976 and 2003, both classified as drought periods.

Table 4 Trends (hg/ha/year) in yield for selected crops across the three periods analyzed

		Med EU		CE		NA			ME	WA				
Crop	Period	Italy	Spain	France	Germany	Algeria	Egypt	Morocco	Turkey	Burkina Faso	Cote d'Ivoire	Mali	Niger	Nigeria
Wheat	1961–2014	**345**	**427**	**898**	**976**	**203**	**937**	**158**	**278**			**433**	**196**	−119
	1971–1990	223	**709**	**1293**	**1180**	74	**897**	298	**362**			−72	410	−143
	1995–2014	**478**	488	0	367	**421**	398	462	**386**			**1029**	385	−506
Maize	1961–2014	**1264**	**1842**	**1261**	**1283**	**622**	**1147**	−5	**1277**	**260**	**357**	**261**	**76**	**182**
	1971–1990	**1362**	**1801**	**1290**	**1286**	201	**1010**	71	**1382**	208	144	293	−85	262
	1995–2014	−65	**1490**	544	**1158**	850	511	177	**2898**	137	168	660	237	286
Rice	1961–2014	**350**	**318**	2044		**−406**	**1129**	**588**	**740**	**321**	**254**	**68**	**660**	**288**
	1971–1990	625	108	**1411**		348	**693**	611	342	**633**	−38	−22	1424	**810**
	1995–2014	347	**530**	10,780		36	**706**	**1754**	**2068**	96	**618**	73	**675**	−395
Soybean	1961–2014	**341**	**288**	**268**			**400**		**619**	268	10	**−259**		**143**
	1971–1990	**578**	**544**	399			**973**		401	56	518	42		−1
	1995–2014	−189	**449**	123			**480**		**996**	−80	−67	**−647**		171

In **bold** significant trends

A drought period was detected in Turkey along 1999–2000, when cereal production fell by 6% if compared to the 5-year average (De Pauw 2005).

In the same 1999, cereal crop was reduced to 8 Mtons (−31% of the previous year) across Morocco, Algeria and Tunisia; the 2000 harvest was also below normal. Still in Morocco, approximately 1 Mha of cropland was affected by drought in 2001, forcing the country to import approximately 5 Mtons of wheat and allocate more than $500 million for cereal imports (FAO 2004). Other important events for Morocco were detected in 1994–1995, with the production of cereals dropping from 9.5 to 1.6 Mtons, and in 2006–2007, with production of cereals reaching only half of the normal level. According to Masih et al. (2014), Algeria was instead affected by an extended drought in 1983–1984 and to a less extent in 1972–1973, both seasons corresponding to negative anomalies in cereal yield.

Concerning West Africa, Masih et al. (2014) describe extended droughts during 1972–1973, 1983–1984 and 1991–1992: from FAOSTAT, negative maize yield anomalies occurred in key West African countries in the same periods, except in Burkina Faso in 1991–1992.

In Nigeria and Egypt, key producers of rice, related yields were affected by droughts in 1972–1973 and 1983–1984, still according to Masih et al. (2014). Similarly, the largest producer for soybean, Nigeria, experienced loss of yield during extended drought in 1983–1984 and 1991–1992.

In the future (Table 5), the regional scenarios of maize yield analyzed for the present work show a general decrease, the strongest one (12 ÷ 13%) projected for West Africa in the far future as average between RCPs and regardless if using or not irrigation. For Mediterranean Europe and secondarily for Central Europe, losses of maize yield (up to −7% in the far future for Mediterranean Europe) can be avoided, switching to increase only if irrigation is applied, thus strengthening the competition over diminishing water resources.

The future scenarios for wheat yield are driven by losses in West Africa (up to −26%), North Africa (−21%) and Middle East (−10%) in the far future without using irrigation. Even considering the irrigation scenario the anomalies in wheat production show a similar pattern for African countries, with a substantial decrease up to 18%, 14% and 11% in West Africa, North Africa and Middle East, respectively, along the far future scenario.

Soy cultivation, key also for climate mitigation strategies due to the production of biofuels, seems experiencing an overall decrease of yield across all the Trans-Mediterranean domain (up to 17% in the worst scenario—and under irrigation—for West Africa) while a significant increase is projected over Central Europe (well higher when irrigating) and a slight rising for the Mediterranean Europe (but only in case of using irrigation). This suggests the key role of water to maintain agricultural production.

Concerning rice yield, the Central and Mediterranean Europe should increase the productivity for around 39% and 12%, respectively, of historical yield under irrigation (lower yields in case of no irrigation have slightly lower increase), while the West Africa will experience the most pronounced decrease (around 11 ÷ 12%, regardless of irrigation).

Table 5 Anomalies in crop yield (%) for the periods 2016–2035 (2025, near future) and 2041–2060 (2050, far future) vs. the reference period 1996–2015 (2005), averaged across the two RCPs examined and separated in case of irrigation (IRR) or not irrigation (NO IRR) scenarios

	% change in crop yield	Maize		Wheat		Soybean		Rice	
	vs. 2005	2025	2050	2025	2050	2025	2050	2025	2050
IRR	Central Europe	6.22	6.90	0.37	−3.00	15.04	23.14	19.24	38.95
	Mediterranean Europe	−0.80	1.52	0.40	−1.99	2.59	1.90	6.39	12.00
	Middle East	−1.83	−5.33	−3.75	−11.25	−10.18	−11.23	−3.26	−10.83
	North Africa	−3.30	−7.29	−4.97	−14.16	−5.98	−14.86	−1.80	−8.27
	West Africa	−4.83	−12.09	−6.60	−18.08	−6.28	−16.54	−3.80	−12.30
NO IRR	Central Europe	1.85	−0.36	0.00	−3.43	6.60	4.51	17.08	33.00
	Mediterranean Europe	−1.16	−6.72	−0.43	−3.75	−1.45	−12.21	6.66	7.82
	Middle East	−3.06	−4.91	−2.97	−10.39	0.00	−1.85	2.50	2.50
	North Africa	−2.63	−7.89	−8.20	−20.54	−1.72	−8.62	−1.04	−2.08
	West Africa	−5.48	−12.77	−9.38	−26.04	−4.32	−11.11	−3.96	−11.23

6 Conclusions and Recommendations

The present study provides an overview of the likely climate change impacts on the past, present and future food security conditions that, combined with the geopolitical context of the Trans-Mediterranean area, can act as potential drivers of human migration across the region.

Take home messages of the analysis are that it is not only the area of origin and transit of Trans-Mediterranean migrations (African countries and Middle East) that will be increasingly affected by climate change hazards impacting on water and food systems, but also the (destination) European countries. This scenario constitutes not only a risk but also an opportunity for food production in the northern portion of the domain, as the modified climate conditions have the potential to increase suitability for new or currently minor cultivations around the Mediterranean basin. The southern Mediterranean countries will experience a decline in productivity for all crops analyzed if adaptation measures to climate change are not put in place rapidly. Adaptation includes a set of measures, at the international, national and community level. As shown in Dinesh (2016), finance, economic incentives, value chain initiatives (such as certification schemes and networks), national and local planning are critical for climate change adaptation and bring a number of societal co-benefits. Adaptation measures can also strengthen gender equality and social inclusion, especially for youth, and can be strengthen by indigenous knowledge to guide climate action by framing solutions based on local cultures.

Building resilience to climate change becomes crucial for the whole Trans-Mediterranean region. This also includes the development and implementation of climate change mitigation options, including change in diets to counteract the *nutrition transition* that the Mediterranean countries are experiencing and that involves a shift towards increased demand for animal-based foods, and processed foods rich in salt, sugar and fats. Climate action as well as food system transformation is critical for implementing the 2030 Agenda and achieving its 17 Sustainable Development Goals (SDGs),[11] adopted by 193 world leaders in September 2015 at an historic UN summit. The SDGs represent a universal framework of action for all countries, across different territorial scales, to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind. The SDGs already provide robust foundations for the development of climate change adaptation and mitigation strategies. However, the synergies among SDGs remain rather unexplored. The SDG 13 (*Climate Action*) is focused on mitigation of climate and its impacts, without considering migration dynamics in the policies to be formulated. From the other side, the SDGs 8 (*Decent Work and Economic Growth*), 10 (*Reduce Inequalities*) and 17 (*Partnership for the Goals*) mention the necessity to well plan and manage migration policies, without mentioning the challenges that climate change can bring on them.

[11] https://sustainabledevelopment.un.org/sdgs

Last but not least, when looking for climate change adaptation strategies and actions, since the range of likely future developments for the interacting human and natural systems is wide, a robust decision making should not neglect the consideration of the uncertainty, e.g. looking for options and solutions promising to perform well under as many scenarios as possible.

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Nutrition, Health and Dietary Trends

John L. Sievenpiper, Gabriele Riccardi, Camillo Ricordi, and Katarzyna Dembska

1 Nutrition and Global Non-communicable Diseases

Over the past several decades the world has seen a dramatic shift in the way people eat, drink and move (Popkin et al. 2012), leading to a public health crisis that threatens the economies of all nations, particularly developing countries: few countries are immune to the parallel rise of overweight, obesity, and non-communicable diseases (NCDs). NCDs, also known as chronic diseases, tend to be of long duration and are the result of a combination of genetic, physiological, environmental and behavior factors. The main types of NCDs are cardiovascular diseases (like heart attacks and

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_4

stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes (World Health Organization 2018).

A nutritional transition started in the 60s: diets are converging on what we often term the "Western diet" (Popkin et al. 2012) characterized by increased consumption of meat, dairy, sugars, fats and energy-dense food (Alexandratos 2006; Grigg 1995) and the decline in adherence to the so-called 'healthy diets' such as the 'Mediterranean diet'. Although highly heterogeneous among countries, the Mediterranean diet presents several common features: a high consumption of plant foods such as legumes, cereals, fruits and vegetables, nuts and seeds, low consumption of meat and dairy products, olive oil as main source of fat and moderate consumption of wine (Da Silva et al. 2009).

Simultaneously, the epidemiological transition with developments in healthcare and medicine, is drastically reducing mortality due to infectious disease, and extend average life expectancy, which accompanied by increasing prevalence of chronic and degenerative diseases which were more important causes of death today (Omran 2005).

The 2030 Agenda for Sustainable Development adopted at the United Nations recognizes NCDs as a major challenge for sustainable development. Heads of State and Government committed to develop national responses to the overall implementation of this Agenda, including to reduce by one third premature mortality from NCDs.

2 Evolution of Nutrition Guidelines: A Shift from Nutrients to Dietary Patterns

Nutrition remains the cornerstone of therapy for the prevention and management of chronic diseases. The Global Burden Disease (GBD), the largest comparative analysis of the 79 leading risk factors, confirms that poor nutrition is the single most important contributor to the burden of premature morbidity and mortality, accounting for more than 10% of disability adjusted life years (DALYs) especially from cardiovascular diseases and diabetes (Forouzanfar et al. 2016). If poor nutrition is combined with other modifiable lifestyle related risk factors, then it accounts for 25% of premature morbidity and mortality (Forouzanfar et al. 2016). The combination of a healthy dietary pattern with other low-risk lifestyle behaviours that include achieving and maintaining a healthy body weight, regular physical activity, smoking abstinence/cessation, moderate alcohol consumption, and moderate sleep duration is associated with >70% reduction in incident cardiovascular disease (Anderson et al. 2016) and diabetes (Ford et al. 2009; Hu et al. 2001; Mozaffarian et al. 2009).

2.1 Nutrient-Disease Risk Model

Identification of the specific dietary factors that explain disease risk reduction has been of great interest since the time of Hippocrates (Jouanna 2012) and the subject of intense clinical investigation for more than 250 years (Milne 2012). The earliest examples are of investigations of the causal role of specific nutrients (vitamins, minerals, essential amino acids, and essential fatty acids) in diseases of deficiency. An investigation of citrus fruit (vitamin C) for the treatment of scurvy in the Royal Navy by James Lind in 1747 is considered the earliest recorded example of a clinical trial (Milne 2012). Within 200 years of this discovery, the major vitamins and their deficiency diseases were identified: vitamin A (xerophthalmia) vitamin B1 (beriberi), vitamin B3 (pellagra), folate (anemia, spina bifida), vitamin C (scurvy), vitamin D (rickets), vitamin B12 (pernicious anaemia), iron (anemia), iodine (goiter), etc. Despite the incredible public health success of this reductionist model in the prevention of nutritional deficiencies (Mozaffarian et al. 2018), a focus on single nutrients for the prevention of chronic diseases has met with less success.

There are innumerable examples of nutrients supported by biologically plausible mechanisms and/or epidemiological observations that did not produce the anticipated benefits or even resulted in important harm. Large, carefully conducted randomized controlled trials and subsequent systematic reviews and meta-analyses of the available randomized controlled trials have shown that beta-carotene increases lung cancer mortality and all-cause mortality (Alpha-Tocopherol, Beta Carotene Cancer Prevention Study Alpha-Tocopherol Beta Carotene Cancer Prevention Study Group 1994; Omenn et al. 1996); vitamin E, prostate cancer incidence (Klein et al. 2011; Vinceti et al. 2018), selenium, diabetes incidence (Vinceti et al. 2018), antioxidants, all-cause mortality (Jenkins et al. 2018), and niacin, all-cause mortality (Jenkins et al. 2018), while fish oils (Abdelhamid et al. 2018), calcium (Jenkins et al. 2018), and vitamin D (Jenkins et al. 2018) have failed to demonstrate a cardiovascular benefit or mortality benefit. The same is true for a focus on single macronutrients (e.g. "low fat", "low carb", or "high protein"). Network meta-analyses of randomized controlled trials comparing diets of varying proportions of macronutrients show only minimal differences in weight loss between diets at 6 and 12-months of follow-up, suggesting that there is no one best macronutrient-based approach and adherence to anyone diet is the dominant consideration (Johnston et al. 2014). The culmination of these failures has been an important paradigm shift.

2.2 Dietary Pattern-Based Clinical Practice Guidelines

Clinical practice guidelines for nutrition therapy in obesity, diabetes, and cardiovascular disease have begun to move away from a focus on single nutrients to a focus on food and dietary patterns (Sievenpiper and Dworatzek 2013). These guidelines had been historically very macronutrient-centric, recommending a narrow acceptable macronutrient distribution range (e.g. 55% energy from carbohydrate and 30% energy from fat) that became progressively broader (45–65% energy from carbohydrate, <35% energy from fat and 15–20% energy from protein), as more emphasis was placed on quality over quantity of carbohydrate, fat, and protein (Sievenpiper and Dworatzek 2013). The transition to more dietary pattern-based recommendations has occurred with the recognition that a focus on single nutrients misses important nutrient-nutrient and nutrient-food (matrix) interactions that better explain chronic disease risk than single nutrients alone.

Dietary pattern-based clinical practice guidelines have provided clinicians, patients, and the public with a number of evidence-based options for the prevention and management of chronic diseases (Sievenpiper et al. 2018; Anderson et al. 2016). Although the evidence may be stronger for some dietary patterns, these guidelines consider the advantages and disadvantages of all dietary patterns for which evidence is available. The Mediterranean dietary pattern is a dietary pattern with some of the highest quality evidence for benefit. The Prevención con Dieta Mediterranea (PREDIMED) trial, a large Spanish multi-centre randomized trial of a Mediterranean dietary pattern in 7447 participants at high CV risk, showed that a Mediterranean diet supplemented with either extra-virgin olive oil or mixed nuts compared with a low-fat American Heart Association control diet decreased major cardiovascular events over a median follow-up of 4.8 years (Ramón Estruch et al. 2018), a finding supported by systematic reviews and meta-analyses of the available randomized controlled trials and prospective cohort studies (Becerra-Tomás et al. 2019). Secondary analyses of the PREDIMED trial have also shown evidence of modest weight loss, decreased diabetes incidence (single centre) and increased metabolic syndrome reversion (Ramon Estruch et al. 2016; Salas-Salvadó et al. 2011). Other dietary patterns with evidence of benefit include low-glycemic index (GI) (Mirrahimi et al. 2012; Viguiliouk et al. 2018b), Portfolio (Chiavaroli et al. 2018), vegetarian (Glenn et al. 2019; Lee and Park 2017; Viguiliouk et al. 2018a; Fenglei Wang et al. 2015), Dietary Approaches to Stop Hypertension (DASH) (Chiavaroli et al. 2019), and Nordic (Adamsson et al. 2011; Galbete et al. 2018a; Lemming et al. 2018; Poulsen et al. 2013, 2015; Roswall et al. 2015; Uusitupa et al. 2013) dietary patterns as well as dietary patterns emphasizing specific foods including pulses (beans, peas, chickpeas, and lentils) (Ha et al. 2014; Jayalath et al. 2013; Kim et al. 2016; Li et al. 2017; Viguiliouk et al. 2015, 2017), fruit and vegetables (Huang et al., 2016; Xia Wang et al., 2014), nuts (Afshin et al. 2014; Flores-Mateo et al. 2013; Mejia et al. 2014; Sabaté et al. 2010; Viguiliouk et al. 2014), whole grains (Aune et al. 2016; Bao et al. 2014; Ho et al. 2016; Hollænder et al. 2015; Schwingshackl et al. 2017), and dairy (Gijsbers et al. 2016; Imamura et al. 2018). Systematic reviews and meta-analyses have shown that these other dietary patterns improve established cardiometabolic risk factors in randomized controlled trials (Chiavaroli et al. 2018, 2019; Viguiliouk et al. 2014, 2015, 2017, 2018a, b; Fenglei Wang et al. 2015; Adamsson et al. 2011; Ha et al. 2014; Jayalath et al. 2013; Kim et al. 2016; Li et al. 2017; Poulsen et al. 2013, 2015; Uusitupa et al. 2013; Huang et al. 2016; Flores-Mateo et al. 2013; Mejia et al. 2014; Sabaté et al. 2010; Bao et al. 2014; Ho et al. 2016; Hollænder et al. 2015) and are associated with decreased diabetes and cardiovascular disease incidence and mortality in prospective cohort studies (Glenn et al. 2019; Lee and Park 2017; Mirrahimi et al. 2012; Viguiliouk et al. 2017, 2018b; Chiavaroli et al. 2019; Galbete et al. 2018a; Lemming et al. 2018; Roswall et al. 2015; Afshin et al. 2014; Wang et al. 2014; Aune et al. 2016; Gijsbers et al. 2016; Imamura et al. 2018; Schwingshackl et al. 2017).

The approach to nutrition therapy is to integrate the assessment of the evidence for these different dietary patterns into a shared clinical decision making model to individualize nutrition therapy. The algorithm for nutrition therapy from the Diabetes Canada 2018 clinical practice guidelines provides a good example of this approach (Fig. 1) (Sievenpiper et al. 2018). The algorithm encourages the clinician and patient to align the evidence of advantages and disadvantages of each dietary pattern with the values, preferences, and treatment goals of the patient. As adherence is considered one of the most important determinants of achieving the benefit of any dietary pattern, the overarching goal is to use the available evidence to find the dietary pattern that will allow the patient to achieve the greatest adherence over the long-term and so achieve the intended benefits.

Dietary pattern-based clinical practice guidelines continue to evolve. The most recent clinical practice guidelines for nutrition therapy in diabetes and cardiovascular disease in Canada (Anderson et al. 2016; Sievenpiper et al. 2018), the United States (American Diabetes Association 2019; Grundy et al. 2018), and Europe (Catapano et al., 2016) have further expanded their focus on dietary patterns. Other clinical practice guidelines have also begun to adopt this focus, including Obesity Canada which will release its updated CPGs in 2019 (https://obesitycanada.ca/resources/clinical-guidelines/) and the European Association for the Study of Diabetes (EASD), which has commissioned a series of systematic reviews and meta-analyses of dietary patterns for diabetes to inform the update of their Clinical practice guidelines (Chiavaroli et al. 2018, 2019; Glenn et al. 2019; Viguiliouk et al. 2018a). As the evidence for different dietary patterns increases, an even greater shift toward dietary patterns is expected.

3 The Relationship Between Dietary Patterns and Chronic Non-communicable Diseases: The Mediterranean Diet

There is ample evidence that the cardiovascular risk can be modulated by lifestyle factors and, in particular, by dietary habits. In the last decades, the science of human nutrition has shifted from a reductionist approach focused on specific nutrients to a broader view emphasizing the role of food groups/dietary patterns in modulating people's health. This paradigm change is due to convincing scientific evidence showing that body functions are influenced not only by single nutrients, but also by

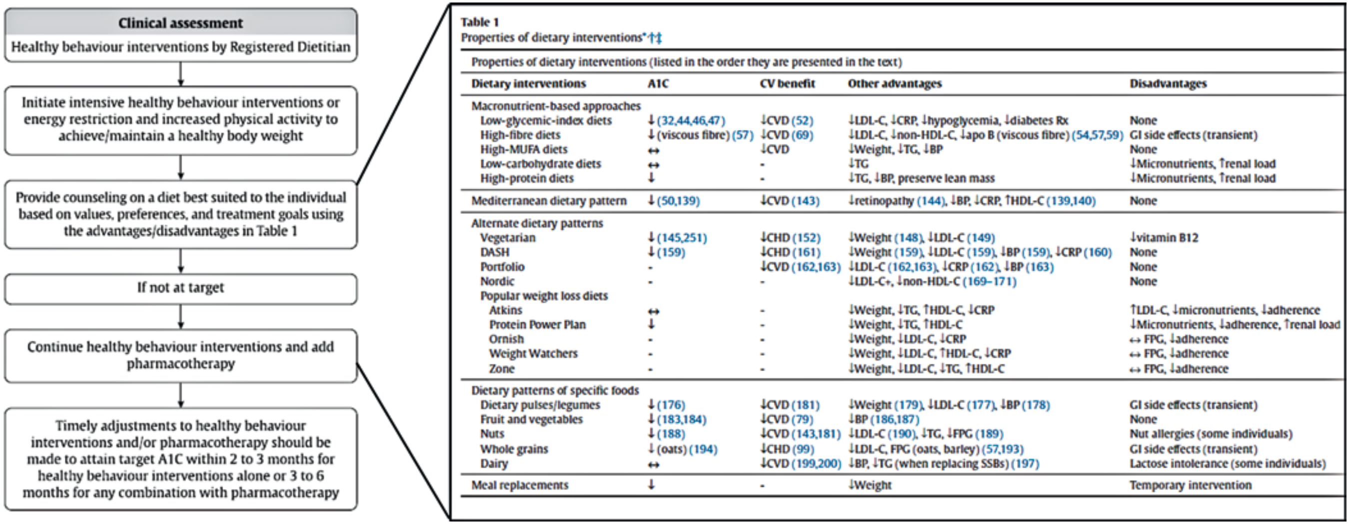

Table 1
Properties of dietary interventions*†‡

Properties of dietary interventions (listed in the order they are presented in the text)

Dietary interventions	A1C	CV benefit	Other advantages	Disadvantages
Macronutrient-based approaches				
Low-glycemic-index diets	↓ (32,44,46,47)	↓CVD (52)	↓LDL-C, ↓CRP, ↓hypoglycemia, ↓diabetes Rx	None
High-fibre diets	↓ (viscous fibre) (57)	↓CVD (69)	↓LDL-C, ↓non-HDL-C, ↓apo B (viscous fibre) (54,57,59)	GI side effects (transient)
High-MUFA diets	↔	↓CVD	↓Weight, ↓TG, ↓BP	None
Low-carbohydrate diets	↔	-	↓TG	↓Micronutrients, ↑renal load
High-protein diets	↓	-	↓TG, ↓BP, preserve lean mass	↓Micronutrients, ↑renal load
Mediterranean dietary pattern	↓ (50,139)	↓CVD (143)	↓retinopathy (144), ↓BP, ↓CRP, ↑HDL-C (139,140)	None
Alternate dietary patterns				
Vegetarian	↓ (145,251)	↓CHD (152)	↓Weight (148), ↓LDL-C (149)	↓vitamin B12
DASH	↓ (159)	↓CHD (161)	↓Weight (159), ↓LDL-C (159), ↓BP (159), ↓CRP (160)	None
Portfolio	-	↓CVD (162,163)	↓LDL-C (162,163), ↓CRP (162), ↓BP (163)	None
Nordic	-	-	↓LDL-C+, ↓non-HDL-C (169–171)	None
Popular weight loss diets				
Atkins	↔	-	↓Weight, ↓TG, ↑HDL-C, ↓CRP	↑LDL-C, ↓micronutrients, ↓adherence
Protein Power Plan	↓	-	↓Weight, ↓TG, ↑HDL-C	↓Micronutrients, ↓adherence, ↑renal load
Ornish	-	-	↓Weight, ↓LDL-C, ↓CRP	↔ FPG, ↓adherence
Weight Watchers	-	-	↓Weight, ↓LDL-C, ↑HDL-C, ↓CRP	↔ FPG, ↓adherence
Zone	-	-	↓Weight, ↓LDL-C, ↓TG, ↑HDL-C	↔ FPG, ↓adherence
Dietary patterns of specific foods				
Dietary pulses/legumes	↓ (176)	↓CVD (181)	↓Weight (179), ↓LDL-C (177), ↓BP (178)	GI side effects (transient)
Fruit and vegetables	↓ (183,184)	↓CVD (79)	↓BP (186,187)	None
Nuts	↓ (188)	↓CVD (143,181)	↓LDL-C (190), ↓TG, ↓FPG (189)	Nut allergies (some individuals)
Whole grains	↓ (oats) (194)	↓CHD (99)	↓LDL-C, FPG (oats, barley) (57,193)	GI side effects (transient)
Dairy	↔	↓CVD (199,200)	↓BP, ↓TG (when replacing SSBs) (197)	Lactose intolerance (some individuals)
Meal replacements	↓	-	↓Weight	Temporary intervention

Fig. 1 Algorithm for nutrition therapy for type 2 diabetes from the Diabetes Canada 2018 Clinical Practice Guidelines. ∗↓ = <1% decrease in A1C. †Adjusted for medication changes. ‡References are for the evidence used to support accompanying recommendations. *A1C* denotes glycated hemoglobin, *apo B* apolipoprotein B, *BMI* body mass index, *BP* blood pressure, *CHD* coronary heart disease, *CHO* carbohydrate, *CRP* C reactive protein, *CV* cardiovascular, *CVD* cardiovascular disease, *DASH* Dietary Approaches to Stop Hypertension, *FPG* fasting plasma glucose, *GI* gastrointestinal, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol, *MUFA* monounsaturated fatty acid, *SSBs* sugar-sweetened beverages, *TC* total cholesterol, *TG* triglycerides. Adapted from Canadian J Diabetes, 42, Diabetes Canada Clinical Practice Guidelines Expert Committee, Sievenpiper JL, Chan CB, Dworatzek PD, Freeze C, Williams SL., Nutrition Therapy, S64–S79, Copyright (2018), with permission from Elsevier

	Cardiovascular diseases	Cancer	Diabetes
High energy intake	X	X	X
Inadequate consumption of fruit, legumes, nuts and vegetables	X	X	X
Too much processed and red meat	X	X	X
High intake of refined starch and sugar	X	X	X
Too much trans and saturated (animal and tropical) fat	X		X
Low fish consumption	X		X
Too much salt	X		
Too much alcohol	X	X	X

Fig. 2 Food choices associated with higher risk for the most relevant chronic diseases at the population level

their complex interactions and by their interplay with other active substances present in food. These are likely to act synergistically and, therefore, their impact on human health may not be appreciated unless evaluated within the context of the whole diet. Furthermore, characteristics other than nutrients combination (i.e. physical features of the foods, technological processes, cooking procedures) may influence the absorption and bioavailability of nutrients and in turn modulate their metabolic effects. Therefore, awareness is growing of the relevance of dietary patterns in relation to the risk of disease or death. The Mediterranean Diet is one of the dietary patterns that has been more extensively evaluated and strong evidence from observational and intervention studies has accumulated on its health benefits for primary and secondary prevention of cardiovascular disease and other major chronic diseases such as type 2 diabetes, cancer and probably cognitive impairment (Fig. 2) (Bonaccio et al. 2018; Ramón Estruch et al. 2018; Galbete et al. 2018b).

3.1 The Mediterranean Diet for Prevention of Cardiovascular Disease, Diabetes and Cancer

The so called "Mediterranean Diet" is a model of healthful eating habits for the prevention of coronary heart diseases (CHD), the major cause of premature death and disability in industrialized countries. It was first proposed by Ancel Keys in the fifties: he was interested in the relationship between dietary habits and cardiovascular diseases and in order to clarify this issue he undertook an epidemiological study, the Seven Countries Study, which is still considered a milestone of research in cardiology and nutrition. This study demonstrated that cardiovascular diseases were half as common in populations living in the Mediterranean area than in those living in northern Europe or in the USA; this was largely accounted for by dietary habits which were markedly different in the populations with a high or a low rate of cardiovascular diseases.

The health benefits of the traditional Mediterranean diet have been tested over the year in hundreds of studies that have consistently shown that people following a diet resembling that model have a longer lifespan and a lower of mortality rate. (1) Other studies have shown that this type of diet is also associated with a lower risk of diabetes, cardiovascular diseases and cancer. Even cognitive decline or chronic digestive diseases occur less frequently in people following such a diet. These findings have been reproduced in different countries and in various ethnic groups and, therefore, cannot be ascribed to genetics but must be due to the features of this dietary regimen (Galbete et al. 2018a).

3.2 Characteristics of the Mediterranean Diet

Mediterranean Diet is a broad term used to describe the traditional food choices of people living around the Mediterranean basin. They are largely similar in the different populations and are characterized by a relatively high intake of vegetables, fruit, nuts and legumes, a moderate consumption of fresh and processed meat and by the use of olive oil as the main culinary fat while animal fat is utilized only occasionally (Fig. 3) (Fidanza et al. 2004; Vitale et al. 2018).

However, socially-and culturally-driven differences in food habits exist between Mediterranean Countries. Dietary patterns based on local foods may lead to specificities in the nutrient composition and other characteristics of the diet which, in turn, may lead to diverse health effects (Karamanos et al. 2002).

One relevant example is wheat which is consumed in different quantities and under different food forms (i.e. pasta, bulgur, couscous, bread, porridge) in the various populations. Other differential features of the Mediterranean diet according to local habits are the consumption of specific types of legumes (dry beans, chickpeas, lentils, or fresh peas) as well as the quantity and quality of fat and the amount of added sugars and sugary beverages.

Fig. 3 Features of the traditional Mediterranean Diet

⇑ Vegetables and fruit
⇑ Cereals (pasta and whole-meal bread)
⇑ Legumes and nuts
⇑ Olive oil
⇑ Fish
One or two glasses of wine
⇓ Meat
⇓ Dairy products
⇓ Animal fat

3.3 Mediterranean Diet and Chronic Degenerative Diseases: Insights on Potential Mechanisms

3.3.1 Dietary Fat

Available epidemiological data indicate that while vegetable/unsaturated fat intake is associated with a lower cardiovascular risk, the opposite is true for the consumption animal/saturated fat and trans-fatty acids. In support of this evidence, intervention studies in humans have clearly shown that replacing saturated fat with monounsaturated fat, largely present in olive oil, or with polyunsaturated fat, derived mainly by seed oils like sunflower or corn oil, lowers plasma low-density lipoproteins (LDL) cholesterol, a very atherogenic[1] lipoprotein. The high consistency of the evidence has prompted the European Food Safety Authority (EFSA)—an independent and authoritative body appointed by the European Community to issue opinions on the scientific substantiation of health claims—to state that "consumption of saturated fat increases blood cholesterol concentrations; consumption of mono- and/or polyunsaturated fat in replacement of saturated fat has been shown to lower/reduce blood cholesterol. Blood cholesterol lowering may reduce the risk of (coronary) heart disease".

Substitution of saturated fat with monounsaturated or polyunsaturated fat improves also other cardiovascular risk factors (RF) and, in particular, endothelial dysfunction, blood pressure, insulin sensitivity subclinical inflammation (Catapano et al. 2016).

3.3.2 Carbohydrate Rich Foods

Elevations of plasma glucose levels in the postprandial period represent an important risk factor not only for type 2 diabetes but also for cardiovascular diseases and cancer. In fact, high glucose levels are paralleled by increased plasma concentrations of insulin and triglycerides; all together, these metabolic abnormalities facilitate the occurrence of cardiovascular diseases and promote cell proliferation, a crucial mechanism involved in the development of cancer. Not all carbohydrate-rich foods are equally hyperglycaemic: differences in the postprandial blood glucose response to various carbohydrate-containing foods have been demonstrated in both healthy subjects and diabetic patients, even if they were consumed in portion sizes containing identical amounts of carbohydrate (Riccardi et al. 2003).

In this context, the amount and the physico-chemical properties of fibre present in each carbohydrate rich food is of paramount importance in relation to the impact on postprandial metabolism. In fact, dietary fibre, which is not digested and absorbed in the small intestine delays the absorption of glucose and fat from the small intestine; moreover it ferments in the gut and produces short chain fatty acids which can contribute to the modulation of glucose and lipid metabolism in the liver.

[1] That initiates or accelerates an abnormal fatty deposit within the walls of arteries.

The vast majority of the studies in this field consistently show a protective role of dietary fibre in relation to the development of major chronic degenerative diseases. Good sources of dietary fibre are legumes, vegetables, fruit, wholegrain, nuts; they are also rich in antioxidants, vitamins and minerals which could contribute to their protective role against most chronic diseases (Catapano et al. 2016; Mann et al. 2004; Parillo and Riccardi 2004).

The physical structure of the foods can also contribute to slow down carbohydrate digestion and this explains why foods like pasta or parboiled rice or potato dumplings have a lower impact on postprandial glycemia, although they are not particularly fibre rich (Riccardi et al. 2003).

3.4 *Towards a Comprehensive Nutritional Approach to Prevent Chronic Non Communicable Diseases: The Role of the Traditional Mediterranean Diet*

Consistent evidence indicates that a diet rich in carbohydrate and fibre, with a low glycaemic index and a high vegetable/animal fat ratio, may contribute to the prevention of many chronic non communicable diseases. Therefore foods with a low glycaemic index and/or high fibre content (e.g. legumes, pasta, parboiled rice, fruits, vegetables, wholegrain, nuts) should replace, whenever possible, those with a high glycaemic index, while unsaturated fat (olive oil) should be a preferential source of dietary fat instead of butter or cheese or fatty meat (Fig. 4) (Mann et al. 2004; Parillo and Riccardi 2004).

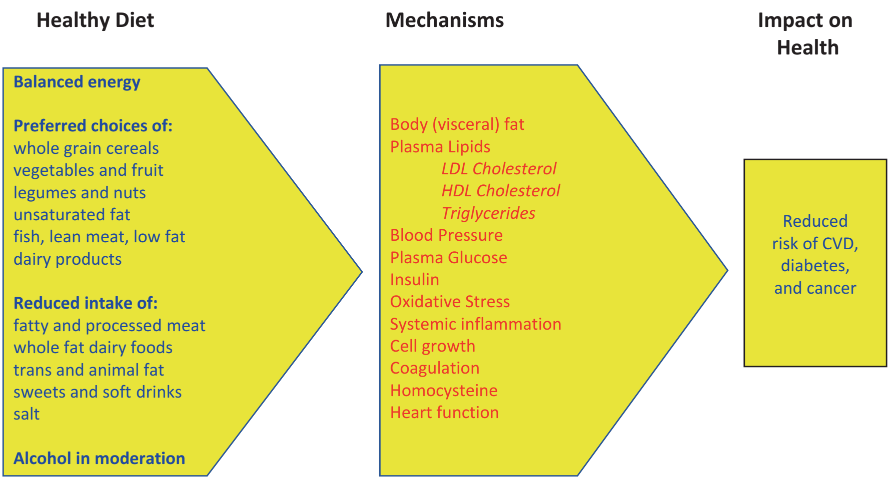

Fig. 4 Features of a healthy diet leading to a lower risk of chronic non-degenerative diseases

This dietary pattern resembles the traditional diet of people living in the Mediterranean region, which is still popular today, especially in the countryside; however these people, too, are experiencing westernization and their nutritional habits are changing towards increased consumption of energy-dense fat-rich products. However, a number of traditional meals and healthy foods are still present in the habitual diet of people living in Greece, Spain or Southern Italy, and it may therefore be wise to make this heritage available to other populations, giving them the opportunity to take advantage of a gastronomic culture that so well links health with pleasure. This is extremely important for the implementation of feasible programs for prevention of chronic non communicable diseases. Long lasting lifestyle changes are difficult to be achieved and, although health motivations may help compliance in the short term, palatability remains an important determinant of any dietary change aimed to last (Grimaldi et al. 2018; Vitale et al. 2018).

4 Possible Role of Nutrition to Prevent Chronic Degenerative Diseases and Improve Health Span

Traditional nutrition and dietary guidelines have focused on easy to understand food groups, such as protein, fats, carbohydrates (carbs), fiber content, etc. Understanding the difference between "good carbs" and "bad carbs", or glycemic index, has been a difficult concept to introduce in nutrition educational programs. It has been even more challenging to understand how nutrition could affect diet-induced inflammation that can be detected by changes in the blood and in the intestinal microbiome (Lopetuso et al. 2014; Sears and Ricordi 2010, 2012). Unfortunately, the evolution of western diets has resulted in an increase of this inflammatory background signature, associated with a progressively increasing rate of chronic degenerative conditions, including obesity, diabetes, auto-immune and neurodegenerative conditions (Ricordi et al. 2015). An interesting example is the potential impact of inflammation on metabolic syndrome and the development of type 2 diabetes, a disease condition typically associated with silent inflammation in the bloodstream (Ricordi et al. 2015; Sears and Ricordi 2010, 2012).

Inflammation is not only associated to the disease condition itself, but could be involved in its pathogenesis and progression, as diet-induced epigenetic changes can occur over time and have been associated with the increase in chronic degenerative diseases that are now affecting over 95% of Americans over age 65. Genetic transcription factors involved in inflammation can in fact be triggered by nutrition (Ricordi et al. 2015; Sears and Ricordi 2012), which can therefore assume a central role in either prevention or progression to many pathologic conditions. We certainly need inflammation to survive, as an inflammatory response to infection, injury, trauma, or poisoning, is essential to keep us alive. However, in these cases it is an acute inflammatory response that is needed in response to an infection or traumatic event. But there is third kind of inflammation that cannot be easily detected, as it is not associated with the typical inflammation cardinal signs of "rubor, calor, tumor and dolor". This is in fact a kind of inflammation that cannot be detected unless a blood test is performed, the so called "silent" inflammation. This is typically a chronic, subliminal (below the threshold of pain) inflammation that is associated to nutrition and lifestyle patterns (Ricordi et al. 2015; Sears and Ricordi 2010, 2012).

This kind of chronic inflammation is thought to result in consumption of repair mechanisms necessary to regenerate injured tissues and organs. For example, endothelial progenitor cells can be "consumed" to repair of the atherosclerotic microscopic lesions that are associated with chronic inflammation associated with atherogenic diets. It is thought that diet-induced silent inflammation (Ricordi et al. 2015; Sears and Ricordi 2010, 2012) could therefore progressively "consume" the cell types that are needed to repair the chronic tissue micro-injury associated with this subliminal "background" inflammation. In the long term, this chronic process could progressively deplete the native regenerative potential, for example, in atherosclerotic plaque deposition, once the repair potential is exhausted, progression of coronary disease accelerates, and progressive plaque deposition can be interpreted not as progressive injury mechanism, but rather a progressive failure of repair mechanisms (Ricordi et al. 2015).

Several markers of silent inflammation, such as oxidative stress, arachidonic acid and hyperglycemia are often related to inflammation. The importance of the glycemic index of food has been well documented (Brand-Miller et al. 2015). The way our diet has evolved over the past 30 years (Sears and Ricordi 2010, 2012), has resulted in a progressive increase omega-6 fatty acids whose precursors present for example in some refined vegetable oils (rich in linoleic acid) could be synergistic in their negative effects with refined carbohydrates with high glycemic index, since insulin-induced metabolism of linoleic acid to arachidonic acid results in activation of the intracellular proinflammatory cascade (Ricordi et al. 2015; Sears and Ricordi 2010, 2012). At the same time the evolution of western diets has produced a progressive decrease in anti-inflammatory, anti-oxidant, protective factors, such as omega-3 fatty acids and polyphenols.

This led to two negative and synergistic effects:

1. The promotion of inflammation by the combination of foods with a high linoleic acid content and high glycemic index, because insulin catalyzes (through desaturase enzymes) the conversion pathway of linoleic acid to the pro-inflammatory arachidonic acid.
2. A decrease in anti-inflammatory protective factors associated with the decreased consumption of polyphenols and omega-3 (Ricordi et al. 2015; Sears and Ricordi 2010, 2012).

This nutritional change has become evident even in countries traditionally close to the Mediterranean diet, such as Italy. In fact, in recent years the Italian population has adopted poor eating habits (e.g., fast food and sugar-added beverages) and the obesity epidemic has now reached Italy as well, where children and young adults have some of the highest rates of overweight in Europe (Ricordi et al. 2015). This trend was associated with the highest degree of silent inflammation measured by blood markers, such as the arachidonic acid: eicosapentaenoic acid (AA:EPA) ratio that was comparable to the ratios observed in inflammatory disease conditions such as diabetes. Normally this ratio should be less than 3. In fact, the population of Japan, which benefits from one of the longest healthy life spans on Earth, has an AA:EPA ratio of approximately 2, whereas a value of 16–18 is found in subjects with inflammatory conditions such as diabetes (Ricordi et al. 2015). It is worrisome that this generation of children could be the first one with a life span inferior to their parents (Ricordi et al. 2015). It is difficult to study longevity or its impact on health or life span, because studies with projections of many decades should be conducted. However, a recent study reported that simple changes in lifestyle can prolong the life span by 14 years (Khaw et al. 2008). The study indicated that adherence to four factors was associated with a longer life span, individually but with an incremental combinatory effect. The four factors were absence of smoking, vitamin C levels greater than or equal to 50 nmol/L in the blood (as a surrogate marker for sufficient consumption of vegetables and fruit servings), alcohol consumption up to 14 servings per week, and moderate physical activity. These four simple factors combined could result in a positive effect on longevity (Khaw et al. 2008).

An interesting emerging research branch, resoleomics, studies native mechanisms of self-healing that occur when the human body repairs itself and resolves inflammation; but this natural process can be prevented by some of the anti-inflammatory or pain medication administered. For example, some classes of analgesic used to treat pain associated with inflammatory conditions could in fact suppress self-healing mechanisms and their chronic systemic use may not be indicated. Now there are much more integrated approaches under consideration. For example, for arthritis there are groups recommending more combinatorial, integrated approaches to therapy, including diet, medication, and changes in lifestyle. To simplify the impact of diet on long-term reparative systems and their possible impact on longevity, we could assess telomere length. If we assume, for example, that the life potential could be 140 years, this could be reduced to 70 years or less when we are exposed to pro-inflammatory nutrition and/or environment. Therefore, an inflammatory diet could be associated with faster "consumption" of repair potential and subsequent accelerated aging, compared to an anti-inflammatory diet. This diet-induced consumption of the native regenerative potential is supported by recent evidence indicating that adherence to a Mediterranean diet is associated with longer telomeres (Crous-Bou et al. 2014).

At the base of an anti-inflammatory diet, there are six basic rules described in the book "The End of Pain" by Peter Wehling, in which innovative approaches are proposed for the treatment of arthritis (Wehling and Renna 2011). Wehling based his book on nutrition rules to follow for the treatment of arthritis, with several requirements considered in addition to avoidance of foods that are direct triggers of inflammation. These requirements/guidelines include avoidance of allergies and other inflammatory reactions to foods, avoidance of foods rich in starch and sugar that affect the level of glucose in the blood and therefore insulin requirements, and eating foods that reduce inflammation. Additional recommendations include taking supplements that reduce inflammation and keeping one's weight down, because obesity increases inflammation (Ricordi et al. 2015). This book also pointed out that while focusing on the rules one by one, we must remember that it is necessary to implement a global approach where each element enhances the other synergistically, as it is impossible to get full results using only an individual component or element that may appear easier to adhere to (Ricordi et al. 2015; Wehling and Renna 2011). Several studies are in progress to evaluate the effect of anti-inflammatory interventions in the prevention and treatment of cardiovascular disease, stroke, cancer and diabetes. The data emerging are indicating that dose and assessment of markers of reduced diet-induced inflammation may be important to assess potential benefit and tailor intervention guidelines (Sears 2018). In fact, it has been shown that a daily dose of 5 g/day of EPA and DHA is generally required to reduce AA/EPA ratios from 23 to 2.5, with a corresponding reduction of pro-inflammatory cytokines including IL-1 (Endres et al. 1989), and a recent trial (CANTOS) has shown that reduction of IL-1 had significant cardiovascular benefits (Ridker et al. 2017). It is unlikely that any cardiovascular benefits could be observed in the absence of a significant lowering of the AA/EPA ratio.

A dose higher than 60 mg/kg EPA and DHA was recently reported to be necessary to reduce the AA/EPA ratio to less than 3 in patients with type 1 diabetes (Cadario et al. 2017). With such a reduction in the AA/EPA ratio, significant improvements in glycemic control were noted, as measured by decreased insulin requirements, lowered HbA1c, and increased stimulated C-peptide production, suggesting preservation of beta cell function (Cadario et al. 2017; Sears 2018). This has led to the recent FDA allowance of the POSEIDON trial to study the effect of high-dose omega-3 fatty acids and high-dose Vitamin D on beta cell function (Baidal et al. 2018). It should be noted that the initial dosing level in the POSEIDON trial will be a daily dose of 150 mg EPA and DHA/kg body weight to titrate each subject to reach an AA/EPA ratio between 1.5 and 3. Future studies will be necessary to determine the potential usefulness of anti-inflammatory nutritional interventions, omega-3 fatty acids and other immunomodulatory/anti-inflammatory supplements in the prevention and treatment of cardiovascular disease, diabetes and other degenerative conditions, to prolong healthy lifespan.

5 Conclusion

Epidemiologic, clinical, and laboratory data have a clearly linked diet with chronic diseases that are largely preventable. The issue is complex, and without action, NCDs are set to become more acute, posing even more challenges for society as a whole.

The evolution of western diets has resulted in an increase of this inflammatory background signature, and besides being associated to the NCDs themselves, it could be involved in its pathogenesis and progression. Also, anti-inflammatory nutrition has been associated with increased lifespan.

Clearly, optimal nutrition plays a key role in keeping people healthy and long-lived. In order to have the greatest impact possible, nutrition science should continue to study important nutrient-nutrient and nutrient-food interactions, with dietary guidelines moving away from a focus on single nutrients to an approach based on food and dietary patterns.

The Mediterranean Diet is one of the dietary patterns that has been more extensively evaluated and strong evidence from observational and intervention studies, and its adoption is a unique opportunity for the achievement of SDG 3 "Ensure healthy lives and promote wellbeing for all at all ages".

Scientific evidence must be translated into effective intervention programs aimed at changing eating behaviors, from individual-level approaches to community-wide campaigns, with a joint effort of the science community, government and policy-makers, citizens, NGOs and the private sector.

Funding statement Dr. John L Sievenpiper was funded by a PSI Graham Farquharson Knowledge Translation Fellowship, Diabetes Canada Clinician Scientist award, and Banting & Best Diabetes Centre Sun Life Financial New Investigator Award for Diabetes Research. None of the sponsors had a role in any aspect of the present study, including design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, approval of the manuscript or decision to publish.

Disclosures Dr. John L Sievenpiper has received research support from the Canadian Foundation for Innovation, Ontario Research Fund, Province of Ontario Ministry of Research and Innovation and Science, Canadian Institutes of health Research (CIHR), Diabetes Canada, PSI Foundation, Banting and Best Diabetes Centre (BBDC), American Society for Nutrition (ASN), INC International Nut and Dried Fruit Council Foundation, National Dried Fruit Trade Association, The Tate and Lyle Nutritional Research Fund at the University of Toronto, The Glycemic Control and Cardiovascular Disease in Type 2 Diabetes Fund at the University of Toronto (a fund established by the Alberta Pulse Growers), and the Nutrition Trialists Fund at the University of Toronto (a fund established by an inaugural donation from the Calorie Control Council). He has received in-kind food donations to support a randomized controlled trial from the Almond Board of California, California Walnut Commission, American Peanut Council, Barilla, Unilever, Unico/Primo, Loblaw Companies, Quaker, Kellogg Canada, and WhiteWave Foods. He has received travel support, speaker fees and/or honoraria from Diabetes Canada, Mott's LLP, Dairy Farmers of Canada, FoodMinds LLC, International Sweeteners Association, Nestlé, Pulse Canada, Canadian Society for Endocrinology and Metabolism (CSEM), GI Foundation, Abbott, Biofortis, ASN, Northern Ontario School of Medicine, INC Nutrition Research & Education Foundation, European Food Safety Authority (EFSA), and Physicians Committee for Responsible Medicine. He has or has had ad hoc consulting arrangements with Perkins Coie LLP, Tate & Lyle, and Wirtschaftliche Vereinigung Zucker e.V. He is a member of the European Fruit Juice Association Scientific Expert Panel. He is on the Clinical Practice Guidelines Expert Committees of Diabetes Canada, European Association for the study of Diabetes (EASD), Canadian Cardiovascular Society (CCS), and Obesity Canada. He serves or has served as an unpaid scientific advisor for the Food, Nutrition, and Safety Program (FNSP) and the Technical Committee on Carbohydrates of the International Life Science Institute (ILSI) North America. He is a member of the International Carbohydrate Quality Consortium (ICQC), Executive Board Member of the Diabetes and Nutrition Study Group (DNSG) of the EASD, and Director of the Toronto 3D Knowledge Synthesis and Clinical Trials foundation. His wife is an employee of Sobeys Inc.

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Eco-Agri-Food Ecology and Human Health

Nadia El-Hage Scialabba

1 Introduction

The food system can be both a risk factor to health, or a cure for many ailments of nature and people. Alas, chronic and non-communicable diseases are rising worldwide and a deeper understanding of the role of the food system is needed in order to guide preventive efforts. 'The right to health means the right to be healthy in the first place, not the right to treatment' (Migaleddu 1952-2017). In considering factors that cause disease, epidemiologists focus on genetic susceptibility and environmental determinants: nutrition and lifestyle, as well as environmental conditions, are prime areas of investigation but seldomly, due attention is given to the role of the food system as a whole in determining health across the supply chain and for related impacts that have long latency, such as chronic diseases.

In linking food system risk factors and disease outcomes in its 2009 Global Health Risks, WHO considers under-nutrition and some nutrition-related risk factors (e.g. high blood cholesterol and glucose), as well as environmental and occupational risks (e.g. unsafe drinking water, occupational carcinogens), without however dealing with agricultural pollutants, while explicitly avoiding to cover 'broad risk factors such as diets'. The 2017 High-Level Panel of Experts on Food Security and Nutrition report on Nutrition and Food Systems highlights the role of diets and the food environment in facilitating health in a rather generic way. Chiefly, the Sustainable Development Goal 3 that aims to 'Ensure healthy lives and promote wellbeing for all at all ages' includes nine targets of which: target 3.4 refers to 'Reducing by one third premature mortality from non-communicable diseases' and target 3.9 refers to 'Reducing the number of illness from hazardous chemicals and

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_5

air, water and soil pollution and contamination'. Interestingly, drug, alcohol and tobacco abuse are explicitly addressed but no reference is made to the crucial role of food systems, despite the fact that the health cost of the eco-agri-food system largely surpass that of the tobacco industry.

Attribution of disease causation is challenging, due to insufficient evidence regarding temporal relation, association, environmental equivalence and population equivalence. Therefore, scientific evidence is equivocal for decision-makers, leaving the ground open for overly delayed policies and public health regulations, in the face of a global emergency to act and safeguard human health and the generations to come from the non-communicable diseases epidemics. In fact, malnutrition in all its form (including under-nutrition, micronutrient deficiencies, and overweight and obesity) affects over two billion people, while the incidence of cancer is expected to increase 70% in the next two decades, neuro-degenerative diseases are doubling, and adverse developmental and reproductive effects of chemicals interfering with the endocrine systems, as well as antibiotic-resistance, are alarming concerns for present and future generations.

2 The Roles of the Eco-Agri-Food System in Disease Incidence

With a view to highlight the urgency to shift to healthier food production and consumption patterns, a brief overview follows on the major disease groups, indicating their global extent, an estimate of societal costs, and the role of different food system pathways in human health.[1]

2.1 Hunger-Related Morbidity, Obesity, Diabetes Mellitus and Metabolic Disorders

2.1.1 Extent

Hunger affects 821 million people, or 10.9% of the world population (FAO et al. 2018). Acute malnutrition is responsible for stunting 150.2 million children, while 50.5 million children are wasted, determining irreversible impacts throughout their lives. Malnutrition is responsible for mortality and acute morbidity from diarrhoeal diseases, malaria, measles, pneumonia for children under 5 years of age and perinatal conditions from maternal underweight.

[1] This preliminary literature review requires a more comprehensive review for each disease group.

In addition, two billion people have nutritional deficiencies, including both those under- and over-nourished. Overweight and obesity rates are increasing worldwide (71% of USA population, 70% in Mexico, 50% in Europe, 22% in China and 20% in India), causing millions of premature deaths, more than for people underweight. In 2017, 672 million people (or 13.2%) of adults over 18 were obese, as well as 41 million children under the age of 5. Obesity is responsible for 4.8% of deaths globally and 8.4% in high-income countries (WHO 2009b). Should current trends continue, almost half of the world population will be overweight or obese in 2030 (McKinsey Global Institute 2014).

Type 2 diabetes, which makes up 90% of diabetes cases, has increased in parallel with obesity: in 2013, there were approximately 368 million people diagnosed, as compared to 30 million in 1985, with increasing rates in young people. The risk of coronary heart disease (23%), ischaemic stroke and Type 2 Diabetes (44%) grows steadily with increasing body mass, as do the risks of cancers of breast, colon, prostate and other organs (7–41%); obesity is among the main reasons of gene mutation, causing 15–20% of all cancer deaths and is associated with a shorter life expectancy. Today, USA median life expectancy is estimated to be 8 years lower for adults aged 55–64 years (Ken Gu et al. 1998).

2.1.2 Some Societal Costs

The global cost of malnutrition to the economy could be 11% of global GDP, or USD 3.5 trillion per year (FAO 2013). Healthcare costs of overweight and obesity are expected to double each decade, reaching 16–18% of total healthcare expenditure by 2030 (Wang et al. 2008). In USA, when one person in a household is obese, the household faces additional health care costs equivalent to 8% of its annual income (IFPRI 2016). Global annual expenditure on diabetes was USD 673 billion in 2010, one third of which in USA, equivalent to 12% of global health care expenditure.

2.1.3 The Role of Diets

Food consumption depends on access to food, both in terms of quantity and quality. While under-nutrition is due to a lack of access to nutritious food, nutrient deficiencies in affluent populations is due to consumption of low-quality foods; rich in fat and sugar, poor in micronutrients. Individual food choices, although influenced by lifestyle and economic affordability, represent a model of 'expressive consumption' consistent with individual conscience (e.g. avoiding meat) but more often than not, choice is guided by centralized political decisions (e.g. sin taxes that discourage sugary drinks and labelling requirements) and in most cases, determined by food corporations in term of offer (e.g. ultra-processed food of a limited number of crops, with excess salt, sugar, fat and additives). The abundance of the so-called 'empty foods' on market shelves, coupled with cheap prices have greatly contributed to malnutrition and the prevalence of unbalanced diets. Research demonstrates that obesity is caused by increased intake of energy-dense foods that are high in fat, as well as insulin resistance related to excessive carbohydrate consumption and can best be prevented by a change of diet (WHO and FAO 2003).

2.1.4 The Role of Food Quality

Industrially grown crops notably have reduced vitamins (A, C), minerals (Fe, Ca) and phenolic compounds. Generally, ionizing radiation is believed to destroy Vitamins A and K and to reduce Vitamins C, B1 and E in food (Hartwig et al. 2007; Stevenson 1994). Exposure to certain chemicals in food (e.g. Di-2-ethlylhexylphthalates), increases adult obesity and diabetes by 40–69%. Highly processed food has also its responsibility in the modern metabolic disorder epidemics, especially refined flour and sugar, as well as the high-fructose corn sugar (Goran et al. 2013) commonly used in processed food and beverages, because they trigger glycaemic peaks.

2.1.5 The Role of the Agri-Environment

Hunger is primarily an access issue, including access to means of producing or buying food; bad agricultural practices contribute to soil erosion and loss of the productive capital of the poor. Soil health is the base of the nutrition continuum (from plants, to animals and humans), as most mineral nutrients become readily available to plants when soil pH is neutral, so a correct soil pH is essential to avoid nutrient deficiencies; interestingly, the ideal pH of the soil, the body fluids and most plant fluids are all around 6.4. Compared to 50 years ago, nutrient values of fruits and vegetables have declined from 25 to 75% (Mayer 1997), partly due to the use of nitrogen fertilizers that inhibit mycorrhizal colonization of crop roots and thus nutrients flow; a properly mineralized soil is key to feeding the plant (Clark and Zeto 2000) and hence, the immune system through enzyme-rich foods. Furthermore, emerging research indicates that grass-fed animals from balanced soils have more Trans-Vasconic Acid (25%) and Conjugated Linoleic Acid (30%) (Daley et al. 2010).

Most importantly, climate change is believed to accelerate photosynthesis, resulting in more glucose than nutrient content in most plant species, due to an ionomic imbalance whereby carbon increases disproportionally to soil-based nutrients, inducing changes in the nutritional value of food, including protein, iron, calcium, zinc, vitamin E and vitamin B complex. Rising CO_2 levels, to which industrial agriculture substantially contributes, is therefore inextricably linked to a global and systemic shift in nutrition quality of human diets. On average, since the Green Revolution, and for 130 species/cultivars, it entails: 46% more total non-structural carbohydrate concentration contributing to obesity and diabetes, equivalent to adding one spoonful of starch and sugar mixture to every 100 g of dry matter of raw plant product; 8% less of 25 important minerals (e.g. calcium, potassium, zinc, iron) contributing to more anaemia and mineral malnutrition; and reduced nitrogen concentration by 10–18%, with protein deficiencies affecting cognitive development, metabolism and the immune system (Loladze 2014). Although the (CO_2-nutrition) dynamic is still being elucidated, it is suggested the issue has potential health consequences for approximately 600 million people (Bottemiller Evich 2017; Zhu et al. 2018).

Endocrine-disrupting chemicals (EDCs) dubbed "obesogens" accumulating in the environment expose health to several metabolic disorders, including the epidemic of obesity and its related pathologies, as it is believed to modify metabolic balance at the central, hypothalamic level (Decherf and Demeneix 2011). In addition, EDCs as diabetogenic compounds are believed to have a role in disrupting insulin production and sensitivity, thus contributing to the diabetes epidemics (Neel and Sargis 2011). Prenatal bisphenol A (found in polycarbonate plastics and epoxy resins that are often used in containers that store food and beverages, such as water bottles) exposure increases childhood obesity by 20–69%; polychlorinated biphenyls and hexachlorobenzene found in the environment are recognized "obesogens" (Trasande et al. 2015) with transgenerational impacts (Decherf and Demeneix 2011).

Air pollution by particulate matter has recently been associated with increased risk of diabetes mellitus, especially when $PM_{2.5}$ is above 2.4 ug/m^3. Globally, ambient $PM_{2.5}$ contributed to about 3.2 million incident cases of diabetes, about 8.2 million DALYs[2] caused by diabetes, and 206,105 deaths from diabetes attributable to $PM_{2.5}$ exposure; the burden varied substantially among geographies and was more heavily skewed towards low-income and lower-to-middle-income countries (Bowe et al. 2018).

2.2 Cardiovascular Diseases

2.2.1 Extent

Cardiovascular diseases (CVDs) are the leading cause of death globally: 17.7 million deaths in 2015 (WHO et al. 2017), 50% of all non-communicable disease deaths and 31% of all deaths. Heart attacks and stroke account for 80% of all CVD deaths.

[2] DALYs: Daily Adjusted Life Years.

2.2.2 Some Societal Costs

By 2030, the global cost of CVDs is set to rise from approximately USD 863 billion in 2010 to USD 1044 billion, including direct healthcare costs and productivity losses (World Heart Federation 2018).

2.2.3 The Role of Diets

Unhealthy diets are an important risk factor to CVDs (WHO et al. 2011). Globally, 33% of ischemic heart disease is attributable to high blood cholesterol and 22% with raised blood sugar (WHO 2009a). Excess dietary sodium (salt) and saturated fats have historically been considered the most important factors (WHO et al. 2011), yet there now exists significant debate on these topics in the scientific literature. Recent research on salt suggests that a moderate consumption is healthier and that excessive reduction increases CVD risk. On saturated fats, a large number of rigorous review papers in recent years have found no link between these fats and heart disease (Hamley 2017). Meanwhile, high intakes of heme iron from red meat has been associated with cardiovascular diseases in USA (Etemadi et al. 2017), but there is not yet clinical trial data to confirm this hypothesis.[3] Ultimately, the dietary fat impact on health is most probably linked to the very quality of the fat (Grosso et al. 2017; Guasch-Ferré et al. 2015). An emerging risk factor for CVD are carbohydrates, with a large body of clinical trial research demonstrating improvement of most cardiovascular markers when these are reduced (Kuipers et al. 2011).

2.2.4 The Role of Food Quality

Excess salt intake is known to contribute to hypertension and the main source of salt comes from processed food and ready-made meals. Processed meat containing nitrate/nitrite pro-oxidants is associated with coronary heart disease and stroke, but the associations are weak, and the available clinical trial data to date does not confirm an effect of red meat on any cardiovascular disease (O'Connor et al. 2016). Regarding the responsibility of saturated fats for human health, cohort studies do not distinguish between grain-fed and grass-fed livestock and related Omega-3 to Omega-6 ratios,[4] nor different levels of trans fats, conjugated linoleic acid, vitamin

[3] The study mentions that Japan and other Asian countries have not shown such associations with red meat intake, which converges with the view related to grain-fed vs. grass-fed red meat qualities.

[4] The ratio of omega-6 to omega-3 in grass-fed beef is roughly 1.56:1, while in grain-fed beef it averages about 7.65:1; a healthy diet is believed to supply these fats in the range of 1:1 to 4:1 but diets in the West tend to have ratios in the range of 11:1 to 30:1.

E and beta-carotene of meat, which could counteract, or enhance, inflammatory effects (Daley et al. 2010; Ponnampalam et al. 2006). Dioxins (e.g. polychlorinated dibenzofurans in rice oil but also from exposure to herbicides) are associated with death from CVDs, particularly ischemic heart diseases (Brown 2008).

2.2.5 The Role of the Agri-Environment

The impact of air pollution (continuous moderate levels of exposure have greater effects than sporadic high levels of exposure) on CVDs is increasingly being recognized. Risk of stroke is twice and risk of ischemic heart disease is 1.5 times at Delhi or Beijing levels of annual exposure (Green Templeton College 2017). The incidence of infant cyanotic heart disease and meta-emoglobinemia (blue-baby syndrome) have been associated with high nitrate levels in drinking water and root crops (Fewtrell 2004).

2.3 Infectious Diseases: Food-Borne and Zoonotic Diseases

2.3.1 Extent

Over the past decade, WHO documented the under-estimated burden of food-borne diseases caused by microorganisms (e.g. Salmonella enterica, Escherichia coli), parasites (e.g. cryptosporidium, trematodes) and chemical contaminants (e.g. cassava cyanide, aflatoxins) in food. Over 30 foodborne infectious diseases encompassing a wide spectrum of illnesses caused 600 million illnesses and 420,000 deaths in 2010, and 40% of all deaths from foodborne diseases are children under the age of 5 (WHO 2015d). Diarrhoea is the acute, most common symptom of foodborne and waterborne illness in all countries, but other serious consequences include kidney and liver failure, brain and neural disorders, reactive arthritis, cancer and death.

Zoonotic diseases are a group of infectious diseases naturally transmitted between animals and humans through direct contact or though food, water and the environment. Zoonoses comprise a large percentage of all newly identified infectious diseases, as well as existing infectious diseases, such as avian, swine and other zoonotic influenza viruses, spongiform encephalopathies and variant Creutzfeldt-Jakob disease, which pandemics have been infamous in recent decades.

2.3.2 Societal Costs

The contamination of food by microbiological agents is a worldwide public health concern. The illness-related costs of 14 most common pathogens amount to USD 14 billion annually (WHO 2015c). Zoonoses are responsible for about 2.5 billion cases of human illness and 2.7 million human deaths per year (Delia et al. 2012).

2.3.3 The Role of Diets

Infectious diseases most commonly result from the ingestion of foodstuffs contaminated with microorganisms (bacteria, viruses and parasites), through consumption of raw or under-cooked food (e.g. meat, eggs, fresh produce, dairy) and food preparation with unsafe water.

2.3.4 The Role of Food Quality

The contamination of food may occur at any stage in the process from inadequate food production to poor storage conditions and post-harvest handling that promotes microbial contamination. Hygienic practices from farm to table prevent foodborne disease outbreaks.

2.3.5 The Role of the Agri-Environment

The greatest risk for zoonotic disease transmission occurs at the human-animal interface through direct or indirect human exposure to animals, their products (e.g. meat, milk, eggs) and/or their environments. Avian and other zoonotic influenza pandemics, that are associated with poor livestock raising conditions and poor food handling and cooking, can cause disease in humans ranging from a mild illness to death. The 2005 outbreak of *Streptococcus suis* in areas of China has raised concern about the risk associated with infected pork meat.

2.3.6 Occupational Hazards

Slaughtering and butchering of sick pigs are occupational risks to farmers, slaughterers, butchers as well as to those processing or preparing the meat for consumption. Human infection is most likely to occur through cuts or abrasions on the skin. Good hygiene practices are needed to avoid all infectious diseases (WHO 2018b).

2.4 *Antimicrobial-Resistant Infections*

2.4.1 Extent

Antimicrobial-resistant micro-organisms (bacteria, parasites, viruses and fungi) can develop and move between food-producing animals and humans by direct exposure, or through the food chain and the environment. Bacteria that already show concerning resistance level include: third generation cephalosporin-resistant Klebsiella pneumonia (respiratory, blood stream and urinary tract infections); third generation cephalosporin-resistant Escherichia coli (urinary tract and blood stream infections); methicillin-resistant strains of Staphylococcus aureus (skin, bone and blood stream infections); and non-typhoidal Salmonella enterica serotype Typhimurium (diarrhoea, blood stream infections and gastroenteritis) (WHO 2014).

New resistance mechanisms are emerging and spreading globally, threatening our ability to treat common infectious diseases, resulting in prolonged illness, disability, and death. Globally, antibiotic resistance is responsible for 700,000 annual deaths and by 2050, this number could reach ten million deaths a year (Centers for Disease Control and Prevention Antibiotic/Antimicrobial Resistance 2018); a good part of this burden could be attributed to excessive antibiotic use in livestock production (Centre for Disease Control and Prevention Antibiotic Resistance, Food and Food-Producing Animals 2018). Drug resistance affects 35% of common human infections, including 230,000 people who developed multi-drug resistant tuberculosis globally, and drug resistance is starting to complicate the fight against HIV and malaria (WHO 2018a).

2.4.2 Societal Costs

Antimicrobial resistance increases the cost of health care with lengthier stays in hospitals and more intensive care requirements. Antimicrobial resistance is putting the gains of the Millennium Development Goals at risk and endangers the achievement of the Sustainable Development Goal on health. In USA, it is estimated that two million resistant infections require treatment and 23,000 deaths (of which 22% are assumed to be foodborne bacteria) have direct health costs of USD 22 billion and lost productivity of USD 35 billion. This does not account for bacteria originating on farms; should data be collected from antibiotic animal use and animal infection, annual costs would increase by a factor of 10 (Centers for Disease Control and Prevention Antibiotic/Antimicrobial Resistance 2018).

2.4.3 The Role of Diets

Livestock and fish raised with antibiotics develop antibiotic-resistant bacteria which contaminate animal products; eating raw or undercooked meat, or produce contaminated with resistant bacteria, spreads antibiotic-resistance to human guts.

2.4.4 The Role of Food Quality

Recent research on glyphosate hypothesize that the selection pressure of the herbicide on bacterial resistance could lead to shifts in the gut microbiome composition, resulting in transfer of antibiotic resistance from soil to plants, animals and humans through the food web, even in urban and hospital environments. Although the link between glyphosate and antimicrobial resistance is still scarce, there is an urgent need to better understand indirect health risks for glyphosate residues in water, food and feed, through research on the associations between low-level chronic herbicide exposure, distortions in microbial communities, expansion of antibiotic resistance and the emergence of diseases (Van Bruggen et al. 2018).

2.4.5 The Role of the Agri-Environment

In the EU, 8 million kg of antimicrobial drugs were used in 2012 for food-producing animals and 3.4 million kg for humans. Worldwide, 50–80% of antibiotics are used for livestock, including macrolides and tetracyclines, penicillin, sulphonamide and bacitracin, as well as the last resort antibiotic colistin (O'Neill 2014), not only for animal treatment but also for preventive use and growth promotion purposes. Antibiotic-resistant bacteria can spread from animal feces to the environment, which can then contaminate soil and water used to grow fruits and vegetables (Centre for Disease Control and Prevention Antibiotic Resistance, Food and Food-Producing Animals 2018).

2.4.6 Occupational Hazards

Besides through spreading of resistant genes in the environment (terrestrial and aquatic), including via cow manure, slaughtering facilities present further hazards to workers through animal carcasses (mainly pork but also beef and poultry) infected, for instance, by *Clostridium difficile.*

2.5 Chronic Respiratory Diseases

2.5.1 Extent

Chronic respiratory diseases include the most common chronic obstructive pulmonary disease (COPD), asthma, occupational lung diseases and pulmonary hypertension. In low-income countries, the leading cause of death is pneumonia and in high-income countries, pneumonia and chronic bronchitis are the third cause of death after coronary artery diseases and cancer.

2.5.2 Societal Costs

Globally, outdoor air pollution leads to 3.3 million premature deaths annually; after emissions from residential energy use, such as heating and cooking, agriculture is the second leading cause of outdoor air pollution, accounting to 20% of the total disease burden, or 664,100 deaths per year (Lelieveld et al. 2015), more than half of which occur in China where large cities with the highest $PM_{2.5}$ are all surrounded by intensive agriculture facilities (Gu et al. 2014).

2.5.3 The Role of Diets

While most healthy children can fight infection with their natural defences, children whose immune systems are compromised are at higher risk of developing pneumonia; a child's immune system may be weakened by undernourishment (e.g. zinc deficiency), especially in infants who are not exclusively breastfed (WHO 2016a, b).

2.5.4 The Role of the Agri-Environment

In addition to tobacco smoking (which is the main cause of lung cancer (WHO 2011), the main risk factors of lung diseases (excluding cancer) include air pollution, occupational chemicals and dusts (Calvert et al. 2008), resulting in frequent lower respiratory infections during childhood. Atmospheric pollution from factory farms and pesticide drifts from aircraft spraying are particularly associated with respiratory diseases. Atmospheric pollution from factory farms increases by 20% respiratory diseases; it is reported that exposures to large animal confinement farming produce a wide spectrum of upper and lower respiratory tract diseases, due to the complex diversity of organic dust, particulates, microbial cell wall components and gases, and resultant activation of various innate immune receptor signaling pathways (May et al. 2012).

2.5.5 Occupational Hazards

Exposure to chemicals and dusts (fine particulate matter) is estimated to cause 12% of deaths due to chronic obstructive pulmonary disease (WHO 2009b).

2.6 Neoplasms

2.6.1 Extent

Neoplasms, or cancers, figure among the leading causes of morbidity and mortality worldwide, with approximately 17.5 million new cases, and related 8.7 million deaths in 2015. The number of new cases is expected to rise by about 70% over the next 2 decades, up to 22 million.

2.6.2 Societal Costs

The financial cost of cancer is high for both the ill person, their households and society as a whole. One of the major cost is treatment. Lack of insurance and other barriers to health care leads to late cancer diagnose and more extensive and costly, and less successful treatment. In USA, the projected cost of cancer care is USD 173 billion in 2020, representing a 39% increase from 2010 (Mariotto et al. 2011). The biggest financial impact is in terms of loss of life and productivity, in which cancer accounts for 1.5% of GDP loss in USA.

2.6.3 The Role of Diets

Around one third of all cancer deaths are due to five leading behavioural and dietary risks: high body mass index, low fruit and vegetable intake, lack of physical activity, tobacco use, and alcohol use (WHO 2015a). Statistical and epidemiological data attribute to diets in USA 35% of human cancer mortality; on the other hand, healthy diets play a role in protecting against cancer (NRC Committee on Comparative Toxicity of Naturally Occurring Carcinogens 1996). Emerging evidence from animal studies shows some cancers respond to diets high in fat and very low in carbohydrates. Excessive animal protein intake, especially red and processed meat, creates acidifying conditions conducive to inflammation (Schwalfenberg 2012) and for instance, colorectal cancer. Mediterranean diets seem to prevent as much as 66–75% of colorectal cancer, maybe because fruits and vegetables limit the growth of IGF-1 that stimulates cancer. The American

Association for Cancer declared that 60% of cancers in USA can be avoided by simply changing diet and lifestyle.

2.6.4 The Role of Food Quality

Although the dietary contribution to cancer remains a troubling question, evidence is building-up on food system links with cancers of the digestive organs, genital organs, and haematopoietic and related tissues. Many foods on the market shelves carry pesticide residues above the acute reference dose, let alone the cumulative effects of the residues of different pesticide active ingredients and their adjuvants. In particular, toxicological evaluation of pesticides neglects the role of certain pesticides on intestinal microbes that maintain health or on enzymatic activity important to detoxification processes, resulting in unsettled debates regarding the use of certain substances, such as glyphosate's role in Non-Hodgkin's lymphomas.

Environmental exposures that damage DNA are responsible for much of the increased cancer incidence and the increased release of new chemical substances in the environment (e.g. plastics, pesticides) is paralleled with the increase of cancer; for example, polychlorinated biphenyls chemicals are known to be carcinogenic and 90% of human exposure continues to come from animal-derived foods such as milk, eggs and fish (WHO 2016a, b).

Cadmium-containing phosphate fertilizers are associated with increased pancreatic cancer rates and research has demonstrated an association with rural dietary factors, such as high consumption of rice and crawfish of fields fertilized with phosphate fertilizers (Falk et al. 1988). Naturally-occurring chemicals (such as mycotoxins produced by fungi in grains and nuts) and plant alkaloids are recognized to cause cancer in experimental animals.

Nitrosamines in processed meat, endosulphans in farmed salmon (Hites et al. 2004), preservatives and artificial sweeteners (Schernhammer et al. 2012) in processed food and beverages might also contribute to the processes leading to cancer. In particular, industrial red meat—which contains more oestrogens, sodium and Omega-6 and less Phosphorus, Iron and Calcium—is thought to increase colorectal cancer by at least 37% (World Cancer Research Fund/American Institute for Cancer Research 2007).

Combustion residues from cooking, as well as certain food preservatives and colorants, are also believed to contribute to colorectal cancer (Grandi 2008). Cooking at high temperatures produces carcinogenic compounds (e.g. heterocyclic amines, acrylamide) (EFSA 2015) and kitchenware may include carcinogenic compounds.

2.6.5 The Role of the Agri-Environment

Many approved agriculture pesticides are significant toxicants responsible for initiation and promotion in carcinogenesis, including both DNA-reactive carcinogens that can be active with a single dose and are effective at low exposure, and non-genotoxic carcinogens requiring high, sustained exposure. In USA, approximately 40 chemicals classified by the International Agency for Research on Cancer as known, probable, or possible human carcinogens, are used in EPA-registered pesticides found today on the market (IARC and WHO 2009).

Nitrogen fertilizers may increase cancer risk due to the breakdown of nitrogen by digestive enzymes (Ward 2009). Most of the nitrogen in fertilizers (both synthetic and organic) is converted to nitrate that seeps into groundwater. Ingesting nitrate contaminated drinking water (Weyer et al. 2001) leads to the body's formation of N-nitroso compounds (NOC), which have been shown to cause tumours at multiple organ sites in every animal species tested, including neurological system cancers following trans-placental exposure. It is believed that nitrates in drinking water cause colon cancer (IARC and WHO 2018). NOC formation is inhibited by dietary antioxidants found in vegetables and fruits, which may account in part for the observed protective effect of fruits and vegetables against many cancers.

2.6.6 Occupational Hazards

At least 150 chemical and biological agents are known as probable causes of cancer and many of these are found in the agricultural workplace. Greenpeace 'Toxic Load Indicator' identifies 101 pesticides that meet one of the several human toxicity cut-off criteria (e.g. carcinogenicity, mutagenicity, immunotoxicity) and which are currently authorized for use in the EU (Lars 2016). Numerous pesticides (e.g. phenoxy herbicides, carbamate insecticides, organophosphorus and organochlorine insecticides (Guyton et al. 2015)) constitute direct hazards to pesticides applicators (Schinasi and Leon 2014; De Roos et al. 2004; Alavanja et al. 2014) and their families: leukaemia rates are consistently elevated among children who grow-up on farms, among children whose parents used pesticides in the home or garden, and among children of pesticides applicators (Monge et al. 2007; Menegaux et al. 2006; Meinert et al. 2000).

Tumour viruses (e.g. herpes virus/avian sarcoma, reticoloendoteliosis, linpho-proliferative disease of turkeys) in poultry are associated with non-Hodgkin lymphoma among farmers and slaughterhouse workers.

2.7 Developmental and Reproductive Deficiencies (Endocrine Disruption)

2.7.1 Extent

Concerns are increasingly being raised for chemicals that could interact with the endocrine system (i.e. oestrogen, androgen and thyroid signalling pathways) and thus, disrupt a number of processes critical for successful development and reproduction (FAO and WHO 2009). EU expert panels achieved consensus at least for probable (over 20%) Endocrine-Disrupting Chemicals (EDCs) causation for the following conditions: Intellectual Quotient loss and associated intellectual disability, autism, attention-deficit hyperactivity disorder, childhood obesity, adult obesity, adult diabetes, cryptorchidism, male infertility, and mortality associated with reduced testosterone. EDCs induced effects on human development may be expressed through altered viability, growth, structural or functional abnormalities, due to either mutations, or biochemical/physiological disturbances, and which may be expressed immediately or delayed, especially when exposure is during the fatal period.

EDCs' trans-generational epigenetic inheritance has led to a new paradigm for non-communicable disease referred to as the Developmental Origins of Health and Disease (DOHaD) (Street et al. 2018). Precaution suggests not to wait for conclusive evidence of harm to human health in order to ban certain pesticides (e.g. organochlorine, organophosphates and pyrethroids) and certain foodware additives (e.g. phthalates, BPA).

2.7.2 Societal Costs

Simulations produced a median EDC-related health cost of €157 billion annually in the European Union, or USD 217 billion, corresponding to 1.28% of EU gross domestic product (GDP) (Trasande et al. 2015). In USA, EDCs disease costs are much higher than in Europe, or USD 340 billion annually (of which USD 42 billion from pesticides alone) corresponding to 2.33% of GDP, due to poly-brominated diphenyl ethers (used as flame retardant) impacts on IQ and intellectual disability—while in the EU the largest contributor to health costs are organophosphate pesticides (Attina et al. 2016).

2.7.3 The Role of Diets

Neonatal development may be influenced by chemicals or their metabolites that are present in the maternal diet and subsequently transferred into maternal milk, or via consumption of infant formula containing certain additives, phytoestrogens (in soy-based formula) or migrants from infant feeding bottles. In particular, exposure to

EDCs (e.g. phthalates, bisphenols and per-fluoro-otanoic acid) used in plastic bottles, tins, cans, foodware and non-stick cookware (European Food Safety Authority 2014) is associated with 40–69% of anomalies of male reproductive hormone balance (infertility, cryptorchidism, hypospadias) and 0–19% incidence of testicular cancer (Trasande et al. 2015).

2.7.4 The Role of Food Quality

Long-term and low-level exposure to a wide range of pesticide residues over recommended levels in conventional fruit and vegetable (Chiu et al. 2016) has been reported to cause male reproductive disorders. Also, artificial colorants (i.e. E102, E104, E110, E122, E124) in food have been linked to Attention Deficiency and Hyper-activity syndrome (McCann et al. 2007).

2.7.5 The Role of the Agri-Environment

Globally, close to 800 chemicals are known or suspected to interfere with hormone receptors, synthesis or conversion but only a small fraction of these chemicals has been investigated for endocrine effects. No systematic neurotoxicity testing is required for the registration process of substances, despite the fact that at least 100 different pesticides cause adverse neurological effects. The European Union is taking the lead on regulating EDCs, including regulations on pesticides and biocides: 194 of the 432 candidate substances listed by the EU have evidence of endocrine-disrupting properties in at least one living organism.

Some EDCs produce effects that can cross generations, suggesting that the increase in current disease rates may be due to exposure of our grandparents to EDCs; transgenerational transmission and continued exposure are likely to increase effects over each generation. Despise knowledge gaps hampering progress to better protect public health, what is certain is that the increase of endocrine disease incidence over the recent decades rules-out genetic factors as the sole plausible explanation (WHO and UNEP 2013).

2.7.6 Occupational Hazards

Undescended testes in young boys, thus risk of subfertility and testicular cancer in adult life, are linked with exposure to diethylstibestrol (DES) and poly-brominated diphenyl ethers (PBDEs) and with occupational pesticide exposure during pregnancy. The incidence of genital malformations (e.g. cryptorchidisms, hypospadias) in baby boys has increased over time and levelled-off at unfavourably high rates (WHO and UNEP 2013).

2.8 Neuro-Degenerative Diseases

2.8.1 Extent

The cause of neuro-degenerative diseases, such as Alzheimer's Disease (AD), Parkinson disease, dementia, amyotrophic lateral sclerosis and Huntington disease, is generally unknown. Although these diseases are significantly influenced by gene susceptibility factors, underlying environmental risk factors have pronounced effect size on certain conditions, such as AD. An increased risk has been recorded in people with hypertension and those exposed to certain pesticides (Plassman et al. 2016). In 2015, there were approximately 48 million people worldwide with Alzheimer's, especially in industrialized countries. In 2013, Parkinson's disease was present in 53 million people and resulted in about 103,000 deaths globally (WHO 2015b). Deaths due to dementia more than doubled from 2000 to 2015, making it the seventh leading cause of global deaths in 2015 (WHO Mortality and Global Health Estimates 2018). The incidence of neuro-degenerative diseases is expected to double every 20 years, as the world's population ages (JPND Research 2018).

2.8.2 Societal Costs

The current costs of dementia are staggering. The global cost of Alzheimer's disease in 2010 was USD 604 billion, or 1% of the global GDP. In USA, people suffering from Alzheimer's and Parkinson's diseases cost the nation nearly USD 200 billion annually in patient care and lost productivity and is estimated to increase to USD 1.1 trillion by 2050 (Institute for Neurodegenerative Diseases 2018). To meet the coming crisis in neurological care, an army of caretakers will be needed.

2.8.3 The Role of Diets

Alzheimer's disease (AD) is highly associated with atherosclerosis and high blood pressure, thus cardiovascular disease risk factors. Diets rich of fibres and antioxidants (polyphenols) are believed to prevent strokes that lead to dementia (Barnard et al. 2014). High levels of Advanced Glycation End-products (AGEs) from (over)cooking animal-derived foods rich in fat and protein (e.g. grilled meat) is linked to increased oxidant stress and AD (Uribarri et al. 2010). Other studies speculate that elevated insulin caused by excessive carbohydrates is linked to AD (Li and Hölscher 2007).

2.8.4 The Role of the Agri-Environment

Monosodium glutamate additive (E621) (FAO 2013)[5] in excessive quantity is associated with brain damage and neuro-pathologies, including AD, as well as Parkinson's and Huntington's diseases (Lau and Tymianski 2010). While diets rich in flavonoids from fruits and vegetables may prevent degenerative diseases by protecting neurons, certain pollutants in food, such as heavy metals in poultry and tuna (Arsenic), dairy products (Lead) and fish (Mercury) and dioxins in animal feed, may accelerate neuro-degenerative processes.

2.8.5 Occupational Hazards

In France, neuro-degenerative diseases are recognized as professional diseases of agricultural pesticide users, especially of viticulture workers (Bolis 2012). In particular, pesticides of strongest association with parkinsonism are: 2,4-dichlorophenoxyacetic acid, paraquat, permethrin, dieldrin, mancozeb, rotenone, maneb, and diquat (Tanner et al. 2009).

2.9 Auto-Immune System Disorders: Celiac Disease and Allergies

2.9.1 Extent

Allergic diseases refer to a hyper-sensitivity of the immune system to something in the environment that usually causes little or no problem in most people, including food allergies (6% of developed world population), atopic dermatitis (20%), allergic asthma (1–18%) and anaphylaxis (Stenius et al. 2011). Although nearly any food is capable of causing an allergic reaction, the majority of reactions is caused by 8 foods: peanuts, tree nuts, milk, egg, wheat, soy, fish and shellfish. Food allergy (i.e. IgE-mediated food allergy, such as asthma) and other food hyper-sensitivities (i.e. non-IgE-mediated hypersensitivity, such as coeliac disease) are adverse reactions to specific foods or food ingredients occurring in sensitive individuals.

2.9.2 Societal Costs

Living with Celiac disease is relatively expensive, including medical costs and lost productivity at work after consuming gluten-containing food and often, procuring and buying gluten-free alternatives to wheat-based foods.

[5]E621 additive is considered safe by US/FDA but is subject to quantitative limits in the European Union.

2.9.3 The Role of Diets

Allergy develops through the process of sensitization (exposure to food allergen) so eating habits may influence its development (FAO and WHO 2009). Celiac disease (distinct from wheat allergy) is an auto-immune disorder of an estimated 1% of the global population that is caused by a reaction in genetically predisposed people to gluten found in wheat, rye, barley and hybrids products made from these grains. Celiac disease also starts with early introduction of gluten-containing cereals in diets, with an increased incidence when babies are not breastfed when gluten is introduced in the diet. Celiac changes gut permeability, leading to poor absorption of nutrients in the intestine, anemia, poor absorption of Vitamin B12 (leading to dementia) and poor absorption of Vitamin D and calcium; it is further found in connection with other diseases, such as type 1 diabetes and rheumatoid arthritis (FAO and WHO 2009).

2.9.4 The Role of Food Quality

Alterations in immune system responses also arise as a result of exposure to chemical contaminants (e.g. persistent organochlorine compounds) in foods. Celiac disease starts with early introduction of gluten-containing cereals in diets but also by consuming cereals with altered gluten levels by the agrifood industry. Food irradiation (with gamma rays of Caesium 137) is used to preserve food, to prevent the spread of invasive pests and delay, or to eliminate sprouting or ripening; wheat irradiation, that increases the level of gluten, is thought to alter non-gliadin components that can lead to damage of intestinal wall and increased autoimmune diseases, such as Celiac disease (Kucek et al. 2015; Parisani 2018; Robson 2018).

2.10 Gastro-Intestinal Tract Disorders

2.10.1 Extent

Digestive disorders and diseases (of the oesophagus, stomach, liver, pancreas, kidneys, gallbladder or intestines), range from mild (gastritis) to serious (cancer), and affect millions of people worldwide. Besides alcohol-related diseases, the main chronic liver diseases are closely related with diabetes and obesity. Gastro-oesophageal reflux disease, functional constipation, and irritable bowel syndrome are highly prevalent diseases, affecting each of them 1 out of every 6 persons all over the world (Guarner et al. 2009).

2.10.2 The Role of Diets

Adequate diets, including enzymes that support metabolic processes, are key to improving metabolic functions, including both prevention and treatment of several disorders. Chronic metabolic acidification is due to the sulphur content of meat amino-acids. Non-Alcoholic Fatty Liver Diseases (NAFLD) are caused by excess intake of saturated fats and soft drinks. Hypertension caused by excess salt in diets may cause renal failure. Some data suggest that chronic kidney disease is mainly due to hyper-filtration of animal proteins, while kidney stones may be induced by excess uric acid (Ambühl 2011).

2.10.3 The Role of the Food Quality

Mineral phosphorus fertilizers introduce Cadmium in the food chain (especially in barley, wheat and vegetables) which contributes to kidney disease (EFSA 2015). Kidney insufficiency is partly due to phosphate additives (pyrophosphate and sodium polyphosphate) in meat and soft drinks (Amato et al. 1998). Crohn disease, colitis and other metabolic syndromes, sometimes leading to lethal cardio-vascular problems, are associated with emulsifiers (i.e. E433 and E466) used in ice creams, ready-made meals, gluten-free products and artificial vitamins (Chassaing et al. 2015).

2.10.4 The Role of the Agri-Environment

Herbicides (i.e. atrazine, metolachlor, alachlor, paraquat and pendimethalin) and insecticides (i.e. permethrin) are associated with high risk of kidney disease (Lebov et al. 2016), as well as with exposure to environmental pollutants, especially overloads of toxins from heavy metals. Glyphosate-based herbicides are associated with NAFLD and its progression to non-alcoholic steatohepatitis (NASH) (Mesnage et al. 2017). In USA, increased kidney diseases for the young, elderly and immune-compromised, are associated with factory farm pollution of water by pathogens such as E. coli (Hribar 2010). Calcium phosphate fertilizers contaminated with polonium phosphates have detrimental effects on gut health by enhancing intestinal colonization of Gram-positive pathogens and subsequent pathogenesis, especially in diets containing corn oil (Sprong et al. 2002).

2.10.5 Occupational Hazards

Climate change-caused dehydration of field workers has been reported to cause chronic kidney disease (one fifth of the sugarcane field harvesters in El Salvador (Wallace-Wells 2017)).

2.11 Poisoning, Injury and Certain Other Consequences of External Causes

2.11.1 Extent

Millions of acute poisoning cases are reported for pesticide handlers (formulators, manufacturers, applicators), of which 300,000 deaths are estimated to occur annually at the global level (Schafer et al. 2004). The farming, fishing and forestry industries have a suicide rate consistently higher than the rate of the general population, five times as high in USA, twice as high in Australia and UK and 18% as high in India (IPES-Food/Global Alliance for the Future of Food 2017).

2.11.2 Societal Costs

Statistics from many countries or regions show that agriculture consistently has one of the highest accidents and injury rates of the industrial sectors (Litchfield 1999). In USA, the annual costs of occupational morbidity across the economy is USD 250 billion and the agricultural sector, including food manufacturing and food preparation industries, is the biggest contributor (Newman et al. 2015).

2.11.3 The Role of Food Quality

Acute toxicity may also be caused by veterinary drug and pesticides residues in food, as well as microbiological contaminants (mycotoxins and marine biotoxins) or low-digestible carbohydrates (such as polyol sweeteners) (FAO and WHO 2009). Substances that can give rise to acute health effects in short periods of intake include certain metals, mycotoxins, veterinary drug residues, pesticide residues or low-digestible carbohydrates.

2.11.4 Occupational Hazards

Agricultural workers suffer a wide variety of disorders as a result of their occupation. These range from minor (cuts, bruises) to more severe (deep wounds, fractures), permanent (amputation, spinal cord injury) and fatal injury. Ill-health as a result of contact with animals, micro-organisms, plant material dusts or chemicals are associated with certain types of agriculture. There is also an underlying but unquantified incidence of pain, stress and injury as a result of ergonomic problems due to poor working procedures and conditions that vary from benign lower back pain due to physical workload, through various musculoskeletal diseases, to

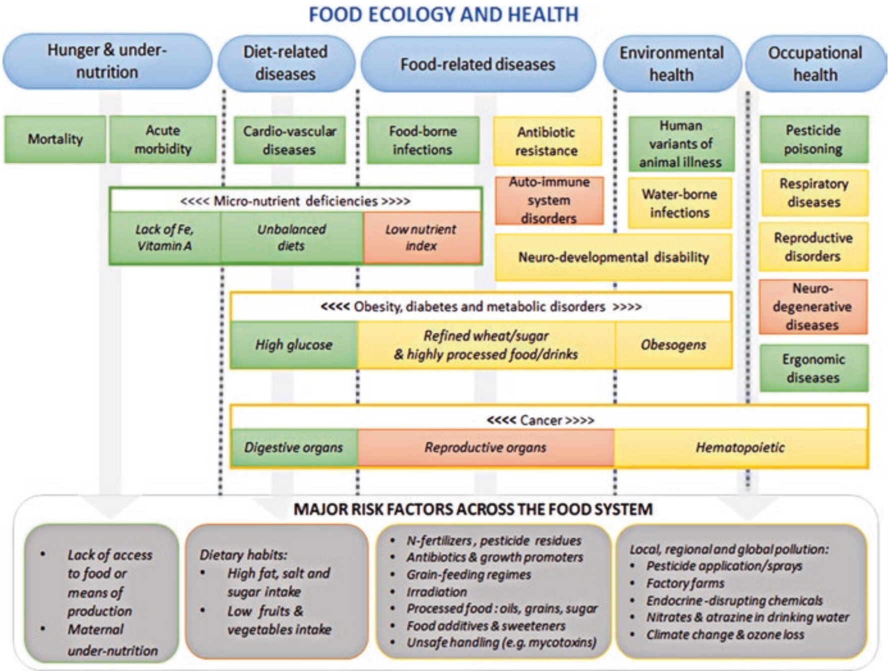

Fig. 1 Food Ecology and Health. The food-health nexus requires considering the entire eco-agri-system. The green coloured boxes refer to areas with sufficient scientific evidence, orange boxes refer to emerging evidence, while red boxes represent poorly understood or insufficiently documented links between health and the food and agriculture system

severe carpal injury in food processing industries (notably poultry in USA) (Gottfried 2016).

3 Addressing Eco-Agri-Food Ecology and Health

3.1 Food Ecology

A preliminary representation of the main disease groups related to eco-agri-food systems, grouped according to major exposure routes, is presented in the Fig. 1. It brings together knowledge from nutrition science, environmental health and epidemiological, toxicological and clinical medicine under the common umbrella of food ecology. Clearly, Fig. 1 over-simplifies the complexity in real life, as no disease can be defined according to strict boundaries. Such representation is a first step towards building a more consistent framework for understanding eco-agri-food system-related health. It highlights the fact that disease outcomes follow different pathways and often respond to multiple risk factors within eco-agri-food systems, in addition to lifestyle and other factors.

3.2 The Way Forward

Healthy food is the cornerstone of good health. As described above, disease outcomes are highly influenced by the food system, from seed breeding, fertilization and irradiation that maximize calorie yields at the expense of vitamins, minerals and polyphenols, to factory farm products low in Omega 3 and other anti-oxidants, pesticides and veterinary drugs that cumulate chemicals in our bodies, additives and sweeteners in processed food, endocrine-disrupting chemicals in packaging, coating cans and non-stick cookware, poor handling practices resulting in aflatoxin or microbiological contamination, or cooking at high temperatures that further adulterate our meals with acrylamide or other toxins. In addition, industrial agricultural practices substantially contribute to unhealthiness through air pollution, climate change and drinking water contamination. Thus, addressing health cannot but take a system thinking in order to consider the eco-agri-system as a functional whole, with inter-connected and self-reinforcing impacts on health.

Implementing SDG 3 will require the concerted efforts from policy-makers, researchers and practitioners involved in: SDG 2 (zero hunger) in order to undertake multi-disciplinary food research among agriculturists, nutritionists, environmentalists and health providers, away from the single nutrient focus; SDGs 6 (water), 7 (energy), 13 (climate change), 14 (life below water), 15 (life on land) in order to minimize ecological drivers through precautionary policies that restrict agricultural chemicals with cut-off criteria for human health and that phase-out chemical agricultural substances in the longer-term; SDG 12 to incentivize responsible production and consumption systems (such as organic and regenerative agriculture), that safeguard public goods, namely public health and ecosystem services; and SDG 17 (partnerships) for framing the nutrition and health debate around food democracy and access to diverse nutritious food. The SDGs provide the aspirational holistic perspective for policy coherence in addressing human health and in particular, all the eco-agri-food system pathways that affect health outcomes.

Acknowledgments The author wishes to thank the following colleagues for having provided insights to an earlier version of this paper, including: Barbara Gemmill-Herren (Biovision Foundation), Bruce Hirsch (Clarence Heller Foundation), Bernhard Johannes Kahl (University of Copenhagen), Peter Kenmore (Santa Clara University), André Leu (International Federation of Organic Agriculture Movements), Alexander Mueller (TMG Think Tank on Sustainability), Nina Teicholz (New York Times), Domenico Scanu (International Society of Doctors for the Environment), Cristina Tirado (International Union for Nutritional Sciences) and Kevin Gallagher (Future of Agriculture Think Tank). Thanks are also due to Isabella and Daniele Scialabba for having checked and organized the list of references.

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Challenges of Youth Involvement in Sustainable Food Systems: Lessons Learned from the Case of Farmers' Value Network Embeddedness in Ugandan Multi-stakeholder Platforms

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1 Introduction

This chapter delves into the fundamental societal question of why challenges to youth involvement in sustainable food systems persist. Themes of youth and agriculture currently lie at the core of a socio-political debate worldwide (Bezu and Holden 2014; Deotti and Estruch 2016; Lai et al. 2017a), as agri-food systems face urgent wicked problems and increasingly require deeper and larger systemic change (Dentoni et al. 2017, 2018a). Youth are widely recognized to have the potential to contribute actively to the transition towards more sustainable food systems, through innovative solutions and concrete actions (Ginwright and James 2002). However, factors such as lack of adequate access to resources and sub-optimal working conditions may prevent economies and societies from fully harnessing this potential (Hardgrove et al. 2015). In this chapter we first review the existing literature to

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_6

explore which are the challenges that youth need to deal with and how they vary geographically. Secondly, we offer further evidence through a case study set in Uganda. As a means of conclusion, we finally suggest some key leverage points for youth involvement in sustainable food systems.

To discuss some of the key challenges in involving youth in an empirically grounded way, we situate our study in the context of the Ugandan coffee sector, specifically zooming into a multi-stakeholder platform (MSP) in the Manafwa district, in Eastern Uganda (Muthuri 2017). Over the last two decades, MSPs have become an important novel organizational form for adapting and co-developing agricultural research in development projects and programs (Schut et al. 2017). Importantly, the emergence of MSPs has been recognized as both instrumental to achieve several SDGs and valuable as a goal in itself, namely SDG 17, owing to the fact that such platforms inherently include multiple societal actors and operate to build bridges across them (MacDonald et al. 2018). Often organized at a sub-national or national level, MSPs offer a space where the actors involved—e.g., farmers, value chain actors, policy-makers, scientists and civil society—can learn, negotiate with each other and collaborate to overcome collective challenges and capture opportunities through a facilitated innovation process across agri-food systems (Dentoni and Ross 2013; Leeuwis 2013). Although MSPs have been often applauded in policy and academic arenas, MSPs also face the challenge of whether, and how, to include marginalized actors, including youth, in their processes of knowledge sharing and co-creation (Kilelu et al. 2017; Salvini et al. 2018).

To illustrate why challenges of youth involvement in sustainable food systems persist in the empirical context of Ugandan MSPs, we assess in detail the heterogeneity of farmers' embeddedness in their value networks (see key definitions in Table 1). First, we critically review the recent empirical literature on youth involvement in sustainable food systems, suggesting that a knowledge gap persists with respect to youth's value network embeddedness when participating in sustainable food systems (see Sect. 2). Building upon the established concept of value network embeddedness (see Sect. 3), we therefore ask the following more specific research question: *how does young farmers' value network embeddedness influence their challenges in adopting agricultural innovations from MSPs?* To tackle this question, we interviewed 27 smallholder farmers and 10 key informants to gauge in three different locations within the Manafwa district (see Sect. 4). Ultimately, we found that younger farmers struggle more to innovate from what they learn in MSPs relative to elder farmers because they are less embedded in value networks than elder farmers (see Sect. 5). With these findings, this study helps to shed a new light on why the challenges of youth involvement in sustainable food systems persist, specifically in MSPs as novel organizations seeking to support sustainable transitions and achieve the SDGs (see Sect. 6). This ultimately implies that these challenges to youth involvement will most likely continue, unless deeper institutional work (Lawrence et al. 2011) takes place to shift the power structures in which youth are embedded (Waddell et al. 2014; Waddock et al. 2015).

Table 1 Glossary of key terminology in the chapter

Key terms	Short definition
Youth	The definition is inherently country- and context-specific. The United Nations define youth as persons between the ages of 15 and 24 years without prejudice to other definitions by Member States. In the African Youth Charter, youth refers to people between 15 and 35 years of age. In African rural areas, especially when it comes to farming, people below 40 are considered as youth.
Youth involvement	Involvement refers to the fact or condition of participating in something. Furthermore, it refers to the emotional association with someone or something. As such, youth involvement in food systems has two sides of the coin: first, the ability or motivation to participate; and second, the inclusiveness of the system itself in allowing or stimulating youth participation.
Sustainable food systems	Sets of interrelated natural and human agents that are resilient to change, energy and water efficient, economically sustainable for the actors and communities at risk, ecologically healthy, safe, fair, and supportive of multiple forms of urban and rural production (Pothukuchi and Kaufman 1999).
Value network embeddedness	The strategic positioning of an actor in a set of relationships (or network), with the value of the associated resources (e.g., information, knowledge, finance, reputation, natural resources, etc.) that can be accessed through that network.
Multi-stakeholder platforms (MSPs)	In general, platforms are organizations with an interface (Gawer and Cusumano 2002). The interface allows actors to receive information or to communicate reciprocally. Specifically, MSPs refer to interfaces that include multiple stakeholders—companies, farmers, governments, universities and non-profit organizations—seeking to develop a common goal or vision around a sector or issue.

2 Youth Involvement in Food Systems: Empirical Evidence and Knowledge Gaps

As pointed out by White (2012), the global food security is at stake when young people, both in the Global South and in the Global North, are reluctant to be involved in farming activites and consequently contribute to the loss of traditional family farms. A wide empirical literature worldwide has already reported and analyzed multiple facets of youth involvement in sustainable food systems. Global trends like population growth and urbanization, economic growth among the urban middle class and its effect on dietary choices, or the changes in international trade agreements, can all affect youth interest in playing a role in the agricultural sector. Through this literature review, we critically assess the specific challenges that need to be addressed when trying to increase youth's interest in agriculture and food systems.

First of all, a rich literature points out that lack of access to resources, insufficient support from families and inadequate infrastructures all challenge youth interest in contributing to food and agricultural systems. The International Labour Organisation

(ILO) estimates that each year 10–12 million young Africans enter the job market (Asciutti et al. 2016) and the issue of how to provide them with fulfilling employment is now at the top of the development agenda (Filmer and Fox 2014; Gough et al. 2013; Hino and Ranis 2014; MasterCard Foundation 2015). This is necessary because while numerous African economies have undergone significant economic growth in the last few years (AfDB et al. 2014), there has been a lack of new formal sector jobs, in a sort of jobless growth (Bhalotra 1998). In this context, young people in Africa have had to settle for precarious jobs in the informal sector (Honwana 2012; Langevang 2008; Langevang and Gough 2009). The literature reveals that agriculture is increasingly considered as a possible solution to this paradox (Filmer and Fox 2014; IFAD 2014; AGRA 2015; Losch 2012), in a scenario where young agricultural entrepreneurs engage with value chains and reap the related benefits.

A second strand of literature highlights the youth/elderly and rural/urban divides as roots of the unbalances that affect rural youth's interest in investing in agriculture and food systems. A study from Uganda (Ahaibwe et al. 2013) points out how youth, especially if better educated, leave the agricultural sector—in favour of the services sector—more often than the older generation, despite the fact that a significant share of young people still base their living on agriculture. However, the study also points out that the prospect of agriculture being transformed, from one of subsistence to one where some income can be earned, can represent an attractive consideration for young people. Other studies stressed the significant differences between rural and urban youth, and the specific problems faced by the former. In most cases, the lack of physical and social infrastructure in rural areas, together with the scarce profitability of agricultural activities, hinders youth from seeing the possibility of a fruitful future in this sector (Ajani et al. 2015). For example, in the context of rural Nigeria, younger farmers systematically lack adequate credit facilities, access to agricultural insurance and inputs, as well as basic farming knowledge (Adekunle et al. 2009).

There seems to be less evidence to support the idea that access to land would be a major factor, but this is valid for all rural population, not just youth specifically; however, it should be kept in mind that it is only by addressing deep structural issues such as access to land, that more youth-specific programmes can be implemented. It should also be noted that much of the available research highlights young people's negative attitude toward agriculture, a crucial point for those policies and programmes targeting the engagement of youth in agriculture (Asciutti et al. 2016). Changing the geographical context, a study from Malaysia, in which 250 youths were interviewed, revealed that the decision to be involved in agriculture is not only related to the attitude of young people towards farming, but is based also on other factors such as family support, government support and the intensity of promotion by related government agencies and related authorities (Abdullah and Sulaiman 2013).

From this perspective, more bottom-up efforts should be put in place to actively integrate the views of youth in agricultural development planning, so to account for their actual needs. Rural youths in particular should join the discussion in drafting, implementing and evaluating policies and programmes related to agriculture, while capacity building projects should also be defined in a more participatory way (Ajani et al. 2015). A positive lesson in this sense comes from the project Youth for EcoAction, set in Canada, which focuses on urban agriculture and community gardening. This program achieved positive results in terms of community building, youth empowerment and increased environmental awareness, as well as an enhancement in local food security and self-esteem. However, it also highlighted how such programs need multi-year funding in order to maintain their results (Fulford and Thompson 2013) and contribute actively to achieving SDG 11, which aims to make hurman settlements inclusinve, safe, resilient and sustainable.

In spite of this burgeoning strand of empirical work on multiple challenges surrounding youth involvement in sustainable food systems, we found that few studies so far sought to unearth the underlying causes of why these challenges persist. In this chapter, we attempt to address this knowledge gap by focusing on one possible cause underlying this ongoing challenge, that is, that youth are poorly embedded in value networks relative to older generations. Therefore, after a short review of the notion of value network embeddedness, we analyze the case of young farmers in Ugandan coffee MSPs to reflect on how to stimulate youth involvement in sustainable food systems in the future public and private endeavours.

3 Theory: Value Network Embeddedness

This study introduces the concept of value network embeddedness in the context of farmers engaged in a MSP in rural Uganda to illustrate why challenges in youth involvement in sustainable food systems persist over time. As such, it explains why MSPs may fail to achieve SDG 17, as well as other interrelated SDGs (such as SDG 11), if the social and strategic context in which rural youth are embedded is poorly understood (MacDonald et al. 2018). Broadly speaking, *value networks* represent sets of relationships in a system (e.g., a community, country or region) associated with key resources, both tangible (e.g. money, products, infrastructure) and intangible (e.g. rules, knowledge, reputation) that create value to the actors receiving them (Allee 2009; for a visual representation of value networks applied to African food and agriculture, see Dentoni and Krussmann 2015). These features make the concept of value networks different yet complementary to similar ones—namely, value chains, social networks and net-chains (Lazzarini et al. 2001)—in understanding an actor's strategic position in complex systems (Dentoni et al. 2019). While value chains focus only on an actor's position relative to others in their value chain (Gereffi et al. 2005), value networks concern with the broader set of networks surrounding each actor. While social networks focus only on the sets of relationship connecting each actor, value networks also consider the valuable resources (e.g., money, information, knowledge, etc.) flowing through each relationship (Dentoni et al. 2019).

Given this definition of value networks, it follows that *the configuration of value networks in any system, including agricultural and food systems, is of strategic* *importance* both for the individual actors embedded in that system as well as for the system as a whole (Dentoni et al. 2019). For the individual actors, the configuration of the value networks surrounding them means having easier or more difficult access to valuable resources, i.e. information about market opportunities, policy influence, reputation, academic knowledge, human capital, funding from investors, etc. In other words, consistently with resource dependence theory (Hillman et al. 2009; Pfeffer and Salancik 2003), the configuration of the value networks surrounding an individual actor determines its power to influence a system (Rossignoli and Lionzo 2018; Casciaro and Piskorski 2005). Moreover, the configuration of value networks matters also for the system as a whole. From complex adaptive systems theory, we know that the systems that are most modular (i.e., have the highest heterogeneity of value networks among its actors; see Dentoni et al. 2019) are the least resilient. The whole system may be at risk (for example, because of socio-economic, political or environmental crises) if a few actors are highly interconnected among each other, while most of the others are poorly interconnected (Day 2014; Levin et al. 2013).

Given the strategic importance of value networks for individual actors and for the system as a whole, it is not surprising that *value network embeddedness* represents a critical feature also for farmers to innovate, reduce risk and create social and economic value (Dentoni and Peterson 2011; Ferris et al. 2006; Zott and Amit 2010). Therefore, in order to discuss the challenges to youth involvement in sustainable food systems, this study analyzes specifically the heterogeneity of farmers' value network embeddedness in the context of Ugandan MSPs in relation to their age. Given the original notion developed in the literature (Allee 2009; Grudinschi 2014), we focus on three dimensions of value network embeddedness that can be operationalized in the context of rural Uganda. The first dimension is *reciprocity*, which represents the extent to which an actor shares resources bi-directionally with other actors in its network. The second dimension involves *resource diversification*, that is, the heterogeneity of resources provided or received by an actor from other actors. Finally, the third dimension of value network embeddedness entails *channel diversification* or, in other words, the number of channels through which the resources (e.g., information, or knowledge, or money) of an actor are shared with others.

4 Methods: Assessing Young Farmers' Value Network Embeddedness

To analyze the heterogeneity of farmers' value network embeddedness in the context of emerging MSPs engaged on issues of rural development, this study focuses on the case of 27 smallholder farmers purposively selected in the Manafwa district,which specializes in the production of Arabica coffee. Located at the feet of Mount Elgon, this MSP seeks to facilitate the participation of coffee farmers, in particular young and female farmers, into local and global coffee value chains

(Iza et al. 2019). Uganda constitutes one of Africa's major coffee exporters with approximately 4.60 million kilograms exported in 2016/2017, equal to a value of USD 545 million (UCDA 2018). Furthermore, Ugandan coffee exports are now booming in the international market, considering that in 2015/2016 they equalled 3.30 million kilograms or USD 326 million (UCDA 2018). Nevertheless, Uganda's coffee market is highly dependent on the 500,000 smallholder farmers who produce it (Chiputwa et al. 2015). More broadly, the Ugandan context provides an archetypal country to investigate dynamics of youth inclusion in agriculture, with 77% of the population under 30 years of age, 80% of which living in rural areas (UNFPA 2017).

Within this country context, the 27 smallholder farmers were selected to be representative of some key geographical and gender differences among coffee producers in Manafwa and, furthermore, to be already reachable through the network of the "Value chain Innovation Platforms for Food Security" (VIP4FS) project, which funded this research and facilitated the MSP where this study is situated. In particular, farmers were sampled to display heterogeneous location, gender, age and farm size. Farmers' locations were distributed across highlands (around Mukoto village, 48 km and 2.30 h from Mbale market), midlands (Namabya, 40 km and 1.30 h from Mbale market) and lowlands (Bukhofu, 39 km and 1.00 h from Mbale market). Data collection took place in November-December 2016. On average, and despite the wide variations, the sampled farmers had 52 years old, a 7-unit household, 3,6 acres of total arable land and a coffee production between 65 kg and 1.5 tons. Through semi-structured interviews, the selected 27 farmers were asked to describe the following aspects in detail: (1) the constraints to innovation that they currently face in their coffee production, input supply and demand; (2) the set of actors that influence these innovation constraints; and (3) how these actors exercise influence by giving or receiving resources to and from them. As a form of triangulation, nine key informants also involved in the same coffee value network (input supplier, middlemen, government workers, processors/exporters and an area cooperative enterprise) have been interviewed.

Subsequently, to assess the heterogeneity of farmers' value network embeddedness in the context of Ugandan MSPs, data have been analysed according to the following four steps. First, **value network analysis** was employed qualitatively by mapping the existing actor relationships in and around the value chain associated with the key resources that these actors exchange or share with each other (Figures 1, 2, and 3; Allee 2008). Second, **three key indicators of farmers' value network embeddedness**—namely reciprocity, resource diversification and channel diversification—were operationalized along a three-point scale (low, medium and high) in the specific study context (Table 2). Third, a **cluster analysis** was performed to assess farmers' heterogeneity in terms of value network embeddedness, demographics and farm characteristics. Ten inputs were used to establish the different clusters of farmers, namely: reciprocity, resource diversification, channel diversification, gender of household head, age, sub-county, amount of land used for coffee production, use of pesticides, use of artificial fertilizers and typology of buyers. Fourth, the emerging clusters of farmers were

Table 2 The three contextualized dimensions of farmers' value network embeddedness

	Reciprocity	Resource diversification	Channel diversification
1. Low	These farmers do not share or exchange any resources bi-directionally with other actors in the value network.	These farmers receive three or less different types of resources, most often seedlings, information and fertilizers, and provide only one resource, namely their grown commodity (i.e., coffee).	These farmers exchange resources with three different types of actors at most, including other farmers, buyers and extension officers.
2. Medium	These farmers exchange predominantly information and knowledge with other actors in their networks.	These farmers receive four/five different types of resources, including also pesticides and training. Along with commodities, they also provide information and knowledge.	These farmers exchange resources with four/five different types of actors at most, including input suppliers and cooperatives.
3. High	These farmers own a coffee pulping machine and, with it, they exhcnage pulping services for money with other actors in their network.	These farmers receive more than five types of resources, including knowledge from key informants and loans. Along with the above, they also provide pulping services to the actors in their network.	These farmers exchange resources with at least six different types of actors., including banks, non-governmental organizations (NGOs) and others.

Note: The categorization within this three-point scale is highly contextual, inductive and therefore inherently interpretative (Gioia et al. 2013). It is contextual, because grounded on the local conditions of rural Uganda; in other contexts, for example, low, medium or high reciprocity would have very different meanings. It is inductive, as it emerged from the empirical data rather than from theory itself. Thus, it is interpretative since the research team has subjectively assessed, through team trainagulation, the development of the emerging scale

related to the **key innovation constraints** that they face in the processes stimulated by the MSP. These entail, among the others, limited access to extension services, limited access to financial capital, low coffee prices, high price fluctuations and limited access to agricultural inputs.

5 Findings

Results from the value network analysis show that farmers widely differ from each other in terms of their value network embeddedness (assessed in terms of reciprocity, resource diversification and channel diversification) in relation to their age. Furthermore, this heterogeneity closely relates to the innovation constraints that each cluster of farmers faces. The three key clusters of farmers emerging from the 27 smallholders interviewed are synthesized in the following sub-sections.

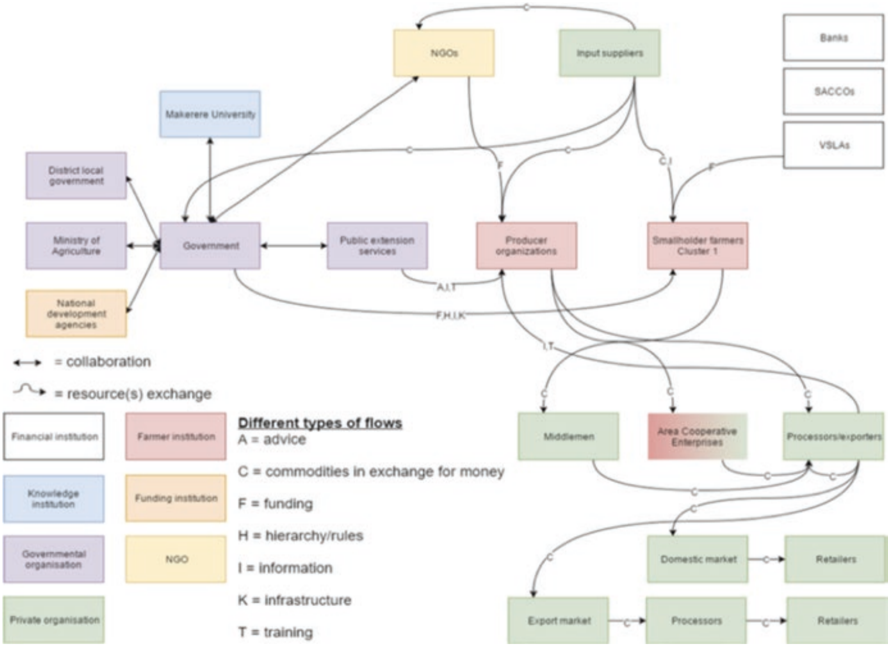

Fig. 1 Value networks embeddedness in Cluster 1 (predominantly younger males in Mukoto)

5.1 Cluster 1: Young and Predominantly Male Farmers from the Highlands

This cluster includes farmers of 36 years of age on average, prevalently males, whose farms are located in the highlands. These farmers have only a small coffee production, with less than 0.5 acres dedicated to coffee. They make little use of agricultural inputs and sell predominantly to middlemen. As Fig. 1 shows, they are not directly involved in coffee producer organizations.

The value network mapped in Fig. 1 shows that these farmers display *significantly lower resource diversification* and *lower channel diversification* compared to the other two clusters. First of all, they do not receive training (T) nor advice (A) from any other actor in their network. Second, they rely only to the Government, without the intermediation of any government agency, to gain access to physical (e.g. roads) and knowledge infrastructures (K, which stands for knowledge), as well as knowledge about the existing legislation (H, i.e. hierarchy/rules). Third, they receive information (I) on agricultural inputs to be purchased (C, i.e. commodities such as agricultural inputs) mostly from input suppliers and the government, without the chance to triangulate the information received with other actors in the network. Fourth, these farmers are not connected to the formal financial markets nor

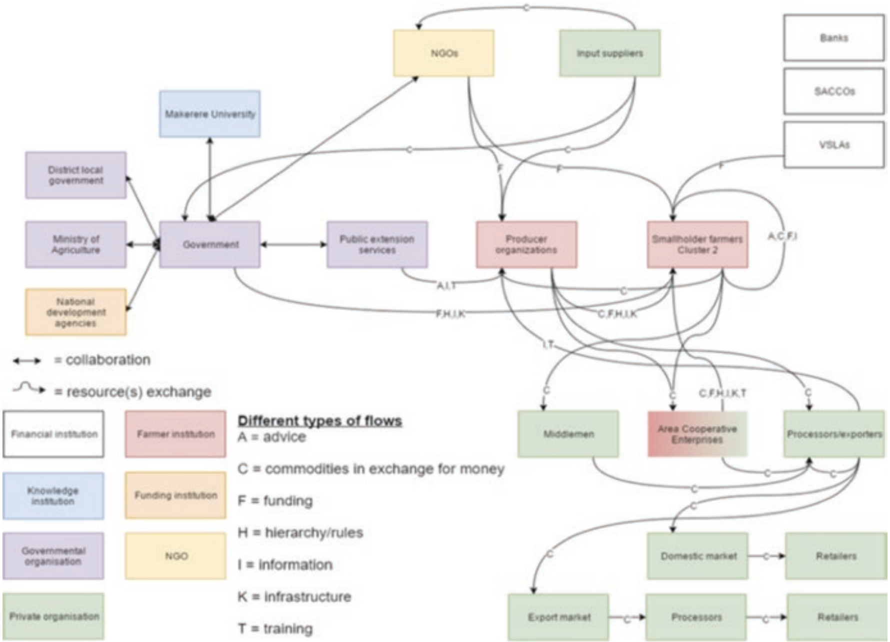

Fig. 2 Value networks embeddedness in Cluster 2 (predominantly elder female in Namabya)

microfinance institutions. Therefore, when they have access to credit (F), they only have it through village savings and loans associations (VSLAs). Finally, given their geographical distance from the markets, they trade their coffee (C, i.e. commodities such as coffee) only through middlemen. Given their limited embeddedness in value networks, it is perhaps not surprising that—despite their participation to MSPs—this cluster of farmers faces the toughest innovation constraints in relation to what they learn through the MSP.

5.2 Cluster 2: Elder and Predominantly Female Farmers from the Midlands

This cluster includes predominantly elder female farmers located in midlands, with average coffee production (0.5 < 2.5 acres). These farmers make little to no use of agricultural inputs and sell predominantly to middlemen and their cooperative.

The findings in Fig. 2 show that these farmers have *a remarkably higher reciprocity* than the other two cluster groups. In particular, through their predominant participation in cooperatives and other producer associations, they exchange more knowledge and information with each other than farmers in Cluster 1. Relative to farmers in Cluster 3, though, these farmers have more limited access to input suppliers and formal financial markets.

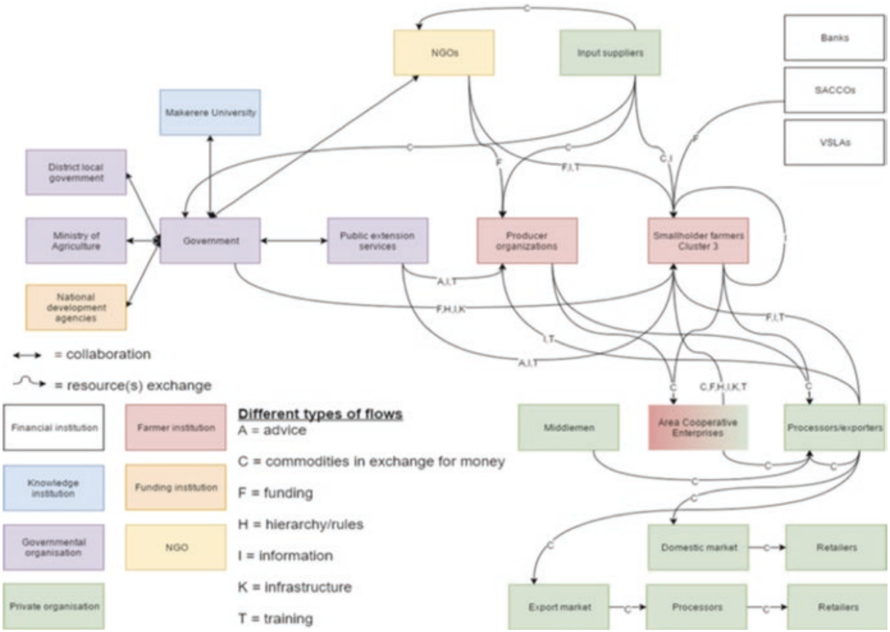

Fig. 3 Value networks embeddedness in Cluster 3 (predominantly middle-aged males in Bukhofu)

5.3 Cluster 3: Middle-Aged and Predominantly Male Farmers from the Lowlands

This cluster includes mostly middle-aged male farmers located in lowlands with larger coffee production (2.5+ acres), making extensive use of agricultural inputs and selling predominantly to cooperatives and processors/exporters.

Findings from Fig. 3 highlight that these farmers show *lower reciprocity yet higher resource diversification* than farmers in the other clusters. Being more geographically connected to the formal coffee and financial markets, these farmers have higher access to relationships associated with commodity exchange, better access to knowledge, information and finance than farmers in Clusters 1 and 2.

6 Discussion

Using the lens of value network embeddedness, these findings highlight that younger coffee farmers in the Ugandan MSPs indeed struggle to play a critical role in sustainable food system transformation. Why do youth face such a persisting challenge? Although limited to a small sample of 27 smallholder farmers in one district, the findings highlight that younger farmers tend to own smaller farms, in more remote areas from the markets and thus more disconnected from the denser value networks (Fig. 1) that instead characterize the lowlands (Fig. 3) closer to the Mbale market. Furthermore, the findings also suggest that these younger farmers are also less organized in groups or cooperatives than, for example, elder women in the midlands (Fig. 2). On the one hand, the findings confirm the problems related to farm ownership constraints that youth face in agriculture (Holden and Otsuka 2014). Until the time that they inherit the land, in fact, the farm belongs to their parents, and as such they have limited control and decision-making over the land (Fitz-Koch et al. 2018). Moreover, when they inherit the land, this often needs to be divided into smaller plots among several siblings (Bezu and Holden 2014; Holden and Otsuka 2014). On the other hand, these findings confirm that younger farmers engage less in collective action. This may be either because of their shorter experience or even their more precarious commitment to agriculture (Moore 2015), but it may also because of the more difficult access to infrastructures such as roads and information technology (Wyche and Steinfield 2016).

Given the differences in terms of embeddedness in value networks, these findings suggest the following set of implications for projects building and/or supporting MSPs for the achievement of SDG 17 and other interrelated SDGs (MacDonald et al. 2018). First of all, farmers from the highlands (Cluster 1) predominantly need a wider set of resources than knowledge, which is usually what they obtain from peer farmers and other stakeholders in MSPs. In particular, these farmers may find MSPs mostly useful to build relationships with input suppliers, buyers, financial and training institutions. For example, developing more inclusive governance mechanisms in MSPs (Dentoni et al. 2018a; Helmsing and Vellema 2012; MacDonald et al. 2018; Tenywa et al. 2011) may stimulate the involvement of younger farmers towards the achievement of SDG 17 and other interrelated SDGs. Furthermore, in complementarity with MSPs, youth access to dedicated producer organizations or agricultural commodity exchanges may embed them further in value networks which, in turn, would make their involvement in MSPs more beneficial to them. Nevertheless, to make MSPs more inclusive, or to promote youth-led organizations that complement MSPs, either the government or NGOs may need to provide sustained financial support. A further contribution to the involvement of youth in the creation of a more sustainable food system could come from a new wave of education based on experiential learning: by engaging in non-formal education and cross-sector collaboration practices (also in relation to the agricultural sector), youth can foster certain soft skills (such as systems thinking) which are fundamental for the achievement of SDGs (Allievi et al. 2018).

7 Conclusion

The available literature highlights geographical differences in the challenges faced by young people in their contribution towards a more sustainable food system. In particular, in many African countries one pressing factor is the scarcity of infrastructures. In other areas, a lack of adequate support, by institutions but also by family members, has been idenfied as an influential factor. Taken together, the results of this review and empirical study underline the need for a greater involvement of youth in the development of agricultural planning. Youth can contribute positively to the achievement of SDGs, but it will be enabled to do so only if its needs are addressed properly, in terms of physical and financial resources, as well as education and empowerment. As such, these findings remark the need—not only for agricultural actors such as farmer associations or MSPs, but also for governments, companies and other powerful stakeholders in the broader agri-food system—to address the context-specific challenges faced by young farmers.

The contribution of this analysis, and related findings, is both methodological and theoretical. From a methodological standpoint, the use of value network analysis to understand constraints and opportunities for a deeper food system transformation (Dentoni et al. 2019) contributes to the growing literature on the use of map diagnostics to set up, understand and if necessary re-organize collaborative organizations in Sub-Saharan Africa, including MSPs (Schouten et al. 2018). Value network maps visually show the differences among actors within a system, therefore raising awareness about why certain challenges persist and offering points of entry for engaging in strategic networking or even for organizing new forms of collective action. From this methodological perspective, the focus of value network embeddedness also confirms that the configuration of actors in a value network is tightly interrelated with the nature of the collective problems that those actors face (Allee 2009; Waddock et al. 2015).

From a theoretical standpoint, the findings from this study suggest that young farmers' value network embedeness may relate to their struggle to engage in sustainable food systems. For what concerns the literature on MSPs as a novel organizational form seeking to support transitions towards more sustainable food systems, these findings suggest that the topic of youth inclusion and inclusiveness in MSP governance mechanisms would deserve specific attention (Tenywa et al. 2011). For example, with specific knowledge of which young actors are poorly embedded in identified value networks, MSPs can potentially undertake specific interventions that close the 'missing links' or 'blind spots' in a local system (Dentoni et al. 2019). Furthermore, findings on this heterogeneity in value networks may support knowledge institutions, including universities, to provide more tailored entrepreneurship education programs (Lai et al. 2017b) to address complex systemic problems (Dentoni and Bitzer 2015). With a stronger focus on processes of including specific population segments of marginalized farmers, such as resource-scarce and network-disembedded youth, MSPs may overcome organizational challenges towards a more adaptive and transformative governance (Biermann 2007) necessary for supporting sustainable transitions towards the SDGs.

Acknowlegments The authors are grateful to the Australian Center for International Agricultural Research (ACIAR) for generous funding granted under the project FST/2014/093 titled "Value chain Innovation Platforms for Food Security" (VIP4FS). Furthermore, the authors wish to acknowledge Makerere University, the National Forestry Resources Research Institute (NAFORRI), University of Adelaide, and the World Agroforestry Centre for their supportive cooperation during the data collection.

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Innovation for Sustainable Food Systems: Drivers and Challenges

Angelo Riccaboni and Alessio Cavicchi

1 Sustainable Development as a "Wicked Problem"

Since the publication of "Our Common Future" in 1987 by the World Commission on Environment and Development (WCED), there has been a growing interest in the conceptualisation and application of sustainability: several initiatives at global and local levels carried out by governments, civil societies, business leaders, common people, are described and analysed by thousands of academic publications.[1] Nevertheless, achieving a sustainable development is a very difficult task. According to Pryshlakivsky and Searcy (2013, p. 109), one of the reasons of this shortage of results is related to the concept of "wicked problem": "like all wicked problems, Sustainable Development issues are often characterized by a lack of clarity, uncertainty, ambiguity, high risk, and limited understanding. Among other challenges, these characteristics make establishing appropriate analytical boundaries problematic". In 2008, Sandra Batie, in her milestone article in the American Journal of Agricultural Economics (Batie 2008), addressed the main characteristics of a wicked problem. In general, no agreement exists about the real nature of the problem and every attempt to create solutions (that cannot be "true or false", they can only be "better or worse") changes the same problem over time. Thus, in light of the high uncertainty in terms of system components and outcomes, different stakeholders can have different ideas about the "real" problem and its causes, and it is difficult

[1] The search for these keywords "Our Common Future" on scholasr.google.com retrieves 77.900 results (beginning of January 2017)

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_7

to find share values with respect to societal goals. She gives a clear illustration of this lack of shared values, common solutions and joint points of view about sustainability.

> "*For example, with respect to sustainability of ecosystems, environmental ethicists may focus on the intrinsic value of nature; applied economists may focus on the instrumental value of nature; and non-academics may bring tacit knowledge garnered from practical experiences and personal values associated with nature and resource use. Also, management agencies might consider natural resources from the viewpoint of wildlife survival, whereas project agencies might consider natural resources as commodities. Even when dialog occurs and includes all of the actors, clear solutions rarely emerge; rather, via negotiation processes are identified which are judged as better or worse (not right or wrong) in addressing the wicked problem*".

Similarly, Dentoni et al. (2018) highlight that sustainability issues cannot be easily framed in "linear cause–symptom–effect relationships (*knowledge uncertainty*), evolve unpredictably over time (*dynamic complexity*) and involve conflicts of values among stakeholders (*value conflict*)". As a consequence, wicked problems such as sustainable development and the implementation of Agenda 2030 call for different and innovative approaches, able to activate deeper and broader systemic change (Ferraro et al. 2015).

Mediterranean food systems, in particular, are under strong pressure due to climate change, unsustainable agricultural practices, changes in dietary habits and a huge coastal urbanisation. To deal with such crisis, technological innovation is crucial. Precision farming, new water management techniques, drones, blockchains, Decision Support Systems are only a few of the tools which are becoming available. However, the technological side is not sufficient to tackle challenges of sustainable food systems. The social dimension of change is relevant as well. Farmers and producers who want to behave in a sustainable way need also more entrepreneurship, access to new markets, capacity of answering to new dietary needs, new professional figures, more modern extension services, and sharing of experiences. Furthermore, sustainable food systems need a better political and policy coherence, alignment, coordination and cooperation among agriculture, health, water, energy and other related sectors, such as tourism and economic development (Réquier-Desjardins and Navarro 2016).

In this perspective, identification of solutions becomes as much a social and political process as it is a scientific endeavour (Kreuter et al. 2004). Furthermore, multi-stakeholder engagement and global partnerships become extremely relevant in order to balance different stakeholders and their respective objectives. This is particularly true with reference to food systems. Such systems include complex and interconnected activities going from the field to the fork, with many actors and often within a very large geographical area. They also present clear and intertwined economic, social, cultural, environmental dimensions. As a consequence, it is impossible to tackle sustainability issues of such systems without the contribution of different and coordinated actors, ranging from farmers to producers, regulators, policymakers, innovators, academics, NGOs and customers. Too many objectives and interests are at stake. Without a good balance among them, any solution will leave discontent and open issues.

In order to analyse the importance of multi-stakeholder partnerships, Dentoni et al. (2018) recently discussed the interesting concept of "Harnessing wickedness," i.e., the approach of taking into account and responding to the different dimensions of wicked problems. This approach requires a governance process that enables networked action carried out by different actors such as business, NGOs, governments and academia, to stimulate collective processes and deal with complex dynamics to achieve small wins. In this context, Higher Education Institutions can have a crucial role. According to Dentoni and Bitzer (2015), academics in multi-stakeholder initiatives in the agrifood sector can play five key roles:

(a) knowledge experts,
(b) agenda-setting advisors
(c) facilitators,
(d) providers of new knowledge on multi-stakeholder initiatives by theorizing from their observation and reflection,
(e) creators of international bridges between students and multi-stakeholder initiatives.

In short, many studies (see also Rinaldi et al. 2018) provide empirical evidence that, to address the challenges of sustainability, universities need to play new functions and missions, going beyond the traditional economic focus of the third mission and conventional technology transfer practices.

To find innovative approaches and pathways of sustainable development, new modes of interaction with stakeholders are needed. This brings to a switch and expansion of the traditional model of the "triple helix" (Amaral et al. 2011) to a "quadruple helix", being the community the new subject of this model together with Universities, Public bodies and Business actors. Within such model, universities are called to new forms of networking and co-working, within living labs shared with the communities of their territory and beyond. As stated by Van Winden and Carvalho (2015, p. 10): "The quadruple helix opens up issues around the nature of demand and may also move innovation from having a narrow technological orientation towards a more societal focus". These transformations and transition towards a new concept of Universities' missions are happening in different higher institutions throughout the world, to varying degrees (Rinaldi et al. 2018). Sometimes such "co-creation for sustainability" (Trencher et al. 2013) is recognized as a fourth Universities' mission, even though this function is still new, not established yet in the academic literature like the third mission and could also be embedded in an expanded version of the third mission.

In parallel to the rise of such third/fourth mission, an increased role is given to universities in the development and capacity building within their local economies (Kempton 2015). According to Goddard et al. (2012), the functions of what they call "civic university" should be the following:

(a) Provide opportunities for the society of which it is part (individual learners, businesses, public institutions).
(b) Engage as a whole not piecemeal with its surroundings
(c) Partner with other local universities and colleges.
(d) Be managed in a way that facilitates institutional wide engagement with the city and region of which it forms part.
(e) Operate on a global scale but use its location to form its identity.

Such new roles of Universities were highlighted by policy strategies such as Europe 2020 (European Commission 2010) and are taken into consideration in the definition of the new Horizon Europe Research programme. As Mazzucato (2018) underlines, societal missions are much more complex because they are less clearly defined and indeed must be co-defined by many stakeholders. Higher Education Institutions can be crucial to mediate between sectoral, regional and national ecosystems of innovation, linking them, in a dynamic way, to different public and private actors and to international institutions. New challenges arise for Universities, called to reconsider their role in society and their contribution to regional, economic, social and cultural development (Cavicchi et al. 2013). Also because globalisation is being accompanied by a regionalisation process and Universities are expected to contribute to the development of the territory where they are embedded. They can do it putting themselves at the center of local and regional learning and innovating partnerships, bridging different partners, creating a sustainable learning organisation and developing on-going leadership capacity in the region (Rinaldi et al. 2018). In short, addressing sustainability challenges means for Universities to be engaged in place-based, multi-stakeholder partnerships to solve real-world issues. "Co-creation for sustainability" should become a new function (fourth mission) of Universities, switching from entrepreneurial to transformative university, conceived as "a multi-stakeholder platform engaged with society in a continual and mutual process of creation and transformation" (Trencher et al. 2014, pp. 7–8).

2 Multi-Stakeholders Partnerships for Innovation in Mediterranean Food Systems

After the approval of the Agenda 2030, the contracting parties to the Convention for the Protection of Marine Environment and the Coastal Region of the Mediterranean, commonly called "Barcelona Convention" (participated by 21 Mediterranean Countries and the European Union), adopted the revised Mediterranean Strategy for Sustainable Development 2016–2025. Such strategy provides a strategic policy framework built upon a broad consultation process for securing a sustainable future for the Mediterranean region, consistent with Sustainable Development Goals: "It aims to harmonize the interactions between socioeconomic and environmental goals, adopt international commitments to regional conditions, guide national strategies for sustainable development and stimulate the regional cooperation between stakeholders in the implementation of sustainable development" (UNEP/MAP 2016, p. 7).

The European Union is also playing an important role in enacting Agenda 2030. Since its Agenda for Change,[2] the EU declared its will to play a leading role into the implementation of an ambitious, transformative, and universal agenda that delivers poverty eradication and sustainable development for all, increasing the impact and effectiveness of EU development policy. Among the principles of the Agenda, coordination seems to be a relevant one. In fact, to avoid fragmentation of aid and further increase the impact, the EU and its member states highlight the centrality of joint programming among different actors and Countries. The EU also defined a broad European Neighborhood Policy (Dannreuther 2006), within which the Union for the Mediterranean was boosted. This is an intergovernmental organization bringing together the 28 European Union member states and 15 countries from the southern and eastern shores of the Mediterranean. It provides a unique forum to enhance regional cooperation and dialogue in the Euro-Mediterranean region. A major policy approach that the EU implemented to boost sustainable development through Multi-stakeholders Partnerships is the Smart Specialization Strategy. The core idea of such strategy is that a limited number of promising priorities has to be selected to stimulate regional growth, job creation and collaboration among research and knowledge institutions, businesses, and the investors (Stančová and Cavicchi 2018).

Regions and Countries enhance their R&I systems by looking beyond their national/regional administrative borders for opportunities, and by supporting transregional and international R&I activities. As a consequence, trans-regional cooperation in R&I becomes an essential element of Smart Specialisation. Radosevic and Ciampi Stancova (2015) argued that the transformative power of Smart Specialisation can be seen in the capacity of the regions to combine locally accumulated knowledge and technologies with international knowledge and production networks. Internationalisation within Smart Specialisation includes not only export and foreign direct investments (FDI) but also 'strategic alliances, joint research, co-development, outsourcing, relocation, mergers and acquisitions, licensing intellectual property rights (IPR), soft landing, and technology showcase' (Foray et al. 2012, p. 94). Smart Specialisation matches research strengths with business needs in an international environment. Internationalisation and Smart Specialisation should create a context within which regions are able to identify domains for (present and future) competitive advantage, and relevant linkages and flows of goods, services and knowledge that reveal opportunities for collaboration with other regions. Rakhmatullin et al. (2016, p. 78) suggested that regions should consider opening up their smart specialisation strategies to gain access to wider business and knowledge networks; get necessary research capacity; reach out to other markets; expand business opportunities; combine complementary strengths; and join global

[2] The Agenda for Change, adopted in 2011, is the basis for the EU's development policy. The primary objective of the Agenda for Change is to significantly **increase the impact and effectiveness of EU development policy** and, to this end, a series of key changes in the way assistance is delivered have been introduced. These key orientations have changed EU development policy significantly and have informed the programming process for the current 2014–2020 period (https://ec.europa.eu/europeaid/policies/european-development-policy/agenda-change_en)

value chains. Smart Specialisation is by definition an on-going, evolutionary process based on continuous exploration and exploitation of research and business potential and opportunities. A novelty is represented by the role given to regional entrepreneurs to identify business opportunities, as they are positioned close to the market, in the best position to collect information on economic trends, competitors, market gaps, industrial trends and new markets. It should be noticed that one in five priorities reported by EU countries and regions focus on agro-food technologies, the others being key enabling technologies, health, energy, and the digital agenda.

Agro-food is probably one of the most transversal domains, intersecting, besides bioeconomy and agriculture, the fields of technology, tourism, health and well-being, services, sustainable innovation, cultural and creative industries. This means, in practice, that Regions and EU member States are now called to increase their international collaboration in Agri-food research and innovation as a prerequisite (*ex-ante conditionality*) to get European Structural Funds (Stančová and Cavicchi 2018). Such place-based policies can be defined as policies that take into account the special dimensions and the specific context where economic activities are embedded. For instance, developing labor markets or innovation in a city may not entail the same type of instruments and may require a different sort of approach than in a rural area. This means that "one size fits all solutions" do not exist and participatory approaches, stakeholders' engagement activities and a constant problem-based research are crucial elements to implement diversification strategies (Cavicchi and Stancova 2016).

In line with this orientation, many universities are rethinking their roles and responsibilities, exchanging knowledge with actors outside academia and collaborating with stakeholders. A European Commission report states: "There is a growing recognition between universities and local/regional leaders of the potential for mutually beneficial relationships, and the active role of universities in terms of their contribution to local and regional development, and innovation has gained a new salience in the context of smart specialisation as a future focus for European regional policy" (Kempton et al. 2013). Also the Joint Research Center of the European Commission recently analysed the role that universities might play in local development, showing that HEIs can build innovation capabilities in Regions and play a much broader role than usually considered.[3] The debate is open and extremely alive, also because, given public funding constrains, universities are called by governments to show that their activities are worth to be funded. Being able to contribute, through an effective multistakeholder engagement, to economic and social growth in key sectors such as the agrifood can be a good answer to such request.

[3] Launched in March 2016, the HESS project focuses on how higher education and HEIs can contribute to the successful implementation of S3. It has two broad aims: (a) To help build innovation capabilities by strengthening the role of HEIs in regional partnerships, (b) To promote the integration of higher education with research, innovation and regional development in S3 policy mixes, particularly in the use of European Structural and Investment Funds (http://s3platform.jrc.ec.europa.eu/hess)

3 Major Institutional Multistakeholder Initiatives for Sustainable Mediterranean Food Systems

Besides the Union for the Mediterranean, cited above, other institutional partnerships are deeply involved in promoting more sustainable Euro-Mediterranean food systems.

CIHEAM, International Center for Advanced Mediterranean Agronomic Studies, founded in 1962, is a Mediterranean intergovernmental organisation devoted to the sustainable development of agriculture and fisheries, food and nutrition security and rural and coastal areas. Participated by 13 member states, and based in Paris, its collaboration, research and education activities are performed in four Institutes in Italy, Greece, France and Spain. According to the aim of this Center, all its activities are based on a bottom-up collaboration approach and pursue problem-solving approaches, in relation with the specific needs of the countries and in line with Agenda 2030 in the Mediterranean in some specific fields.

Another important initiative is represented by **UNIMED**, the Mediterranean Universities Union, founded in 1991. It counts 113 Universities coming from 23 countries of both shores of Mediterranean (data updated to November 2018) and its aim is to develop research and education in the Euro-Mediterranean area in order to contribute to scientific, cultural, social and economic cooperation. Through the many initiatives carried out over the two decades, UNIMED has promoted the collaboration between universities of the Mediterranean, becoming a point of reference of the international university cooperation. Particularly relevant for the aim of this work, is the establishment of agri-food UNIMED sub-network. Such sub-network allows an intensive exchange of information among the participating actors of the two Mediterranean shores for the creation of partnerships, collaborations and projects. The aim of these projects is to strengthen the economic and social cohesion, in order to promote cross-border, transnational and interregional cooperation in the field of food systems and local sustainable development.

A recent policy initiative pursued by the European Union in the field of food systems is boosting the collaboration between Higher Education Institutions and enterprises on both shores of the Mediterranean. With the Decision 2017/1324 of the European Parliament and of the Council of 4 July 2017 on the participation of the Union in the Partnership for Research and Innovation in the Mediterranean Area, a new initiative, **PRIMA**, was adopted by the EU. The aim of this partnership is to develop much-needed solutions for a more sustainable management of water and agro-food systems. The main objective of the 10-year initiative (2018–2028) is to devise new R&I approaches to improve water availability and sustainable agriculture production in a region heavily distressed by climate change, urbanisation and population growth. The partnership currently consists of 19 participating countries,[4] and it is financed through a combination of funding from participating

[4] Algeria, Croatia, Cyprus, Egypt, France, Germany, Greece, Israel, Italy, Jordan, Lebanon, Luxembourg, Malta, Morocco, Portugal, Slovenia, Spain, Tunisia and Turkey (http://ec.europa.eu/research/environment/index.cfm?pg=prima)

Countries (currently €274 million), and a €220 million contribution from the EU through Horizon 2020, its research and innovation funding programme (2014–2020). In line with the priorities of Horizon 2020, the general objectives of PRIMA are to build research and innovation capacities and to develop knowledge and common innovative solutions for agro-food systems, to make them sustainable, and for integrated water provision and management in the Mediterranean area, to make those systems and that provision and management more climate resilient, efficient, cost-effective and environmentally and socially sustainable, and to contribute to solving water scarcity, food security, nutrition, health, well-being and migration problems upstream. The involvement of all relevant public and private sector actors in implementing the strategic agenda by pooling knowledge and financial resources to achieve the necessary critical mass, is one of the specific objectives of PRIMA. Particularly, the Strategic Research and Innovation Agenda of the Programme, outlines the importance of promoting local (country based) and Euro-Mediterranean multi-level stakeholder/actor networks to improve governance-related capacity in agricultural water and agro-food systems, integrating and bridging different (and opposite) interests and stakes.

4 Some Preliminary Evidence and Challenges for the Future

In order to implement more sustainable food systems some universities are reconsidering their role in society, promoting multistakeholder involvement and the establishment of innovation working labs based on principles of co-creation and co-working. Such labs allow universities to better interact with their multiple local stakeholders, allowing the definition of more effective sustainable development paths. They act as physical locations to guarantee an "initial hearing" for ideas and business projects, supporting university spin-off projects, without becoming incubators. Such labs represent concrete places for hybridization among different scientific and operating perspectives, offering valuable opportunities for dialogue among stakeholders and concrete support to joint creativity and innovation. Researchers, teachers and experts meet with farmers, entrepreneurs, students, technicians, discussing common issues, sharing experiences, proposing new partnerships and testing solutions. Experts contribute from different fields, including agronomy, engineering, digital, economy, business, law, natural sciences, marketing, and sociology.

This new approach is not simple to follow. Difficulties depend upon some conservatosm in the academic field and mis-aligned incentives. It is not easy to convince researchers from different scientific fields to share experiences, tools and networking and to co-work with business. Even more problematic is that incentives to make academics dialogue with local partners and stakeholders are weak. If the sole incentive for university careers is the number of publications on impacted journals, everything else will fall into second place. Therefore, regulatory institutions, governments, the academic community and the public opinion should define incentives for researchers coherent with the promotion of innovation and sustainable development. New careers paths giving attention to multistakeholder engagement could be devised and positive outcomes from joint activities between academic and business should be taken into consideration by Universities to assess individual careers. Furthermore, more investments should be dedicated to professional figures and innovation centers to support researchers in their connection with business. This is particularly important in the field of food systems, where a wide range of expertise is required to deal with technological changes and social and environmental challenges in front of the sector.

In short, implementation of Agenda 2030 and dealing with issues of Mediterranean food systems represent a breeding ground for policy innovation and for a reflection on the role of Higher Education Institution. In particular, they require more and more international, North-South and regional cooperation and multi-stakeholder partnerships, crucial to facilitate knowledge sharing, capacity creation and adoption of sustainable solution. In this way, different kinds of expertise, advanced technologies and financial resources could be mobilized and processes of sustainable co-innovation activated. Within such scenario, Universities can play a pivotal role, promoting effective public-private partnerships, contributing to the empowerment of key local community stakeholders and creating conditions to boost more sustainable food systems and local economic growth.

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Part II
Solution Oriented Approach

Sustainable and Healthy Diets for Achieving the SDGs: The Role of Consumers

Cecilia Rocha and Daniela Spagnuolo

1 Introduction

Changes in current food systems are essential for achieving the Sustainable Development Goals (SDGs). How we produce, distribute, process, consume, and dispose of food can affect levels of poverty (SDG 1) and food insecurity (SDG 2); the health and well-being of people (SDG 3); gender equality (SDG 5), decent work (SDG 8) and inequality (SDG 10). Changes in the way we produce, distribute, and process food will certainly impact climate change (SDG 13) as well as life below water (SDG 14) and on land (SDG 15). The concept of *sustainable diets* is relevant to all of these (Mason and Lang 2017), but it relates most pertinently to SDG 12—responsible consumption and production.

The need for diets to be more environmentally sustainable is detected from a list of environmental problems associated with food systems. Food production, for example, is largely responsible for much water pollution and water scarcity, soil degradation and erosion, deforestation and loss of biodiversity, depletion of fish stocks, and climate change (IPES-Food 2016). Food losses and waste are major contributors to inefficiency in the use of resources and creation of greenhouse gases (FAO 2011). At the same time, these same conditions are negatively impacting human health (IPES-Food 2017).

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_8

The concept of sustainable diets has emerged with the promise of a positive transformation of food systems through changes in what global populations eat. Its alluring message of a win-win outcome—better health and sustainable environment—is increasingly incontestable given mounting evidence of its potential benefits (Fischer and Garnett 2016). But in a world in which food is mostly a commodity, bought and sold through markets, how do we make the transition from unsustainable and unhealthy food systems to sustainable diets? Can consumers, through their choices of what food to buy, lead the way to that transformation?

In this chapter we look at the concept of sustainable diets and its interaction with the concept of responsible consumption. We explore the possibility of having consumers as drivers of change in the food system through their food choices in market contexts. As expanded below, while consumer choices have the potential to influence the food system we have, these choices are also in turn shaped by the existing food system. We, thus, argue for the necessity of policy to facilitate consumer agency. In conclusion, we propose that responsible consumption (and responsible production) needed for achieving SDG 12 and other sustainable goals cannot be realized without responsible (and responsive) public policy.

2 Sustainable and Healthy Diets

While some specific high-risk foods can be identified, it is diets in their entirety and overall balance that are increasingly being associated with health and environmental impacts. Healthy diets are generally considered to include a diversity of nutrient-rich foods, such as vegetables, fruits, whole grains, and pulses (beans, legumes, nuts and seeds), modest amounts of meat and dairy (for non-vegetarians or vegans) and unsaturated vegetable oils (GLOPAN 2016). Conversely, unhealthy dietary patterns are characterized by foods high in added sugar, sodium, saturated fat and trans fat, and low in fruit, vegetables, pulses, whole grains and nuts.

Unhealthy dietary patterns have become increasingly prevalent in recent decades—a trend that has been accompanied by growing rates of overweight, obesity and non-communicable diseases (NCDs) worldwide. Indeed, unhealthy dietary patterns have been identified as a risk factor for a range of NCDs, both directly and by contributing to obesity (Kaveeshwar and Cornwall 2014). The growing prevalence of obesity is a global health concern, as it heralds increasing incidence of several debilitating diseases, including type 2 diabetes, hypertension, coronary heart disease, metabolic syndrome, respiratory conditions, cancer and osteoarthritis, as well as reproductive, gall-bladder and liver diseases (Butland et al. 2007; Grundy 2016; Wang et al. 2011).

Overweight and obesity have reached epidemic levels in many countries. Since 1975, the worldwide prevalence of obesity has nearly tripled, with 39% of adults estimated to be overweight and 13% to be obese in 2016 (WHO 2017). Among children, 38 million under the age of 5 (UNICEF et al. 2018) and over 340 million under the age of 18 are now overweight or obese (WHO 2017). Non-communicable diseases are now the leading cause of death globally, with 71% of all deaths (WHO 2018). The global prevalence of diabetes (closely linked with the rise in obesity) is estimated to be 6.4% among adults aged 20–79 years. The International Diabetes Federation (IDF) estimates that by 2040, one in 10 adults globally will have type-2 diabetes (IDF 2015).

These same unhealthy diets are linked to the unsustainable use of planetary resources (land, water, and air). Hence, diets have a significant effect on individuals' health and on the health of the environment—the premise (and the reality) behind the concept of sustainable diets. In 2010, the Food and Agriculture Organization (FAO) together with Bioversity International proposed a definition of sustainable diets as:

> *[…] 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, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources* (FAO 2010).

Since the introduction of the concept, many studies have shown the health and climate change co-benefits of transitioning towards diets based on minimally processed foods and comprised mostly of plants (see, for example, Ruini et al. 2015; Springmann et al. 2016; Auestad and Fulgoni III 2015; Fischer and Garnett 2016), reassuring that it is possible to eat well for both environmental and bodily health. More nuanced research has focused on, for example, how low the consumption of meat and dairy could be in maintaining a healthy diet, given that the bioavailability of key nutrients is higher when they come from animal- versus plant-based foods (Barré et al. 2018; Seves et al. 2017). Similarly, the role of meat consumption in healthy and culturally relevant diets, or the differences in the nutrition quality of meats produced in different ways (grass-fed x grain-fed) are further topics for research. The fact remains, however, that a sustainable and healthy diet is one with much lower consumption of meat and dairy products than what is now seen in most North American and European countries, and what is expected for consumption patterns throughout the world if trends are not reversed.

The concept of sustainable diets also embodies a preoccupation beyond individual and planetary health. It includes calls for diets that are *culturally acceptable, economically fair and affordable*. It is a view of diets as shaped by the overall food system, and its social, economic, and cultural characteristics (Meybeck and Vincent 2017). It signals a concern with human health in broad terms, as a product of food systems.

In its 2017 report, *Unravelling the Food-Health Nexus*, the International Panel of Experts on Sustainable Food Systems (IPES-Food) identified five key channels through which food systems are making people sick: (1) people work under unhealthy conditions; (2) they are affected by contaminants in water, soil or air; (3) they eat foods that are unsafe for consumption; (4) they have unhealthy diets; and/or (5) they are food insecure and can't access adequate, acceptable foods at all times (IPES-Food 2017). This systemic approach to human health expands the view of sustainable diets as beneficial to the health of individuals consuming them and to the natural environment, but also beneficial to other individuals on the planet. It invites a consideration of "health" beyond individuals and the natural environment, to incorporate social, economic, and cultural wellbeing.

3 Responsible Consumption and Alternative Markets

How can we minimize the health impacts of food systems when food is a commodity, bought and sold through markets, through the interactions of buyers and sellers, consumers and producers? Modern intensive agriculture has explicitly aimed to simplify biological diversity and promote uniformity in order to facilitate economies of scale (IPES-Food 2016). This has led to decreasing diversity in agricultural production and food supplies and has had impacts on the environment, defining and maintaining cultural identities and livelihoods, and nutrition (Jones 2017).

The concept of sustainable diets suggests the possibility of consumers as agents for change through their ethical choices of what to eat (Gillani and Kutaula 2018). The premise is that, through "responsible consumption", ordinary people can effect change by carefully selecting the products they buy. However, diets are also results of particular food systems and of particular food environments within which consumers make their choices (Cannuscio and Glanz 2011). Healthy and sustainable diets are more likely to prevail in a food system characterized by conditions and opportunities to facilitate consumers' access to such diets (Kraak and Story 2015).

This dynamic of diets as both drivers and consequences of food systems is behind the vicious circle of food consumption we find today: consumers choosing, for the most part, diets that are not healthy and not environmentally sustainable, but which also contribute to a food environment (and a food system), which favors such detrimental choices. This vicious circle can also be described by starting with the food system, whose characteristics include incentives (e.g., marketing promotion) for consumers to make unhealthy and unsustainable choices, which in turn reinforce that system. As a consequence, price, convenience, and brand familiarity are often the most important decision criteria for most consumers (Vermier and Verbeke 2006), rather than fairness, sustainability and health.

The concept of sustainable diets envisions a break in the vicious circle and its transformation into a virtuous one. And at the center of it is the idea of "responsible consumption". However, is it realistic or reasonable to put this heroic task on the shoulders of consumers?

There is no doubt that a growing number of consumers (particularly in the Global North, but increasingly as well in the Global South) profess a desire to consume ethically and sustainably. While conventional food markets attempt to respond to some aspects of ethical and sustainable consumption (the growth of sales of organic food through conventional supermarkets testify to that), conventional markets have not been able (or willing) to make the changes fast enough or thorough enough for consumer satisfaction. This has led to "alternative food markets" emerging everywhere, attempting to reduce the negative environmental and social impacts associated with large scale, industrialized food systems. These alternative markets often aspire towards regional self-sufficiency and farming systems that are community-rooted, sustainable, and ecologically sensitive (Hodgins and Fraser 2017). Through these systems, initiatives such as community supported agriculture, farmer's markets, small scale processing, and fair-traded products are intended to generate alternatives to the conventional, industrialized global food system (Kloppenburg Jr et al. 2000). The fundamental premise of this type of consumption is that shopping for commodities from more humane, just, and environmentally sustainable origins can create positive social change and greater sustainability (Gunderson 2014). Thus, alternative food systems present consumers with a different way of engaging with their food that is perceived to be (and often is) more sustainable and ethical than conventional models of production and consumption.

However, alternative food markets continue to be few in number, unevenly distributed, and often small. Many are established under precarious conditions, dependent on volunteer labor, and few are able to sustain themselves over a long period of time (Feenstra 2002). In the overall scheme of things, these alternative markets have not been able to effect significant changes—at least not yet. They are often seen as "niche" and expensive, outside the reach of the vast majority of consumers (Vermeir and Verbeke 2006; Johnston et al. 2011; Hodgins and Fraser 2017).

A few factors can be forwarded to explain the poor performance of alternative markets. While a growing number of consumers profess a desire to consume sustainably, this desire has not translated into significant changes within the food system. This may be attributed to structural factors that impede the ability of consumers to engage in "responsible consumption", along with what researchers have referred to as the "attitude-behavior gap". The attitude-behavior gap denotes the disconnect between consumer attitudes and their behavioral patterns, such that while public interest and attitudes towards sustainability may be mostly positive, behavioral patterns are not always consistent with these attitudes (Vermeir and Verbeke 2006; Shaw et al. 2016). Throughout the literature, this gap has been attributed to many causes including the perceived difficulty of sustainable consumption, a "green stigma" associated with green consumers and messages, and consumer reservations around whether their consumption choices will make a difference (Johnstone and Tan 2015). In light of this, a food system designed to encourage unsustainable choices, along with uncertain and distrustful attitudes among consumers more generally may limit the extent to which consumers can or are willing to participate in responsible consumption. Not as many consumers professing their concern with fairness and sustainability in food systems translate these concerns into actual market choices (Johnstone and Tan 2015; Pekkanen et al. 2018).

Alternative markets also tend to be fragmented (and small) due to different priorities of ethical consumers. Determinants of food choice are context specific and different factors will dominate depending on the cultural, socio-economic, and geographic settings within an individual region (Lindgren et al. 2018). Different consumers may interpret the concept of sustainability in different ways (Joerß et al.

2017). This leaves room for significant variations in how consumers practice sustainability through their choices. For example, one person's definition of sustainability may relate to practices of purchasing local food products to reduce the environmental impact of importing produce from abroad. On the other hand, a different consumer may object to the practice of utilizing migrant labor to produce local food and prefer to support fair trade initiatives that support sustainable consumption and more just labor practices in the Global South. The lack of trust in and lack of consensus on what practices define responsible consumption, inhibits the ability for alternative markets to transform the food system in the midst of competing values and priorities.

Other researchers have focused on the difficulties in guaranteeing the continuity of alternative food markets once they are established. DuPuis and Gillon (2009) suggest that the sustainability of an alternative food system depends on (1) what makes it different from the conventional system (boundaries), and (2) if those participating in the alternative system can trust that difference (legitimacy). These two aspects present significant difficulties for the maintenance of alternative food systems based on private market solutions. How do these markets "maintain their legitimacy as 'alternative' and apart from the conventional ('free') market system?" (DuPuis and Gillon 2009: 44). The authors go on to illustrate the issue with the case of the market for organic foods in the United States, whose legitimacy as alternative has been challenged with the increasing participation of large industrial producers and retailers. In other words, "organic", once considered "alternative", has now become part of the conventional system. Boundaries are blurred.

4 Sustainable Diets as Public Goods

One reason why alternative markets for sustainable diets may fail is that sustainable diets have public good characteristics. They provide benefits for individual consumers, but those benefits are extended to others throughout the world, even to those who may not themselves have chosen these diets (the so-called "free-rider problem"). In the language of economists, sustainable diets generate high positive externalities, but there are no incentives for private markets to go beyond offering a certain level, since producers cannot charge free-riders for the external benefits (e.g., cleaner environment) that they generate. As such, markets for these goods, conventional or alternative, cannot provide the socially optimal quantity of sustainable diets without some government intervention. The public-good nature of sustainable diets leads to market failures (Rocha 2007). Left on its own, responsible consumption will fall short of the transformation needed for healthy, sustainable, and fair food systems. Without government action, there is nothing preventing the market failures of conventional systems from emerging in alternative (but market-based) systems. Paraphrasing DuPuis and Goodman (2005: 364), food systems do not become something just (or sustainable) by virtue of making them alternative.

The public-good nature of sustainable diets suggests the need for policy in facilitating responsible consumption. Given the importance of prices in consumer behavior, governments can facilitate consumer choices towards sustainable diets by increasing the relative prices of detrimental food items through taxes (for example, taxes on sugar-sweetened beverages or the use of chemical inputs), decreasing the relative prices of beneficial items through subsidies (for example, subsidies for agroecological production), or reducing the significant subsidies provided to conventional, chemical-intensive, industrial agriculture and food production.

The behavior of consumers in favor of more sustainable diets can also be promoted through more information, education and nudging (Pekkanen et al. 2018). In this area, and based on IPES-Food 2017, we emphasize the following two particular "entry points" leading to greater consumer preference for sustainable diets:

4.1 Bridging the divide between food and agriculture

Some analysts suggest that part of the problem in having consumers behave responsibly lies on a divide between consumption and production, a broader disconnection of the general public from the process of food production. This disconnection may be observed on three levels: physical (between high-population urban zones and the rural zones where food is produced); economic (more intermediaries between consumers and farmers, with a greater share of value moving up the supply chain at the expense of farmers); and, cognitive (decreasing knowledge of how food is produced and processed) (Bricas et al. 2013).

As a result, the fact that food choices have implications for farming (and the environmental sustainability of the overall food systems, as well as the health of those working within them) has become less obvious to consumers. Even when farm issues are reported and brought to broader public attention, the links to the foods—and the brands—people buy on a daily basis are not always clear (Cook 2010). Given the dispersed accountability and opaque nature of long global value chains, the connections to agricultural workers in distant countries are even less intuitive. The global nature of food systems leaves many people one-step removed from the realities of food production. For example, while European consumers may see animal agriculture in their own regions, as much as 70% of the protein-rich animal feed used in EU livestock production is imported (Schreuder and De Visser 2014), in particular from South American countries where deforestation, evictions, pesticide poisoning, and rights abuses have been alleged in intensive export cropping zones (Ezquerro-Cañete 2016; Mekonnen et al. 2015).

The physical and cultural disconnect from agriculture may also undermine awareness of impacts to which people are themselves exposed, especially impacts transiting through environmental contamination. Chronic exposure-based impacts are particularly hard to trace to specific sources at specific points in time, but are closely associated with industrial agriculture. Agricultural contamination of air and water often occurs significantly upstream or upwind of where health impacts actually manifest themselves, e.g., in urban settings. Impacts of this type may be more readily associated with contributing factors in closer proximity (e.g., transport pollution, factory waste), particularly in the absence of connections to and knowledge of upstream agricultural realities.

This does not mean that the general public is indifferent to the plight of food and farmworkers or the ways in which food is produced. However, public awareness of the problems in food systems—and particularly those affecting food and farmworkers in distant locations—remains sporadic. A critical mass of public awareness is required to force issues up the political agenda, particularly when those affected have the least power and visibility. The challenge may be to build understanding that the poor working conditions and environmental distress that periodically come to light are the norm, not the exception, for many around the world. Moreover, these conditions are sustained by the personal food choices we make as consumers and the policies decided (at least nominally) in our name. Ultimately, a pool of cheap and insecure labor, dangerous conditions and systematic stresses for farmers and the environment are what sustains the low-cost commodity production at the base of global food systems. Keeping the bulk of these problems out of the public eye and off the record-books—and ensuring that these problems, when they emerge, are perceived as anecdotal rather than systemic—is what maintains the fragile contract between consumers who want affordable and abundant (but not exploitation-based or unsustainable) food, a system that provides it, and the governments who shape the underlying priorities (e.g., through agricultural, food, and trade policies favoring cheap commodity production). Reconnecting people with the realities of the food they eat—and bringing the true cost of the cheap food model to light—is therefore a major requirement for responsible consumption.

4.2 Broadening the frame on the nutrition problem

Debates around diets and nutrition—both under- and over-nutrition—are particularly vulnerable to framings that obscure key connections and undermine the basis for comprehensive understanding and systemic action to address health risks in food systems.

Food security, for example, is often framed in terms of "feeding the world," i.e., delivering sufficient net calories at the global level. Narratives and solutions put forward by agribusiness firms, international agencies, governments, and a variety of other actors often emphasize this aspect of the challenge. Approaches of this type tend to minimize the questions of how, where, and by whom additional food is grown, and the questions of distribution, access, and power on which hunger is often contingent (see IPES-Food 2016). In many development schemes and research programs, the focus has been placed on single nutrients through supplementation, fortification, and biofortification, with little emphasis on durably improving people's access to diverse diets (Frison et al. 2006; Burchi et al. 2011).

A focus on single nutrients also remains pervasive in discussions around dietary guidelines. These approaches have been criticized for promoting "nutritionism"—the reduction of food's nutritional value to its individual nutrients—at the expense of broader understandings and more systemic solutions (Scrinis 2013). For some, nutrient-focused guidelines are a legacy of a time when food insecurity was the primary diet-related issue, and risk promoting the (excess) consumption of foods that nominally meet nutrient cut-offs, regardless of their broader implications for health and how they fit into a healthy dietary pattern (Jessri and L'Abbe 2015; Mozaffarian and Ludwig 2010). A focus on single nutrients also paves the way for multinational food companies to use "nutritional positioning" to bolster their power and influence (Clapp and Scrinis 2017: 578).

In response to such criticisms, new approaches to dietary guidelines are increasingly food-focused, emphasizing greater consumption of foods that most contribute to healthy and sustainable diets, as well as the avoidance of those foods whose consumption is most likely to lead to unhealthy and unsustainable diets (Fischer and Garnett 2016; Seed and Rocha 2018).

A more nuanced and holistic debate about the nutritional outcomes of food systems can be also observed in discussions around "nutrition-sensitive agriculture" (Jaenicke and Virchow 2013). This concept expands the scope well beyond calories and specific micronutrients, considering the nutritional implications of food production models and their environmental interactions (e.g., via soil health), as well as the implications of food processing and utilization for nutritional value. In other words, this approach questions the assumption that nutrition can be improved without explicit consideration of food production, distribution, processing, policy, and programming. However, not all interpretations of the concept—and not all interventions—reflect this holistic view. The US Agency for International Development (USAID 2015) has defined nutrition-sensitive agriculture simply as "agriculture investments made with the intention of also improving nutrition". In this context, technological approaches such as seed biofortification can also be framed as "nutrition-sensitive agriculture", and the focus on delivering nutrition through the food system is at risk of dilution.

Similarly, a tension can also be observed between attempts to frame diets as a function of broader food environments and persistent narratives suggesting that diet-related health is simply a question of personal responsibility. Framing health impacts in relation to the food environment changes their complexion considerably, shifting the attention from individuals onto the socio-economic factors in which people's choices are embedded. However, reviews of public and media discussion around obesity, for example, have found persistent framing around individual responsibility, with environmental and structural drivers less frequently mentioned (De Brún et al. 2015; Saguy and Almeling 2008). A return to individual responsibility has also been identified in the prevailing advice to consume various items "in moderation." While advice of this nature may be fundamentally sound, it has been criticized for downplaying the factors shaping people's choices, as well as implying that all foods can be part of a healthy diet (Nestle 2003; Heiss 2013).

5 Conclusion

The achievement of the Sustainable Development Goals needs the participation of all actors in society. Through "responsible consumption", ordinary people are given the potential to effect change by carefully selecting the products they buy. The concept of sustainable diets suggests the possibility of consumers as agents for change through their ethical choices of what to eat. However, while consumers have an important role to play, responsible policy is needed to support responsible consumption and sustainable diets.

"Alternative food markets" present consumers with a different way of engaging with their food that is perceived to be (and often is) more sustainable and ethical than conventional models of interaction between buyers and sellers. The fundamental premise of this type of consumption is that shopping for commodities from more humane, just, and environmentally sustainable origins can create positive social change and greater sustainability. Nevertheless, alternative markets do not reach the scale needed for fundamental transformation of the food system. Not as many consumers professing their concern with sustainability in food systems translate these concerns into actual market choices, and different interpretations leads to significant variations in how consumers practice sustainability through their choices.

Whatever the reason, left on its own, responsible consumption will fall short of the transformation needed for healthy, sustainable, and fair food systems. The public-good nature of sustainable diets suggests the need for policy in facilitating responsible consumption. Changing relative prices through taxes and subsidies is an important area of policy to impact consumer behavior. But consumer preferences can also be impacted through information, education and nudging.

The report by IPES-Food (2017) suggests two important areas as entry-points in changing consumer preferences through information, education and nudging: (1) bridging the divide between food and agriculture; and (2) broadening the frame on the nutrition problem. Shifting the attention from individuals onto the socio-economic factors in which people's choices are embedded and reconnecting people with the realities of the food they eat will support responsible consumption and a greater adoption of sustainable and healthy diets. By taking into account the roots of these socio-economic factors and addressing them through policies that facilitate sustainability in the local context, a more effective model for responsible consumption and sustainable development can be promoted and achieved.

Diets are results of particular food systems and of particular food environments within which consumers make their choices. Given the disconnection between consumers' intentions and their behavior (the attitude-behavior gap), their further disconnection from the process of food production, and the various market failures plaguing the food system, it is not reasonable to expect responsible consumption without policies to facilitate that. Thus, while consumers are often depicted as protagonists in the transformation of our food systems, consumer action is insufficient to genuinely transform the food system towards the achievement of the Sustainable Development Goals. In order for this transformation to occur, responsible consumption must be supported by responsible policy.

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Unlocking Global Investments for SDGs and Tackling Climate Change

Chiara Trabacchi and Barbara Buchner

1 Introduction

The launch of the United Nations' Sustainable Development Goals (SDGs) in 2015, and the agreement reached in Paris the same year to combat climate change—so-called Paris Agreement—, have provided a strong signal about the political will to transition towards a resource-efficient, low-carbon and resilient growth model. They have made clear that action by the public sector is critical, but not enough to address priority societal challenges like food security, climate change, poverty eradication, inequality and prosperity. The international community counts heavily on the private sector to address such challenges, and the agreement sealed in December 2018 by 196 states at the Katowice Climate Change Summit (COP24)—the "Paris rulebook"—further signal the call for action and the direction of travel.

The private sector has started to react to this call for action. Over 2013–2016, for example, private resources accounted for around 87% of total investments in renewable energy (IRENA and CPI 2018; Buchner et al. 2017). However, while the overall positive trend is good news, we are falling far short of what is needed to achieve global climate and sustainable development goals and, to limit global average warming to 1.5 °C above pre-industrial level—one of the Paris Agreement's overarching goal. To these ends, as noted by the IPCC's 2018 Special Report, rapid, far-reaching and unprecedented changes are required in energy, land, urban, infrastructure and industrial systems (IPCC 2018).

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https://doi.org/10.1007/978-3-030-23969-5_9

To allocate capital towards high-impact projects that address some of the most urgent problems the world is facing, corporations, investors and financiers would need to realize that the SDGs make business sense. Existing estimates are already highlighting the investment case: a study from the Business and Sustainable Development Commission (BSDC), for instance, states that achieving the SDGs could open up US$ 12 trillion (more than 10% of global GDP) worth of market opportunities in food and agriculture, cities, energy and materials, and health and well-being alone, and 380 million new jobs by 2030 (BSDC 2017).

In food and agriculture, in particular, BSDC (2017) estimates that a system in line with the SDGs has the potential to create new economic value of more than US$ 2 trillion by 2030; it would also be much more capable to withstand climate shocks and deliver nutritious, affordable food for a growing world population. The untapped investment potential is significant considering, as a proxy, how much resources are currently flowing towards "climate-smart" agriculture forestry, land-use, and natural resource management measures—about US$ 7 billion according to the latest Buchner et al. (2017) estimates.

In the energy sector, the clean energy investment potential amounts to US$ 360 billion by 2030 according to Tonkonogy et al. (2018) estimates based just on the top eight emerging markets alone. However, even as clean energy technology advances rapidly, and technology costs continue to fall quickly, traditional financing approaches are lagging. What has worked in the past for coal or gas does not necessarily work for renewable energy or other sectors.

The real stumbling block is translating such opportunities and potential into concrete actions. This calls for a structural and systemic change in capital allocation decision-making processes, risk management frameworks, and the use of appropriate disclosure rules and impact assessment metrics. Investors and financiers would need to deeply understand the relevance of the SDGs for their investment and financing strategies, policy and asset allocation; they would need to know how contributing to the SDGs will help them fulfill liabilities and clients' expectations about risk-adjusted returns (PRI 2017). Further, as noted for instance by the signatories of the Dutch SDG Investing Agenda[1], they would also need to know through which vehicles and financing models they could invest in SDGs-relevant activities, particularly so in sectors that constitute an untapped potential in high risk markets.

Such a structural and systemic change of the financial systems would need to happen fast to meet the Paris ambition of restricting global warming to well below two degrees Celsius above pre-industrial times and meeting the SDGs. Albeit emissions of greenhouse gases (GHGs) are rising, not falling (International Energy Agency (IEA) 2018a), these goals are not yet out of reach, but could be unless the shifting of financial flows away from high-carbon and climate vulnerable industries and assets towards 'greener' and resilient ones steps up a gear (IPCC 2018).

Against this background, this chapter aims to provide investors and financiers with insights on the business case for SDG-informed capital allocation strategies (Sect. 1), and on the instruments that can help deploying capital in activities sup-

[1] Launched in 2016, the Dutch SDG Investing Agenda is available at https://www.sdgi-nl.org/.

porting the SDGs (Sect. 2). It focuses on, in particular, SDG 2 and 13 because of the relevance and cross-cutting nature that agriculture and climate change—the core of these two goals—have for the sustainability of food systems and the achievement of the other SDG goals. Agriculture, the dominant occupation for the world's poorest people, in fact, accounts for 70% of water use (World Development Indicators 2018) and it is both a victim and a cause of climate change. Unlocking global investments towards sustainable agriculture can hence help make great strides on many SDG goals. The final section concludes and provides suggestions on how to scale up investments.

2 The Business Case for SDG Finance

Financial impacts, regulatory-related pressures, market dynamics and investment opportunities are key reasons why investors and financiers should invest in climate action (SDG 13). These aspects are evidenced by several facts described in the following paragraphs.

2.1 Financial Impacts Stemming from Unmanaged Climate Risks Are Already Evident

If unmanaged, the risks arising from climate change can have direct and/or indirect operational, strategic, financial and social implications that can spread across the investment value chain (BOE 2018; TCFD 2017; GARI 2017), as highlighted by Fig. 1.

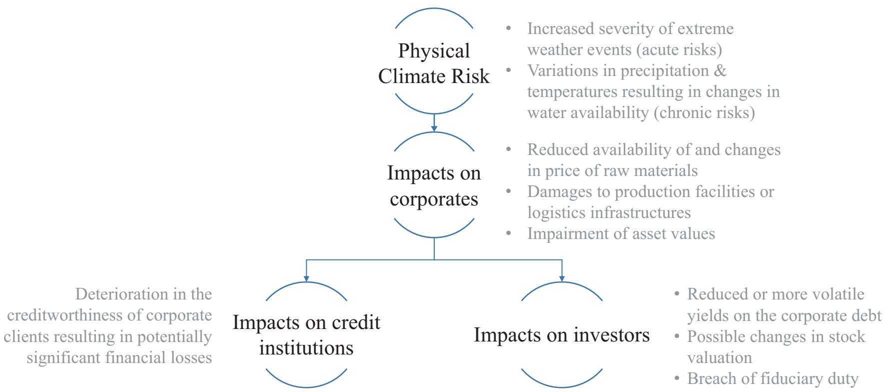

Fig. 1 Physical climate risks and related implications along the investment value chain. *Source: authors' elaboration*

Such risks can emerge from physical climate risks and/or transition risks. The former, physical climate risks, refer to the risks arising from the acute or chronic physical effects of climate change. The latter, transition risk, refer to the risks resulting from the policy, legal, technology and market changes occurring in the shift to a low carbon economy (TCFD 2017). Transition risk—also often described as "stranded asset risk"—may involve the repricing or write-downs of carbon-intensive assets that could quickly become unusable or reduced to lower/zero value.

Registered weather-related loss events, the impact of weather-related events on the earnings disclosed by S&P's 500 companies, and climate-led rating actions provide good insights on the financial materiality of environmental, climate and social factors.

- Inflation-adjusted insurance losses have increased from an annual average of around US$10 billion in the 1980s, to around US$ 55 billion over the past decade according to Munich Re NatCatSERVICE statistics (2017). As noted by BoE (2018), if such losses are insured, they can directly affect insurance firms through higher claim. If uninsured, the burden can fall on companies impairing asset values, and reducing the value of investments held by financial institutions. The associated potential financial risk exposure is evident when considering that public and private re/insurance entities only covered about 36% (US$ 80 billion) of the economic damages caused by the exceptional Hurricane Season in the Atlantic in 2017 (Benfield 2018).
- In 2017, 73 companies (15%) on the S&P 500 publicly disclosed an effect on earnings from weather events according to S&P (2018). The average materiality of events for the companies that quantified it was a significant 6%.
- S&P (2017) identified 717 cases where climate-related and environmental concerns were relevant to credit rating, and 106 cases where climate-related and environmental concerns factor resulted in a change of rating, outlook, or a CreditWatch action.

If unmanaged, change-related risk could result in US$ 4.2 trillion expected losses and, if global temperatures continue to rise, could reach as much as US$ 43 trillion—30% of the entire stock of manageable assets (EIU 2015).

2.2 Financial Regulators Acknowledge That Climate Change Presents a Systemic Risk to the Financial System

The changing international context defined by the Paris Agreement and the SDGs has strengthened calls for thoughtful consideration on how regulation and policy could be aligned with, and promote, investment practices and sustainable financing to the goals and targets of these landmarks commitments (BCSD 2017a, b). This call for action emerged also in light of the financial regulators' recognition that climate change and policies to mitigate it could affect the ability of central banks and regulators to meet monetary and financial stability objectives (Carney 2015; BoE 2017). A too rapid transition towards a low-carbon economy could indeed lead to a "climate Minsky moment" (Carney 2018).

Noteworthy regulatory-related development are Article 173 of the French Energy Transition and the recommendations released in 2017 by the Task Force on Climate-Related Financial Disclosure (TCFD)—an initiative established by the Financial Stability Board under the request of the G20. Both assigned enhanced climate-related reporting responsibilities to financial market participants. The former, Article 173, sets out mandatory disclosure requirements to French institutional investors who are now asked to explain whether and how their policies and targets align with national strategies for energy transition. The latter, the TCFD, recommends voluntary consistent disclosure of climate-related risks to companies in the financial and non-financial sectors. By recommending scenario analysis referring at least to the two degrees Celsius scenario envisaged by the Paris Agreement, it prompts to a future-oriented approach for the identification, evaluation and management of climate risks GIIN (2018).

The release of the Task Force's recommendations prompted several Central Banks and Supervisory authorities across the world to investigate the environmental and climate-related risks for the financial sectors under their responsibilities (NGFS 2018). The Dutch Central Bank, for instance, following an evaluation of the climate risks relevant to the Dutch financial sector, announced the introduction of climate-related risks in its supervisory assessment frameworks (DNB 2017a, b). The Bank of England, following similar work, is looking into enhancing the Prudential Regulation Authority's approach to supervising the financial risks from climate change, and enhancing the resilience of the UK financial system by supporting an orderly market transition to a low-carbon economy (BoE 2018; GIIN 2018).

2.3 Stakeholders and Shareholder's Pressures Provide Clear Signals of the Changing Market Dynamics

Many businesses, investors, industry groups and other stakeholders are increasingly vocal about the need to urgently transition to a low-carbon economy to deliver sustainable economic growth.

Key examples of stakeholders and shareholder's pressures are:

- Larry Fink, Chief Executive Officer (CEO) of US$ 6.3 trillion asset manager BlackRock Rock, recently called business leaders of the world's largest public corporations that they need to contribute to society if they want to receive the company's support (BlackRock 2018a). BlackRock also ramped up its investor-stewardship initiative and proxy voting by making climate risk a primary issue on which to engage portfolio companies (BlackRock 2018b). Other leading asset managers have followed suit.

- The Climate Action 100+ investors-led initiative—backed by 296 investors with US $31 trillion in assets under management—targets 161 companies considered systemically important greenhouse gas emitters. Its goal is prompting them to act to reduce emissions across the value chain consistent with the Paris Agreement's below 2° goal (CERES 2018).
- 500+ corporations have committed to set science-based targets on their emissions profile in line with two degree Celsius scenarios, to assist investors in assessing their low-carbon commitments.[2]
- The wave of billion-dollar legal challenges demanding accountability for climate change to the oil and gas industry. The number of cases across the globe reached more than 1000 suits according to the litigation database of the Sabin Center for Climate Change, and include e.g. the fraud investigations launched by two American state against Exxon, and the law suit launched by nine cities and counties, from New York to San Francisco, to major fossil fuel companies—BP, Exxon Mobil, Chevron, ConocoPhillips and Shell—seeking compensation for climate change damages.

2.4 *The SDGs and Climate Change Are Opportunities to Gain Competitive Advantages*

The SDGs and the Paris Agreement are opening opportunities for investment and financial innovation. The Business and Sustainable Development Commission (Business Commission for Sustainable Development 2017a, b, c) estimates that SDGs could open up US$ 12 trillion market opportunities for the private sector. Achieving the Paris Agreement holds the potential of generating over US$ 23 trillion in climate investment opportunities according to estimates of the International Finance Corporation (IFC 2016).[3] FTSE Russell (2018)[4] estimates that the green economy represents today 6% of the market capitalization of global listed companies, approximately US$ 4 trillion which is about the same size as the fossil fuel sector.

These opportunities translate into the opening up of new markets, and new ways of doing business and serving the existing customer-base to gain competitive advantages (Trabacchi et al. 2018). These manifest as opportunities to finance/invest in e.g.:

- Products and services helping to identify, assess and manage climate-related risks, or other SDGs-related challenges e.g., technologies to improve efficiency in the use of natural resources such as water

[2] See Science Based Targets website: http://sciencebasedtargets.org/2017/09/18/more-than-300-to-set-science-based-targets/

[3] Estimates based on selected sectors in 21 large emerging markets - see IFC (2016) for details on the methodology.

[4] See FTSE Russell (2018) for details on the methodology.

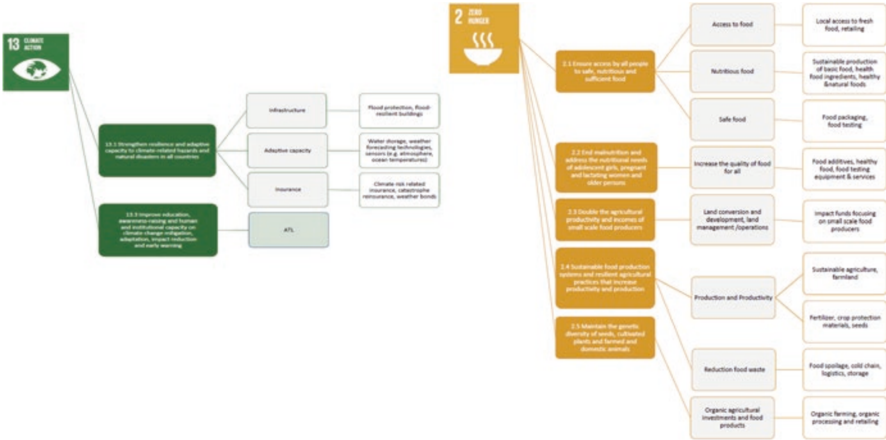

Fig. 2 An investor's view on Sustainable Development Investments. *Source:* APG and PGGM (2017)

- Projects or practices that reduce climate-related risk e.g. renewable energy infrastructures
- Companies offering such products and services
- Green, social or sustainable securities such as green, social or sustainable bonds issued to raise capital for use in projects or activities with the specific environmental and/or social purposes
- Investment vehicles targeting sustainable companies or assets.

Banks and investors are already sizing these opportunities. The Bank of England (BoE 2018), for instance, noted that banks are considering the opportunities related to green finance through two main channels: their primary balance sheet activities (i.e. "green" lending activities), and capital markets through e.g. securitization of green projects and assets. Investors are also seeking to enhance their business proposition to contribute to the SDGs. Some have already set ambitious financial targets to communicate their commitment or developed methodologies to identify investment opportunities linked to the SDGs (APG and PGGM 2017, see Fig. 2).

3 Investment Approaches to Drive Capital Towards the SDGs

Despite the relevant pressures and opportunities to seize, capital is not yet flowing at the speed and pace required to ensure a sustainable future. A substantial shift from brown to green is needed. This is particularly evidence by:

– The volume of fossil fuel investments, which still dwarf climate-related investments. When total upstream and downstream investments are included, fossil fuel investment amounted to US$ 825 billion in 2016, more than double climate investments estimated in US$ 383 billion by Buchner et al. (2017).

– About 60% of world's total primary energy supply still comes from oil and gas sources (IEA 2018b—2016 data), highlighting that a major shift in the structure of energy systems, and in related capital allocations, still has to happen. As an example, banks' exposure to the coal and mining industry is still significant. The top 35 global coal-exposed banks are providing around US$75 billion to the coal power industry and £58 billion to the coal mining industry during 2014–2016 (Rainforest Action Network 2017).

Key barriers hindering or slowing down the transition are:

- Lack of clear and consistent definitions of "sustainable" and "green assets" that in turn leads to a lack of investment opportunities and identifiable green' assets (HSBC 2018; Green Finance Task Force 2018)
- Lack of data on the green investment opportunity (FTSE Russell 2018)
- Inadequate data for measuring both the SDGs and sustainability at large
- Knowledge, regulatory, risk coverage and viability gaps including e.g. counter-productive subsidies (Trabacchi et al. 2015) or lack of clear guidance on international and national low-carbon trajectories
- Fund managers and investors' short-termism, and perception that sustainable investments may come at the expenses of good returns—even though empirical evidence shows the contrary (Nelson 2018)
- Inadequate integration of sustainability in the duties of institutional investors and their asset managers (HLEG 2018)
- No alignment of financial incentives and the business models of intermediaries with sustainable development (HLEG 2017)
- Ultimately, notwithstanding noteworthy process on carbon pricing initiatives, the lack of an adequate and coherent carbon price that would appropriately capture the so-called external costs of activities that produce carbon emissions.

Several efforts are ongoing to tackle these barriers, and innovative tools, approaches and vehicles are emerging to help close the SDG funding gap and tap into the related market opportunity. There is no silver bullet to financing the sustainable development transition. We need to think out of the box and when we find good solutions, we need to scale and replicate them rapidly. New and transformative instruments are needed to strategically use concessional capital to de-risk projects and drive private sector investment.

One example of how to come up with solutions are public-private initiatives such as the Global Innovation Lab for Climate Finance and its national Labs in India and Brazil (the Lab).[5] The Lab is a public-private initiative engaging leading experts in sustainable investment—from governments, development finance institutions, investment banks, institutional investors and other private institutions. Its goal is to unlock private investment in sustainable development at scale. It identifies, develops, and supports the launch of new solutions that can tackle barriers and attract invest-

[5] For more information and the Lab's impact see https://www.climatefinancelab.org/ and https://www.climatefinancelab.org/wp-content/uploads/2018/04/Lab-Impact-Report-2018.pdf

ment. Since the Lab's start in 2014, it has developed and launched 35 innovative financial instruments and business models that have mobilized over 1.4 billion dollars for concrete projects in emerging markets. Many of these instruments combine blended finance approaches, with public investors, impact investors, and institutional investors working together to overcome financing or non-financing barriers.

The Lab's experience highlights two noteworthy investment approaches, blended finance and impact investing.

3.1 Blended Finance Can Attract Private Capital in High Risk Markets

Blended finance—the strategic use of public and/or philanthropic funding to catalyze private sector capital in SDG-related investments (IFC et al. 2017)—holds much promise, particularly to attract private capital in in high risk markets/market segments. Blended finance, in fact, allows to improve the risk-return profile of investments, or improve a project's probability of reaching financial close and of delivering climate change-related benefits.

The Climate-Smart Lending Platform and the Climate Resilience and Adaptation Finance & Technology Transfer Facility are two examples of innovative blended finance instruments. Their endorsement by the Lab signals their innovative and promising potential.

The Climate-Smart Lending Platform is a mechanism that brings together the tools, actors and finance necessary to help lenders (traditional and non-traditional) to manage climate risk in their loan portfolios, while incentivizing the adoption of climate-smart farming methods by smallholders (see Fig. 3). The Platform aims to

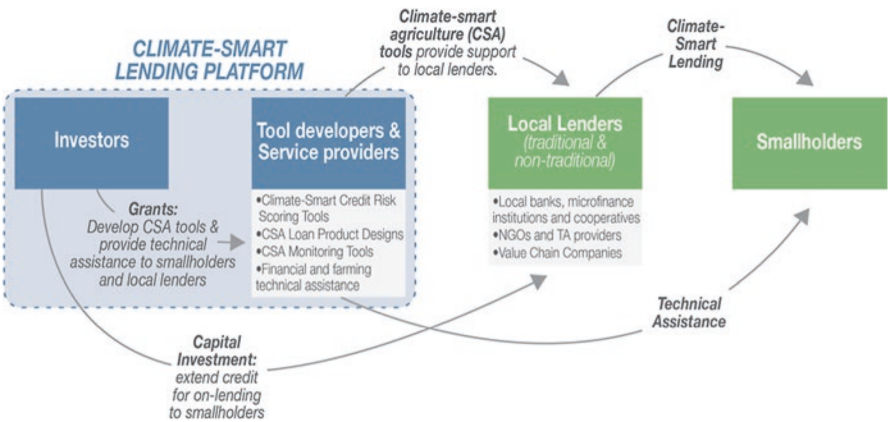

Fig. 3 The structure of the Climate-Smart Lending Platform. Source: The Lab (2016)

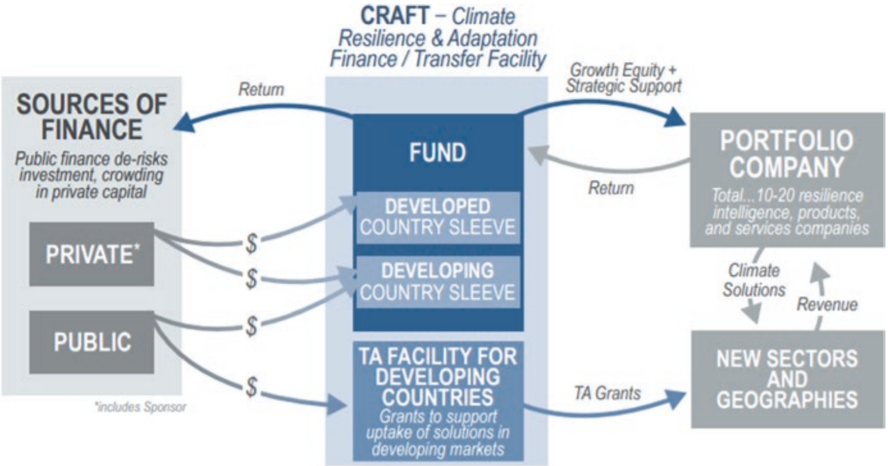

Fig. 4 The structure of the climate resilience and adaptation finance & technology transfer facility. Source: The Lab (2017)

scale up climate-smart lending to smallholders, whilst reducing climate-related default risk.

The Climate Resilience and Adaptation Finance & Technology Transfer Facility is the only commercial investment vehicle to focus exclusively on companies providing technologies and solutions for helping businesses, financiers, and communities to manage climate risks (see Fig. 4). An example could be a company providing precision agriculture data analytics, or drought resistant seeds and crops.

3.2 *Impact Investing Can Accelerate More Inclusive and Sustainable Financial Markets*

Impact investing refers to an investment made into companies, organizations, and funds with the intention to generate social and environmental impact alongside a financial return[6]. A handful of impact investors have begun to raise capital, create new products and proactively target and incorporate the SDG at various stages of the investment cycle, thus making them the central focus of their investment decision-making.

An example is Blue like an Orange Sustainable Capital and its Sustainable Capital Latin America Fund I (Fund) aimed at catalyzing private debt capital into SDG-relevant companies in Latin America and the Caribbean. The Fund has inte-

[6] Source: GIIN web site accessible here https://thegiin.org/impact-investing/need-to-know/#what-is-impactinvesting

grated the SDGs into due diligence, impact target-setting for each investment, and impact monitoring throughout the duration of each loan.

Through the co-financing framework agreement Blue like an Orange established with IDB Invest—a multilateral development bank—the company benefits from IDB Invest's proprietary evaluation system called DELTA. By using DELTA, IDB Invest can rate the potential impact of a jointly-financed transaction at the outset, set targets, monitor environmental, social, and governance (ESG) compliance, and align its impact with the SDGs. Therefore, by co-financing transactions with IDB Invest, Blue like an Orange can benefit from this tool, enhancing the ability to offer investors state-of-the-art impact reporting.

4 Conclusions

The threat of climate change has never been more daunting. Mobilizing private capital is a critical element of achieving the world's climate and sustainable development goals. This chapter sheds light on the business case associated with the SDGs and the Paris Agreement for investors and financiers; it also offers insights on concrete instruments and approaches that can help deploying capital in activities supporting the achievement of these goals.

Financial impacts, regulatory-related pressures, market dynamics together with investment opportunities and innovative investment approaches demonstrate a sound business case for SDG investment. Blended finance instruments and impact investment examples embody innovative approaches developed with the purpose of unlocking global investments for SDGs and tackling climate change.

Yet, there is a need to go from pilots to scale. Despite the positive signs, the sustainable finance market is still incipient and a major shift in public and private capital allocations needs to occur if we are to change the structure of economic systems and minimize the impacts of climate-related risks. For this to happen, the success of current approaches can be increased by targeting the high-impact opportunities; adjusting the mix of financing instruments to address the most prevalent risks; and achieving scale through replicating successes, building internal capacity across the finance industry, supporting financial intermediaries and streamlining approval processes.

This, in turn, requires a new collaboration amongst multiple actors, including:

- Regulators, government related and industry bodies as well as Stock Exchanges, who can play a role in enhancing the availability of clear and consistent definitions of "sustainable" and "green assets". They can also play a key role in enhancing the availability of SDG and climate-relevant data and promote investors to embrace longer-term horizon to overcome short-termism. The efforts of the High-Level Expert Group on Sustainable Finance established by the European Commission and of the Task Force on Climate-related Disclosures go in this direction and need to scale up further—particularly beyond EU borders.

- Development banks, philanthropic organizations and practitioners, who can play a role in attracting private capital in high risk markets by helping to expand the reach and breadth of blended finance instruments.
- Investors and financiers, who can play a role in enhancing data availability and promoting sustainability through the investment chain. They can do so by, for instance, adopting the recommendations of the Task Force on Climate-related Disclosures, scaling up engagement with the companies in their portfolios, and systematically integrating the SDGs and climate-related risks in their in decision-making processes, risk management frameworks and investment/credit policies.

Ultimately, we need to re-frame the climate finance challenge as one of mobilizing financial institution and industry realignment with the Paris Agreement's Article 2.1.c. Mobilizing the finance sector to fully commit to a holistic approach to climate change, which ensures consistency of all financial flows with the climate and sustainable development goals will allow to truly mainstream SDG considerations into finance.

"Exponential progress is necessary, and it is achievable. The moment has come to move from knowing that it is achievable, to actually achieving it. And that is what we're gathered here to do. This is an invitation to join the journey of exponential transformation" (cit. Figueres C. 2018)

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The Age of Foodtech: Optimizing the Agri-Food Chain with Digital Technologies

Andrea Renda

1 Introduction: Digital Technologies as Enablers of Sustainable Development

Looking at current trends such as the resurgence of nationalism in politics, deteriorating rule of law in many countries, new protectionist stances and tariff wars in trade, short-termism in social policy and reiterated denial on climate change, the agreement reached in September 2015 by 193 countries on the Sustainable Development Goals (hereinafter, the SDGs) seems to belong to a very distant era in human history. Indeed, much has changed since then, with the United States reaching a record low in its commitment to SDGs, Brazil entering a new era of populist government and China struggling to show leadership on environmental, and even more social, achievements. In this relatively gloomy atmosphere, digital technologies are increasingly recognized as an essential contributor, if not the real lifeline, to achieve the 2030 goals. And the debate has gradually become broader, and deeper: while the possible contribution of digital technologies to the SDGs has initially been limited to the discussion of Goal 9 (industry, innovation, and infrastructure), there is now a well-established understanding that digital technology can help drive progress for all goals, and it might be essential to harness this potential to be able to reach the goals by 2030, as time is running out. Untapping this potential requires that policymakers integrate technology developments into a coherent policy framework for the achievement of the SDGs. This is not yet happening, in particular when it comes to emerging, disruptive and pervasive digital technologies that bear the highest

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_10

potential for SDGs, such as blockchain and (more generally) distributed ledger technologies,[1] the Internet of Things, and Artificial Intelligence (hereinafter, AI).

This chapter looks at the current developments in digital technologies, as defined in Sect. 2 below, which also illustrates the prospective impact of technologies like AI, the Internet of Things, and blockchain on the agri-food chain. Section 3 discusses possible use cases in various parts of the value chain, with specific emphasis in particular on smart and precision farming, value chain integrity, personalized nutrition and the reduction and prevention of food waste. Importantly, the cooperation of the private sector is considered, alongside with the need for awareness-raising and education in order to empower users in the agri-food chain. Section 4 briefly concludes by projecting humanity into 2030 and discussing possible shifts in technology that may further disrupt the agri-food chain, for good.

2 Big Data, AI, IoT and Blockchain: The "new stack" and Its Impact on the Agri-Food Chain

The past few years have been characterized by the rise of a new wave of technological developments, which promise to revolutionize the digital economy, bringing it towards and era dominated by dramatically superior computing power and connectivity speeds; a skyrocketing number of cyber-physical objects connected to the Internet (the so-called Internet of Things, or IoT, powered by nano-technology and by 5G wireless broadband connectivity); and the pervasive spread of AI into almost all aspects of personal and professional life. This new stack will be composed of powerful hardware, including faster processors (mostly a combination of CPUs, GPUs and TPUs); distributed computing capacity through edge (or fog) computing; new, distributed and decentralized platforms such as blockchain, able to keep audit trails of transactions and other asset-backed values; and a pervasive presence of AI-enabled solutions, mostly in the form of data-hungry techniques such as smart analytics, deep learning and reinforcement learning (Renda 2018, 2019). Focusing on all layers of this emerging stack is extremely important when it comes to scaling up these technologies to the benefit of society: merely focusing on one element, such as AI or blockchain, would not harness the full potential of this emerging world.

Figure 1 portrays the technology stack. The Internet of Things (IoT) layer generates an unprecedented amount of data, requiring sensor technology, nano-tech, enhanced connectivity through 5G or satellite, and devices like drones or robots, able

[1] Distributed ledger technology (DLT) is a digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple places at the same time. DLTs do not rely on centralized data storage or administration. Blockchain is a specific type of DLT in which a log of records is shared by means of blocks that form a chain. The blocks are closed by a type of cryptographic signature called a 'hash'; the next block begins with that same 'hash'.

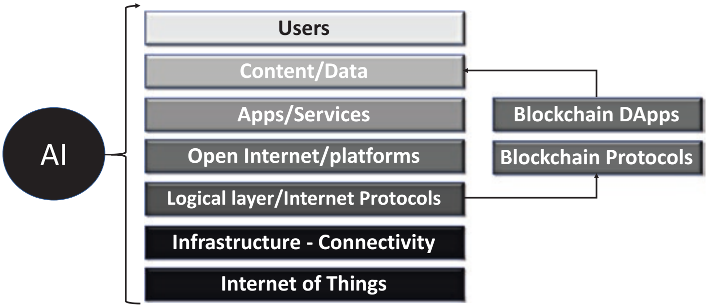

Fig. 1 The emerging digital technology stack. Source: Author's elaboration

to generate live data remotely.[2] Regardless of the way in which data are generated, stored and exchanges, the use of AI will be ubiquitous in most supply chains. At the top of the supply chain, end users very often constitute the weakest link, due to the need to equip them with adequate skills in using digital technologies (Renda 2019).

Although no real estimate of the combined impact of these technologies on the future economy exists, several studies have already been published on the economic impact of AI, as well as on the impact of IoT in specific sectors. For example, recent reports by Accenture/Frontier Economics, McKinsey and PWC conclude that AI will be a game changer for total factor productivity and growth, by gradually rising as a third pillar of production, together with labor and capital. PWC (2018) concluded that by 2030, global GDP will be 14% higher due to AI development and diffusion; the Accenture study (Purdy and Dougherty 2017) finds that growth rates will be doubled by 2035 thanks to AI. The latter study also shows an industry-by-industry breakdown, which includes agriculture, forestry and fisheries: this sector is expected to more than double its growth rate by 2030, from 1.3 to 3.4% on a yearly basis thanks to AI. Similarly, the Internet of Things is expected to massively contribute to future growth: by 2020 approximately 30 billion devices are expected to be connected to the Internet, and according to one recent forecast the number will soar to 125 billion in 2030 (IHS Markit 2018). ARM, a big semiconductor firm recently acquired by Softbank, predicted that there will be as many as one trillion connected devices in 2035 (Renda 2018). Finally, distributed ledger technologies are expected to complement these developments by solving several market failures along supply chains, as well as empowering end users in their consumption choices; some commentators go beyond these expectations, and foresee a revolutionary impact of blockchain in many sectors, including agriculture and food, as will be explained in Sect. 3 below.

[2] Data can be stored in various ways, including through remotely accessible, cloud-enabled solutions; through distributed databases; or through distributed ledger technologies such as blockchain. Some of these technologies are key enablers of value chain integrity, monitoring and trust, since they produce "audit trails" that enhance the verifiability of transactions and contractual performance across the value chain.

3 Key Changes in the Agri-Food Chain

Changes triggered by digital technology in the agri-food sector can be located along a number of areas, ranging from precision farming to the empowerment of small farmers, the promotion of supply chain integrity and traceability, better signaling of food quality to the end users, and support for the circular economy with more effective management of food waste (Bonanno and Busch 2015). Below, we briefly describe and discuss each of these changes.

3.1 Precision Farming: Promise and Perils of Smart Agriculture

A recent report by the World Economic Forum (2018) observed that smart agriculture has the potential to "fundamentally change agriculture even more than twentieth century mass farming methods did"; and these changes "may spread more rapidly than previous ones"; in particular, Artificial Intelligence could enable farms to become almost fully autonomous (WEF 2018). Farmers will be able to grow different crops symbiotically, using AI to spot or predict problems and to take appropriate corrective actions via robotics. For example, should a corn crop be seen to need a booster dose of nitrogen, an AI-enabled system could deliver the nutrients. AI-augmented farms could also automatically adjust crop quantities, based on supply and demand data. This kind of production could be more resilient to earth cycles.

A recent paper by Liakos et al. (2018) explores various uses of AI in agriculture. Here, what will really make the difference for productivity, growth and sustainability is the technology stack, not AI in and of itself. For example, by applying machine learning to sensor data, farm management systems can evolve into real time AI-enabled programs that provide rich recommendations and insights for farmer decision support and action. The key fields of application include: crop management, including applications on yield prediction, disease detection, weed detection, crop quality, and species recognition; livestock management, including applications on animal welfare and livestock production; water management; and soil management. More specifically:

- In crop management, there are several fields of application. They include most notably yield prediction, which impacts key activities such as yield mapping, yield estimation, matching crop supply with demand, and crop management to increase productivity. Use of AI also massively improves disease detection, particularly in the area of pest and disease control, where the use of machine learning allows much better targeting of agro-chemicals input in terms of time and place, thus avoiding the uniform spraying of pesticides; and breakthroughs in image processing and recognition can enable real-time control of plant infection, as well as real-time plant classification.

- Another well-developed area in which AI is dramatically changing agriculture is in the management of livestock, and in particular in protecting animal welfare and livestock production. For example, in the field of animal welfare, AI is helping in the monitoring and classification of behavior based on data from cameras and drones, the recognition of the impacts of dietary changes (in cattle), and even the automatic identification and classification of chewing patterns (in calves) thanks to data collected by optical sensors. In the area of livestock production, studies have led to the accurate prediction and estimation of farming parameters to optimize the economic efficiency of the production system. Researchers are increasingly able to avoid the use of Radio-frequency identification tags to recognize and monitor animals, and this removes a source of stress for the animal itself, at the same time reducing costs.
- Finally, AI can help agricultural firms also in water and soil management. On water, Machine Learning is being applied to the estimation of evapotranspiration, important for resource management in crop production; and to the design and the operation management of irrigation systems and the prediction of daily dew-point temperature. For what concerns soil management, machine learning leads to a more accurate estimation of soil drying, condition, temperature, and moisture content, at the same time dramatically reducing costs. Using high-definition images from airborne systems (e.g. drones), real-time estimates can be made during cultivation period by creating a field map and identifying areas where crops require water, fertilizer or pesticides, with consequent resource optimization.

More generally, the use of IoT in combination with various AI techniques is revolutionizing agriculture, and the process is unlikely to stop any time soon. Precision agriculture is expected to increasingly involve automated data collection and decision-making at the farm level, increasing the resource efficiency of the agriculture industry, lowering the use of water, and even more that of fertilizers and pesticides, with ensuing benefits to the ecosystem. Besides AI and IoT, smart agriculture will also entail significant deployment of robot labor, as well as synthetic biology and advanced materials. In the coming years, many of the mentioned technologies are expected to reach significant progress. Smart agriculture may evolve through a combination of remote sensing and observations (e.g. through drones and computer vision, as well as satellite images); and proximity sensing. For example, in soil testing remote sensing requires sensors to be built into airborne or satellite systems, whereas proximity sensing requires sensors in contact with soil or at a very close range: this helps in soil characterization based on the soil below the surface in a particular place.

3.2 Empowering Small Farmers

Smallholder farmers grow about roughly half of global food calorie production and 70% of the world's food supply on farms that are less than one hectare. They are critical to the global food system. One of the most often evoked dangers of the ongoing reindustrialization of agriculture is the gradual transition from small farms to large industrial conglomerates, which very often enjoy massive economies of scale and build large, global supply chains vertically integrating production with distribution. The need for substantial investment in technology and equipment already led to the prevalence of large industrial firms such as Monsanto, or Bayer in agricultural production during the past century. Today, the prospected merger between these two giant producers may leave small farmers in an even more disadvantageous position vis à vis these mega firms (Lianos and Katalevsky 2018). But this is not necessarily the only, or even the biggest, challenge faced by farmers in the next decade. As agriculture transforms itself into a new technological stack, the real value will be captured by those players that can get hold of the massive amount of data that will be generated by farms and, more generally, the agri-food supply chain.

This, however, does not necessarily have to occur, especially if policy choices are made in order to empower small farmers. The use of AI solutions and the attribution of data ownership, in particular, can benefit small farmers even more than the mobile revolution benefited trade in agricultural products in least developed countries.[3] One way to use these tools for smallholder farmers is to create probabilistic models for seasonal forecasting, by merging into one dataset several variables including soil nutrients, seed bed preparation, germination rate, irrigation, cultivation, minerals, microorganisms, pests, and disease.

Projects related to digital agriculture for small farmers are being developed in various parts of the world. In India, companies like Microsoft are helping by providing several solutions, from basic technological support (i.e. automated voice calls to inform farmers whether their cotton crops are at risk of a pest attack, based on weather conditions and crop stage) to providing governments with AI-powered price forecasts and informing farmers on the optimal sowing date based on large datasets.[4] In Africa, small farmers have the prospect of significantly profiting from index insurance thanks to advanced use of satellite imaging and remote sensing. This reduces their vulnerability due to climate-related risks, which typically strike farmers in the same area and at the same time, making most risk management approaches unfeasible. A project implemented in Senegal by the Weather Risk

[3] For example, the CGIAR Platform for Big Data in Agriculture employs biologists, agronomists, nutritionists, and policy analysts to use Big Data tools to create AI systems that can predict the potential outcomes of future scenarios for farmers. The ultimate goal is to seamlessly integrate real-world data from farms around the world into algorithms that generate critical insights that can then be shared back with farmers. The CGIAR Platform is already showing results of potential benefits for smallholder farmers, such as for the Colombian Rice Farmers Federation. After multiple seasons of challenging rain patterns, rice farmers in Colombia were struggling to know when to plant their crop. Depending on whether there was going to be above average or below average rainfall, farmers would need to decide whether to plant earlier or later in the season. If there was going to be too much rain, they might decide not to plant at all that season.

[4] To calculate the crop-sowing period, historic climate data spanning over 30 years—from 1986 to 2015—for the Devanakonda area in Andhra Pradesh was analysed using AI. To determine the optimal sowing period, the Moisture Adequacy Index (MAI) was calculated. https://www.business-standard.com/article/companies/microsoft-ai-helping-indian-farmers-increase-crop-yields-117121700222_1.html

Management Facility (WRMF) showed that the potential of these instruments is significant, but is also constrained by lack of high quality data and adequate skills in government and among farmers (IFAD 2017).

Similar projects have consistently concluded that data and skills are major obstacles to the empowerment of small farmers. Data can be used by farmers in many ways along the chain, and in particular for planning, monitoring and assessment, event management and intervention, and autonomous action through ICTs. It is therefore very important that projects are developed in order to tackle the specific challenges of each data use, in a way that is tailored to the needs of small farmers. This includes i.a. aggregating farmer data and services through joint action that empowers and gives voice to farmers; developing platforms and mechanisms that enable open data sharing; and reaching international agreements to facilitate data access, ownership and flows.

One key issue in this respect is data ownership (Craglia 2018). This creates at once problems of data protection, security, ownership and imbalances in bargaining positions of small farmers vis à vis service providers, as well as larger players along the value chain such as large agri-food corporations and distribution giants. At the EU level, a Code of Conduct on Agricultural Data Sharing by Contractual Arrangement was launched by a coalition of associations from the EU agri-food chain in April 2018 to facilitate data management in the agri-food chain, and attribute ownership to farmers. The Code provides that the right to determine who can access and use the data is attributed to the data originator, i.e. the individual or entity who created/collected the data either by technical means or by himself or who has commissioned data providers for this purpose. This initiative echoes similar self-regulatory schemes such as the American Farm Bureau's Privacy and Security Principles for Farm Data and New Zealand's Farm Data Code of Practice.[5] Sanderson et al. (2018) analyze these schemes and conclude that strong governance will be needed, including independence in evaluating and monitoring their effectiveness and impacts on players along the value chain. In particular, the problems identified are extreme complexity of agri-food data contracts, lack of awareness on the side of producers of what can be done with their data, as well as the terms of data licenses that they are entering.

More generally, there seems to be growing awareness of the need to support small farmers with more than simple data ownership, which already helps them in retaining control of their data. In particular, awareness of the practical, ethical implication of the data-driven age are needed. For example, already in 2001 the Club of Bologna presented a "Code of ethics for the agricultural machinery—manufacturing sector", and is now working to extend to the AI age its principles and value of integrity, compliance, fair competition, conservation of natural resources, ecological standards, fair and equal treatment of people (employees), health and safety, labor standards, social justice, high quality of products as well as documentation of development and products (Balsari et al. 2018).

[5] Farm Data Accreditation Ltd, New Zealand Farm Data Code of Practice, ver 1.1, Cl 4. American Farm Bureau Federation, Privacy and Security Principles for Farm Data, https://www.fb.org/issues/technology/data-privacy/privacy-and-security-principles-for-farm-data/

3.3 Using Blockchain to Re-intermediate the Agri-Food Supply Chain

Originally emerged as the underlying architecture of Bitcoin in Satoshi Nakamoto's seminal contributions, blockchain has quickly become much bigger than the most famous crypto-currency; and is now considered as a very promising solution for generating trust and transparency in many industrial settings, including the agri-food chain. Blockchains, and more generally Distributed Ledger Technologies (DLTs), have the potential to integrate supply chain transactions in real-time, as well as identify and audit the origin of goods in every link of the chain. When applied to the agri-food supply chain, critical product information such as origin and expiration dates, batch numbers, processing data, storage temperatures, and shipping details get digitized and entered into the blockchain at every step along the chain. Using smart-phones to read QR codes to get details on the source of meat, including an animal's date of birth, usage of antibiotics, vaccinations, livestock harvest, dispatch and shipping can easily be traced. Increasingly, companies are now developing infrastructure to leverage blockchain to make supply chains more robust, efficient, and traceable.

In early 2017, food giants like Wal-Mart, Nestlé, and Unilever (among others) collaborated with tech companies to apply blockchains to global agri-food supply chains. A recent report by Forbes highlighted that while by conventional methods Walmart took more than 6 days to trace the exact farm location of mangoes being distributed in its stores, using blockchain the same task can be completed in under 3 s.[6] Projects being developed by startups like FreshSurety, AgriDigital, HarvestMark, FoodLogiQ and Ripe.io all move in the direction of increasing the transparency and traceability of the value chain. A mapping of these projects (Ge et al. 2017) concluded that the key areas of application include: the registration of holdings, animal, plant and transactions; the tracking and tracing of products with credence attributes (i.e., qualities that are not directly observable by users or end consumers, on which see Sect. 3.4 below); true pricing, which aims to convey information on the externalities of food production; transfer of import & export certificates; inclusive development by ensuring access of smallholders to better market and better payments or financing possibilities (e.g., FairFood, AgriLedger); creating opportunities of automating business processes triggered by a conditioned transaction.

More generally, the use of DLTs can help reduce transaction costs in all those cases in which global value chains rely on a complex nexus of contractual agreements. The emergence of global value chains significantly affected the original dilemma of corporations on whether to revert to a more pluralistic, or a more proprietary business model. As observed by academics like Ronald Coase (1937) in his seminal work on the nature of the firm, the decision whether to bear transaction costs related to market transactions, or the administrative costs related to the setting

[6] https://www.forbes.com/sites/rogeraitken/2017/08/22/ibm-forges-blockchain-collaboration-with-nestle-walmart-for-global-food-safety/#3e9c1b843d36

up of more hierarchical structures such as firms, determines the heterogeneity of governance structures observable today. A more *nuanced* view was offered by Ian Macneil and later Oliver Williamson (1979), who distinguished possible governance arrangements as falling into more short-term market transactions ("classical contracting"), more long-term recurrent transactions based on repeated performance ("neoclassical contracting"), and more structured schemes that form quasi-integrated relationships, often coupled with dispute resolution schemes and deeper governance arrangements ("relational contracting"). These schemes, along value chains, already presented some risks for the parties, including the emergence of superior bargaining power and abuses of economic dependency, but also contractual risks of non-performance by players located in jurisdictions with faulty rule of law.

This trend towards the hybridization of contractual relationships on the value chain was later affected by several other factors, including the ongoing globalization of exchanges, which exacerbated contractual risks and information asymmetries. This is even more problematic since not only the authenticity, but also the so-called "credence qualities" of many goods and services are increasingly important in guiding consumer demand: for example, the fact that goods have been produced in compliance with workers' rights in all phases of the production chain; that food has been locally sourced; or that all players along a supply chain are compliant with environmental standards are often decisive elements in guiding consumers' willingness to pay: the lack of verifiability and clarity on these aspects of goods and services can lead to problems such as adverse selection (so-called "market for lemons"); and moral hazard, which further reduces the quality of available products, since competing on quality is not a winning strategy.

Can DLTs remedy some of these problems? In principle yes, as testified by the fact that several companies and intermediaries are developing ambitious projects to improve the integrity and efficiency of complex supply chains. A notable example is the Tradelens project recently launched by IBM and Maersk, which applies blockchain to the world's global supply chain, through shipping solutions designed to promote more efficient and secure global trade.[7] The project triggered competition by alternative, equally big platforms (e.g. GSBN, powered by Oracle in cooperation with Evergreen Marine, CMA CGM, Cosco Shipping, and Yang Ming, representing about one-third of total global container ship capacity). These schemes, however, face significant governance challenges.[8]

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[7] https://newsroom.ibm.com/2018-08-09-Maersk-and-IBM-Introduce-TradeLens-Blockchain-Shipping-Solution. As many as 94 organizations are actively involved or have agreed to participate on the TradeLens platform built on open standards, including more than 20 port and terminal operators across the globe, global container carriers, customs authorities in five countries, custom brokers, cargo owners, freight forwarders, transportation and logistics companies.

[8] According to some commentators, the fact that Maersk owns a stake of the TradeLens and the intellectual property associated with the joint venture creates conflicting interests in the governance of the platform, in particular when it comes to attracting members that are also competing with platform owners. Commitment to profit-sharing and an open IP policy would probably remedy current problems. https://www.forbes.com/sites/andreatinianow/2018/10/30/how-maersks-bad-business-model-is-breaking-its-blockchain/#476280234f4d

Lessons learnt from the first steps of Blockchain/DLT applications in the agri-food supply chain suggest that the potential is great, but the impact so far still very small. Most of current investment focuses on supply chain integrity and traceability, as well as on financial transactions. Moreover, it must always be recalled that DLT applications for the supply chain cannot entirely solve the problem of informational asymmetries, lack of verifiability of credence qualities and opaque supply chains. Blockchains/DLTs only record transactions: they do not entail the creation of any "Internet of Value", contrary to what some commentators argued. This means that while they offer key advantages in terms of verifiability and traceability of information related to products as appended to the ledger, they cannot guarantee that the information introduced in the system is not false.[9]

Furthermore, what is commonly called blockchain in the supply chain world is effectively a permissioned DLT, in which several parties agree to share a ledger and act as validating nodes for it. Rather than dis-intermediating the supply chain, and thus remove costly intermediaries, these applications effectively re-intermediate the supply chain, with large potential efficiency gains, but no permissionless environment. In other words, these applications are technology-enabled variants of relational contracts, which potentially achieve coordination in settings that are characterized by collective action problems: they are far from the permissionless, fully decentralized architecture described by Nakamoto (2008). This also means that they economize on redundancy and synchronization in the name of full scalability: depending on the technical specifications, these systems may scale up more easily than a fully decentralized blockchain. This feature will be particularly important as the number of nodes in these networks increases, and even skyrockets thanks to the emergence of IoT-enabled solutions.

3.4 Empowering Consumers: Quality Signals and AI-Assisted Technologies

Towards the end of the agri-food supply chain, digital technologies can have a substantial impact on the way individual consumers manage and approach their consumption behavior and decisions. This is, again, due to a combination of technologies

[9] A good example of past attempts to increase verifiability through globally shared commitments to certify the origin and distribution of products was the Kimberley process, established in 2002 to break the link between diamonds and armed conflict. The scheme engaged participants from governments, civil society, and the private sector to eliminate the trade in "conflict diamonds," or rough diamonds used by rebel groups to finance conflict with an aim toward overthrowing legitimate governments. Compliance was monitored with certificate data, statistics, and annual reports, among other types of information: but these monitoring efforts were largely unsuccessful: fraudulent certificates soon emerged in Angola, Congo, Ghana, and Malaysia. Could blockchain solve these problems? Only partly: for example, a startup called Everledger created a blockchain application that tracks assets over the course of their lifetimes, and claims to be able to drastically reduce the estimated USD45bn lost every year due to insurance fraud. In reality, blockchain and DLTs can help solve some of the associated problems (e.g. checking certificate numbers to avoid fraud by spotting duplicative certificates), but the problem of trust among the players in the supply chain shifts "upstream", to the moment in which a given transaction is appended to the ledger.

in the "agri-food stack", including connectivity, IoT, blockchain and AI. One good example is the use of blockchain to enable more transparent and reliable decision-making by end users when deciding which food to purchase and consume. As already mentioned in the previous section, the use of blockchain can solve some of the problems associated with so-called "credence qualities" in food, which can otherwise create problems of adverse selection. Since opacity and lack of trust in the value chain can limit the trustworthiness and observability of quality attributes of food, consumers end up choosing cheaper products as they do not trust the signals provided by their distributor. With blockchain, end users could trace the origin of food by themselves (if supported with adequate data), and may then decide to place more value on quality signals. This can address the issue of high-quality food being otherwise excluded from the market (as in Akerlof's market for lemons), thus restoring the allocative efficiency potential of market exchange, as well as incentives to invest in quality on the side of producers and distributors. This is even truer now that Walmart's original proofs of concept with IBM on mangoes and pork have been scaled up to a large coalition of retailers and producers, including Kroger, Wegmans, Tyson, Driscolls, Nestle, Unilever, Danone, McCormick, and Dole (Yiannas 2018). More recently, in November 2018, Auchan, the world's 13th largest food retailer, announced the implementation of TE-FOOD's blockchain based farm-to-table food traceability solution in France, with further international roll-outs expected to follow in Italy, Spain, Portugal and Senegal.[10] Outside the United States, French retail giant Carrefour has taken similar steps to Walmart by integrating IBM's tailored blockchain data system known as Food Trust with a view of improving food safety.

Needless to say, the implementation of blockchain technology for traceability and integrity in the agri-food supply chain also has important consequences for the SDGs, and in particular to avoid the spread of diseases such as, i.a. the recent Romain lettuce e.coli outbreak in the US and Canada.[11] In particular, blockchain can assist in tracing the cause of the outbreak to a specific distributor, farm or grower in the supply chain. This prevents blanket warnings which affect everyone even when the cause is limited to a particular origin. This positive effect is also one of the reasons why food safety regulators have started to consider using the technology on a large scale. In October 2018, the US Food Standards Agency announced the successful completion of a blockchain trial to track beef from the slaughterhouse to the end consumer. The expansion of the use of DLTs in agri-food is by now considered to be likely, and promising: however, the governance attributes of existing projects are constantly evolving, and the need for a distributed, if not decentralized structure is often evoked as the only way to avoid that the re-intermediated sector falls into the hands of large corporations, creating problems of competition and also reducing the possibility for public authorities to fully observe the data being stored on the chain.

[10] This follows an extended pilot in Vietnam, where more than 6000 companies are using it, including leading international food conglomerates like AEON, CP Group, Lotte Mart, Big C, Japfa, and CJ. https://www.foodingredientsfirst.com/news/globalized-blockchain-auchan-implements-food-traceability-technology-on-international-scale.html

[11] https://thespoon.tech/after-more-romaine-recalls-is-blockchain-the-missing-link-in-preventing-outbreaks/

Besides blockchain, also AI can empower end users in many ways. These range from purely technological solutions to behavioral assistance in consumption decisions. For example, a new dataset of common grocery store items was recently developed by Klasson et al. (2018), using a smartphone camera and photographing 5125 images of various items in the fruit and vegetable and refrigerated dairy/juice sections of 18 different grocery stores. The dataset contains 81 fine-grained products which are each accompanied with an iconic image of the item and a product description including origin country, the estimated weight and nutrient values of the item from a grocery store website. Such system can reportedly help visually impaired people when they shop in grocery stores, and can complement existing visual assistive technology, which is confined to grocery items with barcodes. More generally, still on the technical side, image recognition and computer vision can enable more trust in remote shopping, where enhanced ability to recognize the conditions and quality of the food being purchased is needed. If coupled with remote sensing through IoT in the future, these systems can improve on the experience of purchasing food directly in the store, at the same time distancing consumers from their direct, hands-on experience.

Besides purely technical solutions, there is reason to expect that the real revolution brought about by AI in the short term will be on personalized services in nutrition. Food giants like Nestle are now launching ambitious programs to boost personalized diet advice through AI, coupled with new technological breakthroughs such as instant DNA testing. In Japan, this already led more than 100,000 users of the "Nestle Wellness Ambassador" program send pictures of their food via the popular Line app that then recommends lifestyle changes and specially formulated supplements. This requires the use of voice assistants powered by natural language processing and machine learning, and ends up into so-called "mass customization of food", such as the creation of personalized tea capsules based on individual characteristics and preferences.[12] As the understanding of human dietary needs improvement in the coming decades, these services will become commonplace, with significant impact on SDGs related to health, hunger and malnutrition. For example, the absence of balanced food and nutrition security leads to health problems such as diabetes, obesity, and malnutrition. Personalized approaches can be effective since responses to dietary intervention vary across the population, according to variables such as genetics, age, gender, lifestyle, environmental exposure, gut microbiome, epigenetics, metabolism nutrition derived from diet, and foods.

The combination of user data, DNA and genetic testing and analysis, big data, computer vision, data on environment, healthcare records, data from wearables and implanted devices and advanced AI solutions can generate enormous advantages, but also important risks, for humanity.[13] For example, closely monitoring conversations on social media, companies can use AI to analyze consumer data and identify sentiments or behavior that are crucial not only in building positive experiences but also in the development and design of new product lines. Herranz et al. (2018) study food

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[12] https://www.independent.co.uk/news/science/nestle-dna-artificial-intelligence-health-personalised-diet-japan-nutrition-a8519626.html

[13] https://www.frontiersin.org/articles/10.3389/fnut.2018.00117/full#B7

analysis powered by AI and focus i.a. on recommender systems, which require collecting feedback and user preferences, and in particular, taking health and nutritional aspects in the recommendation. As demonstrated in large randomized controlled trials on personalized nutrition such as Food4Me, such systems can be extremely effective in promoting healthy diets; but can also easily nudge users towards specific food consumption, enabling a new, more season of granular, extremely effective AI-enabled marketing, which can even compromise human agency and self-determination (Verma et al. 2018).

3.5 Optimizing the Prevention, Collection and Management of Food Waste

According to the United Nations, 815 million people lack access to the food necessary to lead a healthy lifestyle today, 98% of which live in developing countries and 75% in rural areas. In stark contrast with this figure, one third of the food produced in the world for human consumption (approximately or 1.3 billion metric tons) gets lost or wasted every year. Digital technologies can help overcome this mismatch in many ways: importantly, they can help the world overcome hunger without having to increase output by 70% (a figure often quoted by experts) (Fig. 2).

Much of the global food waste is due to inconsistencies in the supply chain: inventories are not recorded, suppliers are not informed, and quality is not taken into account. This is a relatively uncontroversial use case for DLTs, subject to our considerations in Sect. 3.2 above. DLTs can, for example, help in the implementation of "cold chains", i.e. temperature-controlled supply chains, which ensure that distance traveled by food does not inadvertently lead to damaged goods.[14] Blockchain can also help in more downstream phases of the food waste cycle, by helping reallocate leftovers. This is what companies like Goodr in Atlanta do to arrange the distribution of leftovers from restaurants to local charities through an app. Estonian company Delicia is using blockchain to create a global, decentralized platform for retailers like grocery and convenience stores to sell food that is nearing expiration to local buyers like restaurants or consumers. These services can easily be coupled with AI-enabled dynamic pricing: companies like Wasteless help retailers to dynamically price and sell products based on their freshness; the automatic tracking of unsold inventory allows effective decisions leading to the most optimal financial outcomes and less food waste (e.g. Spoiler Alert). Coupled with IoT, blockchain can do even more: for example, a startup named Blue Ocean is attempting to deploy a radical business model that would leverage identity verification systems, algorithms, IoT, smart sensors, and blockchain to develop a system in which connected smart

[14] Id. With blockchain, vendors can remotely record a wide variety of predetermined measurements, including storage temperature, at each juncture in the supply chain. If temperature at point B varies dramatically from the temperature at point A and C, product managers can extrapolate this data to pinpoint problem areas and allocate resources accordingly.

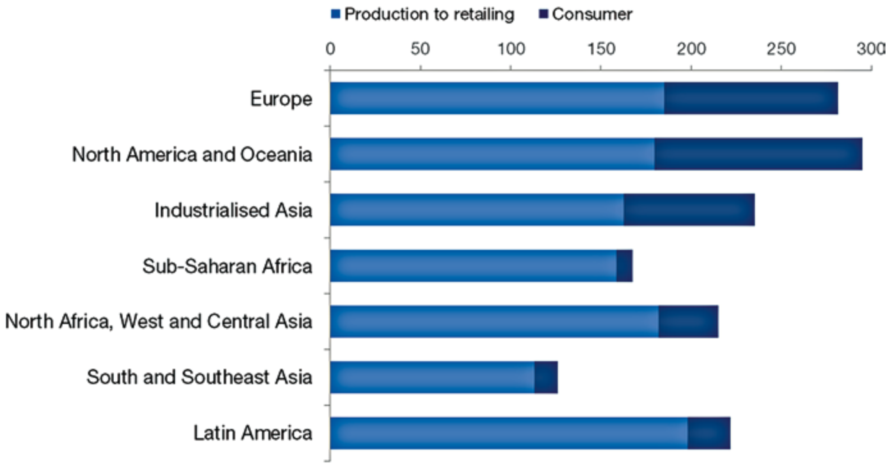

Fig. 2 Food waste by region. Source: The Food and Agriculture Organization of the United Nations (FAO)

bins identify who, when, what and how participants within the ecosystem are behaving. This, in turn, allows the system to immediately reward users for placing food leftovers in the recycling trash bin.[15]

Outside the blockchain universe, the use of AI, mostly in the form of machine learning, to reduce food waste is growing rapidly. For example, Hitachi partners with hospitals to use AI to monitor food waste, improving meal preparation while also relieving the burden on nurses to check these leftovers. The system works by using a camera mounted on a trolley that collects trays, taking pictures of the leftovers. Hitachi systems can recognize patterns in the leftovers that humans otherwise could not see. Similarly, startups like Winnow (a food waste meter technology for restaurants) and Kitro (smart bin that can identify, manage and monitor the sources and quantities of food waste) are developing solutions that combine data collection and sensing with AI. AI-enabled algorithms are being used also to improve food inspections using images taken by a mobile phone (AgShift), hyperspectral images (Impact Vision) and sensor data.

4 Concluding Remarks: Using Policy and Spending Programs to Nurture FoodTech

FoodTech, intended as the use of disruptive digital technologies along the agri-food chain, features an outstanding potential to contribute to the SDGs, and in particular to help combat and eradicate hunger without a massive increase in food production.

[15] https://e27.co/ai-waste-management-startup-blueocean-20181011/

Foodtech could be usefully combined with holistic approaches to the management of the agri-food chain (such as agro-ecology, see Wezel et al. 2009), which incorporate also the social and environmental dimensions. This chapter reviewed emerging applications of technologies like IoT, DLTs and AI at various phases of the agri-food chain, focusing in particular on smart and precision farming, value chain integrity, personalized nutrition and the reduction and prevention of food waste. In all these use cases, the potential appears egregious, but a strong role of policy and public investment seems to be needed in order to avoid equally significant risks.

First, it is important that the focus of governments is not limited to one single technology, but to the whole stack. There are two main reasons for this: on the one hand, it is the combination of technologies like remote and proximity sensing, big data analytics, 5G, blockchain and AI that seems to be generating the most high-impact innovation; on the other hand, the potential of every single technology depends on the relative advancements of complementary technologies in the stack, and without sufficient attention to all complementors a number of bottlenecks could emerge, thereby limiting the overall potential of FoodTech. Government spending on research and innovation, as well as policies aimed at incentivizing private investment will be needed to ensure a harmonious development of the FoodTech ecosystem.

Second, very often the weakest players along the value chain are unable to make the most of the data revolution. Small farmers have limited knowledge of how to use their data, and consumers can easily be nudged into sub-optimal, profit-motivated advice by suppliers. Awareness-raising, training and smart policy choices are thus complementary actions that governments may consider in order to ensure that data ownership belongs to farmers and users, and that both categories are adequately assisted and informed when participating in the FoodTech ecosystem. Recent actions, such as self-regulatory schemes on data sharing in agriculture, should then be adequately monitored and enforced, and complemented by information provision and training initiatives.

Third, blockchain/DLT technologies need to be subject to dedicated policies. The governance of emerging initiatives based on distributed ledger technology are far from the public, permissionless architecture featured by Bitcoin or Ethereum, which exhibit significant scalability problems along with very positive dis-intermediation and decentralization potential. Existing initiatives aimed at securing value chain integrity and food traceability should be carefully monitored in terms of their concentrated governance and possible re-intermediation effects, before they are fully supported in terms of policy. Otherwise, problems such as manipulation of information, imbalances of contractual power along the value chain and lack of trust among players in the ecosystem would simply be replicated in different form. Even the creation of national or international federated ledgers (e.g. the Australian National Blockchain, the Spanish Alastria and the nascent EU blockchain platform) should come with enhanced attention for the underlying government and technology: very little is known today on the likely evolution of platforms such as Ethereum and Hyperledger, and large conglomerates like Tradelens have already experience internal consensus problems.

Fourth, the use of AI in agriculture is already leading to important results in terms of optimization of processes, prediction of events, detection of diseases, and user empowerment through personalized nutrition. However, in line with what occurs in AI applications in other sectors, there is a need to establish shared ethical and legal standards to avoid that AI use impinges on user self-determination and agency, as well as privacy and integrity, leading to cases of discrimination, hyper-nudging, and intrusive use of personally identifiable information. The emergence of "mass customization" in FoodTech thus constitutes both a big opportunity, and a big risk. Government policy is needed to ensure that a predictable legal environment emerges with respect to the use of AI, both in B2B and B2C settings. In many countries AI strategies are emerging to this end: the European Commission High Level Expert Group on AI published ethical guidelines on Trustworthy AI in April 2019 (Renda 2019).

Fifth, FoodTech heavily depends on the availability of high quality data infrastructure and digital skills. Therefore, any solution that relies on digital technologies will need to be inclusive, otherwise the risk will be to widen the digital divide, excluding entire categories of users and geographical areas from the benefits they will provide. Very often, governments are attracted to digital technology without realizing how divisive and discriminatory its deployment can be, if these technologies are not adequately supported. Recent initiatives, such as Finland's decision to offer AI training courses for free to its citizens, go in the direction of ensuring inclusive development of digital technologies; these should be coupled with ad hoc policies to ensure the availability of high quality data, including through open data policies in government.

Finally, and more generally, FoodTech is a very important contributor to future government and global governance objectives, but it is not the only one. It is important to realize how to make FoodTech compatible with all SDGs, including environmental and social objectives. For example, automation of jobs and the carbon footprint of data centers very often challenge the achievement of important SDGs such as limited or zero carbon footprint (SDGs 7 and 13); inclusive growth, full and productive employment, and decent work for all (SDG 8); quality education (SDG 4); and the promotion of women empowerment (SDG 5). In this respect, proposals to steer AI development in a direction that is fully consistent with SDGs appear to be more likely to achieve this form of policy coherence than proposals merely based on GDP and competitiveness.

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Exploring the Migration-Food and Nutrition Security Nexus: How Aid Policies Can Maximize the Migration-Related Sustainable Development Opportunities

Roberto Sensi and Michele Pedrotti

1 Introduction

Migrations have always been intimately linked to social and economic development processes: they are considered both the result of imbalances determined by development processes, and as factors that can influence these. The international community's vision of the nature of the complex migration/development relationship has changed over time, alternating optimism and pessimism depending on the ideologies in vogue; naturally, such visions have also played a key role in determining the relevant policies.

The 2014–2015 refugee crisis gave a sharp turn in the European vision and policies on migration. Their external dimension has been shaped through the strengthening of tools like international development cooperation, technical and political dialogue with the aim of preventing further migration flows to Europe. One of the key strategy for this purpose, drawn up in the new European Agenda on Migration adopted in 2015 (European Commission 2015), is to intervene on the so called "root causes" of migration, based on the principle of "more for more". This principle is based on the idea that more financial resources are given to migration countries that are origin and/or transit of migration in return of their increasing commitment to

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_11

combat irregular migration, support refoulement and return of migrants in the framework of bilateral agreement (partnership framework).

The main source of funding for the implementation of this strategy comes from the European Development Fund (EDF) which is the main funding source of the most important financial instrument developed by the European Union to support its externalization of border strategy: the EU emergency Trust fund for Africa (EUTF).[1] The EUTF is an emergency trust fund adopted as a follow up of the Valletta Summit on Migration in 2015 (European Council 2015) and aimed at addressing the "root causes of irregular migration and displaced persons in Africa to foster stability and to contribute to better migration management, including by addressing the root causes of destabilization, forced displacement and irregular migration".[2] With this instrument, the European Commission wants to carry forward aid programs at European and national level aimed at the maximization of the positive impact of development on migration. Namely, the commission wanted to prevent migration flow by taking as assumption that behind migration there are driver like poverty, insecurity, environmental, demographic pressure and humanitarian crisis (European Commission 2015). Beyond the creation of alternatives, the EUTF aims to strengthening resilience, including governance and conflict prevention and, it seems to be the main scope given the share of money received, to improve migration management, namely containing and preventing irregular migration through the externalization of the EU border control.

2 Migration and the 2030 Agenda for Sustainable Development

In the Millennium Development goals agenda migration was not taken into account. This was due to several reasons. Firstly, the magnitude of the migration phenomena was not like today: since 2000s international migration has increased by 32% and recorded remittances have increased (Lönnback 2014). Secondly, "when migration pathways were available, there was—rather paradoxically—a high degree of concern about the so-called brain drain" (IOM 2017). Finally, and this is the most important reason for the actual debate around migration and development, migration itself has assumed strongly negative connotations and it was prioritized as a security issue focusing on border control and repression of movements (*ibidem)*.

Migration has been included in the 2030 Development Agenda with a specific target 10.7, which prescribes the facilitation of "orderly, safe, and responsible migration and mobility of people, including through implementation of planned and well managed migration policies". The SDGs Declaration recognizes migration as a dimension of sustainable development. What it seems less clear reading target 10.7

[1] https://ec.europa.eu/trustfundforafrica/

[2] More info at: https://ec.europa.eu/europeaid/regions/africa/eu-emergency-trust-fund-africa_en

text is the kind of role migration can play for development. As a matter of fact, migration interacts with all dimensions of development. Beyond the specific target 10.7, the 2030 Agenda includes a number of targets which recognize the economic value of migrants including SDGs 4, 5, 8, 10, 16 and 17 (Foresti et al. 2018). As underlined by Foresti et al., "the multi-disciplinary and cross-sectoral nature of the 2030 Agenda is a useful platform to assess the impact of migration and human mobility on a range of development issues This is not just important in terms of problem analysis but also offers opportunities for finding policy solutions" (*ibidem)*. Nevertheless, the SDGs agenda is silent on the migration broader contribution to development outcomes. How migration can help in achieving the SDGs goals needs to be investigating through the analysis of the multiple linkages, its positive impacts and potential challenges and developing clear strategy and a coherent approach.

The Global Compact for migration (GCM)[3] represents an opportunity to bridge the gap among global development and migration policies. The text recognizes that the GCM aims to leverage the migration potential for the achievement of all Sustainable Development Goals,[4] stating that Member States commit to aligning the implementation of the GCM, the 2030 Agenda and the Addis Ababa Action Agenda, recognizing that migration and sustainable development are multidimensional and interdependent (Foresti et al. 2018).

3 Going Beyond the "Root Causes", Exploring Migration and Development Nexus

European policies aimed at containing the flows of recent years have reduced the nexus to a cause-and-effect relationship that sees the development of a country as a solution to stop migration. In reality, in the short term, greater development generally constitutes a push factor to migrate, by putting people in conditions to move owing to the increased resources available (Carling and Talleraas 2016). These simplifications have led to erroneous justifications to resolve the so-called "root causes" of migration, through additional investments in development in origin countries, making the instrumental ambition to put a stop to the more evident flows.

Years of research and experience in development field suggested the relation between migration and development is hardly this simple (Fratzke and Salant 2018a). The debate on the nature of the migration and development nexus highlights a basic political issue, which emerges increasingly in the European approach to the

[3] In the New York Declaration for Refugees and Migrants, adopted in September 2016, the General Assembly decided to develop a global compact for safe, orderly and regular migration. The process to develop this global compact for migration started in April 2017. The General Assembly will then hold an intergovernmental conference on international migration in 2018 with a view to adopting the global compact. https://www.ohchr.org/EN/Issues/Migration/Pages/GlobalCompactforMigration.aspx

[4] Global compact for safe, orderly and regular migration, final draft 11 July 2018.

topic: i.e. that the objective is to curb or accelerate the flows, and that the underlying policies and approaches have instrumental characteristics and are not intended to maximize the positive impact of migration. The goal of working on the root causes of migration should not be reduction of the flows, but to make migration a choice rather than a necessity (FAO 2017): an option among the various ones available to people to improve their lives from every point of view.

The EU vision contributes to consider migration as a "development problems" instead of as part of wider development processes and structural transformations *(ibidem)*. It would be more correct to consider migration as a part of wider development processes and structural transformations, depending on specific social, economic and political contexts and the nature of the development processes, which make it impossible to infer *a priori* the type of impact that this relationship will produce on one or other factors (UNESCO 2017).

4 Migration and Food and Nutrition Security: Exploring the Nexus

To better understand the relationship between migration, agriculture, and rural development, the FAO has developed a standard conceptual framework highlighting how the drivers that determine the migration of young persons from rural areas are due to a lack of employment opportunities and situations of underemployment (FAO 2016). The lack of decent work opportunities—inside and outside the agricultural sector—is the result of a series of factors linked to specific contexts, which can be defined as "root causes". These include: rural poverty and food insecurity, lack of income, strong inequalities between urban and rural areas, limited access to social protection mechanisms, climate change, natural and environmental disasters, and depletion of resources (*ibidem)*. These causes relate in turn to specific conditions that characterize rural contexts: low or stagnant agricultural productivity, poorly developed markets (in terms of financial services, physical infrastructure, technical assistance) plus a lack of adequate protection networks and social infrastructure (*ibidem)*. Also taken into consideration are factors at the family level: the age of the household head, gender and level of education, size and composition of the family, its social network, social and cultural standards, and basic assets (*ibidem)*. Lastly, the individual determinants: age, work, and personal aspirations (*ibidem)*.

Rural migration can be a strategy to diversify risk and family income in the face of food insecurity, the latter being influenced by risk factors that include variable rainfalls and climate change. At the same time, to address the risks of food insecurity, choices other than migration can be made (Herrera and Sah 2013), which is therefore seen as an important strategy, but not the only one, to face situations of food insecurity.

Migrations involve risks and opportunities for origin, transit, and destination countries. For example, they can reduce the pressure on the natural resources of a specific territory, accelerating more efficient allocation of jobs in rural areas, and potentially causing an increase in farm income (FAO 2017). At the same time, they may cause the loss of the most vital and dynamic part of the workforce: the youth, and therefore determine the ageing of local communities and the "feminization" of the rural population, with a consequent increase in the workload on the shoulders of women.

To understand the nexus between migration and food and nutrition security it is necessary to consider a series of elements that often receive scarce attention, especially in the European debate.

For instance, for political contingency reasons, literature on migration policies focuses more on analyses of international migration, ignoring the fact that most migrations occur within the borders of the same country (740 million people) or even within the same region (Flahaux and De Haas 2016). West African countries, for example, have the most mobile population in the world: intra-regional mobility is seven times greater than the volume of migrants from West Africa to the rest of the world. In addition, particularly in Africa, most of the attention is on migration in rural areas, geared to agricultural and rural development (FAO 2016). This is entirely understandable, since most migrants are from those same areas. However, in view of today's high rates of urbanization, it is fundamental to pay more attention to food security in urban contexts within a broader analysis of food economies. The effects of urbanization on rural areas can no longer be interpreted exclusively as an exodus from the countryside to the cities (Global Donor Platform 2017); rural areas, small and medium-sized cities and conurbations are closely interconnected, and their interactions can be seen as a part of broader food economies and transformation processes, both rural and urban. This implies the development of new and complementary approaches to food and nutrition security strategies, such as the planning of interventions on food systems starting from an improvement in context data (*spatial data*) and a greater attention to social protection systems.[5]

Another factor to be carefully considered is nutrition. Nutritional transition in Africa,[6] associated with the "double burden" of malnutrition,[7] is occurring in a context of high rates of migration between the rural and urban areas, along with high urbanization, and represents one of the most significant threats to public health, particularly among the poor. Nutritional transition also occurs in the context of

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[5] Social protection policies can, in fact, promote economic and social development in both the short and the long term, ensuring people an income, access to medical care and other social services, strengthening their capabilities and making them better able to manage risks and economic opportunities.

[6] By nutritional transition is meant a shift in food consumption determined by changes of an economic, demographic, and epidemiological type. Specifically, the term is used to indicate the transition that is happening in developing countries from traditional diets characterized by a high rate of consumption of cereals and fibre to a more "Western" one characterized by sugars, fats, animal proteins and processed food.

[7] With the term "dual burden of malnutrition" the United Nations intend the coexistence of the problem of malnutrition together with that of overweight and obesity, the latter also defined as non-communicable diseases linked to diet, between individuals, families, and populations throughout their life. http://www.who.int/nutrition/double-burden-malnutrition/en/

international migration, where migrants tend to adopt the diet of the destination country with an increase in the consumption of processed and less nutritious food.

Additional items to be added to the conceptualization of the nexus between migration and food and nutrition security are the need to consider the impacts of migration both at a family level (remittances as a network of social protection, loss of agricultural workforce, etc.) (Lacroix 2011) and at a macro level (agricultural investments, impact on workforce, prices, and agricultural production, etc.) plus the characteristics of individual families that might affect the impact of migration (Warner and Afifi 2014).

Policy coherence is also essential, whether we are talking about migration policies, or others that may have negative consequences on food systems (e.g. climate, trade, investment, energy or development cooperation policies) (Concord 2009). For example, in the case of Kenya, due to the drought in 2008, shepherds were forced to migrate to neighbouring countries in search of new pastures; the borders were closed (also thanks to the incentives that donor countries offered in exchange for a stricter control over borders) and the shepherds were forced to move into the urban suburbs ending up depending on the humanitarian aid system (Adow 2008).

Greater attention must also be paid to the gender dimension and the younger population (two fundamental components constantly growing in migration). Men and women aged between 15 and 24 years living in rural areas are among those having greater propensity to migrate because of a lack of jobs and economic opportunities in the agricultural sector (ActionAid 2017a). However, aspirations and perceptions play a fundamental role in this choice that should not be considered merely "rational", i.e. as a response to specific economic or environmental vulnerability. Women account for 48% of migrants (IOM 2016) worldwide, even if in many areas of Africa, due to conflicts and increased risks associated with migration, this share is decreasing. Women are also a sizeable proportion of "highly professionalized" migrants: in 2005, 11.3% of the nurses from Malawi were working in Organization for Economic Co-operation and Development (OECD) countries (Fleury 2016).

It should also be considered that much of the vulnerability in agricultural production and in food and nutrition security is due to climate and environmental phenomena. Climate change and extreme events (floods and drought) can produce devastating effects on rural communities, which largely depend on agriculture for their livelihood. Support for policies and interventions to improve resilience and adaptation, as well as social protection systems and safe movement, are all fundamental elements that have to be considered in any analysis (ActionAid 2016).

A final priority is the adoption of long-term food and nutrition security strategies for issues inherent to emergencies. In recent years, donors' strategies have gradually embraced the need for a better understanding of the effects of extended internal movements on food and nutrition security in order to prepare medium-long term strategies to ensure access to sufficient food for internal and international refugees. In fact, crisis situations for prolonged periods are an understandable driver of food insecurity. Over the last 30 years, the types of crisis have evolved from short-term disasters – serious and visible events – to more structural longstanding situations determined by a combination of multiple factors, in particular, conflicts and natural disasters, with climate change and financial and price crises accentuating the seriousness and persistence of these predicaments. Exposure to natural disasters is without a doubt one of the major causes of food insecurity.

5 The Challenges of Evaluating the Impact of Livelihood Intervention on Migration from Rural Area to Cities

Addressing the migration implications is undoubtedly complex since both the causes and consequences of migration are multifaceted and difficult to monitor and predict. The FAO indicate demographic unsustainable growth, rural poverty and food insecurity, high inequalities between urban and rural areas, limited access to social protection mechanisms, climate change and the natural and environmental disaster linked to it and the depletion of resources as the primary factors responsible for migration (FAO 2016).

Among these factors, the linkages between development, migration, agriculture, food security and nutrition, is one important nexus that is influencing the migration from rural to urban area. Together with migration, urbanization is another phenomenon that is shaping the current world. By the middle of 2009, for the first time in human history, more people are living in urban areas then in the rural ones due to population growth and internal migration. The migration from rural to urban areas involves especially internal migrants, that represent the vast majority of migrants since it was calculated that more than 10% of the world's population had migrated internally while, international migrants represent approximately 3% of the world's population (UNDP 2009). A progressively greater proportion of the population is moving to towns and cities, not least because usually the rural areas do not offer households the prospect of a decent livelihood or many future perspectives (Crush 2013). Moreover, other main migration drivers in the rural area were found to be the search for a job, the desire to escape social pressures in rural communities, the access to basic infrastructure (e.g. water and electricity) as well as to education and health services (FAO 2018).

This migration pattern can put enormous pressure both on politics agenda in terms of sustainable development since host cities and countries must take into account the needs of internal migrants and enhance their living conditions. For example, the African Food Security Urban Network highlighted that poor neighborhoods in most cities were dominated by migrants (Frayne et al. 2010). These migrants often work in precarious occupation in the informal sector and thy represents a vulnerable group when it comes to food security. The way in which these urbanization processes are managed, the types of jobs that internal migrants can access and their living conditions, will have a great impact on many of the SDGs (ODI 2018) (see Box 1).

Box 1. How Internal Migration Can Help Sustainable Urbanization (SDG 11) and Reduce Poverty (SDG 1)

Migration can give a fundamental contribution to sustainable development and to reach some of the SDGs. According to a recent series of studies from the Swiss Agency for Development and Cooperation (SDC), the migration phenomenon can help to achieve all 17 SDGs (ODI 2018). In relation to internal migration from rural to urban areas, migration can contribute to SDGs n 1, 3, 4, 5, 8, 10, 11 and 17 (Lucci et al. 2016). In particular, internal migration was shown to have a fundamental impact on reducing poverty and on improving livelihoods of both migrants and their families that remains in the rural areas. Evidence suggests that urban migration can lead to an economic benefit for both urban migrants (Deshingkar 2006; World Bank/IMF 2013; OECD 2014) and hosting cities since migrants can contribute to city economy by filling labor gaps (IOM 2015) and many industries nowadays rely on migrant work. Moreover, migration opens up new job opportunities to migrants both in rural and urban areas and the role of remittances can result in reduction of poverty at the macro-level by also increasing the living standards of migrants' families (Castaldo et al. 2012; Hagen-Zanker et al. 2017). However, urbanization with benefits also brings challenges and urban migrants are faced by a number of them when they move to cities (Tacoli et al. 2015). First of all, most of them find employment in the informal sector with all the vulnerabilities and disadvantages brought by this working condition (e.g. unstable incomes, exploitation, lack of social protection). Secondly, often cities do not offer the adequate housing infrastructures to migrants who ends up living in informal settlements without water and sanitation. Despite their potential, internal migrants are usually neglected by local and national policies. This is for example the case of Accra and Kumasi two of the largest cities in Ghana that host high numbers of urban migrants (Lucci et al. 2016). National policies promoted urban migration but half of the migrants in the country live in temporary shelters in informal settlements (Awumbila et al. 2014). Moreover, due to their work and home illegal status migrants in both cities are faced by frequent eviction and harassment by the cities' authorities which pursue slum clearance (*ibidem*). In 2014 and 2016 two different attempts of National Policy on Migration tried to improve the situation by improving policies coherences and promoting 'fair settlement planning' in urban areas in order to maximize the migration benefits (GoG 2016 and 2014).

By following these examples, both local and national governments should promote more inclusive polices in order to:

– Improve the data on internal migration, its effects on urbanization and the generated remittances to demonstrate the potentiality of urban migration in reducing poverty.

– Facilitate migrant living and working conditions in the cities. For example, the report from Lucci et al. (2016) suggests to recognize the informal sector where the majority of migrants works and extend state protections. In this way, migrants will have access to workers' rights, to social security programs and basic housing services. As well, the creation of supporting structures and services for informal workers like markets may help to improve migrants' livelihood (Awumbila et al. 2014).

In this migration context it has become more and more important to understand the dynamics and the factors that affect the nexus between migration and food and nutrition security in order to create and sustain development actions in this directions. In the last decades, different stakeholders have organized development initiatives worldwide to improve conditions in the countryside aimed to prevent migration fluxes to cities by improving rural living conditions; these actions are based on the idea that economic development will allow to reduce migration outflow. In recent years, especially livelihood interventions in the rural areas have gained prominence as a potential way to reduce pressures to undertake irregular and unsafe migration and so contribute to the goals of the 2030 Agenda for Sustainable Development. However, even if the interlinkages between migration and development have been studied since long time, there is a lack of evidence about how livelihood interventions and opportunities impact migration (Fratzke and Salant 2018b). As highlighted by a report from the International Organization for Migration (IOM) and the World Bank (Laczko 2017) this lack of an evaluation culture in the field of migration interventions is due mainly to the technical expertise required, the costs in terms of both money and time to collect the data, and a general "fear factor" of discovering negative findings of a development project since migration is a sensible political issue. For this reason, development promoter stakeholders are often faced with key gaps in their understanding of how their actions may impact migration flows. In the migration field, an answer to the questions about how, to what extent and in which time-order development interventions affect both regular and irregular migration has still to be elaborated.

A comprehensive evaluation is defined as an evaluation that includes monitoring, process evaluation, cost-benefit evaluation, and impact evaluation (Gertler et al. 2011). Evaluating impact is critical in order to understand which type of interventions has determinant effects on migration and how they affect livelihood conditions for providing an effective input to the appropriate design of future development programs and projects.

The lack of impact evaluation can lead to misleading or unconsidered effects caused by development strategies and project, especially in such a complex phenomenon as migration. For example, a recent study by Gibson and Gurmu (2012) found out that installing village-level water taps is associated with increased rural-urban migration of young adults. The fact that rural migration is increased by improving livelihood assets was found also by a report from the UK Department for

International Development (DIFD). The report evaluates a total of 121 livelihood interventions through a rapid evidence assessment according to a modified version of the DIFD's Sustainable Livelihoods Framework in order to determine their impact on migration. The investigation outcomes highlighted that education has an effect in increasing migration rates on the long time since individuals with higher education may have more opportunities to migrate. Other drivers for migration were found to be a desire for higher salary and the perception of lack of employment or livelihood opportunities while especially migration to urban areas may be a household adaptation strategy to diversify income (Fratzke and Salant 2018b). However, the report recognize that even if some broad trends can be observed there is a big variability in migration patterns and migration decisions and actions are influenced mainly by the perception about migration as alternative livelihood strategy, the information available about specific migration opportunities and the actual cost of migration.

Evaluating the impact of development initiatives on migration remains a challenge. More effort should be spent for complete evaluations of the migration effects brought by development interventions through a more robust data collection extended on a larger time span. In order to maximize positive impacts of migration and development and reduce the negative effects, each livelihood intervention in a rural area should be carefully planned by taking in consideration all the specific communities and countries conditions and by establishing a long-term impact evaluation framework. For example, the "Food Value Chains" (Hawkes and Ruel 2012) concept may be of interest when planning a development intervention involving agricultural activities in the rural area in order to consider the impact that may have on the rural community and therefore on migration. In this way it would be possible to integrate in the best way the SDGs the new strategies to reduce inequality, poverty and both internal and international migration.

6 Instrumentalization of Aid: The Case of Italy

Development cooperation becomes a key element of the EU externalization strategy. Although the primary aim of development cooperation is to reduce poverty, due to migration priorities aid has been progressively exploited to migration purposes and this approach has now been embedded into EU development policy: tackling migration is included among the goals of the Union's, the European Consensus on Development, which will guide programming until 2030 (European Union 2017).

This instrumentalization of aid is happening in three ways. First, by inflating aid-spending thanks to the fact that aid spent in donor countries to support refugees arriving are eligible as ODA (Official Aid Assistance) for the first 12 months of their stay. Second, as underlined talking about the EUTF, aid is aimed to serve the interest of donor to impede immigration diverting it from its main purpose: alleviating poverty (Concord 2018). Finally, such aid is increasingly conditioned to encourage the cooperation of developing countries partners in migration and border control efforts, which undermines partner countries' ownership of development policies (*ibidem)*.

Italy is a perfect example of what we called "instrumentalization of aid" for migration purposes. Indeed, since the beginning of the so called "refugees crisis", the Italian government has been supporting the new development of EU external agenda on migration. In its contribution to the debate, on April 2016 Italy sent a letter to the President of the European Commission, Jean Claude Junker, proposing a "fair grand bargain" to the countries of origin and transit of migration (Italian Government 2016). Namely, the government proposed new investment projects, measures to facilitate the access to capital markets, cooperation on border management/control, customs, criminal justice, support on management of migrants and refugees, legal migration opportunities and resettlement schemes as exchange for their commitment in reducing migration flows towards Europe. Italy is not only the second major contributor to the EUTF with 102 millions of euro (July 2018), but in 2017 has also launched its own trust fund for Africa (*Fondo Africa*) with an initial allocation of 200 millions of euros which objectives and approach are very much in line with those drawn up in the EUTF.[8]

7 Inflating Aid

The money spent in the first 12 months hosting refugees in donor countries (IDRC—in-donor refugee costs) can be considered as official development assistance (ODA). Until few years ago, It was a small fraction of total ODA but due to refugees crisis this quota reached in 2016 the 11% of the overall ODA (15.960 billions of dollars), doubling since 2000. Supporting refugees arriving in Europe is a legal, as well as, a moral obligation of States, but it should not come at the expense of already relatively scarce aid to developing countries and the world's poorest and most vulnerable people. Labelling this spending as ODA is at least misleading because they do not provide any resources for developing countries. Indeed, the definition of official development assistance endorsed by OECD countries states that ODA needs to have the promotion of the economic development and welfare of developing countries as its main objective. This is not just a matter of definition. As data in Table 1 shows, recording IDRC spending as ODA is inflating the total ODA figures making donors closer than the reality to the 0.7% ODA/GNI (Gross National Income) target endorsed by all Development Assistance Committee (DAC) members. In 2016, Italy spent 1.5 billion Euro in IDRC, the 32.73% of the overall ODA in 2016 (9% in 2012), making the ODA/GNI a 0.27% instead of 0.18% (excluding IDRC).[9]

The IDRC spending in the last years has inflated the overall ODA of the DAC countries moving from 6628.73 millions of dollars (4.8% of the total net ODA) in 2014 to 15,959.51 millions of dollar (10.8% of the total net ODA) in 2016 (OECD

[8] More info at: https://www.esteri.it/mae/resource/doc/2017/02/decreto_africa_0.pdf

[9] Germany would decrease from 0.7 to 0.51% in 2016.

Table 1 G7 IDCR spending 2012–2017 (Million USD, current price)

	2012	2013	2014	2015	2016	2017
Italy	246.69	403.60	839.94	983.03	1665.24	1802.69
Germany	75.94	138.79	171.36	3018.56	6585.08	6083.90
United States	831.53	976.50	1245.64	1202.12	1701.81	1661.18
Canada	266.53	211.15	216.43	212.99	390.43	466.94
Japan	0.75	0.63	0.57	0.22	0.24	0.29
France	506.94	452.82	485.11	363.35	466.57	566.27
United Kingdom	44.96	50.54	221.92	390.49	574.03	491.07
Average G7	281.91	319.15	454.42	881.54	1626.20	1581.76

Source: OECD-DAC database (7th of August 2018)

2018). The OECD-DAC forecast for 2017 report a small decrease to 9.7% of the total net ODA causing a 0.6% decrease in real terms of the total net ODA (*ibidem*).

Comparing the Italian performance with the other G7 countries based on the OECD-DAC forecast for 2017, the country is the runner-up in relation to the overall IDRC spending, but is the first-place if we take into consideration the percentage of the IDRC spending on the overall ODA (Figs. 1 and 2).

In October 2017, the DAC concluded a review of the rules on reporting in-donor refugee costs as ODA. The revised rules make provision for better transparency and consistency of the donors' reporting practices. However, the review fails to address the fundamental question of whether in-donor refugee costs belong in ODA at all, so recent trends of ODA inflation look set to continue in future years (Concord 2018).

8 Diverting Aid: The Role of Italian Africa Fund

As we said, beside to be one of the larger contributor of the EU Emergency Trust Fund for Africa, in 2017 Italy launched its own trust fund (*Fondo Africa*) with an initial allocation of 200 millions of Euro. The *Fondo Africa* is also the Italian finance vehicle for the EUTF. The 2018 Italian budget law (*Legge* 205/2017) has allocated additional 135 millions of Euro (85 million additional) for 2018–2019. The Africa Fund promotes "extraordinary interventions aimed at revitalize the dialogue and cooperation with African countries relevant the migration root".[10] It is considered "as a qualifying element of the overall measures adopted by the Italian government aimed at fighting the irregular migration and human trafficking" (*ibidem)*. The Africa Fund has established 13 priority countries clustered based on different criteria: origin of migration flows (Guinea, Ivory Coast, Sudan, Eritrea and Somalia); relevance for the Mediterranean route management and the fight against human trafficking (Libya, Tunisia, Niger); relevance for interventions along the migration routes (Egypt, Nigeria, Ghana, Senegal, Ethiopia).

[10] More info at: http://www.esteri.it/mae/resource/doc/2017/02/decreto_africa_0.pdf

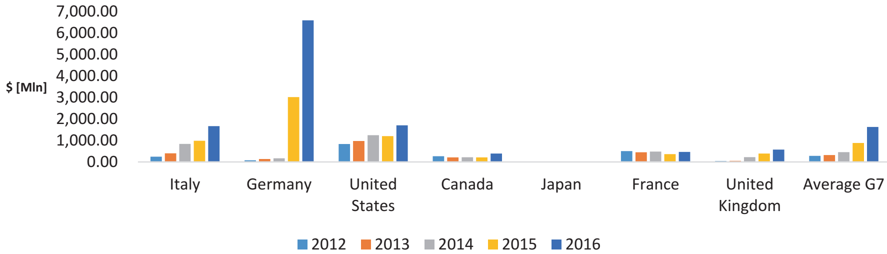

Fig. 1 G7 IDRC spending 2012–2017 (Million USD). Source: OECD-DAC database (7th of August 2018)

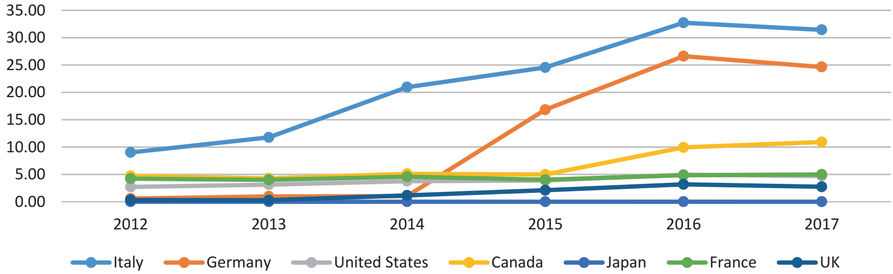

Fig. 2 G7 countries % of IDRC spending on total ODA 2012–2017. Current prices, Million USD. Source: OECD-DAC database (7th of August 2018)

It has several sectors of intervention like receiving and protection of migrants and refugees; development cooperation projects; local communities involvement; awareness raising about the risks of migration, updating and digitalization of population registers; judicial and border authorities trainings; technical equipment and instruments for the control of irregular migration and the contrast of human trafficking; institutional and administrative capacity building; protection of the vulnerable people; assisted voluntary return from the transit to the origin migration countries. With regard to the implementing entities, the Africa Fund can count on the support of the Italian Agency for Development Cooperation (IADC), the Italian ministries (in particular the Ministry of Interior), the European Union (EUTF), the International Organization for Migrations (IOM), the UN Refugee Agency (UNHCR) and the NGOs.

In relation to its implementation, it is important to underline the lack of sufficient transparency regarding specific project allocations details, in particular for those channeled through the EUTF or the Ministry of Interior. In November 2017, the Africa Fund had allocated almost 150 million out of 200 million. About 42.7 million were partially or totally not ODA eligible (DAC-ability). In relation to the recipient countries, 75% of the money have been given to two countries, Libya and Niger—respectively the 45.3% and the 30.1% of the overall allocations—with whom Italy has signed bilateral agreements for the contrast of irregular migration and human trafficking and the return of migrants from transit to origin countries. Tunisia was the third major recipient country with around 14 millions of Euro (10% of the total) (ActionAid 2017b).

The lack of transparency in the information and monitoring and evaluation system makes difficult to go deeper in the analysis of each single projects and their related impacts. Anyway, based on the information available, if we look at the three main recipient countries (Tunisia, Libya and Niger) we can observe as the projects funded focus mainly on the strengthening border control capacity for fighting against human trafficking and irregular migration (Table 2). A preliminary conclusion is that the Africa Fund instead of aiming for development as the overall objective, it serves the interests of donor to impede immigration, through a combination of development work and migration management interventions.

When it is subject to the home affairs agenda of the donors, the purpose of aid and its impact can be distorted, contradicting the poverty eradication objectives stated in the Lisbon Treaty, in the development effectiveness principle of ownership and in the Policy Coherence for Development. As migration is going to remain on the political agenda in the next years, the risk of potential aid diversion will be significant. This risk is well represented by the new Multiannual Financial Framework 2021–2027 where the Commission is proposing the adoption of a single external instrument for "Neighborhood, Development and International Cooperation Instrument (including external aspects of migration)".

Table 2 Sample of project for the three main Africa Fund recipient countries

Country	Title/total cost	Areas of intervention
Tunisia	Italian Ministry of Interior—Support to the Tunisian Authorities (12 mln €)	• Ground vehicles for patrolling (included transport expenditures) • Completion of detection and fingerprints comparison systems • Efficiency and maintenance of six patrol boats • Patrolling equipment aimed at the contrast of the migrants trafficking and to the support of the sea rescue operations • Spare parts furniture for patrol boats and ships' engine
Niger	EUTF—Support to Nigerian Plan against Human trafficking (50 mln €)	• Establishment of new specialized units for border control • New border posts and their renovation • New reception center • Reactivation of the airstrip
Libya	Support to Libyan authorities for an integrated management system on border and migration control (12.5 mln €)	10 mln € through the EUTF for the reinforcement of an integrated management system on border control and migration 2.5 mln € through the Italian Ministry of Interior for: – Efficiency of four patrol boats – Spare parts furniture – Trainings of 22 crew members – Insurance cost

Source: ActionAid, *Il compromesso impossibile*, November 2017

As underlined by Concord, the "EU response to humanitarian crises and the engagement in peacekeeping and conflict prevention operations through the Common Security and Defense Policy missions can play an important role in mitigating the causes of forced displacement. But when it comes to economic human mobility (which represents a significant share of the current migration from Africa), this logic does not stand up to scrutiny. Human mobility is determined as much by investment and opportunity, as necessity or willingness" (Concord 2018). The lack of a clear theory of change on migration and development is resulting in a fragmented and not based-evidence approach. As reported in a recent report released by the NGO Global Health Advocates, "having an impact on the deep-seated drivers of migration would require an in-depth but most importantly contextual analysis of the factors shaping migration flows, a comprehensive set of instruments, and better policy coherence for development" (Global health advocate 2017).

Finally, the initiatives taken under the new external migration management approach through aid are targeting countries of origin and transit of migration going potentially at the expense of other countries which needs assistance but are not relevant for migration, resulting in the contradiction of the recently agreed 'leave no one behind' principle in the SDGs agenda.

9 The Conditionality of Aid: Agreements for Pushing Control and Return Policies

Under the new Migration Partnership Framework of 2016 (European Commission 2016), European Union and its member states have intensified their efforts for the implementation of the "external agenda" on migration through the establishment of bilateral agreements (migration compacts) with countries of origin and transit aimed at stopping migration flows and accelerating returns. The EUTF as well as the *Fondo Africa* are the main financial instruments for the implementation of these agreements mainly focusing on short term European interest of stopping migration instead of medium-long term development interest of recipient countries. In this way ODA is not just diverted, but politically conditioned to the interest of donors. Countries who will do more on migration will get more funds ("more for more"). In this way, donor countries impose their priorities, interest and perspective on migration that are not the same for African countries (Knoll and Weijer 2016). Furthermore, looking at the program funded, there are serious risk that aid is used for activities which are in contrast and violate basic human rights.

A clear example of that is the case of the memorandum of understanding[11] signed by Italy with Libya in February 2017 aimed at strengthening the role of Libyan authorities in refoulement and detention of migrants whose consequences in term

[11] More info at: http://www.governo.it/sites/governo.it/files/Libia.pdf

for human rights violations of migrants have been widely documented. As Anja Palm from the *Istituto Affari Internazionali* wrote in 2017, “cooperation with Libya on migration and border control is not a new policy choice for Italy: during the 2000s numerous agreements focused on curbing migratory flows and enhancing readmission were concluded with the Gaddafi regime” (Palm 2017). However, the partnership had been suspended in 2012 as a result of both the collapse of the Libyan government and Italy had been condemned by the European Court of Human Rights for violating the principle of non-refoulement (intercepting migrants in the high sea and taking them or escorting them back to the country where they had left) and the prohibition of collective expulsions.[12]

The Memorandum of Understanding (MoU) contains clear indications of the way in which the Italian government is cooperating with Libya by providing support and finance both development programs and the technical and technological means for the fight against irregular migration (Article 1). In particular, Article 2 refers to Italy’s role in financing the local reception centers and their completion ‘in compliance with the relevant provisions’, supplying medicines and necessary equipment to meet the health needs of the migrants detained there, training of Libyan personnel working in such centers with a special focus on their ability to deal with clandestine immigration and human trafficking; supporting international organizations operating in the migration field in Libya; and investing in development programs in the region, particularly in projects for job creation (Palm 2017).

The above mentioned funding of 2.5 million of Euro given by the *Fondo Africa* through the Italian Ministry of interior to Libyan authorities for, among other interventions, the efficiency of four patrol boats has been highly contested by the Italian civil society and subject to an appeal to the Administrative Tribunal (TAR) by ASGI (Association of legal study on immigration).[13] In a nutshell, ASGI contested the scope of these funding which is direct to the support of military apparatus of Libyan authorities instead of contributing to the solution of the humanitarian crisis diverting aid from their original scope set by law.

To conclude, the degree to which aid delivery through the Africa Fund is associated with these activities is a contentious subject. In the case of Italy-Libya MoU, the language seems quite explicit and the approach and objectives seem to reflect the ones contained in the EC Migration Partnership Framework: “Increasing coherence between migration and development policy is important to ensure that development assistance helps partner countries manage migration more effectively, and also incentivizes them to effectively cooperate on readmission of irregular migrants” (Concord 2018).

[12] Case of Hirsi Jamaa and Others v. Italy (Application no. 27765/09), Judgment, 23 February 2012.

[13] More info at: https://www.asgi.it/asilo-e-protezione-internazionale/libia-italia-ricorso-fondi-cooperazione/

10 Conclusion

Migration is part of wider development process and not its negative consequences. It can be induced by negative factors like climate change, conflicts, lack of economic opportunities, but can also be a choice to make life better off. The main challenge for development shouldn't be to stop migration, but to eradicate poverty by at the same time addressing the root causes of global inequality. Migration has to be considered as an opportunity and its conceptualization into development cooperation needs to be aimed at maximizing its positive impact at the same time minimizing negative consequences. In the medium and long term, agricultural and rural development along with improvement of food and nutrition security can certainly help to respond to some of the root causes of current migrations, creating alternatives and improving the means of subsistence available to people. From a European perspective it means to go beyond the idea of the root causes which resulted in the manipulation of development assistance for security purposes and, at the same time, a blunt tool for reshaping migration patterns. European institutions and member states which have been searching for short-term victories need to be open to the idea of working with, rather than against, migration trends (Fratzke and Salant 2018a). This can only happen with a radical rethink of how success in migration and development policies itself is defined (*ibidem*) and only if impact evaluation programs of development initiatives will be effectively implemented.

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The Role of Advocacy and Activism for Achieving the SDGs in Food, Health, and Social Justice

Danielle Nierenberg, Sarah Axe, and Ellen Gustafson

1 Introduction

In 1995, Chef Alice Waters had a simple idea. Next to her restaurant, Chez Panisse, in the foodie enclave of San Francisco, she started a garden at King Middle School. It certainly wasn't the first school garden in San Francisco and the idea of encouraging students to know where their food comes from was not uncommon, particularly in California. But Waters' dedication and passion for creating an environment where children could learn about math, social studies, science, and English from a school garden while also learning how to cook what they're growing—and also eat and enjoy that food—helped spark a revolution among educators across the United States and the world. There are now more than 5500 Edible Schoolyard Projects in 53 U.S. states and territories and 64 countries across the world (Mapping the Movement 2018).

And what may be Waters' most revolutionary idea for transforming the food system is now underway. The chef and activist, who is also the Vice President of Slow Food International, wants to change how schools across the U.S. procure food for school lunch programs. Her idea is to use the already existing National School

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_12

Lunch program, which spends about US$13 billion every year to feed over 30 million children (Campbell and Cove Delisle 2015).

Thankfully, visionaries like Waters are all over the world, innovating in kitchens, fields, board rooms, laboratories, and town halls and coming up with ways to advocate for a food system that does more than just fill people up, but actually nourishes the world.

These farmers, activists, and food leaders are using their voices—and their smart phones and lap tops—to create synergies, find common ground, and build a movement that goes beyond fields and kitchens and helps change policy at the local, national, and international levels. Individuals creating healthy and dynamic food system that is both economically viable and environmentally sustainable are showing decision makers at every level that it is possible to achieve the Sustainable Development Goals.

2 Farmers in the Drivers' Seat

Globally, women make up 43% of all farmers—in India, they make up half of the agricultural labor force. Unfortunately, these women—and millions of other women farmers across the world—often lack access to education, land, credit, and inputs. And, women farmers also tend to be underrepresented in farmers groups and associations, making it harder for their voices to be heard.

Self-employed Women's Association (SEWA) is bringing women, including women farmers and food processors and sellers, together to work collectively for change.

SEWA is a country-wide network of cooperatives, self-help groups (SHGs), training centers, and banks that help women gain access to education, financing, and training.

Today, the organization has more than 1.3 million women members—54% of these members are small based in rural areas, but membership also includes vendors and others who sell among other things, food, door to door.

They've built a training center and farm outside Ahmedabad, India and are training women about agroecological practices such as vermiculture, rainwater harvesting, and growing indigenous crops, aligning with the SDG 12 that focuses ensuring the sustainable consumption, production, and preservation of water resources.

SEWA goes a step further, training urban entrepreneurs to market and sell SEWA's products—rice, lentils, and spices—under SEWA's own label to low-income women slum dwellers. These products are higher quality than most of the products available and the sellers are able to build a reliable customer base, giving them higher incomes. To move women out of poverty says Director Reema Nanavaty, they need "access to markets, access to finance, and access to technical services" (Nanavaty 2016).

The role of women in agriculture is so important that the FAO reports that if women had the same access to resources—land, credit, inputs, education, and extension services—as men, they could lift up to 200 million people out of hunger (Nierenberg and BCFN 2018). And further, empowering women can help achieve multiple SDG goals. Greater gender equality increases economic resources to women, which can lift whole families—and entire generations—out of poverty, putting an end to global poverty which is SDG 1.

But to ensure that women have the resources they need, governments and policymakers as well as civil society and businesses must push for women's equality in all aspects of their lives.

Organizing women farmers "brings collective strength, and it increases the bargaining power of the women farmers" (SEWA's Director 2016), says Nanavaty. SEWA is empowering women and helping to achieve greater gender equality by strengthening the capacity of women in a traditionally male-dominated sector.

And the importance of farmers organizing together isn't only beneficial for women. Organizations around the globe have been organizing rural and urban farmers for decades in ways that help improve food security, raise incomes, prevent loss and waste, and cultivate equality.

In the 1960s, Delores Huerta and César E. Chávez founded the National Farm Workers Association, now known as the United Farm Workers of America, the largest farmers union in the United States. Huerta, a union organizer and feminist movement leader, is largely credited with securing disability insurance for farm workers in California and helped implement the Agricultural Labor Relations Act of 1975, which allowed for collective organizing and bargaining among farm workers in California. With her leadership, she created a path for the future of organized farm worker advocacy. Even today she fights for the rights of farmers, women, and children (Dolores Huerta).

Two decades later, La Via Campesina (LVC), or 'The Peasants Way', established a transnational movement of peasants and family farmers founded on the basis of autonomy, linking a common identity of social struggle (Martínez-Torres and Rosset 2010). LVC has been working towards achieving SDG 10 long before it was even established. By bringing the voices of 182 member organizations in 81 countries to the table, they have helped reduce inequalities and break down barriers. The campesinos are a group of "social defenders who struggle for land, the territory, natural resources and dignity" (Honduras: interview 2016), in Honduras and all over the world, says Rafael Alegría, regional coordinator for La Via Campesina in Honduras and Central America.

LVC has become the voice of the peasants and a political force where NGOs have not been successful. The movement has helped show that food is more valuable than a commodity for trade, and that agriculture is a stimulus for local markets. Bringing communities closer together can help preserve rural livelihoods, and is a key component of building sustainable agri-food systems. Maintaining rural livelihoods is essential to promoting productive employment and decent work, achieving SDG 8.

Engaging small farmers in a way “that is not primarily profit-oriented, but to keep soil fertile, keep bio-diversity and attain food sovereignty” (Alten Post Interview 2015), says General Coordinator Elizabeth Mpofu, will help farmers across the world.

Over the last four decades, LVC has formulated commissions and campaigns representing climate change, human rights, youth, gender violence and equality, capitalism and agrarian reform, all with the goal to reach equality by empowering those most vulnerable.

And it’s not only farmers in the Global South who benefit from organizing together. The National Farmers Union (NFU), the second largest organized farmer union in the United States, are working tirelessly to defend sustainable farming practices. President Roger Johnson says, their “focus is on the farmer, not the type of farmer” (Fireside Chat 2018a), although he also explains that the challenges farmers face “are more substantial for young farmers” (Fireside Chat 2018a). NFU is currently organizing around the upcoming, and highly debated U.S. Farm Bill, which requires heavy bipartisan compromise for the ongoing funding of programs that support large-scale farmers, but also preserve the integrity of sustainable farm practices. Johnson says, there has always been “a focus on trying to do the right thing about our resources” (Fireside Chat 2018a), which is a significant focus of NFU’s lobbying efforts.

And in rural Ohio, Baldemar Velasquez founded the Farm Labor Organizing Committee (FLOC) in the 1960s to organize migrant farmworkers, giving them a voice in the political process and helping them address industry wide challenges within the supply chain. “The model of advocacy falls short because it fails to empower the actual workers. What FLOC is doing is building institution amongst the farm workers. It’s wresting power from major corporations and big advocacy groups, and giving it directly to the workers” (Five Questions 2015), he says. Today, thousands of farmworkers between Ohio, North Carolina, South Carolina, and Mexico have come together to increase wages, improve housing conditions, and direct collective bargaining agreements.

Farmer led organizations are demonstrating the importance of ensuring sustainable production and consumption practices. They are key to protecting life on the land, which helps reach SDG 15, and ensuring available, safe, and sustainable management of water for all, which SDG 6 aims to improve. These organizations are promoting inclusivity by giving a voice to those working in the agricultural sector and empowering individuals to engage in the decision making process that ultimately will impact their lives and the future of the planet (Table 1).

3 Advocating for Change

In 2016, Sam Kass, former White House Chef and Senior Policy Advisor for Nutrition under President Barack Obama, gathered food justice leaders and social entrepreneurs with the goal to shift the conversation around health, nutrition, and

Table 1 Farmer led organizations across the world

Organization	What they do	Focus area	Impacts
Reseau Organisations Paysannes et des Producteurs Agricoles de l'Afrique de l'Ouest (ROPPA), West Africa (West Africa 2018)	*ROPPA is a network of West African producers who advocate on behalf of farmers from 13 countries in the region. The organization is ensuring that all voices are included in policy and funding decisions that impact farmer livelihoods*	*ROPPA is a member of the Economic Community Of West African States (ECOWAS), the West African Economic and Monetary Union and the Permanent Interstate Committee for Drought Control in the Sahel*	*ROPPA finalized a national program to transform itself and its national members into mature and autonomous organizations.*
Prolinnova, Latin America, Africa, Asia (About Prolinnova 2018)	*Prolinnova is an international, multi-stakeholder NGO that promotes local innovation processes in ecologically-oriented agriculture and natural resource management. They seek to involve local farmers in agricultural research and development to create better ways of farming*	*Prolinnova works with smallholder farming communities in Africa, Asia, and Latin America*	*The Prolinnova network builds on and scales up farmer-led approaches to participatory development that integrates indigenous and scientific knowledge*
National Family Farm Coalition (NFFC), United States (NFFC)	*The National Family Farm Coalition (NFFC) represents family farm and rural groups who experience deep economic challenges in rural areas*	*NFFC focuses on empowering family farmers and organize their work through task forces, such as a Trade Task Force, Farm and Food Policy Task Force, and Credit Task Force*	*NFFC has been the primary family farm voice since the 1980s. They have provided leadership and a strong family farmer presence at international meetings, rallies, and press conferences*
Asian Farmer Association for Sustainable Rural Development (AFA), Asia (About AFA 2018)	*The Asian Farmer Association for Sustainable Rural Development (AFA) is a regional alliance of national federations and organizations of small scale women and men farmers and producers*	*AFA helps promote the ownership rights of family farmers over land, water, forests, and seeds They work towards building rural farm communities that are self-reliant, educated, happy, and have control over their land and basic resources*	*In Cambodia, AFA has supported the System of Rice Intensification, helping farmers increase income and productivity, maintain ownership of local seeds, and decrease their dependence on pesticides to enhance soil fertility (Agroecology and Advocacy* 2011*)*

(continued)

Table 1 (continued)

Organization	What they do	Focus area	Impacts
MASIPAG, Farmer-Scientist Partnership for Development, Philippines (About MASIPAG 2018)	*MASIPAG is a farmer-led network of organizations, NGOs, and scientists working towards building farmer's control over resources, production, and land. Their goal is to improve the quality of life of vulnerable farmers*	*MASIPAG collects, identifies, and Multiplies cultivars of rice and corn, indigenous vegetables, poultry and livestock breeds. They ensure that collected species and varieties are maintained in on-field seed banks for farmers' access*	*MASIPAG has reached over 30,000 farmers in more than 60 provinces, collecting over 2000 rice varieties*
Eco Ruralis, Romania (Eco Ruralis)	*Eco Ruralis is an association of peasants, organic farmers, and academics advocating for peasants rights. They manage large campaigns including, Agrobiodiversity, Land Rights, and Short Food Chains*	*Eco Ruralis leads policy efforts to prevent land grabs. They also coordinate with the WWOOF Romania, an international volunteer program to support organic and conventional farms*	*Eco Ruralis has over 1800 members across Romania, which includes a diverse network of small-scale food producers, activists, and consumers*

the planet from a list of ideas into successful action. He had a vision—to build a bridge between businesses, community organizations, and government entities with individuals and resources. It sounded simple, but he knew that turning goals into reality would require greater cohesion and stronger partnerships across the food system hierarchy (Nierenberg and BCFN 2018).

Kass is the founder of TROVE, an organization of experienced leaders and entrepreneurs who understand the important connections between the health of people and the health of the planet. Together, they invest, advise, and provide communication strategies to help companies across the world create a more sustainable future for the planet.

Kass worked closely with First Lady Michelle Obama while in the White House. In 2009, they built the White House's first large-scale vegetable garden, which provided fresh produce for meals in the White House as well as local food banks. During the Obama administration he used his national presence to raise awareness about issues around food and nutrition. "You look around our country and you see that we have a lot of major challenges, the origin of which is food," he said, "It's not a big step to think about: What am I doing? How is that affecting this problem? How am I helping?" (Nierenberg and BCFN 2018, p. 116). While in the White House, he built the bridge between the food industry and health advocates, and then carried these lessons onto his new firm, TROVE.

Kass leadership in the White House contributed to the 2010 passage of the Healthy, Hunger-Free Kids Act, which aims to reduce the prevalence of childhood obesity in the United States through the improvement of school meals. The United States Department of Agriculture (USDA) revised the school meal standards to focus on increased access to healthy and fresh foods throughout the school day (Fact Sheet 2017). Kass helped shed a new light on childhood obesity and generate deeper public interest in school food and nutrition policy. “I believe in thinking big but that the only way to achieve lasting change is to approach issues with a deep sense of pragmatism” (Nierenberg and BCFN 2018, p. 116), says Kass. His leadership and contributions to the school food system help to set a new baseline in the United States and this work can be been essential in ensuring that the SDGs 2 and 3, the elimination of hunger and the promotion of healthy lives and well being at all ages, is accomplished.

Organizations like Let’s Move and others from all over the world, are transforming methods of food production into more environmentally, socially, and economically sustainable ways. These organizations are building systems, developing strategies, and becoming leading models within the food system.

The James Beard Foundation (JBF) provides a platform to celebrate and cultivate both chefs and food justice leaders. Their ‘Impact Programs,’ which are dedicated to making a “more sustainable food system through education, advocacy, and thought leadership” (JBF Leadership Awards 2018), cross a diverse range of issues in an effort to actively create a stronger food system.

As Susan Ungaro, former president of JBF, explains, “there is no doubt that the American public is fascinated with celebrity. When I came to the Foundation, I felt the tipping point even then, over a decade ago. Chefs were becoming America’s most likable celebrities…When a chef goes in front of a group of school children and talks about why you need to eat more fruits and vegetables, kids listen” (Susan Ungaro’s Reflections 2017c).

Impact Programs, like Chef Action Network (CAN), are working with chefs to unite around critical issues and provide an organized platform for leadership and advocacy. Chefs from all over the world are taking more responsibility for their role in achieving the fourteenth SDG, by using their kitchens to ensure greater conservation and sustainability of marine life and resources. “In just over three years, we’ve trained hundreds of advocates and seen chefs make a real difference in policy fights around child nutrition, local fisheries, global food security, and so much more” (Chefs in the Fight 2016), explains Katherine Miller, Vice President of Impact and Executive Director of CAN.

“Chefs will be important stakeholders in achieving the U.S. government’s goal of 50 percent reduction of food waste by 2030 by addressing waste in their day-to-day business operations and by leveraging their visibility to help educate consumers on creative ways to reduce waste at home” (James Beard Foundation 2016), says Kris Moon, Chief Operating Officer and thought leader behind their Chefs Boot Camp for Policy and Change. Reducing food waste is necessary for achieving SDG seven, working to move the world towards more affordable, reliable and clean energy. Unused food can be repurposed for clean, renewable energy and the Foundation is leveraging the power of the celebrity chef to drive policy change that impacts the food system

When Ungaro joined JBF she "wanted to see the Foundation become the center of thought leadership on food" (Reflections 2017), and through their programs and awards, they cast a spotlight on the people creating joy with food. "One thing that's great about chefs is they actually interact at every point in the food system" (Chefs in the Fight 2016), says Miller. The foundation fosters inclusivity by honoring not only chefs, but all people working to build better health and sustainability, particularly spotlighting women and people of color.

And while promoting these leaders is important, policymakers need to be held accountable for their impact—both positive and negative—on sustainable cities and communities. Food Policy Action (FPA), founded by celebrity chef Tom Colicchio and environmental activist Ken Cook, works to "score" policy makers on food and agriculture legislation and policy.

They developed a publicly available tool called the National Food Policy Scorecard, which tracks activities in the United States (U.S.) Congress. The goal is create more transparency between policymakers and the public. "Voters need a clearer sense of where their legislators stand" (Food Policy Report 2017a), explains Cook. Keeping our institutions accountable to citizens, even in the realm of food systems, helps to achieve SDG 16 and ensures effective, accountable, and inclusive institutions at all levels. The scorecard promotes higher accountability of legislators, which translates into a network of informed and mobilized citizens who feel empowered to demand a healthier, sustainable, and more equitable food system.

In Cook's keynote address at the 2018 Food Tank Summit in Seattle, he explains that Food Policy Action was founded to "create a league of conservation voters for food. Across the food movement we wanted to hold politicians accountable for how they voted on food. And so we started keeping score" (Food Tank Keynote 2018c).

Now, as the new U.S. Farm Bill is negotiated in Congress, FPA is mobilizing stakeholders—organizations and industry groups—to unite and voice their opposition to drafts of the Bill that threaten the livelihoods of small farmers and our most socially vulnerable citizens. "We really need to look at what we are investing in through the Farm Bill and ask: Is this actually good for our health? Are we really making sure that our food is safe? Are we making sure that good food is available to everyone, not just the wealthy?" (Food Policy Action 2018b) says Executive Director, Monica Mills.

And from Cook's perspective, "the most important thing we can do is to focus on things that are at the grassroots level. And the most important thing we can do is to focus on the things at the national level. And the most important thing we can do on everything in between" (Food Tank Keynote 2018c). FPA is working to empower and mobilize citizens through greater transparency. They are changing the way individuals and organizations understand policy and providing the tools to help them make a difference.

Like the Edible Schoolyard Project, Slow Food's work in sub-Saharan Africa is changing the way people grow, eat, cook, and value food.

The Slow Food Foundation for Biodiversity supports what is now called the 10,000 Gardens in Africa project, which initially launched in 2010 with the goal to build just 1000 gardens. Within 4 years, they realized overwhelming success and re-launched the program with the goal to build 10,000 gardens. These gardens are more than a source of food for the community; they preserve traditional food systems, empower small farmers, and promote food sovereignty.

Edie Mukiibi, Vice President of SFI says, "the greatest obstacle to food access and distribution is lack of political will by those in authority to do the right things for their people," and "the 10,000 Gardens in Africa project works to revive hope and return the power of food production to African communities" (Gardens are Emblems 2017b). The philosophy of SFI is that food should be good, clean, and fair and the 10,000 Gardens in Africa project has "created an important network that is growing and working to change Africa, to offer our children a future of peace and justice" (Slow Food Refocuses 2014), Mukiibi says, granting these basic food rights for all.

The gardens are a physical manifestation of the food revolution in Africa. They represent a path towards healthy, safe, and accessible food now and in the future.

And it's not only gardens in Africa that are building community connections and promoting food justice. Kimbal Musk, restauranteur, philanthropist, and entrepreneur is on a mission to expand access to real food for all citizens across the United States. Concurrently Mukiibi and Musk are creating more sustainable and resilient communities and cities across the world, making SDG 11 a greater reality.

Founder of The Big Green (formerly The Kitchen Community), Musk is working to create a replicable and scalable model for establishing school gardens. By transforming the culture around school food, Musk, like Alice Waters, is using gardens to connect children to their food and foster stronger food literacy. And like Waters' vision for an edible education for all, he has built a model for "learning gardens" with a force to mobilize real impact.

The Big Green builds no fewer than 100 gardens in a community to maximize impact and leverage efficiencies and resources that can only be acquired at this scale. At this level, they are able to create a regional shift in food culture, creating deeper and longer-term changes. Big Green currently reaches more than 250,000 students across the United States, and is working to double their impact by 2020. Musk is inspired by the power of education within the natural world and committed to strengthening these connections for children in effort to create a better educated, stronger community, and healthier nation. Both Slow Food Foundation's 10,000 Gardens in Africa and The Big Green's Learning Gardens are being cultivated in urban environments, helping to make those areas safer, more resilient, and more sustainable for people to live in, especially children.

4 Cultivating the Next Generation of Agricultural Leaders

Farming populations around the globe are aging. In the U.S., the average of farmers is 58 years old (Census Highlights 2014) and in Africa, it's 60 years old (Contribution to the 2014 United Nations ECOSOC 2014). Unfortunately, most youth don't see food and agriculture as a career opportunity. It's something they feel forced to do,

Table 2 Ages of Farmers Across the World

Region	Average age of farmer	Percent of farmers (out of total employment) (Employment in Agriculture 2017a)	Percent of population 15–29 years old (Population 2017b)
United States	58.3 (Census Highlights 2014)	2	41
Romania	55[a] (Family Farming 2013)	23	35
China	56.6 (The Impact of Ageing 2015)	18	42
Ghana	55 (Youth in Agriculture)	41	55
Afghanistan	47 (Agriculture and Food 2003)	62	59
Australia	52 (Farm Facts 2012)	3	39
EU-28	40–64[b] (Farmers in the EU 2017)	5 (Farmers in the EU 2017)	17.4 (Children and Young People in the Population 2018)

[a]70% of farmers of small farmers (the majority in Romania)
[b]Over 59% of farmers fall in this age range

rather than something they want to do. Many schools in Uganda use farming as a form of discipline, creating a stigma around agriculture as a vocational choice (Edward Mukiibi's Project DISC 2013) (Table 2).

Fortunately, that's changing—with big and small organizations, research institutions, universities, and foundations investing in the resources, education, and investment to train the next generation of not only farmers, but agricultural business leaders, policymakers, activists, and storytellers.

The Barilla Center for Food & Nutrition Young Earth Solutions (BCFN YES!) initiative, for example, is encouraging young people to put big, creative ideas into action. Each year, they have a contest to challenge graduate students and researchers to come up with concrete solutions to make the food system more environmentally sustainable. They encourage young researchers to take urgent action to combat climate change and its impacts, directly influencing SDG 13.

Winners of the contest include Jamaican researchers Shaneica Lester and Anne-Teresa Birthwright, who are training small farmers to adapt to and mitigate the effects of climate change on the island. Through participatory research practices where they work directly with farmers, they are able to share their knowledge as well as learn from the farmers themselves. And the support they've received from BCFN YES has allowed them expand their research and get more attention for sustainable agriculture practices a solution to climate change in Jamaica.

Similarly, Young Professionals for Agricultural Development (YPARD) is working to increase the involvement of young agriculture and food professionals in high level decisionmaking.

YPARD now has network of more than 15,000 members and more than 60 national working groups. The organization is committed to involving these young leaders in "critical conversations" in agricultural research for development. YPARD is a community by youth and for youth, that imagines "a more sustainable and innovative agricultural sector […] that truly incorporates the views of youth" (Join YPARD 2018).

At the heart of YPARD are its members, who are encouraged to take an active role and to initiate activities relevant to young professionals in their local context. Indeed, there is no sustainable future without the full engagement of the new generation.

And while investing in young researchers and scientists is valuable, food producers and workers also need more support.

In the United States, the National Young Farmers Coalition helps young, new farmers engage, mobilize, and direct more attention to the issues they face—issues that are not dissimilar to farmers in other parts of the world. They lack access to land, mentorship, financing, and education. And they are often burdened by student loan debt and lack of access to healthcare. Their Executive Director, Lindsey Schute, believes that if young farmers are given a real chance of success, they can not only survive, but thrive.

During a keynote at the 2018 Food Tank Summit in Washington, DC, Schute said, "we wanted to give our farmers a platform to take action in their own areas, it's also an essential social network farming can be very isolating and it's incredibly important that farmers have a social network around them….ultimately it's that support network to provide services for farmers and farmer viability…we have to support them throughout to make sure they are doing well and that's really the foundation of our organization" (Fireside Chat 2018a).

And this work is happening across the world. CEJA, the European Council of Young Farmers, provides a forum for young farmers to communicate with European Union (EU) policymakers. Their goal is to support the working and living conditions for young people entering the agricultural sector. CEJA represents more than two million farmers across Europe, 24 EU states, and 32 national organizations. For over 50 years, CEJA has given a voice to young farmers, influencing EU policy decisions, and provides advanced educational opportunities to its young farmers (CEJA).

Universities are also realizing the need to train the next generation of leaders. At Cape Coast University, in Ghana, for example, learning not only takes place in classrooms, but in fields. The University's Department of Agricultural Economics and Extension is training young extension workers to better work with farmers and meet their needs. The program was started in the early 1990s after the Ministry of Agriculture found that its extension workers were not communicating well with farmers, says Dr. Okorley, a Cape Coast professor. The goal of the program, according to Okorley, is "to improve the knowledge of front line extension staff." Because the educational background of many extension workers is "limited" (many don't have the means to attend college) says Okorley, they "couldn't look at agriculture holistically" (Learning to Listen 2010).

But the university is helping change that problem and achieve the fourth SDG to ensure quality education for all. Students learn how to engage with farmers and communities by learning better communication skills. And they are trained to properly diagnose problems, as well as come up with solutions. Expanding access to agricultural education is one important way to promote lifelong quality learning opportunities for all people.

After attending a year of classes on campus, the students go back to their communities to implement what they've learned in Supervised Enterprise Projects (SEPs). The SEPs give the student-professionals the opportunity to learn that particular technologies, no matter how innovative they might seem in the classroom, don't always "fit" the needs of communities, says Dr. Okorley (Learning to Listen 2010). The SEPs also help them implement some of the communication skills they've learned in their classes, allowing them to engage more effectively in the communities where they work. Instead of simply telling farmers to use a particular type of seed or a certain brand of pesticide or fertilizer, the extension workers are now learning how to listen to farmers and help them find innovations that best serve their particular needs. "One beauty of the program," according to Dr. Okorley, "is the on-the-ground research and experimentation." He says "it allows the environment to teach what should be done" (Learning to Listen 2010).

The Center for Agroecology and Sustainable Food Systems at the University of California, Santa Cruz (UCSC) leads an apprenticeship training program that combines the traditional classroom model with field work to educate and train future farmers about the techniques of agroecology and organic farming.

The UCSC apprenticeship program has been in existence for over 50 years and is internationally recognized for successfully intertwining traditional and experiential learning. Students learn practical farming skills such as soil management, composting, pest control, crop planning, and irrigation, as well as businesses practices including marketing strategies and Community Supported Agriculture (CSA) practices (About the Center 2013).

But students learn more than just practical sustainable farming skills, the program addresses farm labor issues, policy, and equity within the food system. Graduates of the program are developing projects all over the world acting as stewards of the land and advocates of food justice (Table 3).

And culinary institutes hope to train young chefs and hospitality workers about the importance of sustainability in the food system—practices that are not only better for the planet, but help improve hotels, restaurants, and businesses bottom lines. As the world continues to industrialize, the need for more training of young people to perform technical jobs is essential for realizing SDG nine. The soon to be opened New Orleans Culinary and Hospitality Institute (NOCHI) will offer intensive programs to train young hospitality leaders. Professionalizing these culinary services can provide incentive and motivation for young people to get involved. NOCHI Founder and legendary restauranteur Dickie Brennan says "we don't want people to think that hospitality is just cooking and waiting tables" (D. Nierenberg, personal communication, July 25, 2018). Organizations like this help promote greater inclusivity and more sustainable industrialization.

Table 3 Farmer education

Cornell University Small Farms Program, United States	The Cornell Small Farms Program helps farmers become experts in all aspects of small farm business development, from initial growth to optimization to maturity (Cornell Small Farms Program 2018) The program is collaboration between campus staff, Cornell Cooperative Extension educators, and other state partners. Their include Small Farms News Service; beginning farmer assistance; statewide work teams on livestock processing, local markets, and grasslands utilization; research on small farm clusters and regional food systems; and professional development training for educators and service providers (Sustainable Campus)	The program initially developed courses for beginner farmers and over the years began developing courses for a broader audience. Today, the program supports a diverse group of small farmers with online resources for business development (Learn About Our Online 2017)
Farmshare Austin, United States	Farmshare Austin's is growing a healthy local food community by increasing access to local food, educating new farmers, and preserving farmland. They envision a future where farmers have livable incomes, everyone has access to organic food, and environmental resources are highly valued. They host a farmer education program on their 10-acre certified organic farm in Texas and run food access programs for food insecure communities in the area (Farmshare Austin)	Farmshare Austin was created in 2014 offering an 18-week 'Farmer Starter Program,' expanding education for organic farming. Currently, they also run mobile markets, bringing local food to communities with limited access to food and high rates of chronic disease risk factors (Farmshare Austin)
IALA Amazonico, Brazil	Iala Amazonico is an agro-ecological institute located in the Amazon region of Brazil. It is part of a network of Institutes for Agro-ecology in Latin America (IALA) created by La Via Campesina. Their goal is to support the use of agro-ecological practices among peasants as a means to guarantee food sovereignty. The IALA's organize workshops and seminars, offer internships, and a post-graduate course in agro-ecology. The IALA's offer structured meeting opportunities for people to share their experiences and exchange ideas (IALA Amazonico)	In 2005, La Via Campesina began establishing the international network of agroecological institutes. With the support from Hugo Chavez, IALA Amazonico was founded in 2009. Post-graduate courses in Rural Education, Agroecology, and Agrarian conflicts in the Amazon were offered starting in 2010 in partnership with the Federal University of Pará (UFPA) (IALA Amazonico)

(continued)

Table 3 (continued)

Global Farmer Field School Platform, Asia, Africa, Latin America, and the Caribbean	The Farmer Field School (FFS) platform focuses on people-centered learning, using participatory methods to freely exchange knowledge and experiences as well as field exercises to encourage "learning by doing" FFS addresses a range of topics including soil, crop and water management, aquaculture, agroforestry, and nutrition. FFS is offered in over 90 countries (Global Farmer 2018)	FFS was started in Asia in the late 1980s Today, FFS offered in over 90 countries, reaching over four million farmers (Global Farmer 2018)
Common Agricultural Policy, Europe Union	The EU's Common Agriculture Policy (CAP) is funded out of the EU budget in an effort to support farmers and agricultural productivity across Europe. They work to ensure EU farmers can make a sustainable living, address climate change through the sustainable management of resources, as well as support and promote the rural economy (Common Agricultural Policy at a Glance 2018)	CAP was launched in 1962 as a partnership between agriculture and society, building stronger connections between farmers and the nation. The policy provides income support through direct payments to farmers, interference in the market during extreme conditions, and the implementation of programs to support rural areas (Common Agricultural Policy at a Glance 2018)

5 Conclusion: Achieving the SDGs

In order for the SDGs to be fully achieved, they need the support of not only policy-makers and business leaders, but individual farmers, activists, and advocates. They are on the front lines of the movement for a sustainable food that is more economically, environmentally, and socially sustainable.

Farmers, particularly, need to have their voices heard and need the opportunity to organize and work together collectively. Youth and women farmers also deserve an opportunity to have equal access to resources and inputs. NGOs and advocacy groups can support these efforts through creating awareness of the challenges and successes happening in the food system every day. And eaters are realizing both the power of their consumption choices as well as their votes.

Thankfully, leaders around the globe are beginning to respect and honor all aspects of the food system—from farming to research to policymaking, all helping to achieve SDG 17. Creating better education and infrastructure and strengthening research institutions can ensure that agriculture is not seen as something backward, but as a way forward. To strengthen and revitalize the global partnership for sustainable development, it will take all of these organizations and their home countries working together. The SDGs provide a powerful set of guidelines for cultivating equality, preserving natural resources, and ensuring that people are not simply fed, but well-nourished. And they provide a chance for democratizing the food system so that all voices can be heard.

Appendix. Summary of Organizations from the Chapter

Name	Website	Description	SDG focus
10,000 Gardens in Africa	https://www.fondazioneslowfood.com/en/category/10000-gardens-in-africa/	Supported by Slow Food Foundation for Biodiversity, they started with the goal to build 1000 gardens and within 4 years, they realized overwhelming success and re-launched the program with the goal to build 10,000 gardens	11,15
Asian Farmer Association for Sustainable Rural Development (AFA)	https://asianfarmers.org/	A regional alliance of national federations and organizations of small scale women and men farmers and producers	8,16
Barilla Center for Food & Nutrition Young Earth Solutions (BCFN YES!)	https://www.barillacfn.com/en/bcfnyes2018/	Encourages young people to put big, creative ideas into action with an annual contest to challenge graduate students and researchers to come up with concrete solutions to make the food system more environmentally sustainable	9,13
Big Green	https://biggreen.org/	Formerly The Kitchen Community, they are working to create a replicable and scalable model for establishing school gardens	11,15
Cape Coast University, Department of Agricultural Economics and Extension	https://ucc.edu.gh/Department/department-agricultural-economics-and-extension	Started in the early 1990s to better work with farmers improve the knowledge of front line extension staff	4
CEJA European Council of Young Farmers (CEJA)	http://www.ceja.eu/	Provides a forum for young farmers to communicate with European Union (EU) policymakers	16
Center for Agroecology and Sustainable Food Systems at the University of California, Santa Cruz (UCSC)	https://casfs.ucsc.edu/	Leads an apprenticeship training program that combines the traditional classroom model with field work to educate and train future farmers about the techniques of agroecology and organic farming	4,12
Chef Action Network (CAN)	http://www.chefaction.org/	Help chefs tap into their inner advocate, and provide the tools, training, and support infrastructure to ensure their success	16

Name	Website	Description	SDG focus
Common Agricultural Policy	https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en	Work to ensure EU farmers can make a sustainable living, address climate change through the sustainable management of resources, and support and promote the rural economy with direct financial investment, market intervention, and program implementation	8,11,13,16
Cornell University Small Farms Program	https://smallfarms.cornell.edu/	Helps farmers become experts in all aspects of small farm business development, from initial growth to optimization to maturity	4
Eco Ruralis	https://ecoruralis.ro/	An association of peasants, organic farmers, and academics advocating for peasants rights	16
Edible Schoolyard Project	https://edibleschoolyard.org/	Founded by Chef Alice Waters in 1995, they are building and sharing a national edible education curriculum for pre-kindergarten through high school	3,4,11
Farm Labor Organizing Committee (FLOC)	http://www.floc.com/wordpress/we-are-floc/	Founded by Baldemar Velasquez in the 1960s to organize migrant farmworkers, giving them a voice in the political process and helping them address industry wide challenges within the supply chain	6, 15
Farmshare Austin	https://www.farmshareaustin.org/	Works to increase access to local food, educate new farmers, and preserve farmland	3,4,11
Food Policy Action (FPA)	https://foodpolicyaction.org/	Provides a scorecard assessing policy makers on food and agriculture legislation and policy	16
Global Farmer Field School Platform	http://www.fao.org/farmer-field-schools/en/	Focuses on people-centered learning, using participatory methods to freely exchange knowledge and experiences as well as field exercises to encourage “learning by doing”	4
IALA Amazonico	http://ialaamazonico.blogspot.com/	As part of a network of Institutes for Agro-ecology in Latin America created by La Via Campesina, they support the use of agro-ecological practices among peasants as a means to guarantee food sovereignty	16

Name	Website	Description	SDG focus
James Beard Foundation (JBF)	https://www.jamesbeard.org/	Works with chefs to unite around critical issues and provide an organized platform for leadership and advocacy	3,16
La Via Campesina (LVC)	https://viacampesina.org/en/	La Via Campesina or 'The Peasants Way', is a transnational movement of peasants and family farmers founded on the basis of autonomy, linking a common identity of social struggle	8, 10
Let's Move	https://letsmove.obamawhitehouse.archives.gov/	Started by former First Lady Michelle Obama, the initiative works to create a healthy start for children, empower parents and caregivers, provide healthy food in schools, improve access to healthy, affordable foods, and increase physical activity.	2,3,10
MASIPAG, Farmer-Scientist Partnership for Development	http://masipag.org/	A farmer-led network of organizations, NGOs, and scientists working towards building farmer's control over resources, production, and land	16
National Family Farm Coalition (NFFC)	http://nffc.net/	Represents family farm and rural groups who experience deep economic challenges in rural areas	11,16
National Farmers Union (NFU)	https://nfu.org/	The second largest organized farmer union in the United States working to defend sustainable farming practices	6, 15
National Young Farmers Coalition	https://www.youngfarmers.org/	Helps young, new farmers engage, mobilize, and direct more attention to the issues they face	16
New Orleans Culinary and Hospitality Institute (NOCHI)	https://www.nochi.org/	Offers intensive programs to train young hospitality leaders	4
Prolinnova	https://www.prolinnova.net/	An international, multi-stakeholder NGO that promotes local innovation processes in ecologically-oriented agriculture and natural resource management	6, 15
Reseau Organisations Paysannes et des Producteurs Agricoles de l'Afrique de l'Ouest (ROPPA)	http://www.roppa-afrique.org/	A network of West African producers who advocate on behalf of farmers from 13 countries in the region	6, 15

Name	Website	Description	SDG focus
Self-employed Women's Association (SEWA)	http://www.sewa.org/	A country-wide network of cooperatives, self-help groups (SHGs), training centers, and banks that help women gain access to education, financing, and training	1, 5
Slow Food Foundation	https://www.fondazioneslowfood.com/en/	Active in over 100 countries, the Foundation involves thousands of small-scale producers in its projects, providing technical assistance, training, producer exchanges and communication	4,8,11
Trove	http://www.troveworldwide.com/	An organization of experienced leaders and entrepreneurs who understand the important connections between the health of people and the health of the planet	11,13
United Farm Workers of America	https://ufw.org/	Formerly the National Farm Workers Association, it is the largest farmers union in the United States	8, 10
Young Professionals for Agricultural Development (YPARD)	https://ypard.net/	Works to increase the involvement of young agriculture and food professionals in high level decisionmaking	16

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The Role of Youth in Achieving the SDGs: Supporting Youth-Led Solutions for Sustainable Food Systems

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1 Introduction: Youth and the Sustainable Development Goals

In the public discourse, young people are often identified as "the leaders of tomorrow". In recent years, however, this mantra has slowly been replaced by a growing emphasis on the role of youth communities as critical agents of change, "leaders of today" who are already contributing to the sustainable development of their economies and societies (UN Secretary-General 2018). Whereas the study of younger generations' strong attitudes towards sustainability and purpose has been an object of research for quite some time (AIESEC 2016; Corporate Citizenship 2016; Deloitte 2016), emerging awareness about the potential of more actively engaging with youth in the solution of sustainable development challenges appears to have

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_13

particularly shaped the narrative around the Sustainable Development Goals (SDGs), which were adopted in September 2015 at the United Nations General Assembly as part of the 2030 Agenda for Sustainable Development (UN 2015).

This narrative essentially revolves around three pillars, namely (i) the striking similarity of the concerns shared by different youth communities across countries and regions (The Economist 2016); (ii) the notion that governments, especially in Western democracies, tend to favor older age groups in developing policy (Wallimann-Helmer 2015); and (iii) the fact that the so-called millennial generation is usually better educated than the generation of their parents (UNESCO 2015a, b; Fry et al. 2018). Taken together, these three pillars suggest that the interests, concerns, and solutions of young people need just as much, if not more, consideration in the SDGs and food systems discourse, particularly as most countries and regions are still shown to struggle with an insufficient pace of implementation of the 2030 Agenda (Bertelsmann Stiftung and Sustainable Development Solutions Network 2018). This argument is supported by a growing, if still relatively recent, body of literature. First, not only does existing research point to the central role of Goal 2 ("No Hunger") in the achievement of many of the other 16 SDGs, it also underscores the disproportionate negative impacts that unsustainable food systems have on rural and urban youth communities worldwide (Ghebru et al. 2018; Kosec et al. 2018; Mungai et al. 2018). Second, a number of reports use empirical case studies to illustrate how youth-led and youth-oriented initiatives are already deploying sustainable agricultural practices and solutions at sub-national and local levels (Kew et al. 2015; IFAD 2018b; SDSN Youth 2018). Third, a widespread consensus exists on the fact that young people face a series of specific obstacles when trying to implement and scale up initiatives in this sector, particularly in terms of regulatory barriers and access to markets, credit, land, and skills (F&BKP Office 2016; White 2012; World Bank and IFAD 2017).

Accordingly, in this chapter we analyze the interplay between the potential contribution of young people to the achievement of the SDGs, with emphasis on Goal 2 ('No Hunger'), and the challenges that these young people face as a result of unsustainable food systems. In doing so, we contribute to the literature on young people's involvement in sustainable food system transitions, which is still largely based on individual case studies and therefore lacks a broader attempt at systematization and conceptualization. The chapter is structured as follows. In Sect. 1, we begin by briefly summarizing the challenges facing young people in an era of rapid demographic, economic, social, technological and environmental transformations. In Sect. 2, we discuss the impact of unsustainable food systems on youth empowerment and inclusion, as well as the obstacles preventing young people from meaningfully contributing to rural economic development in their countries and communities. In Sect. 3, we analyze how youth skills and leadership on the SDGs intersect with themes of rural development and sustainable food systems, and we also provide examples of existing initiatives that seek to address the challenges identified in Sect. 2. Finally, in Sect. 4, we provide a short conclusion highlighting the importance of seeing the youth bulge as an opportunity that, under the condition of a meaningful partnership with rural youth communities, can help deliver a sustainable transformation of food systems and achieve the SDGs.

1.1 The Challenges Facing Young People in an Era of Globalization

1.1.1 The "Youth Bulge" and the Demographic Dividend

The world is home to approximately 1.8 billion young people, understood as individuals aged 10–24 years, with youth populations in the Middle East and Africa expected to dramatically increase in the coming decades (UNFPA 2016; FAO 2018a). This observed and predicted rapid growth in the youth population of many countries is commonly referred to as the "youth bulge." The dramatic rise in the proportional size of youth relative to the rest of the human population, particularly in developing countries, will be accompanied by the need to support a larger labor force (Filmer and Fox 2014), feed an expanding population (FAO 2009), and mitigate the possibility for social or violent conflict that may arise from new or unforeseen resource availability challenges (SDSN Youth 2017a, b).

Given current institutional challenges in providing adequate education, employment opportunities, and social mobility to youth, the youth bulge is perceived to pose a risk to the achievement of the SDGs (UNDESA 2015). However, in the presence of appropriate investments and policies, the youth bulge can be turned into an opportunity for sustainable economic development, a concept known as "demographic dividend". When young people can have access to decent and productive employment, quality education, and good health care, a society will fully reap the benefits of this demographic dividend, including a rise in average incomes, larger investments on children, better access of women to formal employment, and stronger entrepreneurial and innovation systems (Yifu Lin 2012; UNFPA 2014). From this perspective, a growing consensus exists on the importance of agri-food systems for job creation and economic development, particularly in contexts where a large proportion of the youth population lives in rural areas and is still predominantly reliant on agriculture for income and employment (ILO 2012; FAO 2018b).

1.2 Harnessing Youth-Led Solutions and Skills

As a consequence of the current youth bulge, the largest number of young people in human history will enter the workforce over the next few years (UNFPA 2014: 79). In an era of increasing interconnectedness and globalization, the resulting development trajectories are likely to affect the world at large, with implications stretching far beyond the regions in which the proportion of young people is highest. This is especially relevant because, despite persisting challenges in access to education (UN 2018), the current generation of millennials is often described as the "best-educated generation ever" (The Economist 2016). In many countries, rising literacy rates and enrolment ratios create the urgent need to expand formal sector employment and promote opportunities for entrepreneurship and innovation (UNFPA 2014; UNCDF 2014), consistent with the targets enshrined in SDG 8 ("Good jobs and economic growth") and SDG 9 ("Industry, innovation and infrastructure").

Higher educational attainments, coupled with a childhood and young adulthood experience characterized by easier access to digital skills development, arguably give young people an edge in devising, designing, and launching their own solutions. According to Kew et al. (2013), young people are 1.6 more likely to become entrepreneurs than older adults. In doing so, they are also less likely to be affected by the forms of path-dependence which characterize existing organizations and institutions, bringing new ideas to their sectors and revitalized enthusiasm for innovation. As shown in the 2018 Youth Solutions Report (SDSN Youth 2018), there is a significant untapped potential for every region, discipline, and industry in youth-led solutions for sustainable development. However, these solutions often face a range of special challenges and barriers to their implementation, and their success will in large part depend upon youth access to financial services, markets, technology, mentoring opportunities, and visibility (SDSN Youth 2018).

1.3 Global Environmental Change and Its Links to Food Systems and Peace

In addition to social and economic challenges, young people are also uniquely affected by global environmental change. Not only do climate change and environmental degradation serve as dire threats to food systems and agricultural productivity, they also pose risks to sustained peace within and between states. For example, the burden of reduced natural resource availability can exacerbate tension between rivaling or competing social groups, and thus climate change is acknowledged to stress pre-existing vulnerabilities in political and economic stability, including specific vulnerabilities facing young people (SDSN Youth 2017a, b).

While more political science research is needed to fully understand the political ramifications of the climate change and food system nexus, emerging research has also shown that climate-induced food price crises and their negative implications may result in a greater likelihood of urban unrest and instability in developing country contexts (Hendrix 2013). As such, the threats posed to peace and security by accelerating environmental change and its impact on food systems may negatively affect the security and prospects of young people living in developing countries, suggesting the need for a more inclusive representation of youth in policy-making processes relating to these issues (SDSN Youth 2017a, b). Unfortunately, at present, the level of youth civic participation is limited in most countries. Only about 6% of the world's parliamentarians are estimated to be under 35 (UNDP 2014), and evidence of meaningful youth engagement in national pathways for SDG implementation remains anecdotal at best.

2 Unsustainable Food Systems: The Impact on Youth

The challenges posed by the "youth bulge", by countries' failure to harness youth skills for sustainable development, and by the threats to youth, peace and security coming from global environmental change all impact upon, and are impacted by, the sustainability of the global food system. On the one hand, there is a universal consensus that food systems and the agricultural sector require a sustainable transformation that delivers opportunities for the youth of today and tomorrow whilst simultaneously ensuring respect of the planetary boundaries on which humanity depends (Steffen et al. 2015). On the other, unsustainable food systems and the obstacles they create to the achievement of the SDGs appear to have disproportionate effects on the potential contribution of young people to this sector of the economy. This holds particularly true for young people in rural communities, as unsustainable food systems negatively impact aspects including rural outmigration, high levels of rural youth unemployment, and multi-dimensional rural poverty. Only by understanding these obstacles, which discourage young people from participating in agriculture, can policy-makers leverage youth skills and solutions to promote sustainable rural transformation.

2.1 Ageing of Farming Population, Lack of Sustainable Innovation and Outmigration

Not only is the agricultural sector a major contributor to the potential transgression of several planetary boundaries, including those associated with land-system change, freshwater use, biogeochemical flows, changes in biosphere integrity, and climate change (Campbell et al. 2017), but rural communities are also especially dependent upon the quality and availability of natural resources (Baumann 2002). In other words, the global community needs the agricultural sector to advance its commitment to sustainable practices more than any other, and rural communities in turn need to acknowledge that they have the greatest stake in ensuring food security and natural resource availability. Young people can play a fundamental role in this process, as the ageing of farming populations has been described as a major obstacle to sustainable innovation in the agricultural sector (Vos 2014). From this perspective, however, a circular problem emerges, in the sense that as farming populations age, lack of access to land (Ghebru et al. 2018; Kosec et al. 2018) and insufficient investments in sustainable farming practices and internet and communication technologies (ICTs) then deter youth from staying in rural communities and committing to a career in agriculture.

A prime example of this "double-edged sword" facing youth involvement in agriculture has emerged in Mexico's *ejidos*. *Ejidos* are communally-owned lands that have stringent conditions for their passing from an older generation to the next. The infrequent transfer of land rights to younger generations has been identified as a major cause of outmigration of rural youth to the United States, a decline in land productivity, and stymied opportunities for youth. In 2004, the World Bank and government of Mexico launched the Young Rural Entrepreneur and Land Fund Programme to encourage the sale of *ejidos* to young individuals, keeping the land within the community while also providing social welfare access to the older land managers who had sold their land to the youth. The program was successful in providing over 3000 young people with access to land, financial training programs, and financial support. As of 2008, the program's success had even convinced some of the husbands of female landowners to return from the United States, a promising sign that youth access to farming could prevent further depopulation of rural communities and improve land usage (FAO, CTA, and IFAD 2014).

Urbanization, which is both another cause and a result of these interweaving trends of youth outmigration and rural depopulation, presents a fundamental threat to rural communities (FAO 2018e). As urban areas expand with rapid population increases, there are expected to be significant changes in land ownership, the result of which will impact the respect of customary rights and the quality and availability of water and land resources to rural communities. In addition, whilst population growth implies that there will be an overall greater energy demand in 2030, new energy demand will increasingly come from urban areas as a result of urbanization. Thus, as rural youth witness expanding urbanization and become potential participants in outmigration, their decisions as producers, consumers, and migrants will also indirectly influence the sustainability and productivity of the agricultural sector (IFAD 2018a).

While outmigration, as a result of youth migrants moving from rural areas to urban city centers, and urbanization are almost guaranteed to persist beyond the scope of the 2030 Agenda, rural communities are still expected to see a population enlargement in the coming decades due to demographic trends and the fact that many young people will decide to remain in rural areas (FAO 2018b). As a consequence, tackling youth unemployment in rural areas, particularly as it relates to food systems and agriculture, should remain a critical focus of development policy and food security.

2.2 Youth Unemployment and Exclusion from Markets and Financial Resources

Youth unemployment is a serious and growing concern within the SDG framework, especially as the youth bulge becomes more important in discussions around peace and stability and as young people remain two to three times more likely to be unemployed than adults (ILO 2015). Despite the fact that youth unemployment tends to remain a severe challenge for rural regions, however, youth unemployment rates tend to be lower in these areas than they are in cities, and agriculture still represents the primary employer of rural youth. According to the World Bank and IFAD (2017), this means that there are significant opportunities to reverse growing trends in youth unemployment by attracting young people to agriculture, especially through above-mentioned investments in ICTs, youth-oriented vocational trainings, and formalization.

At the same time, young people face added obstacles in entering the agricultural sector and accessing agricultural markets. This market exclusion of youth is compounded by multiple causes, such as limited access to land ownership, gaps in infrastructure provision and development, and difficulties in access to credit and financial services. Young women and girls, facing prejudice on account of their gender as well as their age, tend to be particularly excluded by financial institutions in rural areas. As a consequence, it has been suggested that investments in infrastructure, especially in areas that are typically associated with female tasks—such as irrigation infrastructure to alleviate the onus of water collection—can reduce some of the barriers to female entrance into the agriculture market and ease the costs associated with beginning a youth-led entrepreneurial venture (World Bank and IFAD 2017). According to the recommendations shared by the World Bank and IFAD (2017), as well as by the G20 Initiative for Rural Youth Employment (G20 2017a), local and national governments should also evaluate their fiscal policies and tax schemes to ensure that tax rates, regulations, and license fees are not a prohibitive factor in youth entrepreneurship and innovation.

The finance market also needs to respond to the needs of young people, particularly in rural areas. Youth make up a smaller proportion of financial service provider beneficiaries than their demographic makeup demands. This is the result of the high-risk categorization of the agriculture industry and young borrowers, as well as of the dispersed nature of rural communities. Even when they are provided access to financial services, young farmers are offered access to credit and borrowing options far more often than they are provided with insurance plans—a critical factor for financial stability in the agriculture sector. Imperative to shifting this finance environment for youth will be the creation of finance services customized to rural youth needs, allowances, and capabilities, including the provision of financial literacy programs (FAO, CTA, and IFAD 2014).

All in all, a transparent market system with points of entry for youth and their solutions is considered to be one of the most important factors contributing to a reduction in youth unemployment, raising the attractiveness of investing in rural communities as opposed to migrating to urban areas, and supporting a sustainable transformation of agricultural practices and technologies (G20 2017a).

2.3 Unsustainable Food Systems and Their Consequences on Rural Poverty

The correlation between unsustainable food systems and rural poverty is clear (FAO 2009), and it presents a series of specific challenges for young people living in rural communities. First, beyond its influence on outmigration, rural poverty can reinforce youth unemployment by reducing access to non-farm employment opportunities and creating additional obstacles in securing loans and other forms of financial support. Second, the agricultural sector, which employs up to 65% of the rural youth, often does so in an informal and seasonal capacity, leading to a higher likelihood of labor exploitation and a bleaker future employment outlook (IFAD 2016). Third, rural poverty driven by poor agricultural performance, lack of market access and insufficient investments in rural infrastructure is also a primary cause of malnutrition among youth in rural areas, with 767 million rural individuals living below the poverty line and 795 million suffering from malnourishment globally (Rossi 2017).

Finally, it is unsurprising, given that rural youth face higher rates of poverty and malnutrition than their peers living in urban areas, that there are also disparities between schooling and educational attainment rates in urban and rural areas. Not only are education and educational advancement important in the fight against poverty, unemployment, and social immobility, but skills-acquisition has also been found to promote higher agricultural productivity (World Bank and IFAD 2017). From this perspective, food insecurity is thus inextricably tied to education, both as a cause of poor educational attainment and as a result of low agricultural productivity linked to a lack of opportunities for education and training.

3 Towards Sustainable Food Systems: The Impact of Youth

In addressing pressing challenges including a rising global population, climate change, and unsustainable food systems, the potential contribution of young people is often associated with the concepts of creativity, enthusiasm, and advocacy (UN 2015). The importance of youth activism and civic participation in shaping public debates and promoting SDG implementation is well recognized (UN 2016). Yet, in an era of accelerating transformations, the involvement of young people arguably needs to extend to additional aspects on which they hold a comparative advantage, including their particular interest in environmental sustainability and conservation, their digital and entrepreneurial skills, and their ability to explore niche markets and innovative business models (FAO, CTA, and IFAD 2014). This holds particularly true for the challenge of food system sustainability, given that increases in agricultural productivity and broader rural transformation critically depend on the profitable and sustainable management of existing farms, which in turn require skills and knowledge that rural youth are more likely to possess over older adults (Amsler et al. 2016). On the one hand, it is therefore essential for policy-makers to improve their understanding of the extent to which young farmers and non-farm entrepreneurs are already contributing to innovating agricultural practices and food systems. On the other, it also becomes critical to support this contribution by addressing the obstacles that hold youth-led solutions back in areas including access to funding and financial services, access to mentoring opportunities and business development services, regulatory barriers, and access to visibility.

3.1 Youth Led-Innovation for the SDGs in the Agriculture Sector

Around the world, a growing number of initiatives and partnerships are now seeking to showcase youth-led solutions that can contribute to sustainable development across the realms of entrepreneurship, non-profit, education and research. While there have been limited efforts so far to systematically map the field, and disaggregated data on the topic is rarely available, it could be argued that young people's interest in the topics of sustainable agriculture and food systems is widely reflected in the body of solutions supported by such initiatives. In 2017 and 2018, two editions of SDSN Youth's Youth Solutions Report comprehensively sourced 313 youth-led, SDG-oriented projects from over 60 countries. Among them, 80 (or 25.5%) were found to present direct or indirect implications for SDG 2 on "No Hunger", including (but not limited to) non-profit initiatives promoting sustainable coexistence between local livelihoods and forest ecosystems in the Amazon rainforest, smartphone apps that help restaurants and food businesses in Europe reduce their food waste, innovative applications of hydroponic systems of cultivation, deployment of solar-powered pumps and other renewable energy technologies in rural communities to improve access to water resources for irrigation, and 'smart farming' startups providing farmers with soil and market demand data in real time (SDSN Youth, 2017b, 2018). Since 2012, the Barilla Center for Food and Nutrition has similarly launched BCFN YES!, an annual contest for young researchers working on innovative projects on food and sustainability[1] that has seen the number of applicants (and their countries of origin) progressively grow with each edition, with submissions particularly targeting the areas of food security, sustainable dietary patterns, and sustainable agricultural practices. Other initiatives include the International Fund for Agricultural Development's loan- and grant-funded projects

[1] See https://www.barillacfn.com/en/bcfnyes2018/. Accessed 17 September 2018.

that promote capacity-building and youth engagement in the agricultural sector (IFAD 2018b); global non-profit The Resolution Project, which supports young leaders worldwide and currently counts 131 fellows (or 49% of the total) working on sustainable food systems and agricultural issues in their countries and communities,[2] and Entrepreneurship 4 Impact, a provider of impact entrepreneurship courses across Africa, one third of whose alumni are either involved in food processing, food services or agri-business ventures.[3]

Within this relatively large proportion of young innovators focusing their attention on sustainable agriculture and food systems, some trends are clearly visible. First, young farmers have often voiced the need for a push towards the adoption of climate smart agriculture (CSA) approaches and often led the way on the use of zero tillage practices and the use of ICT tools, despite the lack of recognition of their role on the part of their countries' governments (FAO 2018d; Mungai et al. 2018). Second, young farmers assign a specific importance to the wide range of co-benefits that sustainable agricultural practices can provide to their own economic activity (e.g. enhanced natural resources, efficiency improvements, climate resilience, increased farm revenue) as well as to society at large (e.g. provision of public goods, GHG emissions reduction, sustained biodiversity and ecosystems, healthy diets), thus supporting the type of integrated approach that lies at the core of the SDGs (see for example DeLaval and CEJA 2017). Third, young people living in urban areas are also seeking to contribute to the sustainability of the global food system, particularly from the perspective of reducing food waste and ensuring access to adequate food among vulnerable groups, for example through urban agriculture projects (Nink 2015).

Lastly, the contribution of young people to the challenges in this field appear to go beyond the use of technology for its own sake, as it demonstrates stronger attitudes towards adopting innovative organizational practices and openly confronting institutional path dependencies and other barriers to impact (Kew et al. 2015; The East African 2017). For example, AgroDuuka, an agricultural produce supply chain management app operating in Uganda, was created to connect farmers directly with buyers, thus bridging the traditional barriers farmers experience when trying to expand and access new markets (Lyatuu 2018). Created by Biddemu Bazil Mwotta, a young Ugandan entrepreneur who grew up witnessing the exploitation rural farmers experienced from middle agents who purchase goods at substantially lower prices than what they are later sold at in urban areas, the app helps farmers in developing countries be offered fair trade transactions, attain more income and time for production, and secure partnerships with farmers' organizations on a global

[2] See https://www.resolutionproject.org/issues/agriculture. Accessed 17 September 2018. The Resolution Project specifically counts 29% of fellows working directly on food and agriculture and an additional 20% working indirectly on wider food systems challenges in the areas of environmental conservation and climate change.

[3] See http://e4impact.org/mba/meet-our-champions/. Accessed 17 September 2018. More specifically, 221 of the 659 ventures supported by E4Impact are categorized under the Agriculture and Food sector.

scale. Similarly, in Nigeria, young farmer Emeka Nwachinemere sought to improve the traditional approach to crop value chains and developed Kitovu, a mobile-based platform that uses soil and market demand data in order to provide soil and crop specific inputs which increase crop yields and access to markets. Through the app, soil and geo-location data are collected, analyzed and aggregated, providing the tools for farmers to optimize the use of soil- and crop-specific fertilizers, improved seedlings, and agro-chemicals (SDSN Youth 2018).

3.2 Supporting Youth-Led Solutions for Sustainable Food Systems

Agriculture is the largest employer of rural youth in the majority of low and middle-income countries and improving agricultural performance through food systems is central to sustainable food supply, food security, and the end of hunger. Despite widespread examples of young innovators taking up on the challenge of sustainable food systems, however, the creation of an enabling environment for their initiatives is still fundamentally seen as an area of concern (G20 2017a; IFAD 2018b; Mungai et al. 2018). Across the globe, surveys and dialogues conducted among young farmers and entrepreneurs often emphasize the same challenges, which are usually linked to a failure, on the part of policy-makers, to target the specific barriers that young members of rural households face when designing policy interventions in the agricultural sector (IFAD 2011; DeLaval and Ceja 2017).

From such a perspective, not only are there limited decent employment opportunities in rural areas for youth, but young farmers are severely constrained in their access to markets, credit and land and often held back by bureaucratic obstacles. These bottlenecks hurt the resilience of rural communities, contribute to food insecurity and malnutrition, and ultimately drive the above-mentioned crises of rising inequality, migration, and rapid urbanization. This is why the recently-launched G20 Initiative for Rural Youth Employment (G20 2017a) and the G20 Africa Partnership (G20 2017b) place rural youth employment as a key element of their strategy, with the aim of mobilizing private and public investment that will facilitate the multi-sector engagement of young people.

Similar projects and initiatives, which increasingly take the form of public-private partnerships (World Bank and IFAD 2017: 34), seek to enable youth to participate in multi-dimensional capacity-building programs and to address entrepreneurial needs, while simultaneously advocating for stronger innovation policies by developing country actors. For instance, the G20 Initiative's emphasis on bridging the rural-urban digital divide through investments in ICTs is based on the premise that lack of IT infrastructures prevents rural youth from finding adequate job opportunities in agriculture, food systems, and the broader rural economy, as shown by the positive examples of AgroDukka and Kitovu. In a similar vein, the Boost Africa partnership between the European Investment Bank (EIB) and the

African Development Bank (AfDB), which supports the creation of an efficient entrepreneurial ecosystem in Africa, has specifically targeted young people by establishing an “Innovation and Information Lab” to incubate new ideas and support entrepreneurs, including in rural micro-enterprises and larger agribusinesses. Finally, several initiatives underline how institutions, ranging from farmers' organizations to local and national governments, should create more opportunities for young farmers to participate in debates and decision-making processes, as rural youth are generally excluded from the formulation of policies concerning them (FAO, CTA, and IFAD 2014).

In this process, the role of international organizations is often pivotal, as shown by the Food and Agriculture Organization of the United Nations (FAO) piloting the Rural Youth Mobility (RYM) Program in Tunisia and Ethiopia from 2015 to 2018 (Atlaw et al. 2016). This program also focused on key challenges that hinder the productivity of young people, such as the lack of access to land, finance, equipment, information, and skills. In Ethiopia, the approach used mechanisms to create rural employment opportunities centered on the establishment of youth groups and in addressing barriers to agricultural practices youth face. In Tunisia, the approach was to promote rural entrepreneurships and support selected agricultural projects through a Call for proposal. Selected enterprise ideas were those with the highest potential of innovation, positive enhancement of linkages between migration and development, and employment generation. The project included a wide range of stakeholders, ranging from the federal, national and community level including local governments, institutions, civil society and private actors, who supported the rural youth beneficiaries.

In both countries, the RYM program facilitated land, finance, and equipment access to youth. In Ethiopia, unused land was supplied by local governments and made available to each beneficiary youth group. In Tunisia, the program assisted youth in requesting credit to purchase or lease land, including that of diaspora members. In terms of access to finance and equipment, group savings were set as a condition to the program in Ethiopia and technologies and equipment such as food processing units, livestock, irrigation material, and greenhouses were provided in kind by the RYM project. In Tunisia, 49 selected enterprise projects received in kind equipment grants, with the ten most promising receiving an additional sum.

Through capacity building to address the lack of information and skills, youth participants were provided training in theoretical and technical skills in agriculture as well as skills in entrepreneurship and attaining access to social protection. In Tunisia, an element of success coaching was also utilized to strengthen confidence and self-esteem in entrepreneurship endeavors (FAO 2018c). Overall, dimensions of migration, sustainable agricultural development, and rural youth employment in the RYM program illustrate how the barriers youth experience can be supported by assistance, partnership, and mobility, serving as a model for countries seeking to harness the contribution of young people to the achievement of the SDGs.

4 Conclusion

In this chapter, we have sought to briefly explore the current situation of young people's role in the implementation of SDG 2, in the broader context of the 2030 Agenda. The challenges presented by the youth bulge, by lack of sufficient support to young innovators, and by the impact of global environmental change on youth communities have a broad range of cross-sectoral implications. However, their impacts in the area of agriculture and food systems appear particularly concerning, in that they will both (i) affect less-developed countries that already face severe youth unemployment and a rapidly growing population; and (ii) have negative repercussions on other challenges that these (and all) countries must address in order to achieve SDGs 2, particularly in terms of ensuring food security and improving agricultural productivity. Furthermore, unsustainable food systems in and of themselves contribute to young people's vulnerability and compound the cycle of rural poverty in which they are often trapped, for example by making it more difficult for young farmers to access markets and financial services, or by failing to create opportunities and incentives for them to participate in sustainable agricultural innovation.

This is particularly problematic, as an increasing number of youth-oriented initiatives now suggest that young people's contributions to a sustainable transformation of agriculture and food systems can take a variety of forms and are already positively impacting their countries and communities. Even more importantly, such contributions appear to be particularly aligned with the type of transformative pathways that have been proposed to implement SDG 2 (see for example Schwoob et al. 2016) including the need to consider agriculture as a multidimensional activity where economic, social and environmental sustainability goals should be realized simultaneously, the need to achieve lower resource intensity and improve efficiency through the use of smart farming techniques, the need for deep changes in dietary habits and consumption patterns in urban areas, and the need to confront entrenched interests and path dependencies in the way food systems are structured. In other words, harnessing these types of youth-led initiatives can arguably result in faster food system transitions, contributing to, inter alia, raises in agricultural productivity and incomes of food producers (Target 2.3), diffusion of resilient agricultural practices that help maintain ecosystems, strengthen capacity for climate adaptation, and improve soil quality (Target 2.4), and protection of genetic diversity (Target 2.5).

By means of conclusion, this chapter has suggested that youth skills can represent an opportunity for the development of sustainable food systems only to the extent that the challenges facing young farmers and entrepreneurs can be addressed, and that meaningful pathways for youth civic participation and engagement in SDG implementation are established. International organizations, including the FAO and IFAD, have for several years tried to specifically target young people in some of their areas of work. These efforts have now spread with the launch of the G20 Initiative on Rural Youth Employment and with parallel initiatives carried forward by multilateral development banks, non-governmental organizations, and civil society. With international assistance, pilot programs such as the RYM have been deployed in low- and middle-income countries, and the attention to young African people's role in the agricultural sector has become a central concern of the African Union. Ultimately, however, harnessing youth skills for sustainable food systems will require significant efforts within countries, as barriers in access to land, credit and education are often the result of inadequate legal frameworks and insufficient domestic resource mobilization. For many countries currently experiencing high levels of youth unemployment and disenfranchisement, these investments in youth skills represent the best hope of achieving SDG and the wider 2030 Agenda for Sustainable Development.

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Conclusions: The Way Forward in Achieving the SDGS—The Urgency of Transforming Our Agri-Food Systems

Stefano Zamagni

1 Introduction

What we are now experiencing is the second great transformation in the Polanyian sense. The first was the one masterfully analyzed by Karl Polanyi in his famous book *The Great Transformation*, published in 1944, a study of the impacts on Western society of the first industrial revolution (England, second half of the eighteenth century) and of the second industrial revolution (Germany, late nineteenth century). The second great transformation makes reference to the third industrial revolution (in the 1970s) and to the fourth (typically starting with the new century). We do not yet know how and to what extent the new digital and artificial intelligence technologies will modify the central core of capitalism and its underlying cultural model. However, we do know that the convergent technologies of the NBIC group (nanotechnology, biotechnology, information technology, cognitive science) are having a significant impact on many fronts, in particular on the entire sector of our current agri-food systems, which have become unsustainable for both humans and nature.

The UN Sustainable Development Goal 2 states: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture." (As a reminder: the SDGs are comprised of 17 goals with 169 associated targets). It is well known that the food security SDG includes four components that must be met simultaneously, without any possibility of trade-offs between one and another. The first component is the physical availability of food, supplied through local production

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R. Valentini et al. (eds.), *Achieving the Sustainable Development Goals Through Sustainable Food Systems*, Food and Health,
https://doi.org/10.1007/978-3-030-23969-5_14

or imports (it goes without saying that these two supply sources are not equivalent, as indicated by the heated debate on "food sovereignty" (Patel 2009)). Secondly, the mere availability of food does not in itself guarantee access to it in sufficient quantities. This depends on people's purchasing power, and therefore on disposable income and on food prices, which have risen significantly over the last two decades, with a high degree of volatility. The third component is food utilization, that is, the availability of nutrients in sufficient quantities to ensure a healthy life. Individual food utilization depends certainly on one's state of health, but also on social and familial factors associated with the prevailing cultural matrix in the community of reference. Finally, these three conditions must be met with stability (See Chap. 1). Food insecurity, in fact, can depend on the cyclical trends of crop yields, which are in turn associated with climatic variability, political unrest, unpredictable trends in food prices, and so on. Stability of access is of crucial importance, since even temporary malnutrition can lead to serious health problems, a reduction in labor productivity, and so on (See Chap. 5).

That being said, in the following pages I intend to focus attention on one specific aspect: of all the contemporary economic sectors, agri-food is the production area characterized by the greatest intensity of dilemmas, both ethical and political-institutional. After referring to the empirical evidence in support of this salient aspect, I will indicate the directions in which it is now urgent to move in order to dissolve these dilemmas. From the outset, I would like to indicate the spirit in which these notes have been written. One of the most penetrating dangers of our times is described by the famous twentieth century English writer C. S. Lewis in terms of "chronological snobbery," that is, the uncritical acceptance of what is happening simply because it belongs to the intellectual trends of our times. In my view, we must resist such a danger in every way possible, and this requires not only novelties (*res novae*, in Latin)of our times but also, and perhaps above all, a moral commitment.

2 The Dilemmas That Afflict Our Current Agri-Food Systems

2.1 The First Dilemma

One dilemma of an ethical nature, certainly not a lesser one, can be described in the following terms. Agriculture today is facing a tragic choice (in the sense of Calabresi and Bobbitt 1978): it must respond to the challenge of nourishing—not just feeding—a growing world population without jeopardizing environmental sustainability. Just a few data are sufficient to provide the measure of what is at stake. Around seven billion two hundred million human beings currently live on the planet. The most accurate estimates indicate that the world population will rise to almost ten billion by 2050. To confront such growth—the World Bank tells us—agricultural production will have to increase by 70%, which, in the absence of transformational interventions, will require a 30% increase of the land used for agriculture. Deforestation and depletion of fresh water reserves would be the immediate and tragic consequences.

But there is more. As the average income increases progressively, meat consumption grows more than proportionally, because—as is widely confirmed—the elasticity of the demand for this good with respect to income is greater than one. Currently, the average meat consumption in North America is 83 kg/year per person, in the European Union 62 kg/year, in Asia 28 kg/year, and in Africa 11 kg/year. The conclusion to be drawn is all too obvious: the FAO predicts that meat consumption will increase by 76% globally by 2050, and this following the predictable income increases in Asia and Africa. To give a rough idea of the impact on water consumption, consider that 1 m^3 of water is needed to produce 1 kg of grain; for 1 kg of meat, it takes 15 m^3! As Joseph Poore of Oxford University has documented, if humanity gave up breeding livestock for slaughter, agricultural land use would be reduced by more than 75% (Poore and Nemecek 2018). Meat and dairy products, while supplying 18% of the calories and 37% of the protein consumed globally, require 83% of the agricultural land, since most of the crops grown are used for livestock forage, generating approximately 60% of total greenhouse gas emissions. It should be noted that even raising livestock with more environmentally friendly methods does not solve the problem, though it does mitigate its scope. This is for the simple reason that the advantages of these methods, in themselves praiseworthy, are more than neutralized by the spreading in the advanced Western countries of CAFOs (Concentrated Animal Feeding Operations), a type of intensive farming that generates greenhouse gas emissions twelve times higher than those of other types of farming (Valentini and Miglietta 2014).

The heart of the dilemma in question lies in the trade-off, unknown in past eras, between food and nature conservation. How did we get to this point? For centuries, agriculture evolved by improving crop production and livestock breeding techniques, adapting them to the current land conditions and climatic changes. The first Green Revolution, initiated in the 1960s by Nobel laureate Norman Bourlag, doubled the global production of wheat, rice, soya, and corn—products that alone supply 43% of food calories and 40% of global protein—, though using increasing amounts of pesticides, herbicides, and fertilizers. Today this kind of agriculture is colliding against its own limits, and this fuels the conviction among the populations that agriculture and livestock farming are the major causes of environmental degradation. For more than 50 years, agricultural productivity has increased to an extraordinary degree, so much so that the amount of food currently produced would be more than sufficient to relieve the hunger of the more than eight hundred million human beings who suffer from it, if only there were the wisdom and political courage to change the institutional framework that governs the entire food supply chain. However, this acceleration has led to excessive exploitation of the land, a drastic reduction in the biodiversity of the crops cultivated, and a worsening of environmental pollution. The current management of agricultural systems certainly does not favor the enrichment of organic matter in the soil. In Europe, soil erosion affects some 12 million hectares (Panagos and Borelli 2017). Moreover, climate change manifests itself not only in the form of global warming but also in extreme weather events that are both devastating and unpredictable. It should be noted that there is not only a problem of production loss; there is also a loss of nutritional value in cereals, which, as is well known, are the staples of the planet's diet. For example, as the CO_2 level in the air increases, the protein content of rice is reduced, and there are also substantial losses of vitamins B_1, B_2, B_5 and B_9, iron, and zinc, with considerable harm to the populations whose main food source is rice (Zhu et al. 2018).

Given these data, there are some who believe that the dilemma we are facing could be dissolved if we decided to vigorously address the problem of food waste and loss. About a third of world food production is lost or wasted annually throughout the food supply chain (FAO, Rome 2013). This proportion corresponds to waste of approximately 1.6 billion tons of food; 1.3 billion if we consider just the edible fraction. The distribution of the loss and waste throughout the various segments of the global food supply chain is approximately the following: 32% during agricultural production; 22% in the post-harvesting phase; 11% during industrial processing; 13% during distribution; and 22% in the consumption phase. Clearly, this phenomenon assumes different proportions in the different regions of the world. Overall, around 56% of food waste and loss takes place in the advanced countries and the remaining 44% in the emerging and developing countries. It is easy to imagine the environmental impact, as well as the economic impact, of such an outrageous phenomenon. A recent study by the FAO (2014) gives an estimate of the hidden costs of food production, including costs attributable to conflicts over the control of natural resources; treatment of diseases linked to the use of pesticides; water purification; loss of natural habitat; the effects of reduced water availability, and so on.

It is certainly true that food loss and waste must be eliminated or at least greatly reduced, for ethical reasons first and foremost. The *Global Hunger Index* on 119 countries—based on the combination of three components: the percentage of undernourished persons out of the entire population; the percentage of underweight children under the age of 5; the mortality rate of children under the age of 5—fell from 18.7 (a value above 20 indicates that the problem is alarming) in 1990 to 15.2 in 2013, thanks also to the implementation of waste reduction programs. But the absolute number of undernourished people in the developing countries has actually risen (Von Braun 2014). This suggests that the argument that the problem of food shortages would be nothing more than a problem of distribution—that is to say, that there would be sufficient food in the world to feed everyone if only it were distributed fairly—is an over-simplification that does not help to tackle the root causes of this sad phenomenon. In fact, as we know, in capitalistic market economies, the demand for goods and services that is relevant is the effective demand (in J.M.Keynes' sense), not the potential one; therefore, those who have no income can continue to suffer from hunger, even if the grocery shelves are filled with food! This is why the "zero hunger" goal of the 2030 Agenda still seems very far from reach.

2.2 The Second Dilemma

A second dilemma, this time of an economic-institutional nature, calls into question the difficult relationships between agriculture and other sectors of the economy, above all that of finance. As mentioned above, the right of access to food depends certainly on the level of per capita income, but also and in large part on the cyclical trends of the agricultural commodities markets. I refer to the peculiar and growing price volatility of these goods, which that does not allow farmers to rationally make medium- and long-term investment plans for their farms. Added to this is the variability of the quantities produced as a consequence of climate change and natural adversities. The problem is further complicated for the most vulnerable economies, where the degree of dependence on imported food is high and the characteristics of the production systems are weaker. In the season of globalization, it no longer makes sense to talk about achieving food self-sufficiency on the part of individual countries. At the same time, however, strong dependence on international trade increases the vulnerability of countries with respect to economic trends in the markets that are detrimental to the poor segments of the population. This dependence is on the rise particularly in the developing countries, in which the FAO estimates a food trade deficit of some 50 billion dollars for 2030 (Von Braun 2011).

Underlying the phenomenon of food price volatility, we find one specific cause that should be highlighted, especially because it is almost never brought to the attention of citizens. We know that one of the main factors responsible for the malfunctioning of the market mechanism is that of technical externalities. A typical example is the company that, in order to carry out its production plan, pollutes the surrounding environment. Technical externalities always arise when, given a certain distribution of property rights, the company that, let us say, emits fumes is not obligated to compensate those who are harmed. In the presence of technical externalities, the results of the market process are inefficient, because the choices made by the actors are based on prices that do not reflect the full cost of the resources used, and therefore the market is not capable of correctly informing the actors. But what about when we are faced with the other category of externalities, the pecuniary ones? These are externalities that spread through the price system and whose effect is to inflict unwanted negative consequences on “innocent” subjects who have not taken part in the market transactions from which those externalities originated. A typical case is the worker who loses his job because his company, for one reason or another, has decided—obviously without consulting him—to relocate its facilities. Why—we might ask—do economic science and even public opinion, while dedicating (rightly) so much attention to the technical externalities, neglect, save for rare exceptions, to consider the impact of pecuniary externalities on people? It is easy to take them into account. While the former, representing a case of market failure, do not allow the market to achieve its primary purpose, that is, the efficient allocation of resources, the latter are of the same substance as the market mechanism itself, which makes use of price variations to function and carry out its task.

We must keep in mind that the price system in a market economy not only fulfills the allocative function but also the distributive one. In fact, whenever the relative price system changes significantly, there is a change in income distribution. If—to give an example that actually happened—following speculative maneuvers, the price of cereals and rice at the Chicago Mercantile Exchange increases suddenly (because, as occurred in 2009, the authorities had allowed the issuance of derivatives whose underlying was the prices of those staple goods), the poor populations, whose diet is based on those goods, will see a diminishing of their already meager purchasing power and consequently of their standard of living, without having done anything to cause that result and therefore without any fault other than that of being poor. But the financial operators in the case mentioned did not consider themselves morally responsible for the event—there were many deaths due to undernutrition—because they claimed that it was not their intention to cause that hardship and suffering.

One can understand, then, why there is a profound asymmetry between the ways in which the two categories of externalities are treated. Yet, if we want to take seriously the question of the transformation of agri-food systems, we must first pay attention to the pecuniary externalities, which are often invisible. Firstly, because price changes, as mentioned above, always lead to a redistribution of advantages and disadvantages among economic actors. And so, even if the advantages associated with certain lines of action outweigh the disadvantages in the aggregate, it may happen—as indeed happens—that certain categories of people, unrelated to those decisions, find their own condition of life worsened, leading to a restriction of their autonomy of action. These people are thus induced to make choices under the weight of an "economic constraint" that reduces their space of freedom. Secondly, because very often the pecuniary externalities inflict costs or burdens precisely on those who are least capable of withstanding them, and this raises a problem of corrective justice. To avoid misunderstandings, it should be noted that while the market does not tolerate coercion, it is perfectly compatible with constraints of an economic nature.

The question thus arises spontaneously: given that pecuniary externalities are inevitable as part of the inner workings of the market mechanism, is it reasonable to conclude that no one should be held responsible for the negative consequences that fall on those who are third parties? Is it morally (and politically) acceptable to the reasoning of those who think, since "that's how the market works" and since the market economy has no longer any valid or credible alternatives, that no attribution of responsibility can be placed on those who work in it? No, this would be a typical example of a *post hoc ergo propter hoc* fallacy. The fact is that participation in market transactions is by no means voluntary in societies where there is a division of labor, since in such circumstances exchange becomes a necessity and not a free option. So correcting the negative consequences of pecuniary externalities is a question of corrective justice, because those who bear the damage have done nothing to "deserve" the punishment. In other words, in the presence of pecuniary externalities, it is the category of agency responsibility that must be called into question.

(Agency responsibility indicates that a subject is responsible for something if he caused that something to happen, regardless of his intentions or his predictions).

A famous historical case illustrating the practical relevance of pecuniary externalities is that analyzed by the French anthropologist Germaine Tillon, who lived in the Aures region of Algeria in the 1930s. She returned to the region after the war, only to discover that the society she had described as “balanced and happy in its ancestral tranquility” had become impoverished. What happened? Believing it would help the Aures community, the French government had dispersed DDT in ponds to combat malaria and built a road to Algiers to overcome the region’s isolation. These two policies, certainly legitimate and useful *per se*, produced a chain reaction. The eradication of malaria stimulated a demographic explosion and this caused shepherds’ livestock to rapidly destroy the soil. At the same time, thanks to the road, a small number of people were able to bring surplus livestock to the markets of the capital city. The final result was that a small percentage of people became richer and richer, while the rest of the local population suffered. The determinant responsible for these kinds of processes was the absence of any corrective mechanism, at least after the point of no return has been reached. The accumulation of changes in power and property, as a result of the negative feedback cycle, slowly pushes the system to a tipping point (the so-called catastrophic bifurcation in natural sciences) despite the fact that each of these changes in themselves is fairly small. From that point onwards, the system loses its self-correcting ability and a return to the previous situation is no longer possible.

2.3 The Third Dilemma

I would like to mention a further bio-political dilemma, which concerns the as yet unsettled question of biodiversity, a term coined in 1985 by Walter Rosen to indicate the set of natural environments and living species that populate the biosphere. The dilemma is this: to protect plant species or compromise the development process? Quite appropriately, Pasca Palmer (2018) clarified how biological diversity is the premise of all forms of life, including human life. Indeed, natural capital is a global common good, officially recognized as such in December 1993 during the UN Convention on Biological Diversity. But despite the commitments undertaken there, the loss of biodiversity has gradually increased: about fifty living species disappear every day. It is true that extinction is a natural fact (a single species lives, in fact, a million years, on average), but the current acceleration is one thousand times higher than the natural rate (Schmeller and Bridgewater 2016).

The degradation of ecosystems is a strong violation of the principles of inclusion, justice and equity on which the 2030 Agenda on sustainable development is founded, and this for the simple reason that biodiversity is the way in which life is expressed. The World Economic Forum’s Global Risk Report (2018) includes ecological collapse and loss of biodiversity among the ten main risks in terms of impact.

Biodiversity and agriculture are strongly interdependent. Agro-biodiversity contains the biological diversity that supports the key functions and processes of agricultural ecosystems. But it is a fact, as indicated by United Nations's Global Biodiversity Outlook (2014), that the determinants linked to agriculture contribute 70% to the loss of global biodiversity. Stemming from this is the urgency to modify the trends in agri-food systems. The prevailing logic over the last decades in agriculture—large farm size and monocultures, seeds patented by multinational corporations, excessive use of fertilizers—is certainly the enemy of biodiversity. (For a precise analysis of the phenomenon, see Pingali, "The Green Revolution and Crop Biodiversity", in Hunter et al. (2017), Handbook of Agricultural Biodiversity).

On the many causes of biodiversity destruction in the Anthropocene, one of which is industrialized agriculture, see the recent study by Dasgupta and Ehrlich (2017), which explains why today we cannot rule out the beginning of the sixth mass extinction, if we do not immediately intervene forcefully.

3 Food Policies in the Twenty-First Century

What can we do to try and dissolve the dilemmas mentioned above? The position I defend is that we must intervene, as a priority, even if not exclusively, on three main fronts to begin solving the problem of how to ensure that our agri-food systems are capable of producing food in sufficient quantity and quality for a growing population, while at the same time reducing the overall environmental impact. The food system encompasses everything from production to consumption—processing, storage, transportation, distribution, marketing, preparation—and is shaped by policies at both the domestic and international levels. It is critical for effective food policies to be envisaged in order to create a productive, equitable and sustainable agri-food system. Depending on policies, agri-food systems determine the availability, affordability and nutritional quality of the food supply and influence the amount of foods that people are willing and able to consume. Conflicts over land, technology, natural resources, subsidies and trade are all playing out in the food policy arena, involving many different players: international organizations, multinational corporations, medium-scale entrepreneurs, NGOs, governments, and civil society organizations.

3.1 A First Front of Intervention

A first front of intervention is to increase crop yields in regions such as Africa, Central America and Eastern Europe in a sustainable manner. In concrete terms, this means embracing "Agriculture 4.0", that is, taking seriously the reality of food tech. This is what is referred to when we speak of precision farming: satellites, drones, robots with artificial intelligence, and digital tools, are the main ingredients used to carry out both conservative and regenerative agriculture and organic farming. (The latter should not be confused with biodynamic agriculture, around which the opinions among scientists vary widely).

As regards organic farming, the skeptics believe that yields would be lower than those associated with traditional farming systems, and this would imply the use of more land and increased deforestation. But the results of very recent studies would allay such fears. In fact, the spread of agroecology—a term introduced by A. Wezel et al. (2009) to denote the application of biological principles to food production—appears to be fully compatible with small and medium-sized agricultural enterprises, which are the source of most of the food destined for human consumption. (See also Wezel and David (2012)). On the other hand, the paradigm of industrial agriculture does not allow the traditional knowledge of farmers to be combined with new scientific knowledge into participatory processes that take into account the social, geographical and environmental aspects. This is because agroecology does not separate economic sustainability from social and environmental sustainability, as is the case with the industrial model. It is true that the main applications of the high-tech revolution in agriculture are currently limited to the cultivation of grapes, olives, and cereals, but the path of food tech now undertaken is rapidly expanding. The report *The State of European Food Tech* 2018—produced by Dealroom and the French-Bolognese VC firm Five Seasons Venture—gives a snapshot of the change in progress: investments in genetic breeding for improving livestock, precision agriculture, and robo-farming during the 2-year period 2017–2018 far exceed those of the previous years.

An effective exposition on the impact of the use of big data, artificial intelligence, and blockchain on the agro-industry supply chain is given by A. Renda (See Chap. 10). One point deserves special attention: the agriculture of the twenty-first century can do without genetically modified agriculture (GMO) as it has been known to date. This is because sustainable agriculture will be able to combine the increase in productivity with improvement of the quality of the agricultural product, to create a reality in which agriculture earns more and consumers eat better. It goes without saying that we are still far from this goal, since companies still too dazzled by the prospect of "short-termism" are favoring GMO processes. Just consider that the intellectual property rights on transgenic products impede the use of second generation seeds for the subsequent planting, so it follows that farmers cannot take possession of seed from the previous year's crop in order to reseed it unless they pay the related royalties. This means that it is not true whatsoever that GMO seeds are sterile, as we tend to believe. It is in this specific sense that GMOs must be carefully evaluated, because they represent a reduction in the scope of farmers' freedom of choice and not so much because of the supposed negative effects on health and the environment. Today, evolutionary genomics, based on the combination of innovations such as transgenomics, genome editing, and genomic selection, is able to obtain characteristics of cultivatable crops in our favor without modifying the genetics in a "brusque" manner, as has been done up to now with GMOs. (See Liakos et al. 2018). In essence, evolutionary genomics replicates, by imitation, the mutations that nature from time to time produces.

The good news is that sustainable agriculture, in the medium to long term, will prevail over financialized agriculture, which is defended by neoliberalism, because the economies of scope made possible by the Internet of Things are greater than the economies of scale typical of industrialized agriculture. The same goes for the financialization of agri-food. On one hand, there is the growing importance of financial capital with respect to agricultural capital in generating profit. On the other hand, there is the fact that the majority of profit is realized through the purchase and sale of financial products such as derivatives. While it is true that contracts covering the future prices of agricultural products available for harvest have existed since the nineteenth century, the financial deregulation of the last 40 years has radically changed the situation, allowing the exchange of financial products regardless of production trends. In this way, agri-food goods have been transformed into assets subject to financial speculation managed by actors who have no interest whatsoever in food-related issues. As M. Fairbairn observed (Bonanno and Busch 2015), financialization has been extended to all the components of the agri-food system, including supermarkets and land. In the case of supermarkets, financialization separates the investment from the quality of the service, given that supermarkets are purchased and restructured first and foremost to increase their sales value, rather than the efficiency of the service. In the case of land, its purchase as a financial asset to be utilized for speculative purposes has become one of the most significant global phenomena.

3.2 A Second Set of Changes

A second set of changes that is urgently needed has to do with cultural aspects, and more specifically food and nutrition education. A terminological clarification in this regard may be useful. For example, for the European regulations, "'food' (or 'foodstuff') means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans." As can be understood, this is a "commercial" definition, aimed at regulating those markets where food is considered a commodity like any other. The "scientific" definition most widely used today is that of Brillat-Savarin is his book *Physiologie du goût* published in 1825 (English translation: *The Physiology of Taste,* trans. Anne Drayton, Penguin Books, 1970), which states: "By food we mean those substances which, being subjected to the stomach, can be animalised by digestion, and so repair the losses suffered by the human body through the wear and tear of life. Thus the distinctive quality of food consists in the property of undergoing animal assimilation." We can see, then, why not every foodstuff is a food. And yet, the agricultural sector continues to be conceptualized in terms of its capacity to produce calories, as if these alone guaranteed food security. Policies focused on improving production of big commodity grains like corn, rice, and wheat—which are not so nutrient rich—should be changed if we want to ensure that people are eating healthy foods from a variety of sources. So we need to look across the entire food value chain, which describes the full range of activities required to bring a food product from conception, through the various phases of production, to delivery to the end consumers. To fight food insecurity there needs to be a change in the prevailing cultural patterns. It is not enough to act upon the production systems. For example, food insecurity is not just a developing world issue; in fact, about 25% of Americans are food insecure, even though the United States is a high-income country (See Chap. 5).

It is therefore urgent to initiate coherent and robust food education programs right from early childhood, when our cognitive maps are formed. And it is also essential to inform citizens in a non-distorted way about the difference between *food safety* and *food security.* While the former conveys the safety of the food ingested, the latter is about the availability of food in sufficient quantities to prevent the risk of hunger and/or malnutrition.

As regards food safety, it is important to highlight the difference between the notions of hazard and risk. The former is an undesirable event for a person or an object or a situation that may cause harm. A risk is the likelihood that a person may be harmed or suffer adverse health effects if exposed to a hazard. Human beings eat food every day, hence they are exposed to a risk; however, this risk is strictly related to the quantity and quality of food that is eaten. Clearly, the risk for the consumer is not the same in all parts of the world. In the year 2000, Europe decided to apply a theoretical model developed by WHO and FAO—the risk analysis model—indicating the dimensions of the various types of risks. The model is managed by the EFSA (European Food Safety Authority). It is fair to say that Europe has developed one of the best on-going systems for food risk analysis, even though much remains to be done. (For details, see European Commission 2014, "Food". http://www.ec.europe.eu/food/index_en.hnt.EFSA, 2014. http://www.efsa.europe.eu/en/topics.htn)

We have already mentioned the importance of the fight against food waste and the need to reduce meat consumption, as strongly emphasized by the recent EAT-Lancet Report, signed by 37 scientists from different countries (https://eatforum.org/eat-lancet-commission/eat-lancet-commission-summary-report/). In regard to meat consumption, a valuable aid for the environment and for those who, for cultural or other reasons, still cannot give up a diet based on animal proteins, is offered by stem cell biology. With this technique, terminally differentiated cells (for example, muscle or skin cells) can be genetically reprogrammed which, multiplied ad infinitum in an appropriate culture medium, are differentiated into cell types of interest for food production, as well as for medicine. (See Bryant and Barnett (2018), which explains how all this takes place). It is thus possible to produce meat directly in the laboratory, the so-called "eco-friendly burger", thus preventing animal suffering, to the delight of animal rights activists, and at the same time benefiting from the ecological balance of the planet (Tuomisto 2019). It can be surmised that in the near future the cellular meat of the post-animal bio-economy will radically change the entire food industry, although the not insignificant question of the economic feasibility of cultured meat remains open. (For details, see Godfray et al. 2018).

The reformed Committee on World Food Security (CFS) seems best placed to take center stage in implementing a global education compact on sustainable food security and nutrition. It already has provisions for the involvement of a wider range of stakeholders, including the private corporate sector and a number of civil society organizations, and its mandate was broadened following its reform in 2009. The CFS envisages enhancing coordination at national and regional levels, promoting accountability, and developing a global strategic framework for food security and nutrition.

3.3 The Third Urgent Movement

I turn finally to a third direction in which it is urgent to move in order to feed humanity and reduce the overall environmental impact, and that is the importance of intervening on the economic-institutional structure of the entire agri-food sector, which is characterized by a process of oligopolistic concentration never seen before. Today, a handful of mega-corporations control the world seed and agriculture market. In 1981, there were more than 7000 companies operating in this sector, but currently four groups (Bayer-Monsanto, Dow-Dupont, Chem China—Syngenta, BASF) control almost 90% of the entire market. The formal justification for this is well known: in order to fully exploit the economies of scale, and in order to confront the food needs of a population that is increasing by 80 million per year, the company size must be increased. It matters little that agreements of this kind back farmers into a corner, seriously compromise biodiversity, and reduce the spaces of competition, with the inevitable increase in food prices. In other words, mega-mergers are defended on the grounds of greater efficiency in serving farmers and consumers. But whether that efficiency is worth the side effects to massive consolidation—possible price hikes and less competition in the marketplace—is an open question. In essence, should people put faith in a few large companies to shepherd consumers and farmers into a world that can responsibly feed a growing global population?

But there is more. The top ten processing companies control 70% of the entire world food market, acting as funnels, as oligopsonists, to the production of the over five hundred million farms in the world. It is truly a paradox: at the same time as the praises of free competition in the economy are being sung, unprecedented processes of business and capital concentration are tolerated. Not only that, but in a world where international arbitrations are emerging (CETA is a clear example) that offer companies the power to sue national governments accused of implementing actions deemed to restrict free competition, the concentration tolerated on the supply side of the offer greatly reduces the spaces of freedom of citizens and their organizations. This helps us to understand why, in Europe and elsewhere, there has been a rise in farmer's markets, direct sales, experiences of community-supported agriculture, and other initiatives. These spontaneous initiatives speak of the widespread concerns in the face of the strong power held by the major multinational seed companies, whose market share grew from 22% in 1996 to 55% in 2013. According to the 2013 report of the FAO's ETC Group, 59.8% of the seed market and 76.1% of the agrochemical products sold in the world are controlled by the four aforementioned groups (http://www.etcgroup.org/sites/files/ETCCommonCharityCartel_March2013/pdf).

The main point is that the dominant corporations have become too big to feed humanity in a sustainable way, too big to operate on equitable terms with other food system actors, and too big to drive the types of innovation we need. (See iPES Food 2017).

In light of the foregoing, we can see why it is necessary to adopt a new paradigm for the agri-food sector, built on sturdy pillars (See Chap. 7). Here I will mention just a few of these. First, food prices must be determined taking into account the full cost principle, that is, in business models they must take into account the positive and negative externalities generated by food production. In particular, we must take into account the externalities that impact the natural capital, which continues not to be the subject of any type of assessment. It should not be surprising, then, if our land and water systems continue to degrade more and more, generating real poverty traps in many parts of the world. The argument—too often used—according to which the current method of accounting would be good for consumers because they would only be interested in "paying less, to consume more" is both factually false, as the empirical evidence suggests, and ethically unacceptable. In reality, today's consumers want to "consume better and pay the right price".

Second. Agriculture needs to be included among the strategies aimed at mitigating climate change. This is because protecting and conserving carbon stocks is just as important as the issue of carbon emissions. The carbon stored in agricultural soil must find expression in some metric, whether monetary or non-monetary. Only if we move to macro-level policies based on the accumulation of carbon as a stock rather than on its use as a flow will it be possible to arrive at an appropriate economic assessment standard. (For a concrete proposal, see Porter and Wratten (2014)).

Third. It is urgent to intervene on the current models of consumption, still dominated by ancestral fashions resulting from obsolete social norms of behavior that, today more than ever, are the victim of the many attempts to manipulate people's cognitive maps through the unscrupulous use of personal profiling made possible by the new digital technologies. It is therefore a question of operating at both the cultural level (schools and universities that explain to young people the enormous advantages, for example, of the Mediterranean diet) and the political-institutional level, to ensure that the environmental sustainability of food and its nutritional value are always considered together—and not separately, as still occurs—when it comes to enacting laws or regulations.

Fourth. We need to very quickly address the issue of land grabbing, demanding, in terms of international law, that land deals made by investors in advanced countries and those in transition with African and Latin American states include at least the Equator Principles, the international standards set forth by the World Bank that include clauses intended to allow the export of products grown in the country provided that the local food requirements have been met. These standards also provide for termination of the contract if the investor behaves in an unfair or malicious manner. In reality, not only are these standards ignored, but what is worse, the BITs (Bilateral Investment Treaties) provide for so-called stabilization clauses: such contracts prevail over any new laws of the host country. This represents a real juridical monstrosity, as well as a serious ethical wound. (The Land Matrix database has been in operation since 2012, built on the basis of information gathered at the local level by civil society organizations and research centers. The initiative, which is private and supported by the German Cooperation Agency GIZ (Gesellschaft für Internationale Zusammenarbeit), deals with the land rights of local communities. The major predators, in addition to the United States, include countries such as the UK, the Netherlands, China, India and Brazil).

Fifth. The time has come to tackle the troublesome question of patents. As we know, the exclusive rights for new plant varieties last for 15 years (30 years for trees). But after 15 (or 30) years, it is obvious that the patented varieties will already have become obsolete and therefore no longer usable in farming. They will therefore be replaced by new varieties, to which another 15 (or 30) years will apply, and so on. Now, since we are talking about food, something that is essential to human survival, it is evident that questions arise such as: is it permissible to patent the genetic variability of plants destined for food according to the modalities in force? Can the patent holder change at will the link between product quality and place of production? What limits should be placed on the economic exploitation of the patent to avert the risk of countries losing food sovereignty? These are questions that do not arise for patents on other goods. In the case of food, however, with the current patent system, the agricultural sector is dependent economically on the industrial one, since, in addition to the purchase of seeds, the farmer is also obligated to buy the raw material needed so that the seeds can produce. It is well known, in fact, that some of the companies that hold a patent, in order to protect themselves from the illegal use of their patent, tend to insert genes in the seed that allow its germination only if a special substance sold together with that seed is used. This strategy is known as "traitor technology" in the jargon (HLPE, FAO 2017).

4 Instead of a Conclusion

As can be gleaned from the argument developed here, the serious problems related to agriculture that is both sustainable and able to feed a growing population are connected more to unequal power relations than to a lack of specific technical-scientific knowledge. This is why a more "political" approach is needed to the themes developed from various angles in this book. In 1963, FAO and GATT (now WTO) created the "Codex Alimentarius Commission" (CODEX), the main forum for international cooperation on food safety and quality standards. The Codex rules were then incorporated into the "Sanitary and Phytosanitary" agreement of the Uruguay Round concerning multilateral trade negotiations. Entering into force in 1994, the agreement was one of the first to be ratified. But since the end of the 1990s, this Forum has in fact been abandoned to its fate. Today we need to resume that initiative, naturally adapting it to new times, if we want to avoid serious risks like the one feared by G. Mann and J. Wainwright in their recent book, *Climate Leviathan*, London, 2018. The authors foreshadow—in gloomy shades, perhaps a bit excessive—a geopolitical scenario in which the exacerbation of environmental catastrophe, with the inevitable consequence on food systems, will lead capitalist societies to create a new form of planetary government—indeed, a climate leviathan—that will impose authoritarian measures for the declared purpose of preserving life on earth, but which, in reality, will serve to ensure ever higher levels of well-being to the upper classes of the population. The stakes are serious and deserve to be taken into responsible consideration. In fact, we cannot accept trade-offs like the one between democracy and sustainability.

It must be recognized that the problem characterizing the future of agri-food systems is first of all one of public ethos, difficult to solve without bringing into dispute certain ways of organizing society, without questioning ourselves on the ways we live together and on the values held in civil society. It would be ingenuous to think that the diversity of the interests involved does not imply high levels of conflict. But the task is unavoidable if we wish to overcome both the affliction of a rhetoric at all costs and the clear-eyed optimism of those who see in the new technoscience a sort of triumphal march of humanity towards its fulfillment. Responsible people cannot fall victim to traps of this kind. This is why we urgently need to develop a novel and more robust cultural perspective. To this end, I refer to the fascinating analogy between culture and a tree suggested by the famous British poet T. S. Eliot, who observed that you can't build a tree; you can only plant one, tend it and wait for it to sprout in due time. You can, however, speed up its development with proper watering! For, unlike animals, which live in time but have no time, human beings have the ability to alter their times.

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