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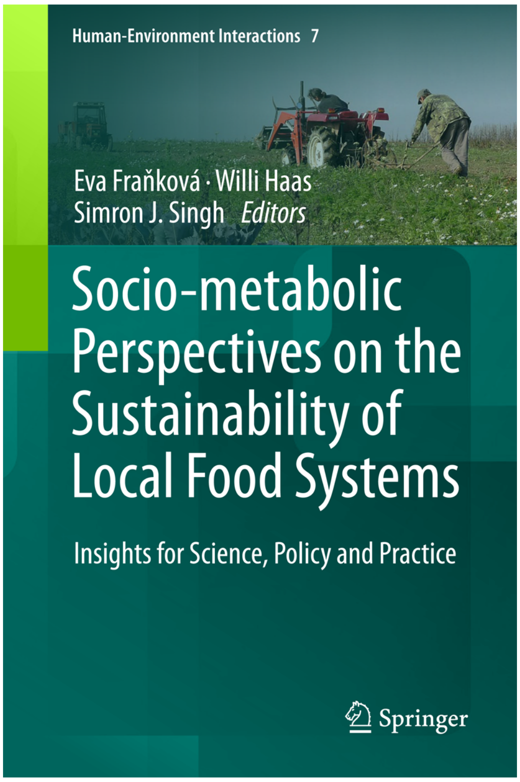

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Chapter 1

Introduction: Key Concepts, Debates and Approaches in the Sustainability of Agri-Food Systems

Eva Fraňková, Willi Haas, Simron Jit Singh

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Abstract

The Introduction sets the tone for the book by outlining the main concepts, debates and applications illustrated by the various contributions in this volume. The theme of Local Food Systems (LFS) is a complex one, and therefore a multidisciplinary and interdisciplinary effort, drawing on a myriad of research concepts and frameworks. The chapter begins by embedding the food debate within the broader sustainability discussion. It highlights issues around future demand and supply scenarios, current production and consumption patterns, and the challenges of addressing some of these issues in the context of climate change. The chapter also provides a review of some of the responses so far to counter the current global agri-food system. Initiatives and concepts such as local food systems, localisation, food security and sovereignty are discussed, drawing on examples from both the Global North and South. Since the volume is about socio-metabolic approaches to agri-food systems, the chapter also introduces the conceptual and methodological underpinnings of this approach, and how this relates to political ecology, social conflicts and environmental justice.

The chapter ends with an introduction to the various contributions in this volume that discuss the following cross-cutting issues: the necessity to consider local cases as nested in regional, national and global scales, including the debate on what might be an optimal scale for food regionalisation or sovereignty; the agenda of re-localisation and its political and ideological background in relation to biophysical/socio-metabolic insights with respect to LFS; the inclusion of trade in the methodological and ideological framework of LFS studies; the multi-functionality of agriculture and various related metrics of efficiency in agriculture (including the energy efficiency/EROI variables); the biophysical performance of other, more sustainability-focused, production regimes; the land-sparing vs. land-sharing debate in connection to the biodiversity and landscape multi-functionality of both historical and existing agri-food systems; the role of livestock in various agri-food systems, and the related issue of meat

consumption and dietary transition as part of a broader metabolic transition happening in many parts of the world; the issue of labour in terms of efficiency, and also in broader social and economic contexts; the political underpinnings of peasant livelihoods, existing social conflicts and uneven ecological exchange related to food; the issue of democratisation of food systems, access to means of production for fulfilling basic needs, and the agenda of food sovereignty.

The contributors to this volume all ask the following two questions:

- Which local food systems or their particular characteristics can serve as the best practice examples for maintaining and designing more sustainable agri-food systems in the future?
- Which scientific and policy relevant insights can the socio-metabolic approach offer with respect to studying the sustainability of local food systems?

Key words: Sustainability, Agri-food systems, Local food systems, Localisation, Social metabolism, MEFA, MuSIASEM, Ecological economics, Political ecology, Food sovereignty

Index key terms: land sparing, land sharing, multidisciplinarity, inerdisciplinarity, multi-scale approach, production and consumption pattern, climate change, food security, Global North, Global South, environmental justice, ecological distribution conflicts, uneven ecological exchange, local scale, regional scale, national scale, global scale, globalisation, efficiency, energy efficiency, EROI, biophysical performance, sustainability indicators, agroecology, organic farming, livestock, biodiversity, dietary transition, meat consumption, metabolic transition, peasant livelihood, social conflict, basic needs, democratization of food system

1.1 The Question of the Sustainability of Agri-Food Systems

We all eat.

If we are lucky enough, we eat every day.

Depending on age and gender, our bodies require about 1,700 kilocalories per day to maintain their basal metabolism, about 2,600 if engaged in sedentary work at the computer, 3,200 for keeping up with manual factory work, and 3,700 for managing hard physical work like ploughing a field (Shetty 2005). Worldwide, the average of 2,903 kcal/cap/day was available in 2014 (compared to 2,196 kcal/cap/day in 1961, FAO 2015:24,48). However, the real calorific intake of all the 7,511,482,383 human bodies (Worldometers 2017) does differ a lot among the world regions.[1] What´s more, there are growing differences within nations as well. Whereas, until recently, the most pressing problem related to food was simply hunger (UN 2015), the more recent term *malnutrition* includes undernutrition (stunting and wasting esp. in the case of children), as well as overweight and obesity that are on the rise worldwide, most rapidly in Asia. (IFPRI 2016)[2] All these various human bodies create a living anthropomass of about 300 million tons worldwide (Smil 2013:226; Walpole et al. 2012:3),[3] and they all demand their calorific energy to maintain themselves and do their jobs.

Every day.

This simple fact has far reaching consequences for both humans and the natural environment. Humans as one species out of almost nine billion (Sweetlove

[1] On the national level, the highest dietary energy supply in 2014 was statistically in Turkey (the average of 3,715 kcal/cap/day, in comparison to 2,957 kcal/cap/day in 1961), in the US, the calorie supply per capita was 3,639 kcal/cap/day in 2011 (but only 2,880 kcal/cap/day in 1961). In China the historical shift is much more striking (above-average 3,156 kcal/cap/day in 2014 in contrast to only 1,439 kcal/cap/day in 1961). From the other side of the spectrum, the people of the Central African Republic had to survive with only 1,940 kcal/cap/day in 2014, whereas in 1961 they had an average of 2,256 kcal/cap/day available. Data for 2014 from FAO (2015), data for 2011 and 1961 from Food Security Portal (2017); data from 2011 used for "the present" where the 2014 FAO information was not available.

[2] Still, the body mass of an average Asian was 57.7 kg in 2005, in contrast to 80.7 kg of a North American. (Walpole et al. 2012) These authors estimate that about 15 million tonnes out of the total human biomass was due to overweight, and another 3.5 million tonnes due to obesity, 34% out of it being based in North America where 70% of the population is overweight.

[3] In terms of Carbon weight, the anthropomass in 2000 accounted for approx. 55 million tons of C, whereas domesticated animals account for more than double this (120 million tons of C), most of it being cattle (80 Mt of C) (Smil 2013:228).

2011)[4] currently appropriate about 24% of the potential Net Primary Production (NPP) of all terrestrial ecosystems (Haberl et al. 2007), and agriculture remains the most important driver of land use change in this process (Krausmann et al. 2013). During the last century, we have witnessed unprecedented growth in both global food production and associated environmental, social, and economic problems connected to the increasingly industrialised, globalised and commodified food production system (Weis 2010, Gomiero et al. 2011a, Mayer et al. 2015, Clapp 2017).

Projections for the future foresee a continuation of rising food demand due to population increase and growing demand for meat which requires disproportionately more farm land and higher overall crop production (Walpole et al. 2012, Tilman & Clark 2014). Against this backdrop, some scholars develop scenarios of a 70% or even 100% crop production increase (FAO 2009, Tilman et al. 2011); others criticise the very assumptions of these scenarios and ask whether such a significant growth in food production is at all necessary, and if so, whether it is possible to achieve that without compromising the regeneration capacity of the biosphere. Instead, they stress the need to influence dietary expectations towards less-meaty diets, and to address the still growing inequality in access to existing food, the alarming amounts of food waste, and also the broader political agenda of peasants' livelihoods (Holt-Giménez & Altieri 2013, Edelman et al. 2014). All, however, emphasise the far-reaching environmental consequences caused by current dietary patterns and the dominant agri-food system (Foley et al. 2011, Gomiero et al. 2011b) as highly disturbing, and call for *some* radical change towards more sustainable agri-food systems (for further debate on what sustainability might actually mean for agri-food systems see Chapter 2 in this volume).

In principle, two distinct strategies on how to achieve sufficient and sustainable diets have been discussed recently in the literature (Phalan et al. 2011, Tcharntke et al. 2012). The *land sparing* strategy is based on increasing agricultural yields, reducing farmland area and actively restoring natural habitats on the land spared, thus counteracting the ongoing loss of biodiversity. Some scholars find that a land-sparing strategy has the technical potential to achieve significant reductions in net GHG emissions from agriculture and land-use change, especially when coupled with demand-side strategies to reduce meat consumption and food waste (Lamb et al. 2016). In contrast, scholars promoting

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[4] Estimations often go as high as 10 billion species. In any case, these include only eukaryotic organisms (Sweetlove 2011). The microbial diversity is even bigger by order, Earth is predicted to be home to upward of 1 trillion microbial species. (Locey and Lennon 2016)

land-sharing (Fischer et al. 2008, Perfecto et al. 2008, Gabriel et al. 2009) doubt that fragmented land plots set aside for nature conservation provide the high quality habitats required for halting loss of species. They promote extensive land use that reduces the pressure on species in an agro-ecological matrix at landscape level (for more on the agro-ecological perspective see Chapter 2, for further argumentation regarding the land sparing vs. land sharing debate, and biodiversity on the landscape level, see Chapter 4 in this volume).

Whatever the strategy, it is clear that when considering the sustainability of agri-food systems, the wider context of food-climate nexus cannot be ignored. Due to climate change, the global agri-food system is expected to supply ever more biomass products for a world population growing in numbers and affluence (Godfray et al., 2010), as well as contributing to climate change mitigation by providing bioenergy and carbon sequestration (Edenhofer et al., 2014; Lamb et al., 2016, for more on multifunctionality, and the energy issues in agriculture, see Chapter 3 in this volume). In the context of climate mitigation, the spatial scale at which drastic reductions in GHG emissions or even negative emissions (sequestration) can be achieved are decisive for improving agri-food systems. All regions can either meet the emission constraint equally, or through specialisation. For example, certain regions are net-GHG emitters, because, for instance, they host intensive agriculture and provide biomass to other regions, which in turn may be net-sinks for carbon if they dedicate their land to forest regrowth. Biomass trade can balance the GHG emissions of these regions. Given the fundamentality of the required changes (Steffen et al., 2015), local "autarky" strategies can play a significant role. At the same time, regional specialisation is considered a suitable means of increasing land use efficiency (Kastner et al., 2014). Therefore, the study of agri- food systems should consider nested design, which embeds the local and regional scale into the national, regional, and global production-consumption context (see Chapter 5 in this volume for a good example of this multilevel approach, including the issue of biomass trade, and Chapter 10 analysing the sustainability implications of different types of supply chains).

This once again reveals the crucial link between food production and consumption, and the challenge of the ongoing dietary transition in the Global South, along with the predominant western diet in the Global North that entails high levels of meat consumption, far beyond what can be considered as healthy (McMichael et al. 2007, see chapter 9, on dietary transition on a Greek island, and the virtues of the Mediterranean diet). A vegetarian diet reduces the relative risk for type II diabetes by 40%, cancer by 10% and coronary mortality by 20% compared to the conventional western omnivorous diet. At the same time, the vegetarian diet reduces CO_2 emissions by more than two thirds compared with the conventional diet (Tilman and Clark 2014). Consequently, changes in diets are one of the crucial components for achieving improved sustainability (Veeramani 2015).

However, so far it has proven to be quite difficult to intervene in the behaviour of individuals (Cecchini et al. 2010), partly because of the high level of disconnection between humans and agri-food systems, both in terms of production and consumption. Especially in the Western context, consumers are often dependent on transnational food chains managed by anonymous individuals and corporations so distant and disconnected from our direct experience, and often ignorant of the complex processes, from photosynthesis, through Haber-Bosch synthesis, to soda glutamate production (in the case of industrially produced and processed food) and to farming itself. While food *consumption* is still a very intimate experience of direct contact between the bodies of animals and plants providing nutrition, and our own bodies that incorporate the organic matter into their very own structures, food *production* is for most intangible and abstract. For most industrialised societies, the focus is about what we want to buy and eat, but rarely about what we want to grow, gather or hunt. This does not hold true for about half of the world's population (Fischer-Kowalski et al. 2011a) that still live off the land, i.e. experience a direct first-hand contact with food production. This segment of the world's population is, however, gradually declining as they join the growing middle class and associated dietary patterns and consumer behaviour.

At the same time, a growing population from both North and South are increasingly engaged in influencing the way the current dominant agri-food system works, reflected in both activist and academic focus on, broadly speaking, "agri-food alternatives". Concepts such as alternative food networks, local food initiatives and local food systems (Renting et al. 2003, Goodman et al. 2012, Zumkehr and Campbell 2015) have become popular during the last 20 years, encompassing many on the ground initiatives such as community supported agriculture (CSA), community gardens, urban gardening, food coops and suchlike. Most of these initiatives are based on the idea that our food systems should be somewhat more (re-)localised, i.e. more embedded in local ecosystems and social relations, and shorter in both physical and psychological distance between producers and consumers.[5] Richard Douthwaite, one of the proponents of food (and also energy and money) localisation, calls for the

[5] Sometimes shortening the distance to the extent of becoming *prosumers* (*pro*ducers and con*sumers* at the same time).

creation of *short circuits,* both in terms of resource flows and human interactions (Douthwaite 1996).

1.2 Local Food Systems, Localisation and Food Sovereignty

In the literature, the term Local Food Systems (LFS) is often used to represent all alternate food production and distribution models to the dominant globalised, industrialised and commodified agri-food system trying to create its more sustainable variants. When defining LFS, physical distance is surely one key ingredient, but still very much dependent on the cultural and geographical context.[6] LFS are also characterised by "the story behind the food" (Martinez et al. 2010:4) or the food "provenance" (Thompson et al. 2008), referring to a combination of cultural, social and environmental attributes, including commitment to a specific place, to concrete people who produce and consume the food, nurturing of traditional and/or sustainable practices of production and processing, knowledge about these processes and the possibility of direct participation in them (Martinez et al. 2010).

According to proponents of "localisation" (see Fraňková & Johanisová 2012 for a systemic analysis of the concept, and Chapter 7 in this volume for its application on a small-scale organic family farm in the Czech Republic), localised food production is supposed to bring predominantly positive results, combining social, environmental and economic benefits of lower transport dependence resulting in less consumption of fossil fuels, lower CO_2 emissions, less waste from packaging, more closed cycles of matter and energy within production systems, and also stronger local economies showing a higher level of local circulation of money, lower dependence on foreign investments, and less dependency on, and more resilience towards, fluctuations of the global economy. Among the potential drawbacks are the possibility of strong community control by a few, and limited choice of local and seasonal goods, but they are mostly seen by the localisation proponents as of lower importance, and as acceptable or – in the case of direct producer-consumer relations – negotiable (Douthwaite 1996, Norberg-Hodge et al. 2002, Desai & Riddlestone 2002).

Such an overtly positive framing of LFS has been criticised by scholars as being too naïve. They argue that the reality of such endeavours, even if positively motivated, can be and indeed sometimes are, socially exclusive, supplying its participants more with a good feeling about themselves than with the required

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[6] Whereas in the USA, a 100 to 400-mile radius might be seen as local, in Europe it is more about 20-100 km (Norberg-Hodge et al. 2002; NEF 2002), and the particular type of goods in question: the supposedly "local" area differs when it comes to eggs, clothes and refrigerators, see NEF (2010) for rough "local" distance indications in the European context.

amount of food; critics also doubt its overall sustainability impacts and potential for spreading beyond small niche markets (Hinrichs 2003, Allen 2010, Cadieux & Slocum 2015). Hence, after the "first generation" of academics enthusiastically "discovered" the grass-root local food initiatives in the 1990s and 2000s, the "second" generation are more critical and aware of the complexity in operationalising these concepts. Their scholarly sophistication is reflected in new labels such as "social or grass-root innovations" and "scaling-up" of alternatives (Seyfang and Smith 2007, Beckie et al. 2012, Zumkehr & Campbell 2015).

Beside the food localisation agenda, the related concept of "food sovereignty", that has been the subject of intense debate in the fields of political ecology and agrarian and peasant studies, should also be acknowledged. This stream of activism and thinking puts a much stronger accent on the political aspects of LFS, including the question of peasant livelihoods, and shows more sensitivity to Global North/South relations. At the same time, the strong point in favour of more localised food systems is also present in the food sovereignty agenda, and thus it can be interpreted as a fresher incarnation of the ideas previously formulated within the localisation movement, mainly in the 1990s. Indeed, in practice many localisation and food sovereignty initiatives overlap and both movements offer cross-fertilisation (see for example, the declaration of Food Sovereignty (Nyéléni 2007) and the recent European CSA declaration (Urgenci 2016)). Thus, it can be said that the LFS has recently been enriched and received impetus by the food sovereignty agenda to include political issues, and to embody characteristics of a global movement trying to build dialogue between different regions of the world.

Still, when looking for sustainable alternatives to the dominant agri-food system, both academics and activists often focus only on Northern initiatives in the sense of the purposeful, often politically engaged LFS initiatives as described above. Yet, there are several other modes of sustainable agricultural and land use practices that have long existed in terms of cultivation management and production-consumption relationships (Martínez-Torres & Rosset 2014). These are often overlooked by academics as contributing to sustainability. In the context of the Global East, Smith and Jehlička (2013) coined the term "quiet sustainability" for the widespread practices of food self-provisioning and gardening, a practice spread across all ages, education levels and socio-economic statuses, providing food in substantial varieties and amounts (see also Sovová 2015, Smith et al. 2015; chapters 8 and 9 in this volume provide other examples of "quiet sustainability": the case of a rural village in Cambodia, and the Greek island of Samothraki respectively).

Besides such prevailing subsistence gardening practices in many Central and Eastern European (CEE) countries, half of the world's population, mainly in the Global South, still remain involved in subsistence farming (Fischer-Kowalski et al. 2011a). This segment of the world's population is often described as backward, poor and underdeveloped (see Escobar 2014 for a critique of the very term development), although by their everyday practices fulfilling, albeit unintentionally, many of the sustainability ideals formulated by the Northern alternative food initiatives. Efforts are underway to change this framing (see e.g. Shrivastava and Kothari 2012) and to take these "quiet sustainability" practices on board, along with the progressive "innovations" discussed in the literature dominated by western scientists.

Thus, we argue that both the intentional and unintentional initiatives and practices discussed above, based geographically in the North, East and South, can be framed within the localisation perspective and may be labelled not only as Local Food Systems, but at the same time as (re-)Localis*ed* Food Systems, i.e. they do fulfil certain aspects of localisation as defined at the beginning of this section, including the potentially positive implications for their sustainability.

Indeed, contrary to what some of the critics argue, we believe there are several environmental, social, economic and political benefits for upscaling (re-)localisation of agri-food systems in comparison to the globalised agri-food regime (see Chapter 2 for a more detailed elaboration on these reasons). However, we also believe that the respective level of desired localisation should be open, case-specific, and thus explicitly questioned, and therefore not a one-size-fits-all approach. On this, there is a high consensus among virtually all (food) localisation proponents, even if some are vague on how and to what extent international trade should be regulated and organised, and what procedures and principles should be used to decide on this (Fraňková and Johanisová 2012). The issue of scale of (re-)localisation and trade are raised in some of our case studies that look at both historical and current practices (see Chapters 5 and 6 for a historical account of the Spanish region of Vallés, and several Austrian agrarian villages respectively).

This also explains why the term LFS is kept analytically open in this volume. The contributors do not presuppose any modern or traditional agrarian practices, nor are the cases conditioned by any political or activist orientation. Further, our understanding of the "local" in LFS is intended to mean anything lower-than-national, i.e. on the level of a household, farm, community, village or region. The focus on local scale is also motivated by our understanding that although sustainable food production is a global challenge that indeed needs to be discussed in the global context, it also has an inevitable local dimension. It is at the local level where people live and work, where environmental, economic, social, cultural and institutional issues are interlocked and experienced (that is, where the food is produced, processed, transported, traded, and consumed or wasted).

From the methodological point of view, available LFS studies use predominantly qualitative research methodologies (Seyfang 2007), discussing the biophysical impacts of LFS only to a very limited extent (Martinez et al. 2010, Kneafsey et al. 2013, Matacena 2016). However, well-founded and tested methods to study the biophysical aspects of agriculture in the fields of social ecology, ecological economics and industrial ecology do exist. The conceptual and methodological framework of Social Metabolism (SM) has been applied to study the nexus between energy, material, land, and time use within agri-food systems for decades (Giampietro 2003, Gomiero et al. 2006, González de Molina and Toledo 2014), however, only rarely in the case of LFS.[7]

1.3 Social Metabolism and Political Ecology

Whether a given local food system is ecologically sustainable or not is a tricky question. This requires a non-reductionist approach to investigate how social and natural systems interact and co-evolve over time and different scales. This interaction entails substantial impacts upon one another, with bidirectional causality (Haberl et al. 2016). There have been efforts to study the biophysical relations between society and nature over the last one-and-a-half centuries. Analogising the metabolism of organisms, Karl Marx first referred to metabolism when he described work as a process in which people regulate, steer and control their metabolism with nature through their own action (Marx, 1968 (1867)). A century later, these considerations were re-introduced from quite another angle by Ayres and Kneese (1969) that led to what is termed as "industrial metabolism" (referring to the material and energy throughput of industrial societies), and later "social metabolism" (to generally refer to the metabolism of any society at any scale) (for an intellectual history of social metabolism, see Fischer-Kowalski 1998).

The fundamental premise of "social metabolism", a term that is now widely used, is that social systems need to maintain and reproduce their biophysical

[7] It is already common to apply the social metabolism approach at national and global scales (Grešlová Kušková 2013, Erb et al. 2016). Existing local studies either focus on describing the transition from traditional to industrial agri-food regimes historically (Haberl & Krausmann 2007, Haas & Krausmann 2015), or focus on contemporary cases in the Global South (Fischer-Kowalski et al. 2011a, Scheidel et al 2013, Ringhofer and Fischer-Kowalski 2016, Birke 2014, Singh et. al. 2001). However, applications of social metabolism studies at the local level in the Global North are still rather exceptional.

stocks (like human and livestock population, and built artefacts) for their survival and evolution. This requires a continuous flow of energy and materials extracted from, and eventually released to, the environment (Ayres and Kneese 1969).[8] Thus, the metabolism of social systems refers to material, substance and energy flows related to socio-economic activities. Maintaining the social metabolism includes the "colonisation of nature" (discussed later in this section), denoted as purposive intervention into natural systems aimed at improving their utility for societal purposes (Haberl et al. 2016).

Socio-metabolic studies range from describing the metabolism of national economies to analysing them across geographical regions over decades or even centuries (e.g. Krausmann et al. 2009, Schaffartzik et al. 2014). Socio-ecological transitions, especially from hunter-gatherer to agrarian, to industrial societies, and to the so-called Anthropocene, provide a specific analytical perspective to understanding long-term changes in society-nature interactions (Fischer-Kowalski at al. 2014, Fischer-Kowalski & Haberl 2007). To better understand these transitions, a series of local studies have been performed (Fischer-Kowalski et al. 2011a, Birke 2015, Haas & Krausmann 2015).

Within social metabolism studies there are different variants such as substance flow analysis (SFA),[9] physical input-output (PIOT), life-cycle analysis (LCA), material and energy flow analysis (MEFA), and multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM). They all share many similarities but differ due to their special focus. For example, while the MEFA's original purpose was to add a biophysical dimension to the usual monetary description as national accounts, MuSIASEM is more focused on analysing processes and functions inside a system and at the same time linking this analysis on different scales in an integrated way (land use, human activity, energy & material flows, monetary flows) (Gerber and Scheidel forthcoming, see also chapters 2 and 3 of this volume).

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[8] Ayres and Kneese (1969, p. 283) claimed that the common failure of (currently mainstream) economics results from viewing the production and consumption processes in a manner that is somewhat at variance with the fundamental law of the conservation of mass; similarly, Georgescu-Roegen (1971) argued that mainstream economic theory and modern economies are at variance with thermodynamics and the law of conservation of mass. These insights, recognising the biophysical aspects of all socio-economic processes, established one of the fundamental theoretical underpinnings of the whole field of Ecological Economics (Røpke 2004).

[9] Substance refers to a single type of matter such as a chemical element, e.g. Cadmium (Brunner and Rechberger, 2004).

MEFA indicators provide now highly standardised methodological inventory that can be derived to discuss a system's sustainability over time, and to compare with other cases or other levels of scale (for standardised accounting guidelines for countries, see Eurostat 2013, and for local systems, see Singh et al. 2010).[10] Over the years, MEFA indicators were further developed to be practicable, meaningful and sound. One of the classic indicators is the Domestic Extraction (DE) that accounts for all material appropriated from nature from the social system's domestic territory, be it harvested biomass, extracted crude oil, mined metal ores or minerals. Since livestock, a biophysical stock of society, can partly feed itself, grazing is considered an extraction as well. In addition to domestic extraction, a social system also imports materials from other social systems, while also exporting some. Thus, imports and exports are also basic indicators. The Direct Material Input (DMI) of a social system is the sum of DE and Imports. Domestic Material Consumption (DMC) is calculated by subtracting exports from DMI and reflects the social system's consumption, which goes far beyond the apparent consumption of households since it includes all losses as well as all materials used to extend, maintain and operate the stocks at the system level. These flows can be disaggregated for a wide range of material categories such as biomass, fossil fuel carriers, metal ores, and non-metallic minerals (essentially construction minerals). All flows are reported in material units (e.g., metric tonnes) in fresh weight or dry matter as well as in energetic units (e.g., joules, kilowatt-hours) and per unit of time, usually per year (see Haberl et al. 2004). The resulting energy indicators deviate from standard technical energy accounting, insofar as the former – besides technical energy – also includes all the primary energy required for the endosomatic metabolism of livestock and humans (feed and food).

MuSIASEM studies, on the other hand, have focused on the performance of societies' subsectors (Giampietro et al., 2012) and often on particular resources such as food and agriculture, energy or water (e.g., for agriculture: Ravera et al. 2014; Scheidel et al. 2014; for energy: Ramos-Martín et al. 2007, Giampietro et al. 2013; for water Madrid-López & Giampietro, 2015). But MuSIASEM is also concerned with the nexus between these resources (Giampietro et al., 2014).

While MEFA focus on stocks and flows, MuSIASEM look at funds and flows. These are not just differences in words but in concepts. "Funds" refer to agents

[10] For nation states such as Japan, as well as in the European Union (EU) and several other countries, material flow accounting (MFA) has become a regular part of public statistics (Fischer-Kowalski et al. 2011b). This allows the provision of reliable annual accounts of material use in physical terms and their comparison across time and with economic accounts.

maintained throughout an economic process such as labour, land or technological capital and "stocks" to human population, livestock and artefacts. In sum, MEFA is a useful framework for understanding the biophysical dynamics between stocks and flows in quantities, and helps grasp the *figure of a social system's metabolism*, in terms of the tonnes processed (Fishman et al., 2014; Matthews et al., 2000). In contrast, the fund-flow approach conceptualises the *functions of a social system's metabolism*. So funds (e.g., labour) require and produce flows (e.g., food) at a given rate (Gerber and Scheidel forthcoming, see also chapters 2 and 3 of this volume).

What different approaches to "social metabolism" have in common is that they encompass biophysical stocks, flows and/or funds and the mechanisms regulating these flows. Any socio-metabolic analysis starts with the definition of the social system under consideration, such as a household, a business, a village, a local food system, a nation state, or the global community. The first step is to define the social system's boundary, a prerequisite for studying society-nature interactions. Delineating this boundary, and deciding which elements are part of the social system and which belong to the system's environment, is not simply an arbitrary construct of the researcher. According to modern systems theory, a social system constitutes itself through the marking and reproduction of its boundaries in order to fulfil its functions. Accordingly, the researcher needs to understand how the social system itself defines its stocks and flows along ownership boundaries, accepted entitlements, or governance responsibility (see also Netting 1981, 1993, Singh et al. 2010).

In addition to material and energy flow analysis, land use reflects another form of society-nature interaction, which is a consequence of the human colonisation of natural systems. Land use involves the colonisation of ecosystems, organisms and, increasingly, the genomes of crop plants. The human appropriation of net primary production (HANPP) is an indicator of the intensity of land use or the colonisation of ecosystems. HANPP is the quantity of energy appropriated through human interventions into energy flows in ecosystems, that is, net primary production (NPP). Net primary production (NPP) is a measure of the quantity of organic material produced by plants through photosynthesis. NPP is an important process in ecosystems; it is the source of entire food energy for humans and all other heterotrophic food webs and provides the basis for the creation of vegetation cover and soils and their associated carbon stocks. NPP is one of the most important indicators of ecosystem capacity and forms the basis for the existence of all biodiversity (Vitousek et al. 1986; Wright 1990). The difference between the NPP of potential natural vegetation (NPP_{pot}, or NPP of the ecosystem with no human influence) and vegetation that is pre-dominant due to a certain land use (e.g. for agriculture, buildings, roads) at a particular point in time (NPP_{act}, or actual NPP) is defined as $HANPP_{luc}$ (HANPP resulting from land use). Added to this is the harvest of biomass for human use ($HANPP_{harv}$, or HANPP through harvest), often the ultimate purpose of land use.

A completely different biophysical indicator, yet a key component of a socio-metabolic analysis, is functional time use (FTU), which views human time as a key resource of social systems. The total time available to a social system each day (for example, a village) is the sum of the population multiplied by 24 hours. This is the maximum time the village has at their disposal per day, also referred to as the stock of time. With respect to the flows of human time, one fraction of daily time use is expended on certain metabolic functions (such as sleeping or eating) necessary for an individual's basic reproduction, whereas the remainder is used according to socio-cultural norms, economic necessities or simply individual preferences. We distinguish between flows serving four functional subsystems, each of which requires time for reproduction: the person system, the household system, the economic system and the community system (for a discussion on methodology, see Singh et al. 2010). Such a systemic analysis offers a perspective on how much human time is available and what it is used for on a system level, thereby helping us to understand the specific opportunities and constraints a society faces in its interaction with the natural environment. At the same time, because the lifetime/labour time ratio is calculated for all the age/sex groups in this system, FTU sheds light on the 'labour burden' or 'time poverty' some of these groups bear with regard to important aspects of social inequality (Ringhofer and Fischer-Kowalski 2016).

These basic components of the socio-metabolic approach (material and energy flow analysis, land use analysis, functional time use analysis) not only provide an important methodological tool, but also generate information that has significant social and political implications, and thus are not only constituent parts of Ecological Economics (see footnote 8) but also contribute significantly to the broad field of Political Ecology. Broadly speaking, political ecology strives to explain the root causes of social vulnerability by studying ecological processes as part of the broader political economy. Michael Watts (2000) defines the role of Political Ecology as being "to understand the complex relations between nature and society through a careful analysis of what one might call the forms of access and control over resources and their implications for environmental health and sustainable livelihoods" (p. 257).

In the context of international trade, the concept of social metabolism and material flow analysis have been used by a few political ecologists to quantify "ecological unequal exchange", that is, the asymmetrical flow of resources from the core (industrialised countries) to the periphery (countries of the Global South) (see for example, Eisenmenger and Giljum 2007, Singh and Eisenmenger 2011, Schaffartzik et al. 2014, Mayer et al. 2017). Joan Martinez-Alier and colleagues have made important contributions to show the links between social metabolism and conflicts. They argue that current patterns of industrial metabolism draw on huge amounts of resources from all over the world, but the costs and benefits of extraction, production, consumption and eventual waste disposal are not equally distributed, often leading to what is termed "ecological distribution conflicts" (Martinez-Alier 2009, Martinez-Alier et al. 2016). European funded projects[11] have resulted in large collaborative efforts to underline these connections through a number of publications framed around environmental justice (Martinez-Alier et al. 2010a, Healy et. al. 2012) and degrowth (Martinez-Alier et al. 2010b). The themes linking social metabolism, political ecology, social conflicts and environmental justice are inextricably woven throughout this book.

The social metabolism approach has thus provided us with valuable insights e.g. on the biomass metabolism occurring at global, national and local scales. For much of the 20th century, biomass dominated total global material extraction for socio-economic activities, and only in the 1990s was it overtaken by construction minerals (Krausmann et al. 2009). Between 1950 and 2010, growth in global biomass extraction was slow, increasing only by a factor of 2.5, unlike other material categories that grew several-fold in the same period. In an absolute sense, biomass production increased from 7 Gigatons (Gt) to 19 Gigatons, or from 2.7 t/cap to 3.1 t/cap, indicating a strong relationship with population growth (Steinberger et. al. 2010). Much of the growth in biomass production was in primary food crops that increased by a factor of 4, but the related land area increased only by a factor of 1.4, indicating a transformation in agriculture with high levels of inputs of fossil fuels and fertilisers (Mayer et al. 2015).

On the other hand, international trade in biomass increased almost 5-fold in the same period, from 0.3 Gt to 1.4 Gt. Most of the new land dedicated to crop production in the mid-1980s was aimed at export. This period corresponds to what is referred to as the "corporate – or third - food regime" that seeks to address global food security through international trade, neo-liberal policies and market instruments. Those with purchasing power could source fresh fruits, vegetables and animal products from supermarkets (Mayer et. al. 2015). The changing dietary patterns of a growing middle class (from plant to animal based

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[11] For example CEECEC (http://www.ceecec.net/), EJOLT (http://www.ejolt.org/), ENV-JUSTICE (http://www.envjustice.org/), ACKnowl-EJ (http://acknowlej.org/).

diets), and growing industrial use of biomass (e.g. biofuels) continues to provide impetus to its production and trade.

Erb et. al. (2009) examined the increasing spatial disconnect between where biomass is being consumed and the environmental impacts on where it is being produced. A closer look at the global biomass metabolism reveals that wealthy industrialised nations of the Global North supply large parts of the Global South with cheap staples (namely cereals and pulses) as well as fodder for meat production, while their imports are comprised mainly of luxury and exotic fruits, vegetables and animal products (Mayer et al. 2015). The unequal distribution of costs and benefits of our current global food production and international trade have provoked resistance movements and related social conflicts worldwide. These trends not only raise questions around food security (i.e. the amount of food available to any given society) but also food sovereignty that emphasises control over food production and access (i.e. who decides to produce what, and how) both in the Global North and South, giving rise to diverse alternate local food movements as discussed in this chapter (McMichael 2009).

1.4 The Contributions in this Volume

As the title suggests, this volume is an attempt to critically examine the sustainability of a wide range of local food initiatives through the lens of social metabolism. The chapters in this book cover a range of methods related to social metabolism at different temporal and spatial scales, with a mix of cases from the Global North, transition economies and Global South. The cases in the book also capture the various stages of production, distribution, consumption, and waste related to LFS. As such, two overarching questions drive our enquiry throughout this book: Which scientific and policy relevant insights can we draw from our LFS cases that might suggest the best practices for maintaining and designing more sustainable agri-food systems in the future? What are the methodological strengths and shortcomings vis-a-vis social metabolism for studying LFS?

Chapters 2, 3 and 4 outline the methodological complexity in studying agro-ecological systems when considering appropriate space and time dimensions. In chapter 2, Enrico Tello and Manuel Gonzalez de Molina review several methods for a sustainability assessment of agri-food systems, and offer an agro-ecological perspective to account for energy and material flows of farm systems, linking them to landscape ecology patterns and processes which sustain farm-associated biodiversity and derived ecosystem services. Tiziano Gomiero, in chapter 3, explains that food production is both multi-functional (having a dual purpose of maintaining both societal and ecosystem health), as well as multi-scale (connecting soil, farm, landscape, watershed and beyond) that requires consideration of different criteria at different hierarchical levels. This implies a significant complexity of sustainability assessment of agri-food systems; within the chapter, the issue of energy efficiency and energy flow (power) are discussed particularly extensively, in the broader context of biophysical and socio-economic analysis, and the different schools of social metabolism that have already been introduced in this chapter (section 1.3). In the same vein, in chapter 4, Joan Marull and Carme Font attempt an integrated approach, combining different spatial scales with long-term socio-metabolic balances and changes in the ecological functionality of farm systems. The authors propose an Intermediate Disturbance-Complexity model of agro-ecosystems to assess how different levels of human appropriation of net primary production affect the regional functional landscape structure and biodiversity.

Chapters 5, 6, 7 and 8 discuss cases in different periods of time and emphasise the social, economic and community aspects of local food systems. Roc Padró and colleagues (chapter 5) present the case of Vallès County in Spain in three periods of time (1860, 1956 and 1999) to show the socio-ecological transition from an organic to an industrial regime. They compare diets and labour productivity, the role of multi-functionality in agro-ecosystems, the loss of landscape diversity and species richness through 150 years of agro history. In chapter 6, Michael Gizicki-Neundlinger, Simone Gingrich, and Dino Güldner take a Long-Term Socio-Ecological Research (LTSER) perspective to focus on the relationship between soil fertility, food provision and social inequality. Using several village level cases in 19th century Austria, the authors highlight a number of social issues underlying pre-industrial agriculture, and what we might learn from this with respect to the current debate on the sustainability of LFS. Chapter 7 (Eva Fraňková, Claudio Cattaneo) provides a historical comparison of traditional and current forms of organic agriculture in the Czech Republic, focusing mainly on the current case study of an organic family farm to illustrate the concept of localisation and food sovereignty. Here, the nexus of Food-Feed-Fuel-Fibre production is extended to include the aspect of *Finance* that is too often neglected in current socio-metabolic studies. In chapter 8, Arnim Scheidel and colleagues present a case from Kampot (Cambodia) that highlights the collective efforts of farmers to intensify farming with low labour input, renewable energy, and buffer food prices and shortages through cooperatives and a community bank. Kampot is an example of "leapfrogging" to showcase a model of sustainable livelihoods embedded in local socio-economic dynamics.

Chapters 9, 10 and 11 provide other examples and assessments of local initiatives and efforts with the aim of nurturing and promoting local and sustainable food systems. Chapter 9 (Panos Petridis and Julia Huber) discusses the ongoing transition on the small Greek Island of Samothraki, socio-metabolically, from a traditional agrarian lifestyle to a modern industrial society, and nutritionally, towards a westernisation of diets. While raising concerns about increasing imports from the mainland, the authors also highlight the significant role of agricultural self-provisioning and informal food networks, as an example of "quiet sustainability". In chapter 10, Gonzalo Gamboa and colleagues provide a comparative assessment of initiatives related to food supply chains in Catalonia (Spain). The authors evaluate the performance of three organic tomato supply chains in the region: the local and global supply chains, and a mixed supply chain based on a set of multidimensional indicators (based on a commodity, environment and livelihoods narrative). The authors show that organic production is not enough to achieve a sustainable food provision system, and the context and the food supply chain in which organic food is commercialised also determine the sustainability of organic food production. Marian Simon-Rojo and Barbora Duží, in chapter 11, present a case of urban metabolism (Madrid, Spain) where efforts are underway to close the nutrient loops. The civil society platform *Madrid Agroecologico* has initiated a bottom-up approach to reintegrate organic waste into the regional alternative food networks. The project was instrumental in raising awareness on the issue of waste and its potential re-use as compost to amend local soils.

The concluding chapter summarises both the promising characteristics of the historical and current local food systems, and the pros and cons of the SM methodology applied at local level to recognise, preserve and offer more sustainable pathways (along with necessary policy context) for dealing with the challenges in the sustainability of agri-food systems.

1.5 Final Remarks

The book is meant as both a scientific and a political project: it's *scientific* in terms of asking critical questions, and discussing the sustainability of local food systems in the context of the existing body of theoretical and empirical knowledge with the aim of providing new data and insights into this debate, including advancement of relevant methodological approaches; it's *political* and value-based in its basic focus on sustainability and local food systems, aiming to bring these into light as potentially beneficial and important, and thus to break the (partly performative) dominance of the industrialised agri-food regime as the only one capable of providing food for the world's population.

Along with Gibson-Graham (2008) we believe that not only activists, but also we as researchers influence and shape reality by making some things and relations visible, and by silencing/ignoring others. We should be aware of this and ethics should inform what we do. According to Gibson-Graham (2008), the dominance of the current global capitalist system (of food production, too) is partly performative, i.e. there are other relations and systems of social and economic organisation than the capitalist, but they are (even by those criticising the capitalist system) framed as "alternative", parallel etc. thus actually confirming the dominant position of capitalism. We as scientists have the power to influence what is seen as "normal", and what is seen at all – in this sense, by this book and the research in it we contribute to making local food systems visible and important as part of the debate on how to feed the world's population, and how to maintain and/or create agro-ecosystems in a more sustainable way.

This book is both academic and activist in nature, thus trying to actively combine these different domains of activities. We tried to make the process of the creation of this book convivial and participative – we are all passionate about our research and the issue this book is about. We see this book as only one part of the process which has to be continuous and democratic – we offer the results of the time and effort which we had the chance to devote for research, but we fully acknowledge that it is only one of many valid ways of creating/gaining knowledge and we do not position ourselves in the roles of those who know and tell others what to do. We try to derive conclusions from our research and experience which can be generalised to some extent (see Chapter 12 for our main conclusions), but we stress the importance of the particular local context and conditions, and the importance of participative processes for exploring and creating more sustainable ways of fulfilling human needs, including the need for food, feed, fibre and fuel provided by agroecosystems.

Thus, we hope to provide rich food for thought on food, and to contribute to a vivid – both academic and political – debate (and action!) on this important topic that affects us all. We would be extremely happy for any feedback, and meanwhile we hope you will thoroughly enjoy reading this book.

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