Agrarian transformative changes of agriculture and food systems: A review

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Abstract

Agricultural and food systems are undergoing transformations because of increasing commitment in international trade with economic growth, dietary change and urbanisation. The importance of food systems for sustainable development: they are interrelated with food security, nutrition, and human health, the viability of ecosystems, climate change, and social justice. Food systems approaches are often undergoes several transformation processes, with particular strengths in linking social, economic and environmental dimensions of food in innumerable ways. Globally, agricultural and food systems need to transform and modify their approach and bring the desired change with new ways to integrate natural capital into social and economic systems. This transformed approach has the potential to secure food and ecological security to all, and to improve unconditional health in the society. It has four parts: first, food systems should enable all people to benefit from nutritious and healthy food. Second, they should reflect sustainable agricultural production and food value chains. Third, they should mitigate climate change and build resilience. Fourth, they should encourage a renaissance of rural territories. Therefore, the new ICT technologies and services help food operators deliver greater efficiency in resource use. In this review paper, we collected the literature majorly focus on the concepts of food systems, agrarian change, political economy, sustainable development and rural livelihood. It emphasizes the challenge of intriguig different paths for food systems transformation in agricultural sectors responding to local and national expectations within the context of global priorities.

Keywords: Food systems, agrarian change, food transitions, agriculture transformation

Introduction

Agriculture is the foremost agenda for many governments around the world due to growing demand for diverse types of food from increasing and wealthier populations. Although global agriculture provides sufficient calories overall for today’s human population, more than 800 million nevertheless remain undernourished [FAO, 2018] [28]. According to the United Nations Food and Agriculture Organisation, there is a need to double food production by 2050 to meet the demands of over 9 billion people [High Level Expert Forum, 2009] [47]. The Green Revolution of the 1960s, through the use of intensive agriculture techniques, crop and livestock improvements and agrochemical use has resulted in many-fold increases in agricultural production. At the same time, increasing production through intensive agriculture has resulted in irreparable damages to biodiversity and the natural environment over the last five decades [Kesavan and Swaminathan, 2018] [59]. Another alarming and related consequence is that the global burden of diseases such as obesity, cardio-vascular diseases, diabetes, etc., is increasing globally [Tilman and Clark, 2014; FAO, 2018] [95, 28]. Therefore, there is a need to take stock of the current situation and measure all the costs and benefits of agriculture and food systems so that they can be transformed to meet the growing food demand as well as protect planetary and human health through appropriate policy responses [The Economics of Ecosystems and Biodiversity, 2018] [93].

The global food system is subject to the conflicting pressures of delivering the food demanded by an expanding and increasingly affluent population, while helping to achieve environmental sustainability [Godfray et al., 2010; Tilman and Clark, 2014] [42, 95]. Along with rising population, higher consumption rates for commodities such as meat and milk, due to rising incomes [Kearney, 2010; Keyzer et al., 2005; Tilman et al., 2011] [58, 60, 90], and increasing non-food demands for agricultural commodities, principally for bioenergy [Muller et al., 2008] [67], all increase the pressures on agriculture. This situation is further complicated by climate...
impacts, leading to changes in land suitability and crop and animal yields [Müller and Robertson, 2014; Nelson et al., 2014] [68, 70]. Meeting food demands either by expanding agricultural areas, causing land use change, or the intensification of production (i.e. seeking higher yields through the use of greater inputs, such as fertilisers, pesticides or water, or changes in management practices) have the potential to cause environmental harm, including greenhouse gas emissions (GHGs), deteriorating soil quality, use of scarce water and biodiversity loss [Cassman, 1999; Johnson et al., 2014; Smith et al., 2013] [19, 36, 84-85]. Although many studies revealed that reducing food losses and waste may play a substantial role in achieving food security and climate change mitigation [Foley et al., 2011; Hall et al., 2009; Smith, 2013; West et al., 2014; WRAP, 2015] [84-85], few have analysed the sources and distribution of global food losses and waste. Further, losses occurring due to food consumption exceeding nutritional requirements have received even less attention, with limited research on consumption in the USA [Blair and Sobal, 2006; Eshel and Martin, 2006; Smil, 2004] [112, 26, 83]. There is also a gap in the understanding of the impact of livestock production on both food system biomass efficiency and feed crop losses. The dramatic food system change that is unfolding at multiple scales, from the scale of the farming household to a process of political and economic regionalisation and globalisation, within a context of global environmental change (Reardon et al., 2019) [77]. Food systems are increasingly influential when looking at the global challenges around production, trade, distribution and consumption of food, bringing together social, political, economic and environmental dimensions. It is a conceptual approach that highlights inter-linkages providing a framework for analysing relationships, dynamics and implications of change (Ingram, 2011) [54]. food systems struggles to i) consider the political and governance dimensions to how such systems are created, and for whose interests and benefit, or ii) to accommodate the diversity of human action, especially in areas of the world going through dramatic change. In contrast, while rural livelihoods focus on the household and recognises the broader influence of multiple transforming structures and processes (markets, policy, norms and institutions), it has struggled either conceptually or methodologically to accommodate the increasingly complex multi-scale interlink ages and interdependencies, and their influence on rural change. Similarly, the literature on agrarian change while addressing the influence of globalisation and capital penetration has tended to focus on the scale of small-scale production of specific crops (Hart et al., 2016) [46]. The review paper deals with the overall purpose is for agriculture and food systems’ to make the greatest possible contribution to achievement of the Sustainable Development Goal (SDGs): food systems transformation should reflect a concord on pathways to be pursued and their potential impact — in terms of environmental, social, nutrition, and health outcomes.

**How to transform global agriculture and food systems?**

Global agriculture has been unable to internalise externalities due to the lack of a common framework or approach and tools to assess them in a way that can be understood by all concerned stakeholders – farmers, business, governments and society at large [The Economics of Ecosystems and Biodiversity, 2018] [93]. This lack of tools and procedures is also a major barrier in understanding the full scale of costs and benefits associated with agriculture and food systems worldwide. Once these impacts are known, policies and programs can be developed to incentivise good practices and penalise detrimental practices and reduce the ecological footprint of agriculture and food systems. It has become something of a truism in the burgeoning field of food studies to describe food as constituting a ‘system’ (Erikcnsen, 2008; Kneen, 1993; Sobal et al., 1998; Tendall et al., 2015) [25, 54, 86, 91]. This is seen as a way to improve food system outcomes and sustainability, in order to deal with competing priorities and address the complex relationships that exist between components of the food system [Erikcens, 2008] [25]. Although food studies lay claims to interdisciplinary research - as the ‘food systems’ concept implies - in practice traditional disciplinary divisions of work have created and maintained a range of methods and approaches to the study of food. This does not mean that researchers have deliberately ignored or dismissed food research stemming from other disciplines. Rather, it is suggestive of the deep-rooted obstacles - epistemological, ontological and methodological - standing in the way of genuine interdisciplinary research without prior commitment to a shared conceptual and analytical framework. The first step to overcoming these obstacles is therefore to commit to constructing such a framework by engaging with and extending the extant food systems literature especially those accounts that have sought to delineate an explicit and interdisciplinary food systems research programme. While the literature is now growing, there are still relatively few contributions that succeed in delineating an explicit conceptualisation of the food system [Erikcnsen, 2008; Gregory et al. 2005; Ingram, 2011; Rotz and Fraser, 2015; Sobal et al. 1998; Tendall et al. 2015; and Horton et al. 2017] [25, 54, 86, 91, 50]. These contributions share an understanding that food needs to be studied holistically in order to capture the multiple activities, interactions and outcomes associated with its production, exchange, consumption and governance. Tendall et al. [2015] [91] argue that food system research thus far has overemphasised biophysical shocks and has neglected political economy and governance. Reardon et al. [2019] [77] also proposes that food system studies to date have prioritised on farm food systems and calls for more work on the post farm gate activities where 40–70% of the food value is added. These tasks, however, are easier said than done given the inherent complexity of the food system and the various ways it intersects with other social, health and environmental systems. The food system is not just characterised by separate activities producing collective outcomes; it is the dynamic interaction between units (or subsystems) that outlines the systemic properties at play. Food system activities and outcomes eventually result in processes that feed back to environmental and socioeconomic drivers [Erikcnsen, 2008] [25], which may lead to unintended consequences [Ingram, 2011] [54]. The food system is thus defied by its dynamic properties, which involve information flows between the system and its components and between the system and the external environment beyond the system boundary. These complex interactions and their implications need to be considered for in the design and implementation of effective policy and management interventions. Such interventions, thus, cannot be treated as isolated changes in one part of the food system [Pinstrup-Andersen & Watson, 2011] [74]. These current contributions above are useful; however, they fail to consider political economy, governance and agency and there is a need to build a more nuanced approach that considers these political aspects. Tendall et al. [2015] [91] calls for more participatory
Transforming food systems from industrial agriculture towards agroecological systems

Industrial agriculture systems occur largely in the global North (with some notable exceptions) and tend to be devoted to large areas of specialized commodity crops or industrialized feedlots for livestock. Whatever the starting point, the transition to diversified agroecological systems is necessary; however, countries in the global North bear a particular responsibility to change their practices. The industrialization of processing, commoditization of all types of food, globalization of markets, increases in distant exchanges, and reorganization of distribution. Agroecology focus mainly on agroindustrial corporations and, instead, call for agriculture based on peasant farming systems. Our approach defends diversity against monoculture and gives local markets priority over the global market. Agroecology favors a gradual transition away from the fossil-energy-based farming. The approach seeks to preserve soil health and to reduce soil erosion. In fact, it is mostly because of its environmental benefits that it is now considered with interest by governments and international agencies. [Schutter and oliver, 2010 [82]]. Even if such changes have touched only part of the agriculture sector, the dynamic that has been generated is very strong. The challenges faced by farmers, especially small- and medium-sized landholders, have been highlighted: appropriation of biological resources [Godfray et al. 2010] [42], land tenure and grabbing [HLPE 2011b] [48], increased competition, exclusion linked to standards and specifications (Reardon et al. 1999) [76], market instability and excessive price volatility [HLPE 2011a] [48], reduced access to credit, dismantling of support mechanisms and services [IBRD/World Bank 2007] [52], growth and emergence of risks—particularly climate [Beddington et al. 2012] [7], and emerging diseases. The investment should result in exploration of a broad range of options and should be explored as a basis for developing novel strategies and practices [Godfray et al. 2010] [42]. Barriers and obstacles that impede action must be identified and overcome. This includes power imbalances and conflicts of interest across food systems [HLPE 2017c] [49], as well as the trade-offs needed to align local systems with global priorities for sustainability. Managing the trade-offs calls for enlightened governance and political arbitration.

Specialized industrial agriculture is a model characterized by monocultures, genetically uniform varieties, intensive use of external inputs, maximization of yield from a single or limited number of products, and production of large volumes of homogenous products typically within long value chains.

Agroecology, on the other hand, applies ecological principles to the design and management of agricultural systems. Its practices diversify farms and farming landscapes, increase biodiversity, nurture soil health and soil biodiversity, and stimulate interactions among different species, such that the farm provides for its own soil organic matter, pest regulation and weed control, without resort to external chemical inputs [lim li ching, 2016] [63]. The potential for incremental shifts within predominantly industrial systems is not addressed in detail here. Steps to introduce individual measures such as conservation agriculture, crop rotation or integrated pest management (IPM) are undoubtedly positive. However, if the vast challenges in food systems are to be met, these steps must be reconceived not as an end point, but as the starting point of a process of change [IPES, 2016] [59]. The shift towards industrial agriculture, alongside the advance of globalized food systems more broadly, has altered the fundamental relationship between humans and nature by increasing the physical and cognitive distances between producers, consumers and their environments (Bacon et al., 2012) [6].

Agrarian and food transitions in agricultural sector

One-third of Earth’s land is devoted to agriculture, more than any other industry. Agricultural sector struggles to keep up with a growing global population and the demands of an expanding middle class. Estimates are that we will need to increase food production by 60-70% by 2050; many developing countries may even have to double food production [Alexandratos and Bruinsma, 2012] [2]. In addition agriculture must reduce the pressure placed on the environment, including land degradation, water depletion, pollution, unbalanced nutrient cycles, greenhouse gas emissions, and threats to bio-diversity. Climate variability and climate change are complicating factors that will likely exacerbate food insecurity in areas already suffering from poverty and hunger [World Bank, 2013] [94]. Interpreted agrarian change in a multitude of ways, where the market integration and economic restructuring in the Asian context has been interpreted as disruptive, and sometimes against development [Bello et al. 1998; Bullard et al. 1998; and Davis, 2004] [9, 16, 23]. Recent literature identifies significant interacting agrarian and food transitions within Southeast Asia (Reardon & Timmer, 2012; Reardon et al., 2019; Rigg et al., 2016; Thapa et al., 2010; Wahlqvist et al., 2012) [78, 77, 79, 92, 101] including commodification of food and agriculture, environmental change, socio demographic transition (for example, rural-urban migration), and dietary transition. These transitions and some of their key features are given in Table 1.

<table>
<thead>
<tr>
<th>Food system transitions</th>
<th>Features</th>
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<tbody>
<tr>
<td>Commodification of food and intensification of agriculture</td>
<td>Policy liberalization and privatization has resulted in: land use change (e.g. monocultures), cash cropping in the uplands (e.g. maize production), rising use and cost of inputs, land grabbing, contract farming, increasing farm debt, food insecurities, increasing inefficiency of large agribusiness and vertical integration (e.g. Chaoren Pokphand Foods), intensification leading to overuse of chemical inputs, globalization and regionalization of food trade. Also increase in medium-small enterprises in the food system.</td>
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<tr>
<td>Environmental change</td>
<td>Changing weather patterns, extreme flooding and drought, acidification of soils, rapid deforestation and associated burning (haze) plus loss of biodiversity, water salinity, fluctuating water levels and declining fisheries plus increasing chemical burden. Plus increasing food insecurity.</td>
</tr>
<tr>
<td>Rural livelihoods</td>
<td>Changing socio-demographics of rural livelihoods leading to growing insecurities, rural –urban migration, feminization of agriculture, rising middle classes.</td>
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<tr>
<td>Dietary transition</td>
<td>Increasing consumption of meat and processed foods, increasing incidence of noncommunicable diseases. Higher proportion of non-staples particularly in urban areas (Bennett’s Law).</td>
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<tr>
<td>Structural changes in value chains</td>
<td>Contract farming, elongation of supply chains, increased competition, declining farmers share of total value, increasing role of technologies, processing and transport plus increasing public and private standards, land grabbing.</td>
</tr>
<tr>
<td>Infrastructure changes</td>
<td>Dams and hydroelectric power along key waterways, major road construction.</td>
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These transitions are leading to an emerging regional food system that is more interlinked and interdependent, but that is also creating new fault lines of risk and potential vulnerabilities. It is a food system that is overwhelmingly a product of policies, and strategies that are market based, and that are underpinned by a discourse of progress and positive change [Rigg et al. 2016] [79]. Friedmann & McMichael [1989] revealed that the concept of ‘food regime’ has been associated with specific periods of hegemony and dominant transitions in capitalist history, where food was incorporated into consumption relations as industrial food system categorised diets with value-added foods, fast foods etc. [Friedmann, 1992] [41]. Araghi [2003] [5] revealed that food regime as a political regime of global value relations, where food is intrinsic to capital’s global value relations. Under the fist food regime, which was characterised by the British domination, firms and states reduced the cost of labour through mass production of staple food and key food commodities.

Maximizing agriculture’s potential to reduce rural poverty is another challenge, particularly in South Asia and Sub-Saharan Africa. Farm sizes are shrinking as populations grow, and inequalities in land tenure and access to resources are pervasive. Efforts to increase farm productivity, improve access to markets, and subsidize inputs may even contribute to inequalities by favouring farmers with greater access to resources and capital. Reducing rural poverty requires long-term agricultural and economic growth that prioritizes the needs of the poor [GSDR, 2015] [44]. Societies must leverage agriculture to meet health and nutrition goals [FAO, 2013]. Lomax [2018] [64] reported that the SFS Framework supports countries to effectively assess their current food systems, identify gaps, and improve food systems governance. This will enhance their capacity to meet resilient and sustainable food systems, besides a number of Sustainable Development Goals (SDGs) Fig.1.

[Source: Lomax, 2018] [64].

Fig 1: Sustainable food systems transformative framework
The benefits of a food systems approach:

- Enhanced capacity of the actors to deal with food system’s complexity;
- Enhanced evaluation of trade-offs in policy options, as drivers and outcomes will be taken into account and in a more holistic way;
- Better coordination of policy actions, institutional frameworks, and actors, enhancing overall food system’s governance;
- Reveal root causes of unsustainable production and consumption patterns;
- Support to resource efficiency of natural resources use, lower environmental impacts, while at the same improving the societal outcomes (such as human health and rural livelihoods) Lomax [2018][64];

Rethinking of smallholder agriculture towards the transformation of agricultural and food systems

An additional 10-15 million young people look for jobs in rural areas every year. They could ignite the structural transformation presented above for a lasting and sustainable growth in productivity. Smallholder farms are a crucial part of national food systems and economies, and will play a large role in the sustainable food systems of the future. However, unlike farmers with large holdings, smallholders may lack capital and other resources, legal rights and tenure, access to markets, and access to agricultural extension services [IFAD, 2011] [53]. Female smallholder farmers face even greater barriers to success, despite the fact that they comprise half of smallholder farmers in East and Southeast Asia and Sub-Saharan Africa. Fortunately, with access to the same inputs, women often produce yields 20-30 percent greater than men [FAO, 2012]. Empowering and encouraging women is not an opportunity we can afford to miss. Other shifts can improve productivity, profitability, and sustainability. Increasing the share of rural household income that comes from non-farm sources acts as an insurance policy against environmental and economic shocks by spreading risk and reducing reliance on agriculture, ultimately reducing poverty and increasing food security. One example is small-scale, rural food processing plants, which could also help reduce food loss and increase food quality, for both safety and nutrition [GSDR, 2015][44]. Food systems approach, we have been able to identify some of the key drivers of these transitions at different scales, key stresses and shocks, and some of the outcomes for the food system (Ingram, 2011)[54]. However, the paper clearly shows that food systems alone do not capture the complexity of the changes particularly with regard to the experiences of small-scale farmers. Also, the agrarian change literature by Cramb et al. (2015) [22] fails to uncover the complexity of the pressures on small-scale farmers.

The small-scale farmers in the rural society often fail to capture the complexity and diversity of household livelihood strategies. While small-scale farmers persist in numbers, their ability to shape decisions about how the farm has long been undermined by unequal power relations with increasingly influential national and regional food system actors [Rigg et al. 2016][79]. To tackle the aforementioned transitions equitably and sustainably, Wahlqvist et al. [2012] [101] repeal for a wider notion of food security to broaden its concept to include issues such as health, impacts of migration and more resilient environmental approach and improved governance.

Assessing the full implications of changes for rural communities and, in particular, smallholder agriculture, requires an analysis of how risks and rewards are distributed both in traditional food systems and modern ones. As production and marketing change, there are obvious implications for smallholder farmers via changes in production costs, output prices and marketing costs. But changes in processing, transport, input distribution and food retail also impact rural households via household incomes (e.g. labour markets, small enterprises) and expenditures (e.g. food prices).

Investments in rural infrastructure, especially roads, electrification, and telecommunications are essential to increase access to markets, reduce food loss, and improve storage and handling. Good governance is key to ensuring fair access to resources, markets, and new technologies. Strengthening farmers’ entrepreneurial and management skills will increase farm value and reduce threats to productivity and profitability [GSDR, 2015][44].

Major elements of sustainable agriculture and food systems

A new global framework for the sustainable development of agriculture and food systems is essential to increase food availability and utilization, improve human health, create more prosperous rural communities, and rejuvenate the environment. Solutions must address population growth, food consumption, food production, and food loss. One significant element is shifting toward healthier diets and reducing food waste and loss. In rich and poor countries consumption of energy-dense, processed and refined foods is rising, with negative impacts on both health and resource use. Dietary behaviors need to change to be healthier and more sustainable, while respecting cultural differences. As much as one-third of all food grown may be lost or wasted from farm to fork [FAO, 2011a]. Today it is unclear how much can realistically be improved, and we do not know whether “recovered” food would reach those in need. Investments in research are urgently needed to guide future action.

Sustainable Intensification of Agriculture (SIA) aims to reduce the environmental footprint of agriculture while meeting all its other social and economic goals. This means higher yields of nutritious food on existing farmland rather than farmland expansion; ensuring food is accessible to all; preventing damage to natural resources and biodiversity; respecting and protecting the health and wellbeing of people, animals, and the environment; and maintaining these principles now and in the future. It requires tailored strategies and solutions at the national level in Fig 2. SIA is a core requirement of "climate-smart agriculture", which unites the goals of the agriculture, development, and climate communities [FAO, 2013a]. The practical implications of climate-smart agriculture are still being debated, as difficult trade-offs undoubtedly exist between activities to intensify agricultural production, mitigate risks, and adapt to climate induced shocks. “Food systems gathers all the elements (Environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes” in fig 3.
Food system losses were considered in six categories, as follows:

**Agricultural production:** losses that occur in the production process. The losses include agricultural residues (e.g., roots and straw), unharvested crops, and the losses during harvest.

**Livestock production:** losses and inefficiencies in the conversion of feed and grass into animal products.

**Handling, storage and transportation:** losses due to spillage and degradation during storage and distribution. These losses occur for primary crops, processed commodities, and animal products.

**Processing:** losses during the processing of commodities.

**Consumer waste:** losses and waste between food reaching the consumer and being eaten.

**Over-consumption:** the additional food intake over that required for human nutrition (Blair and Sobal, 2006) [12].

FOA [2014] identified seven critical factors of success and challenges in making ICTs available and accessible for farmers and rural communities:

- **Content** (adaptation of content to farmers’ needs in terms of format and relevance);
- **Capacity development** (ability to effectively use technologies and information at individual, organizational, and institutional levels);
- **Gender and diversity** (difficult and limited access for women, older, and poor farmers, and people living in remote areas);
- **Access and participation** (gender-based and rural-urban digital divides persist);
- **Partnerships** (few and mostly ineffective public-private partnerships);
- **Technologies** (challenge of identifying the right technologies mix that is suitable to local contexts);
- **Economic, social and environmental sustainability** (difficult scaling up of pilot ICT projects and initiatives).

**Diverse pathways to sustainable development**

Transformative changes are needed in all countries, but the priorities and timing of implementation will differ according to local contexts. Simplistic, universal prescriptions or recommendations will not work; instead, successful models are flexible and built on local knowledge. However, the principles of SIA can be applied to any food production system, including farms of different sizes and degrees of market integration, and will particularly benefit resource limited, smallholder farms. Collaboration will be critical for success. We need to provide farmers, agricultural professionals, agribusinesses, scientists, and local policy makers with the necessary information, resources, tools, and recognition, as well as the space to meaningfully cooperate (GSDR, 2015) [44]. Reardon et al. (2019) [77] for the need for more work on the food system activities beyond the farm gate. Both consumer behaviour and production practices play crucial roles in the efficiency of the food system. The substantial losses occurring during livestock production, and consequently changes in the levels of meat, dairy and egg consumption can substantially affect the overall efficiency of the food system, and associated environmental impacts (e.g., greenhouse gas emissions) (Lamb et al., 2016) [62]. Verdouw et al. [2016] [100] argue that food system sustainability can be dramatically enhanced through the revolutionary potential of the Internet of Things (IoT) perspective that can allow visualizing, monitoring, controlling and, thus, optimizing food chain processes by self-adaptive, autonomous and smart ICT systems. Furthermore, internet technologies and ICTs contributed to the development of new agri-food chain concepts (e.g., food webs, urban agriculture) in which regional producers and consumers are connected [Wolfert et al., 2014] [103]. In fact, ICTs have played an important role in improving communication and coordination between the different parts of short supply chains, especially producers and consumers [Berti and Mulligan, 2015] [106]. Despite their well-documented positive implications in terms of food chain sustainability, the use of ICT can also bring about some negative impacts (Table 2).
Table 2: Impacts of ICT use on agro-food chain sustainability [Source: Bilali and Allahyari, 2018][11].

<table>
<thead>
<tr>
<th>Sustainability dimension</th>
<th>Expected positive impacts</th>
<th>Potential negative</th>
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<tbody>
<tr>
<td>Environmental</td>
<td>Increasing efficiency of the use of resources (water, land, energy) and inputs (fertilizers, pesticides)</td>
<td>Generating e-waste and disposal of ICT equipment in rural areas.</td>
</tr>
<tr>
<td></td>
<td>Reducing footprint and negative environmental externalities of agriculture and agro-food processing (e.g. water pollution)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreasing contribution of agricultural sector to greenhouse gas emissions Reducing of food losses and waste.</td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td>Reducing production, transport and distribution costs Increasing productivity and profitability</td>
<td>Initial increase of production costs because of investment Increasing risk of agro-food market dominance by few multinationals.</td>
</tr>
<tr>
<td></td>
<td>Reducing transaction costs in the food chain Connecting small-scale producers to markets.</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Increasing transparency of food supply chains Making easier access to information by all food chain actors</td>
<td>Disconnecting producers and consumers through virtual relations Increasing dependency on technology Increasing the power of globalisation Risk of increasing exclusion of small-scale and computer illiterate producers</td>
</tr>
<tr>
<td></td>
<td>Improving product traceability / food safety (cf. consumer health) Fostering networking among food chains actors</td>
<td></td>
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<tr>
<td></td>
<td>Empowering small-scale farmers by enhancing their connectivity Improving food practices</td>
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Steps towards sustainable food systems

Given that many industrialized food systems are in countries of the global North, largely propped up by massive agricultural subsidies, these countries have a particular responsibility to embrace such a transition. In addition, rich countries need to reduce their demand for animal products and biofuels, as large areas of farmland in the South are used to cultivate these biofuels or to feed the livestock that will satisfy burgeoning meat consumption. The food systems has brought unprecedented increases in production and wealth, but many concerns have emerged regarding externalities. This has led to questions about the long-term sustainability of current agriculture and food production. They include—firstly—concerns about environmental issues and more specifically to threats regarding species diversity, ecosystem integrity, and ecosystem based services (Conway 1997; Steffen et al. 2015; Maxwell et al. 2016) [21, 88, 66], as well as to related trade-offs (Phalan et al. 2011; Byerlee et al. 2014). Secondly, there are concerns about rural impoverishment, vulnerability, and human rights (Pingali, 1993) which call for attention to dependency on imported food, technologies, or inputs, to health impacts of inappropriate food consumption, and to risks linked to concentration of food processing and of distribution chains (Murphy et al. 2012).

The type of change envisaged would lead to the emergence of what are essentially new food systems with new infrastructures and new sets of power relations. The key is to establish political priorities, namely: to support the emergence of alternative systems that are based around fundamentally different logics centred on agroecology, and which, over time, generate different and more equitable power relations. The 2016 report by IPES-Food gives seven pragmatic recommendations for this shift:

1. Develop new indicators for sustainable food systems;
2. Shift public support towards diversified agroecological production systems;
3. Support short circuits and alternative retail infrastructures;
4. Use public procurement to support local agroecological production;
5. Strengthen movements that unify diverse constituencies around agroecology;
6. Mainstream agroecology and holistic food systems approach into education and research agendas;
7. Develop food planning processes and ‘food policies’ at all levels (Lim Li chang, 2016).

Alexander et al. [2018] reported that the relationship between food system stages and associated losses. It also outlines the estimation method used for each value. Descriptions for each quantity (both total quantities and losses) are detailed below Fig. 4
The food system is strongly related to many sustainability challenges such as climate change, biodiversity loss, water scarcity, and food insecurity [Bruinsma, 2011; FAO, 2014; FAO, 2016; Foley, 2011; IAASTD, 2009; Postel, 2000]. For that, there were many calls for sustainability transitions in food systems [El Bilali, 2018; FAO, 2017; UNEP, 2018]. Sustainability transitions can be defined as “long-term, multidimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption” [Markard et al. 2012]. In agriculture, the notion of sustainability transition applies to a shift from an agri-food system having as a main goal to increase productivity, to one built around the wider principles of sustainable agriculture [Brunori et al., 2013]. According to Spaargaren et al. [2013], food sustainability transitions refer to structural changes that give rise to new production and consumption modes and practices that are more sustainable. Sustainable agri-food system is a knowledge-intensive system that requires a new kind of knowledge. Knowledge and related information, skills, technologies, and attitudes will play a key role in sustainable agriculture [Allahyari, 2009] [4]. It is claimed that moving towards sustainability in agriculture and food systems call for innovative solutions and appropriate technologies such as ICT [Bello and Aderbigbe, 2014; Singh et al. 2014] [8]. ICTs hold the potential to contribute to sustainability transitions due to their disruptive potential [Berti and Mulligan, 2015] [10]. ICTs are increasingly used in modern agri-food sector [Berti and Mulligan, 2015] [10] and they have also been put forward as a means to enhance agrifood systems sustainability and to achieve food security. Svenfelt and Zapico [2016] reviewed the potential of ICT solutions for improved sustainability of agri-food systems by increasing efficiency, enhancing transparency and traceability, creating network between food chains actors, and improving food practices. The same authors argue that the way ICT is used in the solutions to improve sustainability in the food chain can be related to the Visible-Actionable-Sustainable ideas of Bonanni et al. [2010]; ICTs make the food system and its impacts ‘visible’, to render it ‘actionable’ (cf. optimization, decision-making, etc.) for making it more sustainable. ICTs have contributed to the emergence of many alternative food networks (e.g. farmers’ markets, community supported agriculture) and short supply chains [Berti and Mulligan, 2015] [10]. The internet is being used, among others, for creating knowledge networks between producers and for re-connecting farmers with consumers. This connecting of different food system actors can provide opportunities for increasing sustainability [Townsend, 2015; O’Hara and Stagl, 2001]. Although the main feature of farmers’ markets is face-to-face contact, ICT can be used to establish and empower trust relationships between producers and consumers in farmers’ market [Svenfelt and Carlsson-Kanyama, 2010]. Food security in a broad sense is becoming a worry of the future for those who understand the limitations of our earth's ecosystems. Malthusian prophecies have so far been wrong, but there is growing concern that we are rapidly reaching the point where feeding the world’s growing and richer population will be at the cost to our environment that is unacceptable. In the next few decades we face the challenge of growing more food, with less water, with less fertilizer on less land - because of the growth of urban areas on prime agriculture land. We also face the largely unknown consequences that global warming will have on agricultural production. During the last century agricultural scientists were able to bring cutting-edge science into traditional agricultural practices and increase food production sufficiently to prevent global food shortages. The hope that new scientific discoveries will provide the means to keep ahead of world food demand is complicated by a growing public discomfort with biotechnology being applied to food production [Van alfen, 2014]. The contribution of food systems to the SDGs, we need (a) to be able to describe their characteristics with a common language and (b) to measure systems performance in relation to the SDGs. There is still much to be done on how to measure performance: this need is leading numerous authors to propose new methods and indices. The explosion of indices is unsurprising because of the wide range of issues involved. Many countries are already implementing multi-dimensional poverty measures [Alkire and Robles 2016]. The International Food Policy Research Institute (IFPRI) has proposed a Food Security Index (http://ghi.ifpri.org/) to serve as a dashboard.
More recently, FAO has developed the Food Insecurity Experience Scale: this has been adopted in the SDG indicator framework [FAO 2016b]. First, it takes interactions between food and nutrition security, environmental health, climate, and social justice into account. Second, it focuses on ways in which the nexus is influenced by changes in food systems.

We believe that the framework can help with identifying potential indicators and developing them. The combination of framework and indicators should encourage the production of evidence that can support policy decisions and action in different contexts. The framework is described in Fig. 5.

![Fig 5: Assessing the food systems transformation capacity to address the Agenda 2030 through the agriculture–food and nutrition security–environment health–climate–social justice nexus. Suggests a general framework for food systems transformation by highlighting the four parts, each of which can be characterized with specific variables. These can be used to design relevant indicators for assessing the impact of system transformation [Source: Caron et al. 2018].](image)

Firstly, agriculture and fisheries are the primary means of income for most of the world’s poor and vulnerable people [IBRD/World Bank (The International Bank for Reconstruction and Development/World Bank), 2007] [52]. Secondly, food and nutrition insecurity, as well as rural poverty, are root causes of political instability, conflict, violence, and migration [FAO 2016b]. Indeed, the HLPE [HLPE 2017a] [49] reports that “unequal access to food is... a driver of many other inequalities and instability... and (leads to) to low levels of investment in the provision of public goods and services.” Thirdly, agricultural practices are highly connected to environmental health, management of natural resources, and climate change [Smith, 2013] [84-85]. Fourthly, the crop, livestock, and fish sectors are resource intensive. They use 70% of freshwater resources [Kabat, 2013] and are responsible for around 30% of total energy demand [FAO 2011b]. Fifthly, agriculture is at least twice more effective than any other sector in reducing poverty [IBRD/World Bank 2007] [52] and will continue to play a pivotal role in efforts to reduce extreme poverty [Christiaensen et al. 2011].

Conclusion

Food systems need a radical transformation to become sustainable. Sustainable food systems may contribute to four outcomes: (i) enabling all people to eat nutritious and healthy diets, (ii) regenerating ecosystems, (iii) mitigating climate change, and (iv) encouraging social justice through focusing on the resilience and well-being of poorer rural communities. There are economic and political interests which will influence the realization of these outcomes: transformation efforts will be contested and need strong political support, including from within urban areas, if they are to succeed. The food systems transformation depends on enlightened policies, well-adapted processes, local to global integration, and value systems based on justice and human rights principles for arbitrating trade-offs. New ICT technologies and services help food operators deliver greater efficiency in resource use. Therefore, digital technologies hold potential of reducing inefficiencies within food supply chains. They are also critical in helping to bring about the changes in food consumption patterns and practices needed to move towards sustainability in the food chain. ICTs can contribute to this food sustainability transition by providing new ways of visualizing and measuring impacts, communicating necessary changes and connecting food chain actors. In order to maximize the benefits of ICTs in food chains, also in developing countries, it is necessary to develop applications and services that are user-friendly, relevant, localized and affordable. The above examples provide preliminary evidence that a comprehensive application through the entire value chain can enhance potential development of sustainable agricultural and food systems. The SDGs will simply not be achieved without rural prosperity. The interdependence of rural and urban areas should be recognized and form the basis of a new rural–urban social contract. Therefore the need to unpack small-scale farmer pluriactivity and the precarity of rural livelihoods faced with the volatility of global markets and environmental change.

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