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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 apace 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 intriguing 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 [FA0, 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, 96], 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, 56, 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] [12, 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' (Ericksen, 2008; Kneen, 1993; Sobal *et al*., 1998; Tendall *et al*., 2015) [25, 61, 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 [Ericksen, 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 [Ericksen, 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 [Ericksen, 2008] [25], which may lead to unintended consequences [Ingram, 2011] [54]. The food system is thus defied by its dynamic properties, which involve information flws 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 approaches to food system studies are needed with more empirical data (quantitative and qualitative).

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 reorganisation 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 [81]]. 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] [55]. 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].

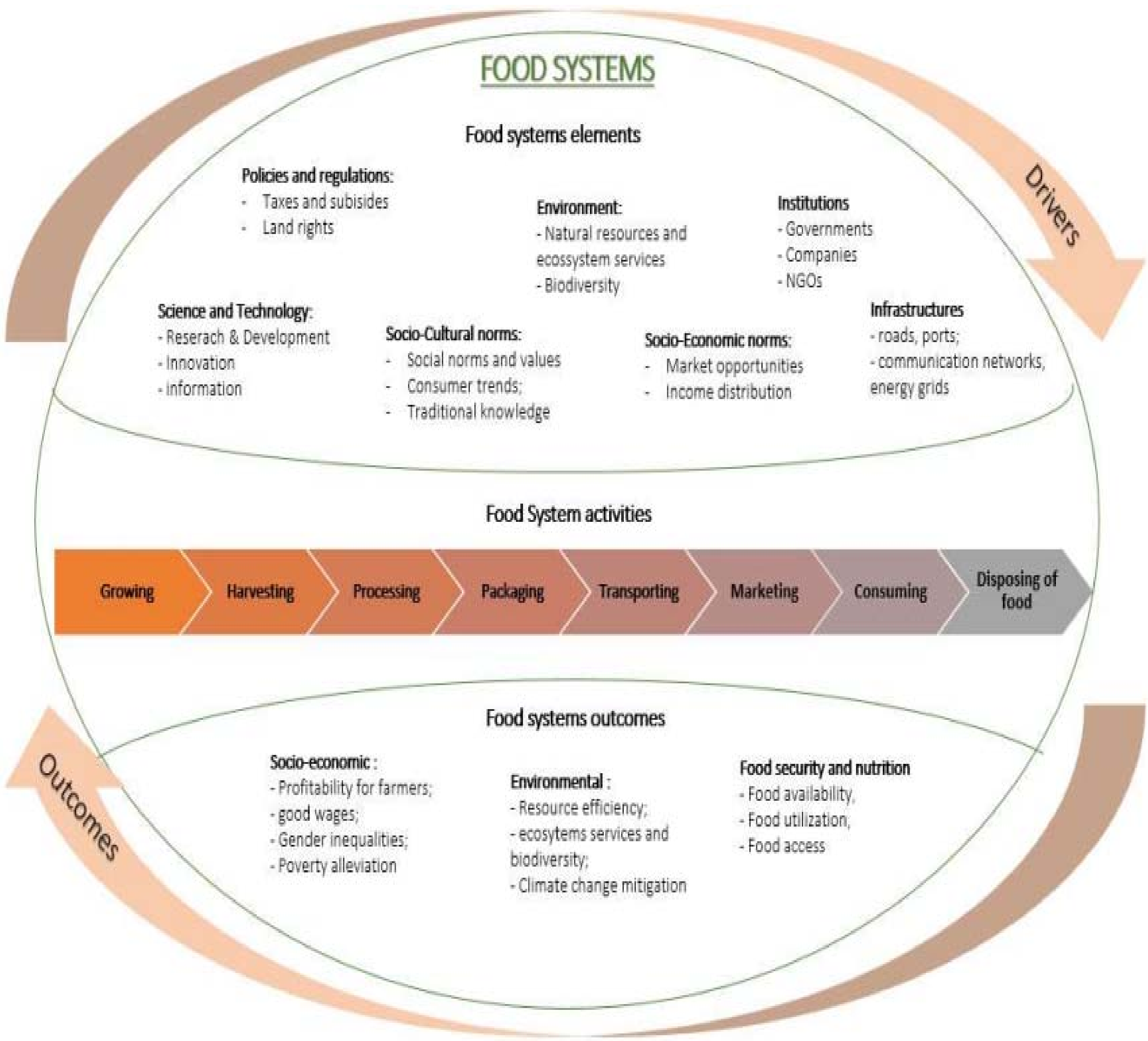
Interpreted agrarian change in a multitude of ways, where the market integration and economic restructuring in the Asian context has been interpreted as disruptive, and sometimes against development [Bello *et al*. 1998; Bullard *et al*. 1998; and Davis, 2004] [9, 16, 23]. Recent literature identifies 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 1: Agrarian & food transitions

Food system transitions	Features
Commodification of food and intensification of agriculture	Policy liberalization and privatisation 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 inflence of large agribusiness and vertical integration (e.g. Charoen Pokphand Foods), intensification leading to overuse of chemical inputs, globalisation and regionalization of food trade. Also increase in medium-small enterprises in the food system
Environmental change	Changing weather patterns, extreme floding and drought, acidifiation of soils, rapid deforestation and associated burning (haze) plus loss of biodiversity, water salinity, fluctuating water levels and declining fiheries plus increasing chemical burden. Plus increasing food insecurity.
Rural livelihoods	Changing socio-demographics of rural livelihoods leading to growing insecurities, rural –urban migration, feminization of agriculture, rising middle classes.
Dietary transition	Increasing consumption of meat and processed foods, increasing incidence of noncommunicable diseases. Higher proportion of non-staples particularly in urban areas (Bennett's Law)
Structural changes in value chains	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
Infrastructure changes	Dams and hydroelectric power along key waterways, major road construction

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 inflential 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, develop-ment, 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.

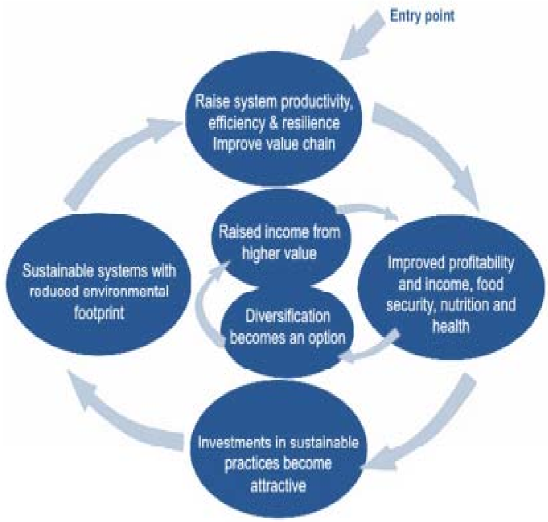


Fig 2: Enhancing system productivity and value is the entry point for enabling farmers to enter a virtuous circle of sustainable agricultural production and livelihood [Source: GSDR, 2015] [44].

Fig 3: Characteristics of a food systems approach to decision making [Lomax, 2018] [64].

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].

FAO [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 reveals the magnitude of losses from consumption of food in excess of human nutritional requirements. The greatest rates of loss were associated with 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] [10]. 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].

Sustainability dimension	Expected positive impacts	Potential negative
Environmental	Increasing efficiency of the use of resources (water, land, energy) and inputs (fertilizers, pesticides) Reducing footprint and negative environmental externalities of agriculture and agro-food processing (e.g. water pollution) Decreasing contribution of agricultural sector to greenhouse gas emissions Reducing of food losses and waste.	Generating e-waste and disposal of ICT equipment in rural areas.
Economic	Reducing production, transport and distribution costs Increasing productivity and profitability Reducing transaction costs in the food chain Connecting small-scale producers to markets.	Initial increase of production costs because of investment Increasing risk of agro-food market dominance by few multinationals.
Social	Increasing transparency of food supply chains Making easier access to information by all food chain actors Improving product traceability / food safety (cf. consumer health) Fostering networking among food chains actors Empowering small-scale farmers by enhancing their connectivity Improving food practices	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

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

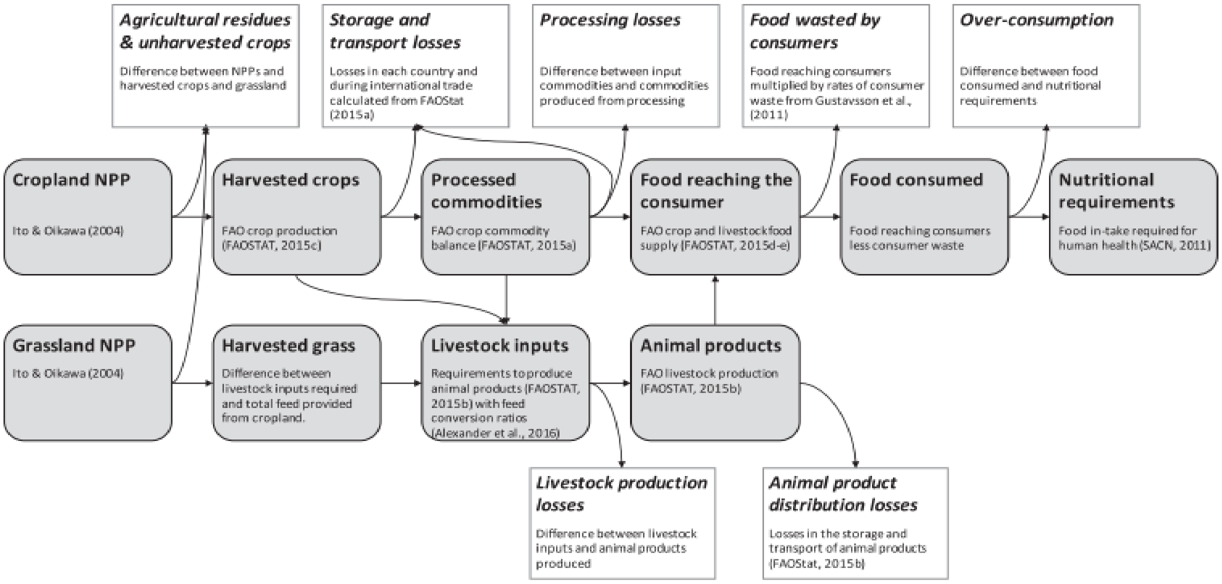


Fig 4: Food system stages associated losses, and summary of approaches used to estimate each quantity [Source: Alexander *et al.* 2018].

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 in agriculture 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.

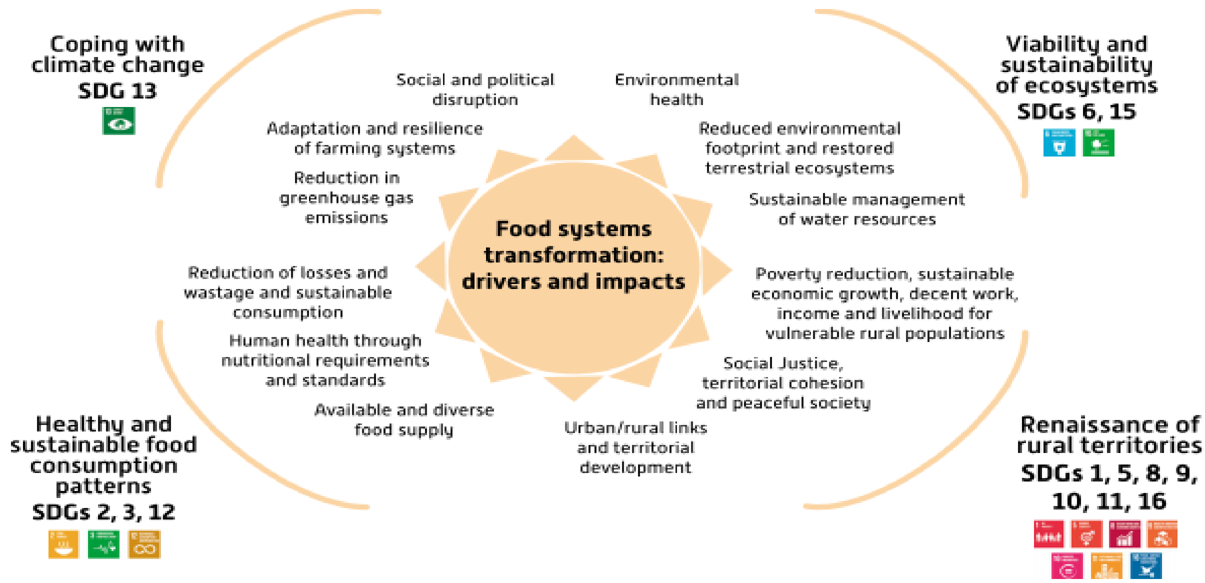


Fig 5: Assessing the food systems transformation capacity to address the Agenda 2030 through the agriculture–food and nutrition security–environment health–climate–social justice nexus. Suggests a general framework for food systems transformation by highlighting the four parts, each of which can be characterized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

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.

References

1. Alexander P, Brown C, Arneth A, Finnigan J, Moran D, Rounsevell MDA. Losses, inefficiencies and waste in the global food system. Agricultural Systems. 2018; 153:190-200.

2. Alexandratos N, Bruinsma J. World agriculture towards 2030/2050: the, 2012, revision. ESA Working Paper No. 12-03. (FAO, Rome, 2012).
3. Alkire S, Robles G. Global multidimensional poverty index. OPHI Briefing 41, University of Oxford, 2016. http://www.ophi.org.uk/wp-content/uploads/A4_OPHIBrief41_2_online_721.pdf.
4. Allahyari MS. Agricultural sustainability: implications for extension systems. Afr J Agric Res. 2009; 4:781-6.
5. Araghi F. Food regimes and the production of value: some methodological issues. J Peasant Stud. 2003; 30(2):41-70.
6. Bacon CM, Getz C, Kraus S, Montenegro M, Holland K. The social dimensions of sustainability and change in diversifid farming systems. Ecology and Society, 2012, 17.
7. Beddington JR, Asaduzzaman M, Clark ME, Fernández Bremauntz A, Guillou MD, Howlett DJB *et al*. What next for agriculture after Durban? Science. 2012; 335(6066):289-290.
8. Bello O, Aderbigbe F. ICT in agricultural sustainability and food security. Int J Emerg Technol Adv Eng. 2014; 4:508-13.
9. Bello W, Cunningham S, Poh LK. A Siamese tragedy: Development and Disintegration in Modern Thailand. London and New York: ZED Books, 1998.
10. Berti G, Mulligan C. ICT & the future of food and agriculture. Stockholm, 2015.
11. Bilali HE, Allahyari MS. Transition towards sustainability in agriculture and food systems: Role of information and communication technologies. Information Processing in Agriculture. 2018; 5:456-464.
12. Blair D, Sobal J. Luxus consumption: wasting food resources through overeating. Agric. Hum. Values. 2006; 23:63-74.
13. Bonanni L, Hockenberry M, Zwarg D, Csikszentmihalyi C, Small Ishii H. Business applications of sourcemap: a web tool for sustainable design and supply. Chain Transparency, 2010.
14. Bruinsma J. Looking ahead in world food and agriculture: perspectives to 2050. Rome: FAO, 2011. http://doi.org/I2280E/1/06.11.
15. Brunori G, Barjolle D, Dockes AC, Helmle S, Ingram J, Klerkx L *et al*. CAP reform and innovation: the role of learning and innovation networks. Euro Choices, 2013. https://doi.org/10.1111/1746-692X.12025.
16. Bullard N, Bello W, Malhotra K. Taming the tigers: the IMF and the Asian crisis. Third World Q. 1998; 19(3):505-556.
17. Byerlee D, Stevenson J, Villoria N. Does intensification slow crop land expansion or encourage deforestation? Global Food Security. 2014; 3(2):92-98.
18. Caron P, Loma-Osorio GF, Nabarro D, Hainzelin E, Guillou M, Andersen I *et al*. Food systems for sustainable development: proposals for a profound four-part transformation. Review article. Agronomy for Sustainable Development. 2018; 38:41.
19. Cassman KG. Ecological intensi fication of cereal production systems: yield potential, soil quality, and precision agriculture. Proc. Natl. Acad. Sci. U. S. A. 1999; 96:5952-5959.
20. Christiaensen L, Demery L, Kuhl J. The (evolving) role of agriculture in poverty reduction—an empirical perspective. J Dev Econ. 2011; 96:239-254.
21. Conway G. The doubly green revolution. Penguin Books, London, 1997.
22. Cramb RA, Gray GD, Gummert M, *et al*. Trajectories of Rice-Based Farming Systems in Mainland Southeast Asia. Australian Centre for International Agricultural Research, 2015.
23. Davis M. Planet of slums. Urban involution and the informal proletarian. New Left Review. 2004; 26:5-34.
24. El Bilali H. Relation between innovation and sustainability in the agro-food system. Ital J Food Sci. 2018; 30:200-25.
25. Ericksen PJ. Conceptualizing food systems for global environmental change research. Glob Environ Change. 2008; 18(1):234-245.
26. Eshel G, Martin PA. Diet, energy, and global warming. Earth Interact. 2006; 10:1-17.
27. FAO. Voices of the hungry, 2016c. http://www.fao.org/in-action/voicesof-the hungry/en/#.V_PZM_l96Uk Assessed 9 November 2017
28. FAO. The State of Food Security and Nutrition in the World. FAO Rome, 2018. http://www.fao.org/state-of-food-security-nutrition/en/
29. FAO. Global food losses and food waste. Extent, causes and prevention. (FAO, Rome, 2011).
30. FAO. Energy-smart food for people and climate. Issue Paper, 2011b. http://www.fao.org/docrep/014/i2454e/i2454e00.pdf.
31. FAO. Building a common vision for sustainable food and agriculture – principles and approaches. Rome, 2014.
32. FAO. The state of food and agriculture – climate change, agriculture and food security. Rome, 2016a.
33. FAO. Peace and food security. FAO, 2016b.
34. FAO. Strategic work of FAO for sustainable food and agriculture. Rome, 2017.
35. FAO. Climate-smart agriculture sourcebook. FAO, Rome, 2013a.
36. FAO. Smallholders and family farmers. FAO, Rome, 2012.
37. FAO. The state of food and agriculture, 2013. (Food and Agriculture Organization of the United Nations, Rome, 2013).
38. Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, *et al*. Solutions for a cultivated planet. Nature, 2011, 478.
39. Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, Mueller ND *et al*. Solutions for a cultivated planet. Nature. 2011; 478:337-342.
40. Friedmann H, McMichael P. Agriculture and the state system: The rise and decline of national agricultures, 1870 to the present. Sociol Ruralis. 1989; 29(2):93-117.
41. Friedmann H. Distance and Durability: Shaky Foundations of the World Food Economy. Third World Q. 1992; 13(2):371-83.
42. Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D *et al*. Food security: the challenge of feeding 9 billion people. 327. Science, 2010, pp. 812-818.
43. Gregory PJ, Ingram JSI, Brklacich M. Climate change and food security. Philos Trans R Soc Lond B Biol Sci. 2005; 360(1463):2139-2148.
44. GSDR. Transformative changes of agriculture and food systems. By the Thematic Group on Sustainable Agriculture and Food Systems, 2015.
45. Hall KD, Guo J, Dore M, Chow CC. The progressive increase of food waste in America and its environmental impact. PLoS One. 2009; 4:9-14.

46. Hart AK, McMichael P, Milder JC, *et al*. Multi-functional landscapes from the grassroots? The role of rural producer movements. Agric Hum Values. 2016; 33(2):305-322.
47. High Level Expert Forum. How to Feed the World in 2050? Office of the Director, Agricultural Development Economics Division. Economic and Social Development Department. FAO, Rome, 2009.
48. HLPE. Price volatility and food security. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome, 2011.
49. HLPE. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome, 2017b, 152.
50. Horton P, Banwart SA, Brockington D, *et al*. An agenda for integrated system wide interdisciplinary agri-food research. Food Security. 2017; 9(2):195-210.
51. IAASTD. Agriculture at a crossroads. International assessment of agricultural knowledge, science and technology for development. Global report. Washington, DC, 2009.
52. IBRD/World Bank. (The International Bank for Reconstruction and Development/World Bank) (2007) World development report, Agriculture for Development, 2008.
53. IFAD. Rural poverty report. (IFAD, Rome, 2011).
54. Ingram J. A food systems approach to researching food security and its interactions with global environmental change. Food Secur. 2011; 3(4):417-431.
55. IPES-Food. From uniformity to diversity: a paradigm shift from industrial agriculture to diversifid agroecological systems. International Panel of Experts on Sustainable Food systems, 2016.
56. Johnson JA, Runge CF, Senauer B, Foley J, Polasky S. Global agriculture and carbon trade-offs. United States of America] –>Proc. Natl. Acad. Sci. U. S. A. 2014; 111:12342-12347.
57. Kabat P. Water at a crossroads. Nat Clim Chang. 2013; 3:11-12.
58. Kearney J. Food consumption trends and drivers. London Series B, Biological sciences] –>Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 2010; 365:2793-2807.
59. Kesavan PC, Swaminathan MS. Modern technologies for sustainable food and nutrition security. Current Science. 2018; 115:1876-1883.
60. Keyzer MA, Merbis MD, Pavel IFPW, van Wesenbeeck CFA. Diet shifts towards meat and the effects on cereal use: can we feed the animals in 2030? Ecol. Econ. 2005; 55:187-202.
61. Kneen B. From Land to Mouth. Toronto: NC Press, 1993.
62. Lamb A, Green R, Bateman I, Broadmeadow M, Bruce T, Burney J, Carey P *et al*. The potential for land sparing to offset greenhouse gas emissions from agriculture. Nat. Clim. Chang, 2016.
63. Lim Li Ching. Towards the transformation of our agricultural and food systems. End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Third World Network, 2016.
64. Lomax J. Sustainable Food Systems Transformative Framework. UN. Environment, 2018.
65. Markard J, Raven R, Truffer B. Sustainability transitions: an emerging field of research and its prospects. Res Pol. 2012; 41:955-67. https://doi.org/10.1016/j.respol.2012.02.013.
66. Maxwell SL, Fuller RA, Brooks TM, Watson JEM. Biodiversity: the ravages of guns, nets and bulldozers. Nature. 2016; 536:143-145.
67. Muller A, Schmidhuber J, Hoogeveen J, Steduto P. Some insights in the effect of growing bio-energy demand on global food security and natural resources. Water Policy. 2008; 10:83-94.
68. Muller C, Robertson RD. Projecting future crop productivity for global economic modeling. Agric. Econ. 2014; 45:37-50.
69. Murphy S, Burch D, Clapp J. Cereal secrets: the world’s largest grain traders and global agriculture. Oxfam Research Reports, 2012.
70. Nelson GC, Valin H, Sands RD, Havlík P, Ahammad H, Deryng D, Elliott J *et al*. Climate change effects on agriculture: economic responses to biophysical shocks. United States of America] –>Proc. Natl. Acad. Sci. U. S. A. 2014; 111:3274-3279.
71. O’Hara SU, Stagl S. Global food markets and their local alternatives: a socio-ecological economic perspective. Popul Environ, 2001. https://doi.org/10.1023/A:1010795305097.
72. Phalan B, Onial M, Balmford A, Green RE. Reconciling food production and biodiversity conservation: land sharing and land sparing compared. Science. 2011; 333(6047):1289-1291.
73. Pingali PL. Green revolution: impacts, limits, and the path ahead. PNAS. 1993; 109(31):12302-12308.
74. Pinstrup-Andersen P, Watson DD. Food Policy for Developing Countries. Ithaca, NY: Cornell University Press, 2011.
75. Postel SL. Entering an era of water scarcity: the challenges ahead. Ecol Appl, 2000. https://doi.org/10.1890/1051-0761010[0941:EAEOWS]2.0.CO;2.
76. Reardon T, Codron JM, Busch L, Bingen J, Harris C. Global change in agrifood grades and standards: agribusiness strategic responses in developing countries. Int Food Agribusiness Manag Rev, 1999, 2(3).
77. Reardon T, Echeverria R, Berdegue J, *et al*. Rapid transformation of food systems in developing regions: highlighting the role of agricultural research & innovations. Agricultural Systems. 2019; 172:47-59.
78. Reardon T, Timmer CP. The economics of the food system revolution. Annu Rev Resour Economics. 2012; 4:225-264.
79. Rigg J, Salamanca A, Thompson EC. The puzzle of East and Southeast Asia’s persistent smallholder. J Rural Stud. 2016; 43:118-33.
80. Rotz S, Fraser ED. Resilience and the industrial food system: Analyzing the impacts of agricultural industrialization on food system vulnerability. Journal of Environmental Studies and Sciences. 2015; 5(3):459-473.
81. Shutter D, Oliver. Agroecology and the right to food, 2010.
82. Singh M, Marchis A, Capri E. Greening, new frontiers for research and employment in the agro-food sector. Sci Total Environ. 2014; 472:437-43.
83. Smil V. Improving efficiency and reducing waste in our food system. Environ. Sci. 2004; 1:17-26.
84. Smith P. Delivering food security without increasing pressure on land. Global Food Security. 2013; 2(1):18-23.

85. Smith P, Haberl H, Popp A, Erb KH, Lauk C, Harper R *et al*. How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals? Glob. Chang. Biol. 2013; 19:2285-2302.
86. Sobal J, Khan LK, Bisogni C. A conceptual model of the food and nutrition system. Soc Sci Med. 1998; 47(7):853-863.
87. Spaargaren G, Oosterveer P, Loeber A. Sustainability transitions in food consumption, retail and production. Food practices in transition: changing food consumption, retail and production in the age of reflexive modernity, New York: Routledge, 2013, p. 1-30.
88. Steffen W, Richardson K, Rockström J, Cornell SE, Fetzer I, Bennett EM *et al*. Planetary boundaries: guiding human development on a changing planet. Science, 2015, 347(6223).
89. Svenfelt A, Carlsson-Kanyama A. Farmers' markets – linking food consumption and the ecology of food production? Local Environ. 2010; 15:453-65.
90. Svenfelt A, Zapico JL. Sustainable food systems with ICT? In: Proceedings of the 4th International Conference on ICT for Sustainability (ICT4S 2016); Aug. 29-Sep. 1, 2016-Amsterdam, 2016, p. 194-201.
91. Tendall DM, Joerin J, Kopainsky B, *et al*. Food system resilience: defiing the concept. Global Food Secur. 2015; 6:17-23.
92. Thapa GB, Viswanathan PK, Routray JK, *et al*. Understanding the next agricultural transition in Asia: a critical review of major facets and future challenges. Millenial Asia. 2010; 1(2):215-239.
93. The Economics of Ecosystems and Biodiversity. TEEB for Agriculture & Food: Scientific and Economic Foundations United Nations Environment, Geneva, 2018. http://teebweb.org/agrifood/scientific-and-economic-foundations-report/
94. The World Bank. Turn down the heat: climate extremes, regional impacts, and the case for resilience. A report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. (World Bank, Washington, DC, 2013).
95. Tilman D, Clark M. Global diets link environmental sustainability and human health. Nature. 2014; 515:518-522.
96. Tilman D, Balzer C, Hill J, Befort BL. Global food demand and the sustainable intensi fication of agriculture. United States of America] –>Proc. Natl. Acad. Sci. U. S. A. 2011; 108:20260-20264.
97. Townsend JH. Digital taxonomy for sustainability. Proc EnviroInfo ICT Sustain, 2015¸ 289-99.
98. UNEP. Sustainable food systems programme; http://web.unep.org/10yfp/programmes/sustainable-foodsystems-programme [accessed June 11, 2018], 2018.
99. Van Alfen NK. Encyclopedia of Agriculture and Food Systems, 2014.
100. Verdouw CN, Wolfert J, Beulens AJM, Rialland A. Virtualization of foo d supply chains with the internet of things. J Food Eng. 2016; 1(76):128-36.
101. Wahlqvist ML, McKay J, Chang Y, *et al*. Rethinking the food security debate in Asia: some missing ecological and health dimensions and solutions. Food Secur. 2012; 4(4):657-670.
102. West PC, Gerber JS, Engstrom PM, Mueller ND, Brauman KA, Carlson KM *et al*. Leverage points for improving global food security and the environment. Science. 2014; 345:325-328.
103. Wolfert J, Sørensen CG, Goense D. A future internet collaboration platform for safe and healthy food from farm to fork. In: 2014 annual global conference SRII, San Jose, CA, USA, 2014, p. 266-73.
104. WRAP. Food Futures: From Business as Usual to Business Unusual, 2015.