Networked Society Lab

ERICSSON

ICT & THE FUTURE OF FOOD AND AGRICULTURE

INDUSTRY TRANSFORMATION
– HORIZON SCAN

STRUCTURE OF THIS REPORT SERIES

This report is one in a series of seven investigating industrial transformation in the Networked Society.

The impact of technology on our everyday lives and economic interactions is undeniable. In conjunction with megatrends such as globalization, climate change, urbanization and aging populations, ICT is helping to transform our society and the economic structures that have formed the basis of industries since the industrial revolution.

Digital technologies allow new organizational forms to emerge within and outside of industrial boundaries, thereby challenging our traditional notions of economic organization in markets. Where once size was an important driver of success, now many smaller companies are able to compete both locally and globally. Where firm, strongly defined boundaries and clearly defined economic roles were necessary, now the ability to dynamically participate in a variety of networks is key to a resilient corporate strategy. ICT is transforming the rules of our world's economic value systems, and industries are being transformed as a result.

It is not possible to provide a deep dive into every industry covered within this series. Instead each report investigates the role of ICT in creating productivity improvements and industrial disruption with a view to gaining a broad perspective on the overall transformation the world is undergoing. Six industries are investigated and across them general themes are identified that form the basis of the final report, "Economics of the Networked Society," which outlines some of the broad economic principles that may help us understand the era we are entering.

These reports represent the culmination of several years' work investigating the changing economic structures of the world in the digital age. We hope our small contribution helps to further not just the vision of a Networked Society, but also its implementation – a society where dynamic, digitally enabled strategic networks allow us to build an economically, environmentally and socially sustainable world.

METHOD & SCOPE OF THE REPORT

METHOD

This document is developed using “safe operating boundaries for industrial structures”, a method that combines systems analysis with traditional measurement methods as well as extensive interviews across various parts of an industry’s value chain in order to try and understand the possible emergent characteristics of industrial structures and the role that digital technologies may play in creating innovation, disruptive or otherwise.

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SCOPE

This document forms one in a series of ‘horizon scans’ designed to generate greater understanding about when, where and how digital technologies may have an impact on existing industrial structures. In particular, we focus on disruptive innovation – innovation that may create a restructuring of existing power relations within an industrial structure or innovation that may create entry points for new players to enter the market.

This document outlines the possible roles of ICT within the food and agriculture industries, with a focus on food production and supply chains. Through understanding the thresholds within this industry, several possible ICT interventions are identified that may enable a transition to sustainable food systems.

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EXECUTIVE SUMMARY

Food and Agriculture are two industrial systems that are fundamental to human life. The structured approach to farming and food production that humans have created over centuries is one of the key factors that have defined how human civilization has developed and progressed, reducing the need for people to spend a large majority of their daily lives fulfilling calorie requirements. ICT has played a role, mostly in supply chain management but is increasingly being included in farm management and even into food development itself. Humanity now faces a choice about what sort of food system it will develop and ICT plays a critical role in that decision.

As a result, Food and Agriculture are some of the industries most vulnerable to digital disruption as critical thresholds are being crossed or neared. Two main sets of ICT interventions will become evident:

1. ICT solutions that allow humanity to push past natural boundaries through the:

> Continued streamlining of the traditional industrialized supply chain through the application of sensors and the creation of more integrated business processes.

> Creation of new forms of supply chains that augment food products through data and new technologies.

2. ICT solutions that place control of food growth and production back into local communities through the:

> Creation of reliable, secure, robust and economically sustainable "short" supply chains. These short supply chains allow the re-territorialization of parts of the food system into local areas.

This second group of ICT solutions – effectively implemented – can fundamentally disrupt the industrial structure of several industries simultaneously by redistributing productive elements of the economy across regions, nations and even the globe.

This report outlines both of these types of technologies and how they will become increasingly integrated into the overall food system.

1. INTRODUCTION

> "The world is in transition from an era of food abundance to one of scarcity. Over the last decade, world grain reserves have fallen by one third. World food prices have more than doubled, triggering a worldwide land rush and ushering in a new geopolitics of food. Food is the new oil. Land is the new gold."
>
> **Lester Brown, Full Planet Empty Plates: the New Geopolitics of Food Scarcity, 2012**

Food and agriculture are cornerstones of human civilization. Over several thousand years, many human civilizations have adapted their social structures to reflect the need for cultivation of crops for food sources. Increases in population have been met with adaptions to farming practices that increased crop yields. Currently, however, the world faces increasing populations, limited crop yields and large amounts of waste both within the food supply chain and by consumers in western economies. Previous solutions to these issues involved increasing agricultural productivity. Over time, however, the approach has led to an extension of monocultures, a significant loss of agro-biodiversity and accelerated soil erosion. Overuse of chemical fertilizers has polluted fresh water, increasing its phosphorus content and leading to a flow of phosphorus to the oceans that is estimated to have risen to approximately 10 million metric tons annually. These human interventions in the natural environment are creating and combining with the complex interactions of climate change and seriously constrain the potential productivity of current agricultural methods.[1, 2]

By 2050 the world's population will reach 9.1 billion – with an estimated requirement to increase food production by 70% globally to feed an additional 2.3 billion people.[3] Environmental pressures on farming are three-fold: Firstly, monoculture farming reduces ecological diversity; secondly, depletion of fossil hydrocarbons will increase the demand for biofuels and industrial materials, which can create a competition between food and biomass; finally, as natural resources are being depleted, climate change is of increasing importance. In contrast with previous generations, merely increasing production of existing crops alone is unlikely sufficient to achieve overall food security.

The global food industry has until recently been extremely focused on the supply side of food – ensuring that sufficient quantity is produced and delivered to various regions of the world: i.e. the availability of food.

[1] http://www.theguardian.com/environment/2014/mar/31/climate-change-food-supply-un

[2] Report of the Special Rapporteur on the right to food, Olivier De Schutter (24 January 2014).

[3] Department of Economic and Social Affairs of the United Nations Secretariat (UN/DESA).

1. INTRODUCTION

At the same time, concerns about "food security" – the ability to provide healthy and environmentally sustainable diets for all people – are increasing. Sustainable food security, however, is not solely a problem of supply, but a function of sustainable food sources and sustainable diets or **"diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources."** [4]

By 2050 the food supply system must be able to develop along an ecological public health framework, [5] which guarantees the balance between availability of food and its health and nutrition requirements without compromising the natural resources of the planet.

ICT is already being applied extensively within the food and agricultural industries for both improved efficiency and productivity in the established food systems. In addition, digital technologies are being increasingly applied to disrupt and completely reform the established industrial structure of food by increasing the numbers of industry players across the globe. Digital technologies may hold the key to the successful coordination of a more sustainable food system.

The world now faces a choice about how to apply technological innovation to the food supply system: to create a global "post-natural food system" in which technologies are applied to increase yields or create new forms of bio-technical food systems, or to create a series of federated local/regional "renaturalized food systems" in which smaller scale local food systems are created and supported through technology. Each of these approaches will need to apply digital technologies in order to balance the needs of growing populations and scarce natural resources with food security.

This report investigates the role of ICT in ensuring the delivery of safe, sustainable and secure food supplies in a rapidly changing world.

[4] FAO, 2012, Sustainable Diets and Biodiversity, Directions and solutions for policy, research and action.

[5] Lang, 2009, Reshaping the Food System for Ecological Public Health.

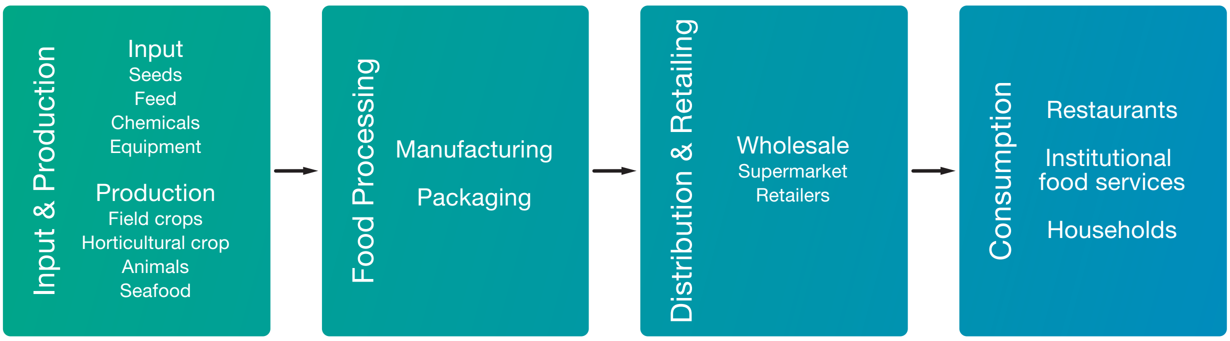
2. INDUSTRIAL STRUCTURE

The modern food supply chain is a well organized and coordinated operation that includes:

- **Farms growing the food,** including plant, meat and dairy products.
- **Complex food processing,** manufacturing and packaging.
- **Bulk handling** and transport of food.
- **Food distribution centers** and coordination systems.
- **Complex, well organized** variations of retail and food service outlets.
- **Supply and demand forecasting** at all stages in the chain, accounting for supply from the farm, global demand, customer demand, new developments/processes/products, and competing demand for non-food products such as cotton, wool, ethanol, minerals.
- **Significant ICT systems** that assist in the management of health and safety regimens, of information flows from a variety of sources, and of large-scale ICT systems.

A simplified supply chain is often conceptualized in a linear model. ICT systems are active in every aspect of this supply chain, as will be discussed in subsequent sections:

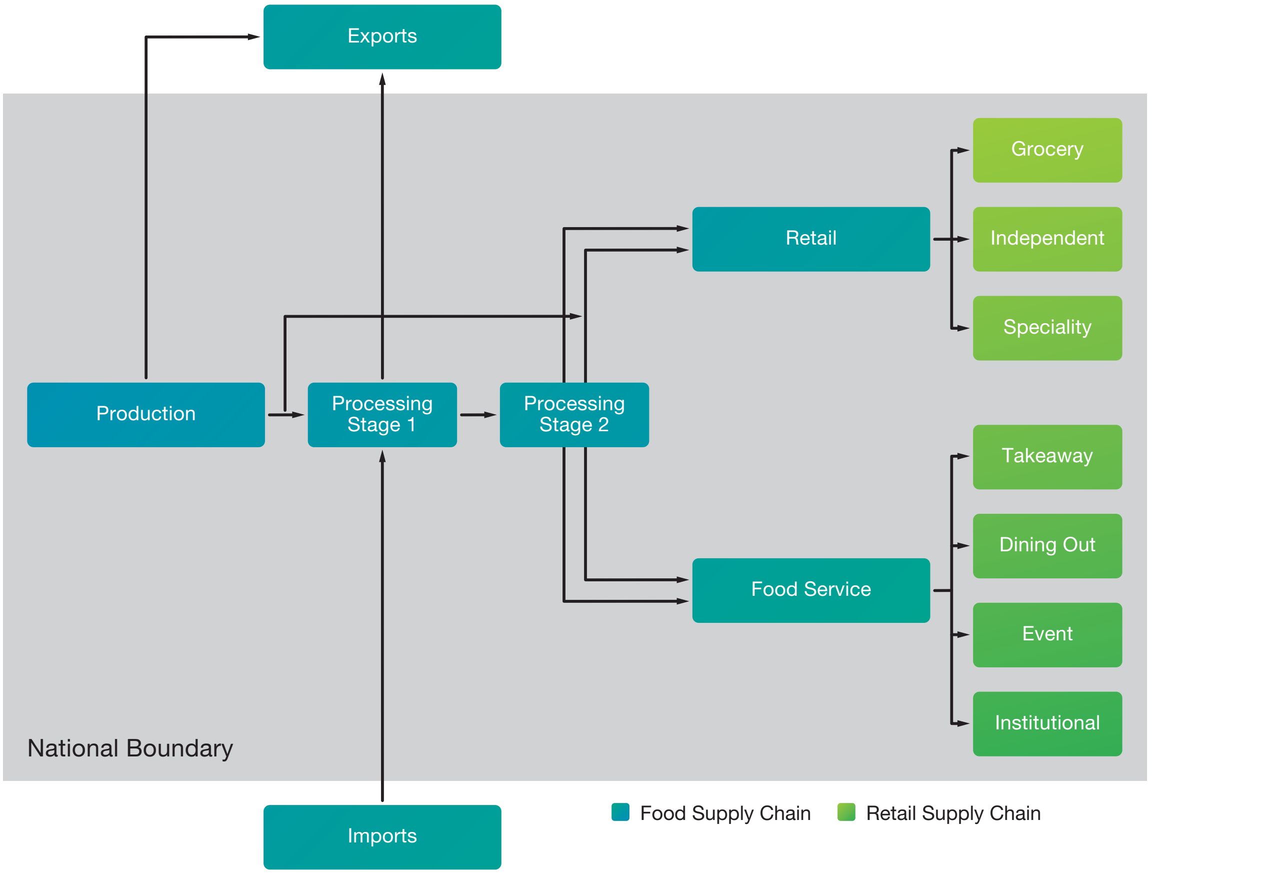
Figure 1: Food Supply Chain – Linear Model



2. INDUSTRIAL STRUCTURE

Raw input into the supply chain of the food industry may be grown/produced within national boundaries but in many cases are imported from a variety of countries. Raw inputs are taken into processing plants that perform first stage processing – for example sizing and marking for eggs, threshing and milling for wheat or slaughter for meat and poultry. Second stage processing turns the products into food items that a consumer would recognize – bread, meat cuts or more advanced prepared meals. These are then delivered to Retail or Foodservice production centers. Figure 2 illustrates the scope of this report. The role of ICT in Retail is covered in more detail in our Retail report[6] and is beyond the scope of this report.

Figure 2: Industrialized Food Supply Chain, illustrating scope of report



[6] Ericsson Networked Society Lab. Industry Transformation – Horizon Scan: ICT & the future of Retail /LME-15:000205 Uen.

2.1 ICT AND THE INDUSTRIALIZED FOOD SUPPLY CHAIN

Over the second half of the last century, large-scale application of ICT led to massive industrialized production and delivery systems for food. Large supermarkets in the developed world streamlined production and delivery of food to end users – supermarket shelves in the UK for example are restocked every 6 hours and the logistics systems of the food industry have been tailored accordingly. This has had a cascade effect all the way through to the agricultural practices used and developed by farmers across the world, spurring increased interaction between agricultural systems and the CO_2 outputs from the logistics industry, as discussed in our Transport report.[7]

In addition, the current food system produces an immense amount of waste. It is estimated that that nearly one-third of food produced for human consumption (30%) is lost or wasted globally along the FSC, which amounts to about 1.3 billion metric tons per year.[8]

The commonly used linear representation of the food supply chain in Figure 1 is misleading, therefore, as it does not represent the interactions between nature and the supply chain, in particular with regards to decreasing crop yields (see figures 4 and 5). Efficiencies attributed to the industrialized food system do not take into account the energy requirements, the CO2 output from food transport and logistics, nor the food waste created by large-scale supply chains. In short, the industrialized food system and its relationship with agricultural practices cannot be fully analyzed without understanding the total system surrounding it, including the simultaneously interacting processes, complex cause and effect relationships and feedback loops.[9] In contrast to other industries, with perhaps the exception of forestry and energy, the food industry is strictly intertwined and dependent upon the natural environment. The links between the industrial boundaries of production – land, energy, water and the industrial boundaries of consumption – dietary patterns, waste and socio-economic drivers are deeply intertwined. These are illustrated in Figure 3. Subsequent sections illustrate how ICT interacts with each of these boundaries and can shift thresholds between them.

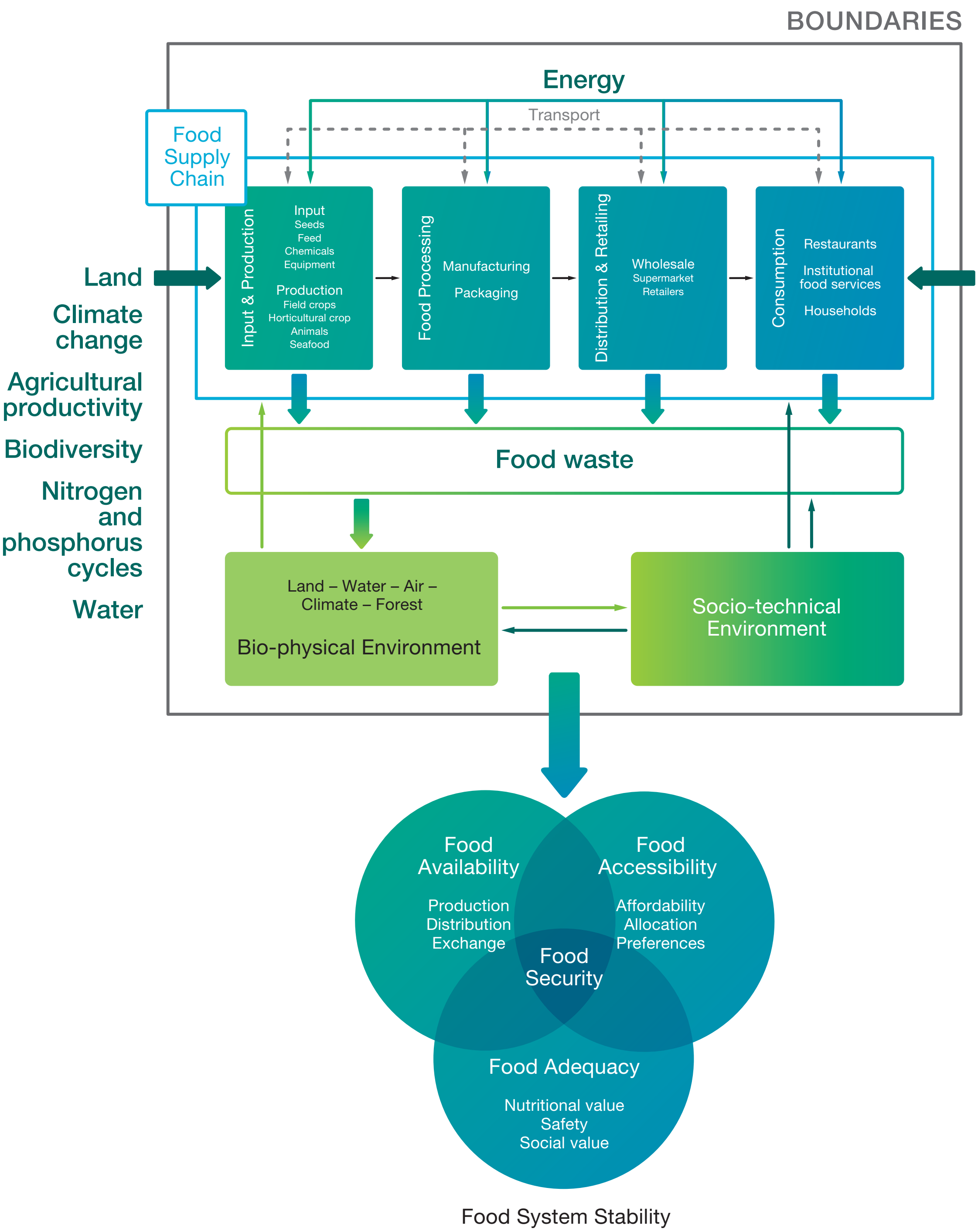
[7] Uen for Transport?

[8] FAO, 2011, Global Food Losses and Waste: Extent, Causes and Prevention.

[9] Kickbusch I. (2010) "Triggering Debate - White Paper. The Food System: a prism of present and future challenges for health promotion and sustainable development" Health Promotion Switzerland. www.promozionesalute.ch

2.1 ICT AND THE INDUSTRIALIZED FOOD SUPPLY CHAIN

Figure 3: Interacting Systems: Food and Agriculture



2.1 ICT AND THE INDUSTRIALIZED FOOD SUPPLY CHAIN

As the industrialized food chain has increasingly been adopted across the world in order to deliver food to populations, most countries now favor large ICT-driven food systems over traditional street food[10] or traditional food systems due to perceived gains in efficiency and food safety. With increasing global populations and decreasing yields of traditional crops, the modern food system is facing a number of rising difficulties that technology must help to address in one form or another.

Figure 4: Decrease in Cereal Yields – 1962 – 2012 (Data source: World Bank)

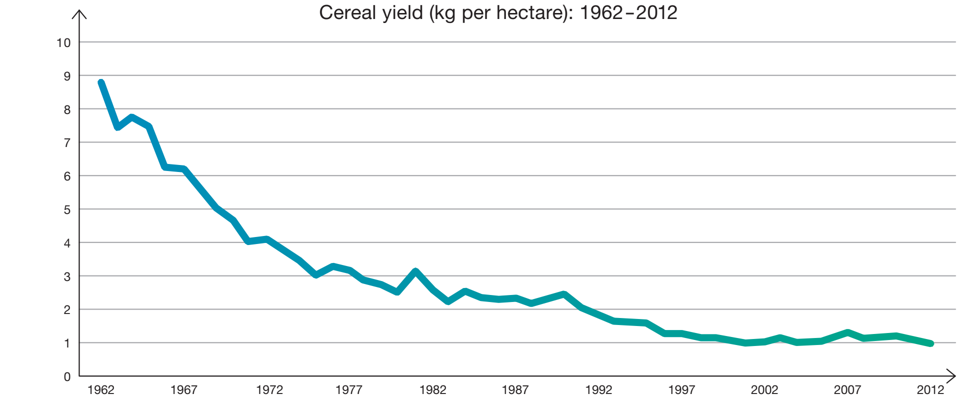
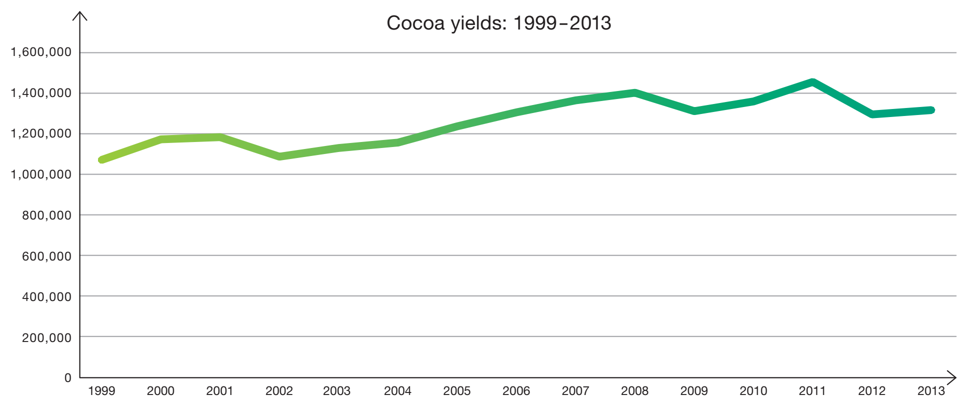


Figure 5: Cocoa Yields – 1999–2013 (Data source: World Bank)



[10] FAO, 1996.

3. INDUSTRIAL BOUNDARIES OF SUSTAINABLE FOOD SYSTEMS

The industrial boundaries of the food system are strongly linked to planetary boundaries. We can view the industrial boundaries of the food and agricultural system as: Production, Distribution and Consumption. Distribution boundaries are covered in our Retail report.[11]

[11] Ericsson Networked Society Lab. Industry Transformation - Horizon Scan: ICT & the future of Retail /LME-15:000205 Uen.

3.1 PRODUCTION THRESHOLDS

In 2009, Rockström et al. developed the concepts of planetary boundaries and safe operating space.[12] The authors identified 9 Earth-system processes and their associated thresholds. Moving beyond these limits will lead to disastrous consequences for humanity by eroding the resilience of major components of Earth-system functioning. Those Earth-system processes are the following: climate change; rate of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; ocean acidification; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading.[13]

According to the authors' analysis three of the Earth-system processes – climate change, rate of biodiversity loss and interference with the nitrogen cycle – have already transgressed their boundaries, and all are linked to 'modern agriculture'.

Table 1: Production Thresholds

Description	Measurement
Intensification of agriculture	Loss of Biodiversity
Concentration in control of inputs to production Larger farm sizes Fragmentation	Land Occupation and Degradation
Water Demands for agriculture	Blue water footprint
Energy demands	Logistics Animal production
Waste	Food loss (supply chain)
Pollution	NOx, SOx, etc
Co_2 outputs	Co_2

[12] Rockström et al. 2009, A Safe Operating Space for Humanity, Nature 461, 472-475, 24 September 2009.

[13] ibid.

3.1.1 FOOD VS. BIOENERGY

Food sources are not only consumers of energy. Over the past decades many have been used as alternative energy sources such as biofuels and biomass. Due to increased demand for environmentally sustainable fuel sources, the price of land and crops such as maize, wheat and oil seeds have all increased. This demand for fuel was considered one of the main causes of food price 'spikes' during 2008.[14] As a result, the use of crops for fuel may increase the vulnerability of the poor who often are more reliant on oils as a main calorie source. With every 1 percent increase in the cost of food, 16 million people will start to have difficulties fulfilling their basic nutritional needs.[15] Approximately 10% of the world's primary energy supply comes from bioenergy,[16] stimulated primarily by biofuel subsidies, fuel blending mandates, as well as national interests in energy security, climate change mitigation and rural development programs.[17]

The first generation of biofuels produced today is from food crops – sugarcane, corn ethanol or oilseed biodiesel. In addition to the broad discussions about the ability of first-generation biofuels to mitigate climate change, further challenges emerge with regards to competition for land, water and the production of food for people and livestock.

Many of the concerns related to first-generation biofuels can be addressed by the second generation of biofuels,[18] which are produced from agricultural and forest residues, as well as from non-food crops. These fuels have the potential to achieve sustainability in their production[19] and may partly reduce the competition for fertile land. The IEA projects a rapid increase in biofuel demand, in particular for second-generation biofuels, if atmospheric CO2 concentration is to stabilize at 450 ppm.[20] The wider use of second-generation biofuels may hold potential to enhance the overall economic development of rural areas.

[14] The FSC is extremely dependent on the oil market. An oil price spike in 2008 contributed to a near-simultaneous doubling of food commodity prices. Other causes included poor harvests due to drought and other adverse weather conditions in several key countries, growing demand from expanding Asian economies, commodity speculation, the decline in the value of the dollar, and the growth in biofuel production. As a result of these high food prices, more than 30 nations saw food riots in late 2008.

[15] IAASTD, 2009, Agriculture at a Crossroads.

[16] Haberl H, Beringer T, Bhattacharya SC, Erb K-H, Hoogwijk M, 2010. The global technical potential of bio-energy in 2050 considering sustainability constraints. Current Opinion in Environmental Sustainability 2: 394–403.

[17] IAASTD, 2009, Agriculture at a Crossroads.

[18] Second-generation biofuels are not yet produced commercially, but a considerable number of pilot and demonstration plants have been announced or set up in recent years.

[19] Sims et al., 2008, A new model of gross primary productivity for North American ecosystems based solely on the enhanced vegetation index and land surface temperature from MODIS, Remote Sensing of Environment 112 (2008) 1633 – 1646.

[20] Eisentraut in IEA, 2010, Sustainable Production of Second-Generation biofuels: Potential and perspectives in major economies and developing countries.

4. CONSUMPTION THRESHOLDS

> "Unhealthy diets are now a greater threat to global health than tobacco."
>
> **Olivier De Schutter, UN Special Rapporteur on the right to food, May 19, 2014**

At the same time as the world population is growing, the average daily calorie availability is projected to rise from 2,789 kcal per person per day in 2000 to 3,130 kcal per person in 2050 – a 12% increase. Overall food consumption is projected to increase globally by 65% between 2000 and 2050.[21] As wages increase globally, both the amount and the calorie content of food will increase dramatically. Global meat production is expected to rise, for example, from 229 million metric tons between 1999 and 2001 to 465 million metric tons in 2050. This trend will put additional pressure on land and water systems, as more land and water is needed to produce meat than to produce plant-based products of the same nutritional value.[22]

As demonstrated by Stehfest et al.,[23] a change in dietary patterns will have a dramatic impact on the environment. The authors calculate that a healthy diet worldwide would reduce the required area of arable land globally by 10%, the area of grassland by 40%, and the associated reduction in costs for mitigation of carbon dioxide emissions could be as much as 50% in 2050.

While dietary patterns influence the shape of food supply chains (FSCs), FSCs also determine the ability of consumers to make food choices. Consumers are only able to choose from the set of possibilities made available to them by networks of farms, manufacturers, retailers and businesses. The democratic access to health-enhancing diets is mediated by the structure and organization of the FSC – and also by price, income, class, location and culture.[24]

[21] 220 percent in sub-Saharan Africa, 112 percent in the Near East and North Africa, and 105 percent in South Asia.

[22] FAO, 2012, Greening the Economy with Agriculture.

[23] Stehfest et al. (2009), Climate benefits of changing diet, Climatic Change (2009) 95:83–102.

[24] Lang, 2009, Reshaping the Food System for Ecological Public Health.

4.1 HUMAN HEALTH BOUNDARIES OF THE FOOD SYSTEM

According to the World Health Organization, malnutrition presents a significant threat to human health. The challenges surrounding nutrition are now becoming more complex due to the twin threats of undernutrition and obesity.

About 870 million people worldwide still suffer from chronic hunger. The vast majority of these, 852 million, live in developing countries. Among children, it is estimated that 171 million children under five years of age are chronically malnourished, almost 104 million are underweight, and about 55 million are acutely malnourished.[25]

In parallel with undernutrition, overweight (in which body mass index is equal to or greater than 25) and obesity (in which body mass index is equal to or greater than 30) are also becoming major global public health concerns, causing the deaths of at least 2.8 million adults per year. About 1.5 billion people are overweight, surpassing the number of undernourished people worldwide. Of these 1.5 billion, 500 million are obese and about 43 million children under age 5 were overweight in 2010, according to 2008 figures. According to the WHO, overweight and obesity together are the fifth-leading risk factor for deaths globally.[26] Figure 6 illustrates food consumption patterns since the 1970s.

[25] FAO, 2012, The State of Food Insecurity in the World.

[26] WHO. 2009. Global health risks: mortality and burden of disease attributable to selected major risks. Geneva, Switzerland. WHO. 2012. Obesity and overweight, Fact sheet No. 311. Geneva, Switzerland.

4.1 HUMAN HEALTH BOUNDARIES OF THE FOOD SYSTEM

Figure 6: Food Consumptions Patterns since 1970 (Data source: USDA)

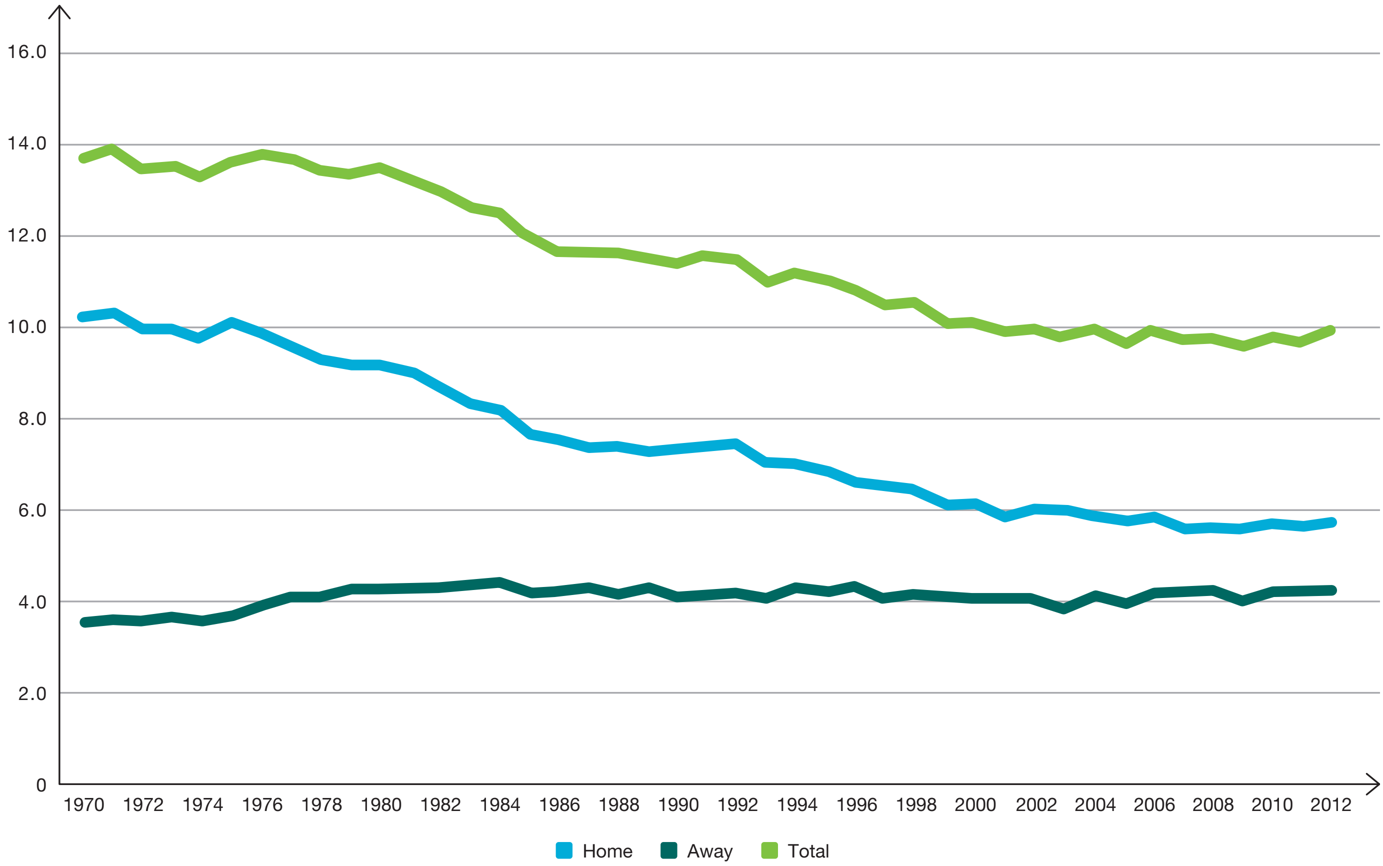


Table 2: Consumption Thresholds

Description	Measurement
Dietary	Food basket Food consumption patterns
Health	Health levels of malnutrition Levels of obesity
Waste	Food waste (consumer)

4.2 INTERACTING THRESHOLDS

Agriculture is the single largest user of water world-wide, dwarfing everything else. It is calculated that it takes 15,000 liters of water to produce 1 kg of beef, or 8,000 liters of water to produce a pair of jeans.[27]

Industrial agriculture's use of water is a cycle of over-use, waste and pollution. Approximately 3.8 trillion cubic meters of water are used by humans annually, with 70% being consumed by the global agriculture sector.[28]

The FSC rests on an unstable foundation of massive fossil fuel inputs. The production of fertilizers, herbicides and pesticides, the tillage, irrigation and fertilization, and the transport, packaging and conservation of food and distribution worldwide take considerable amounts of energy.[29] From an energy perspective, industrialization presents a paradoxical reversal.

Before the industrial revolution, farming and forestry were society's primary net producers of energy. Today the food system is a net user of energy in virtually every nation; this is especially so in industrialized countries, where each calorie of food energy produced and brought to the table represents an average investment of about 7.3 calories of energy inputs.[30] Declining fuel stocks are therefore an issue for the food system. The dramatic changes in the use of corn for fuel instead of food is illustrated in Figure 7.

27 The Water Footprint of Modern Consumer Society By Arjen Y. Hoekstra.

28 http://www.theguardian.com/global-development/2012/aug/26/food-shortages-world-vegetarianism?guni=Article:in%20body%20link

29 Interdependences between energy, water and food are inextricably linked. Water is an input for producing agricultural goods in the fields and along the entire agro-food supply chain. Energy is required to produce and distribute water and food: to pump water from groundwater or surface water sources, to power tractors and irrigation machinery, and to process and transport agricultural goods.

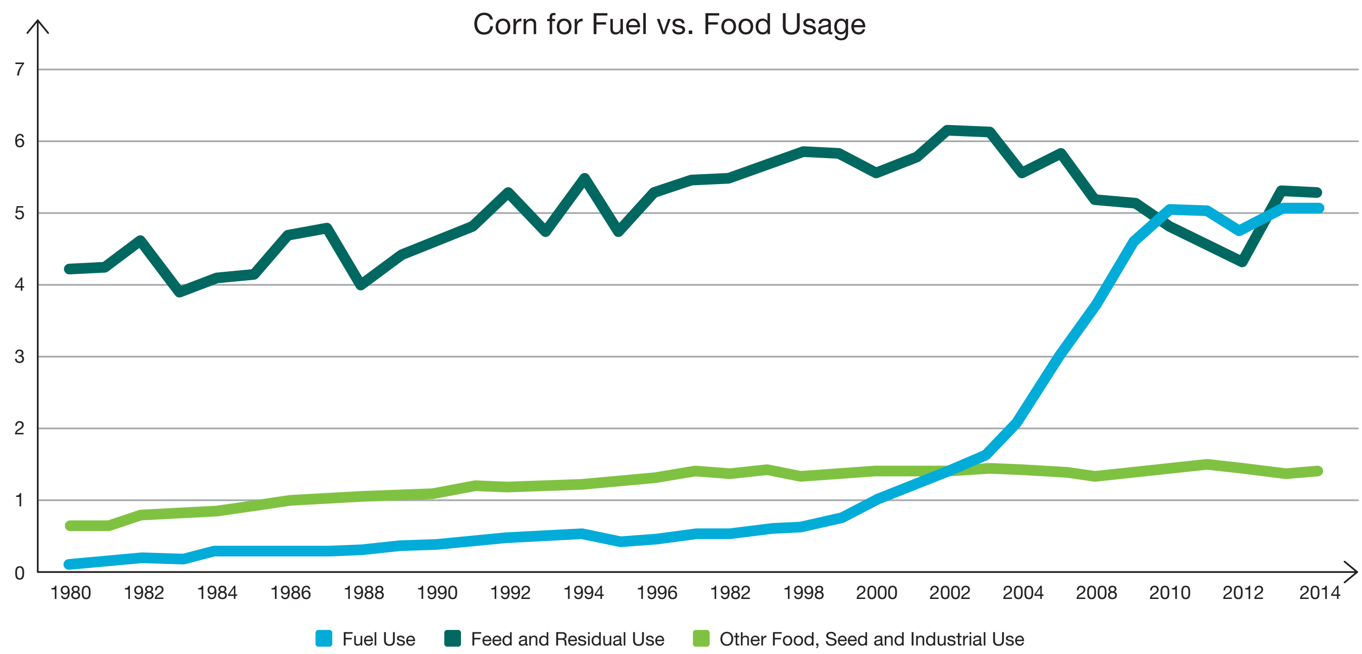
Agriculture is currently the largest user of water at the global level, accounting for 70% of total consumption. The food production and supply chain accounts for about 30% of total global energy consumption.

There are many synergies and trade-offs between water and energy use and food production. Using water to irrigate crops might promote food production but it can also reduce river flows and hydropower potential. Growing bioenergy crops under irrigated agriculture can increase overall water withdrawals and jeopardize food security. Converting surface irrigation into high efficiency pressurized irrigation may save water but may also result in higher energy use. Recognizing these synergies and balancing these trade-offs is central to jointly ensuring water, energy and food security.

30 Heinberg, R., and Bomford, M., 2009, The Food and Farming Transition: Toward a Post-Carbon Food System, Post Carbon Institute.

4.2 INTERACTING THRESHOLDS

Figure 7: Corn usage – Fuel vs. Food (Data source: USDA)

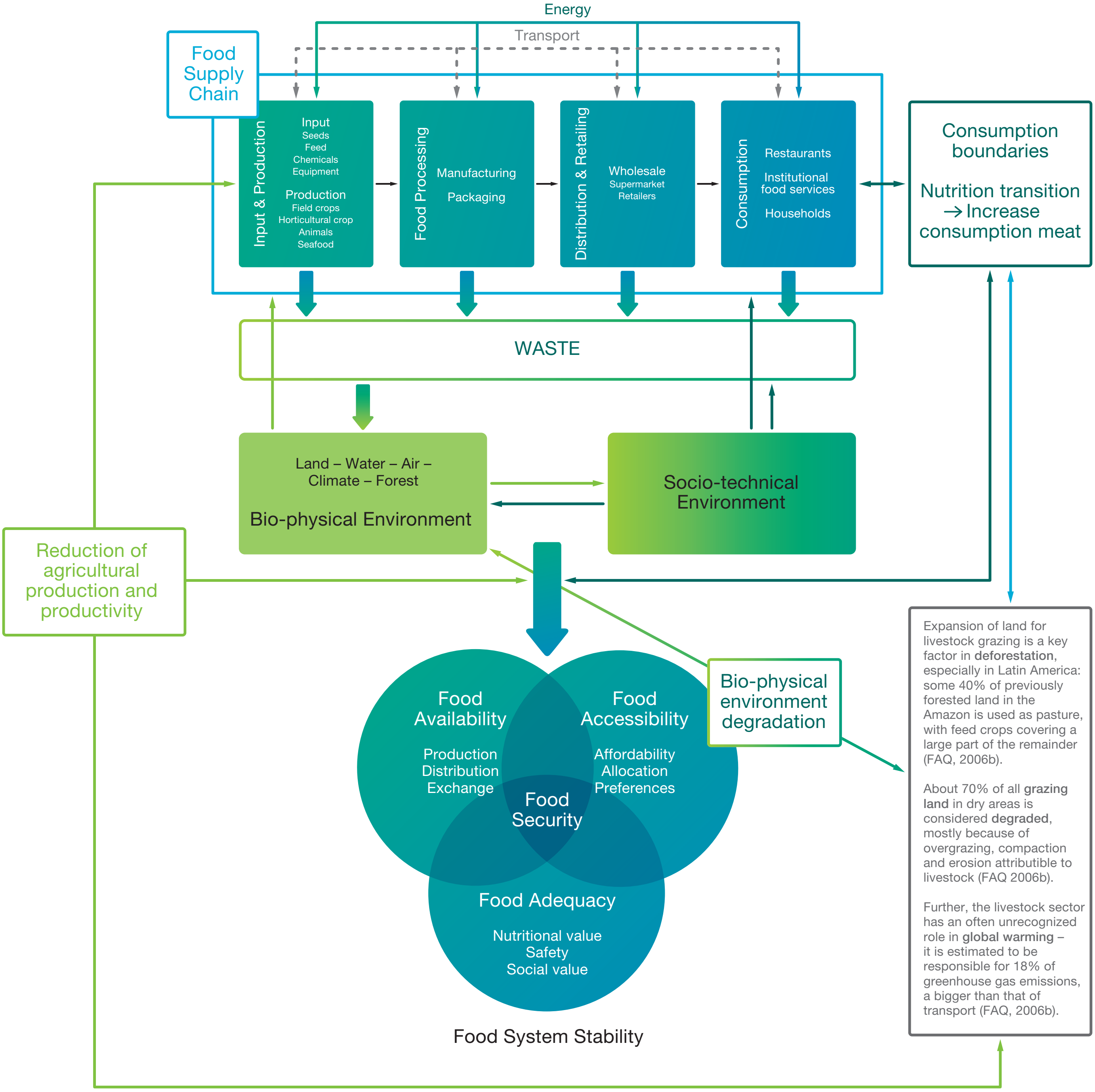


The food industry faces a so-called bioenergy dilemma, in which difficult decisions need to be made regarding whether crops are used to produce food or fuel. Waste is another boundary – as it is in other industries – but has potentially higher relevance in the food system as about 870 million people still suffer from chronic hunger globally. The "nutrition transition" is a boundary related to demand that should be internalized in the supply side of food systems. The massive diversion of grain for fuel production has helped drive up food prices, leaving low-income consumers everywhere to suffer some of the most severe food price inflation in history. As of mid-2012, world wheat, corn, and soybean prices were roughly double their historical levels.

Food security is therefore a complex issue with multiple environmental, social, political and economic determinants. The concept of a FSC as a linear combination of activities ranging from production through to consumption is therefore unable to cope with such complexities. The total interactions between food systems, waste, energy and transport are illustrated below in Figure 8.

4.2 INTERACTING THRESHOLDS

Figure 8: Interaction between industrial boundaries



5.
ICT AND SUSTAINABLE FOOD SYSTEMS – MANAGING THE TRANSITION

The use of ICT in agriculture is far from a new concept, having been applied in various forms since the 1960s. Recent advances and the increasing pressures on the food system have re-ignited the interest around the most effective forms of technical interventions in the food system. Traditionally, the pressures of increasing populations have been met through improvements in agricultural productivity by tailoring crops for higher yields. It is unlikely, however, that future food demands will be met through increasing yields alone.

As discussed, there are two main scenarios for the future of the world's food systems.[31]

1. **A post-natural world, where technology is applied to push further beyond traditional agricultural practices.**

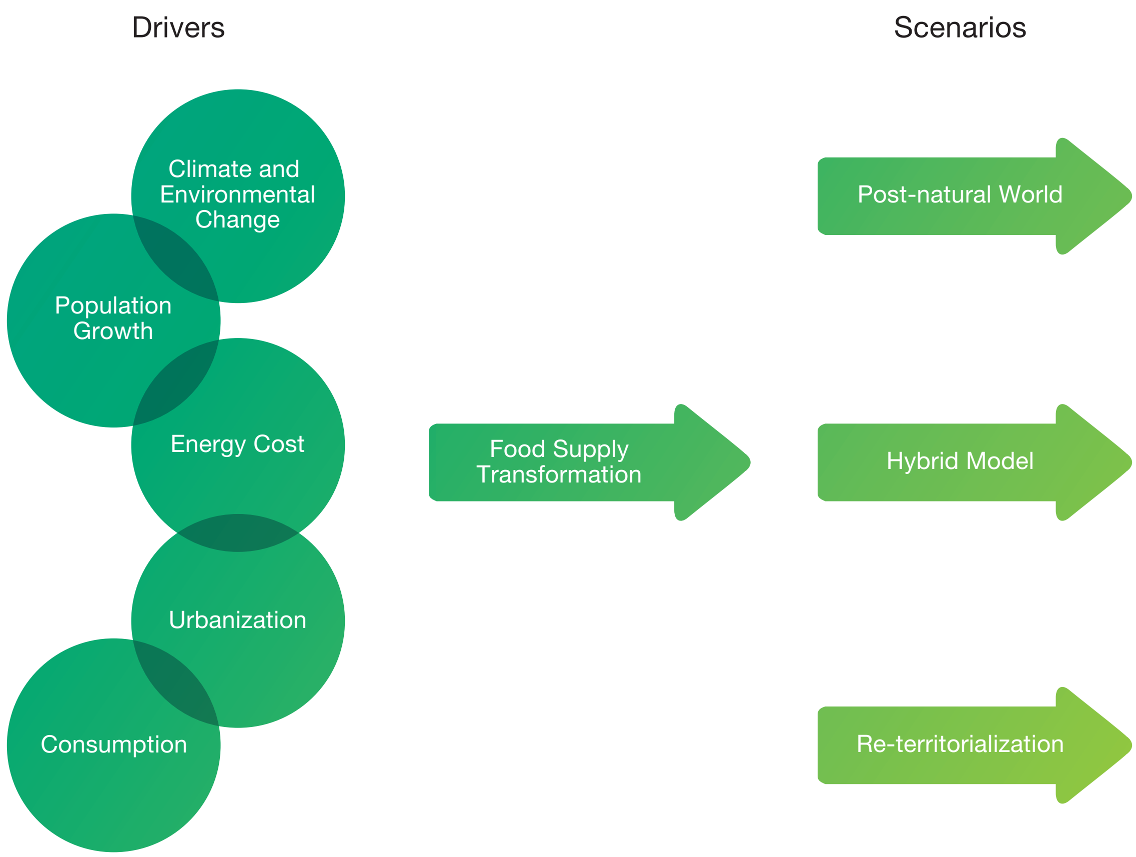
2. **A re-territorialized world, where technology is used to support resource-conservation across the entire supply chain from supply through to demand, with a particular focus on agroecology.**

In reality, the future of the food system will more than likely need to combine a hybrid of both of these models, increasing yields and productive capacity of the industrialized food system in conjunction with shortening supply chains, fostering regionally and locally sustainable food supplies, while reducing waste and consumption of diets rich in fat, meat, sugar and other unhealthy substances. The drivers and three possible scenarios are illustrated in Figure 9.

[31] Les Levidowa, Kean Birch and Theo Papaioannou, EU agro-innovation policy: two contending visions of the bio-economy.

5. ICT AND SUSTAINABLE FOOD SYSTEMS – MANAGING THE TRANSITION

Figure 9: Drivers and Scenarios for Transformation of the Food System

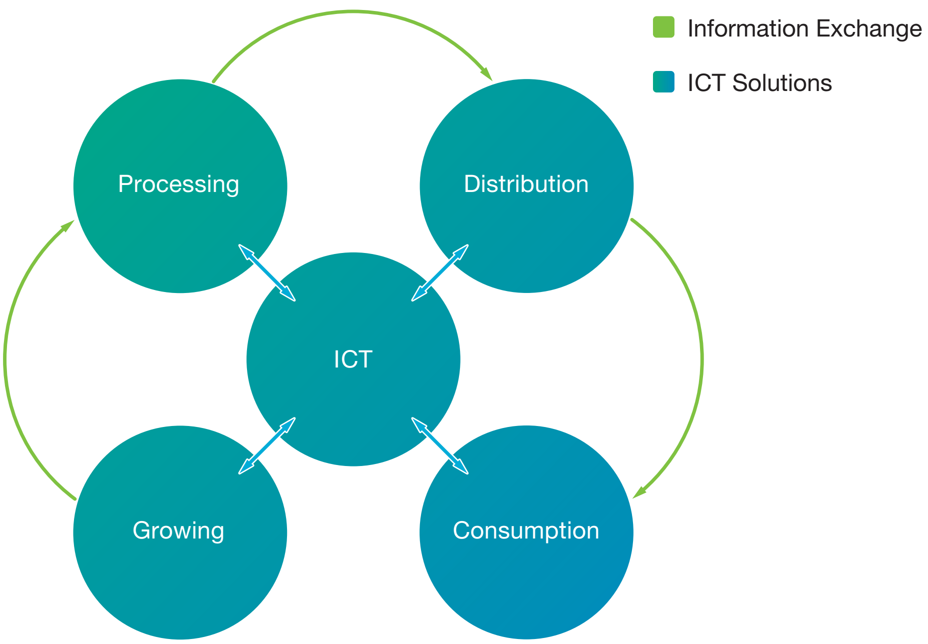


5. ICT AND SUSTAINABLE FOOD SYSTEMS – MANAGING THE TRANSITION

While the transition to a sustainable food system requires significantly more than just ICT, we focus here on the use of digital technologies in order to disrupt the existing or traditional methods of food and waste management, in particular regarding coordination and increased knowledge exchange through the creation of virtual food communities.

From a high-level perspective, we may view ICT as playing different roles in the growing, processing, distribution (logistics) and consumption of food in all of the scenarios that follow, with an increased number of ICT solutions being used within each process and a greater level of information exchange between the processes of the food supply system, as illustrated below in Figure 10.

Figure 10: ICT as Information Exchange and ICT Solutions.



6. ICT AND FOOD SECURITY

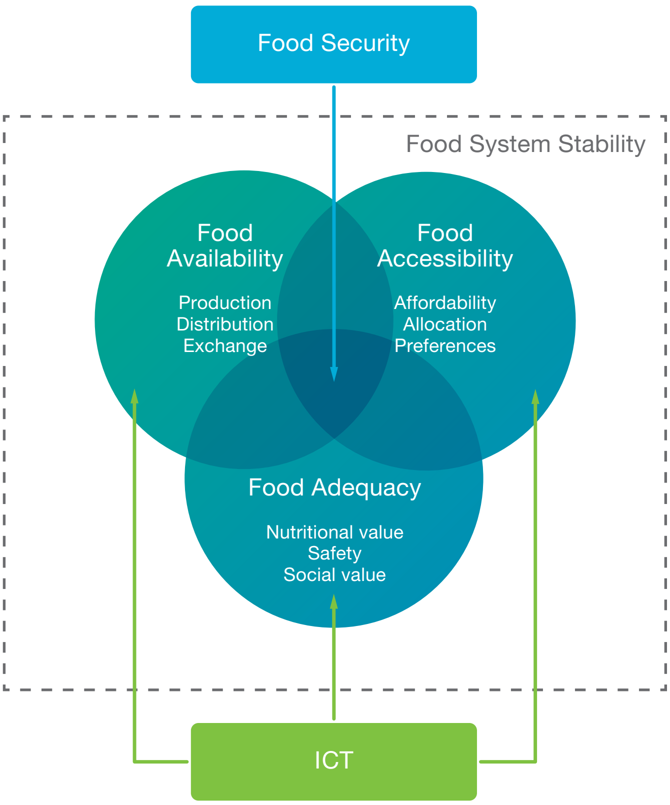
ICT has a significant role to play in the future of food and agriculture. In the face of rising pressure from climate change, rising populations and decreasing crop yields, the world must confront the critical challenge of efficiently delivering sustainable and healthy diets to global populations. There are two main methods that are discussed:

1. A post-natural world, where technology is applied to push further beyond traditional agricultural practices and is more deeply embedded into the food system. In this scenario, ICT is applied beyond just coordination technologies and becomes integrated as a core part of the production process itself.

2. A re-territorialized world, where technology is used to support resource conservation across the entire supply chain from supply through to demand, with a particular focus on agroecology. From this perspective, ICT is used to help coordinate the activities of multiple suppliers in dynamic strategic networks to coordinate the local delivery of food.

Research conducted at Imperial College London[32] indicates that ICT is required to successfully combine secure sustainable food systems, through the application of innovative digital technologies that take into account the interactions between food and agriculture systems, with broader industrial systems, as illustrated in Figure 11.

Figure 11: Role of ICT in Food Security.



[32] Within the EPSRC Project, "Scaling the Rural Enterprise" EP/J000604/2. http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/J000604/2.

6. ICT AND FOOD SECURITY

ICT will play a role in creating food security in both of our future scenarios, the following sections cover when and how ICT will be applied in each of them.

Adapting the work of Ericksen[33] and Ingram,[34] ICT can be seen as an addition to the complex interactions between:

- **Supply chain activities (input & production, processing, distribution & retailing, and consumption).**
- **Environmental and socio-technical drivers:**
  - **Environmental: Land cover & soils, atmospheric comp., climate variability & means, water availability & quality, nutrient availability & cycling, biodiversity, sea currents & salinity, sea level.**
  - **Socio-technical drivers: Demographics, economics, globalization, prices speculation, socio-political context, cultural context, etc.**
- **Energy: Renewable and non-renewable.[35]**
- **Waste (added to the model).**

ICT has a particularly important role to play in improving communication between different parts of the supply chain, as well as through the use of big data, drones and other innovative digital technologies to improve the efficiencies of the overall food system – from production through to reduction of waste in supply chains and on the consumer's table. This is illustrated in Figure 12 on the nest page.

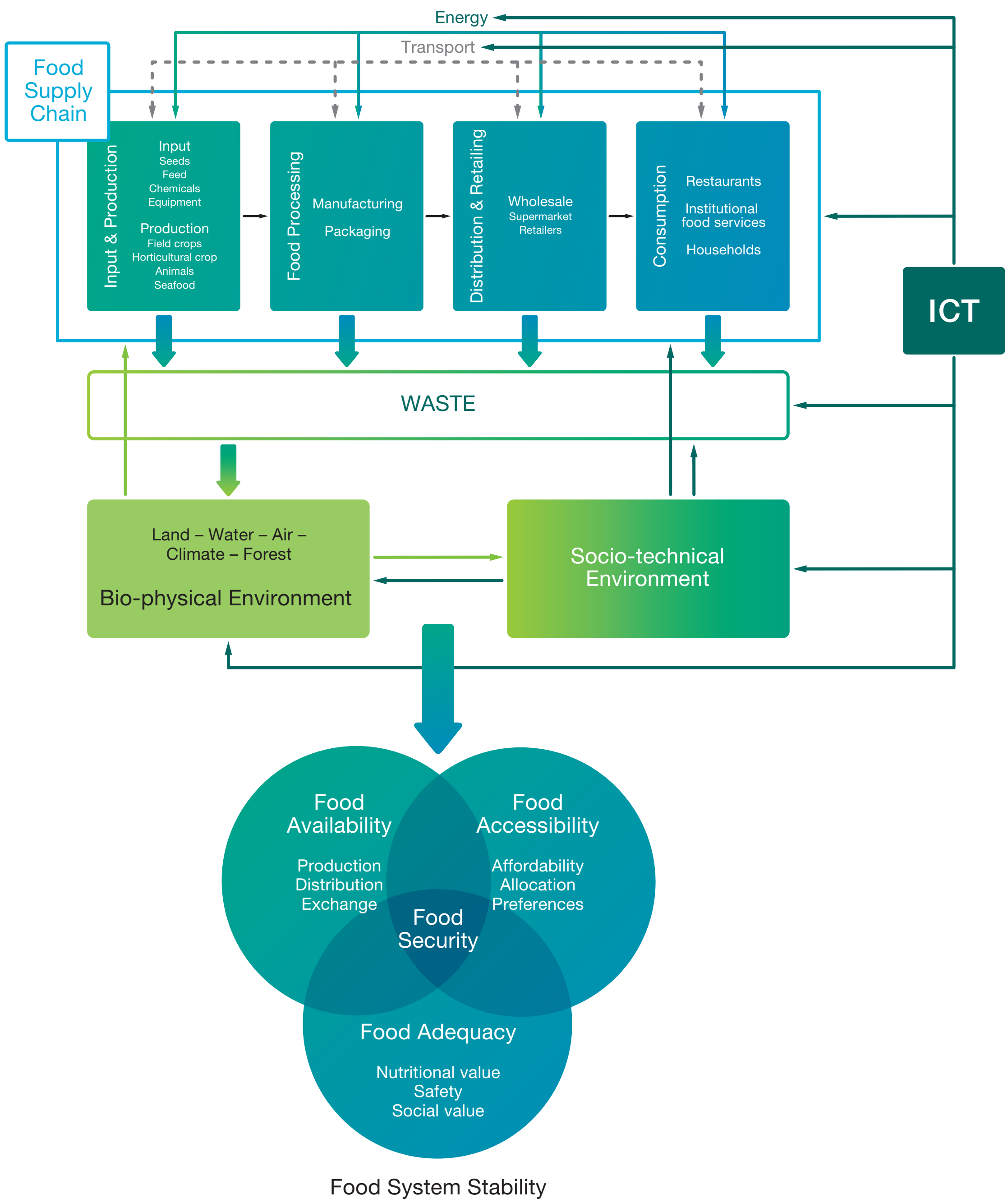
[33] Eriksen, 2007, Conceptualising food systems for global environmental change research, Global Environmental Change 18:234-245.

[34] Ingram, J.S.I. (2011) A food systems approach to researching interactions between food security and global environmental change. Food Security, 3: 417-431.

[35] Utilities UEN.

6. ICT AND FOOD SECURITY

Figure 12: The Food Supply System adapted to include ICT



6.1 ICT AND LARGE-SCALE FOOD SYSTEMS

A post-natural world will be heavily dependent on digital technologies and data to help achieve a sustainable food system. Technological advances will have a strong role to play, from emerging life sciences such as bio- and nano-technologies through to the application of ICT to reduce inefficiencies within the industrialized food system. This section describes this role from a digital technology perspective.

It is possible to conceptualize technology within a post-natural food system as having two main roles:

- **Continued streamlining within the traditional industrialized supply chain through the application of sensors and the creation of more integrated business processes.**
- **Creation of new forms of supply chains that augment food products through data and new technologies.**

Within this report, we focus on the second aspect as the first is well covered.

6.1.2 BIG DATA AND AGINFORMATICS

In order to increase the productivity of agricultural practices across the world, many farms are applying big data to improve operational analysis in the production of monocultures. These so-called "AgInformatics" systems are being heavily invested in by companies such as Deere Co, Dow AgroSciences and Monsanto.

Data analytics is being applied in a broad variety of areas of farming including research and development, maintenance of farming equipment, and mapping of fields and other operational activities to optimize watering and irrigation, the sowing of seeds, etc. These solutions are becoming economically viable due to the reduced cost of tailor-made sensor solutions, the cheaper cost of storage and processing in cloud infrastructures and relatively cheap bandwidth (fixed and wireless) that permits the transmission of data sets from fields across nations and regions. The data is used to not just improve the performance of individual farms, but – through data aggregation – enables enhanced performance for a significantly larger number of farms purchasing seeds and equipment from the same supplier. Moreover, such data can be used within research and development to improve trials and create much larger data sets for analysis to create new agricultural products, from GMO seeds through to highly granular mapping software for farmers that permit companies to 'sell' optimal information to farmers for crop maintenance.

A key factor in the success of such data initiatives will be margins on sales of produce. For example, it is difficult to predict whether farmers will buy access to such information if, for example, "US agriculture returns to $0.50 or lower corn margins as production costs continue to rise".[36] Moreover, there are increasing concerns by farmers and others in the food production sector about how such data will be used by companies like Monsanto or John Deere.

[36] Informa, 2013, The Future Of "Big Data" And Aginformatics: Adoption, Profitability & Economic Implications for AgInformatics Sector Stakeholders.

6.1.3 TRADITIONAL INDUSTRIALIZED SUPPLY CHAINS

In order to continue improving overall agricultural productivity, improved data management and digital technologies will become increasingly important to the food supply system. It is clear that many companies in the food and agriculture industry are already investigating in detail the role that big data will play in managing the entire supply chain from:

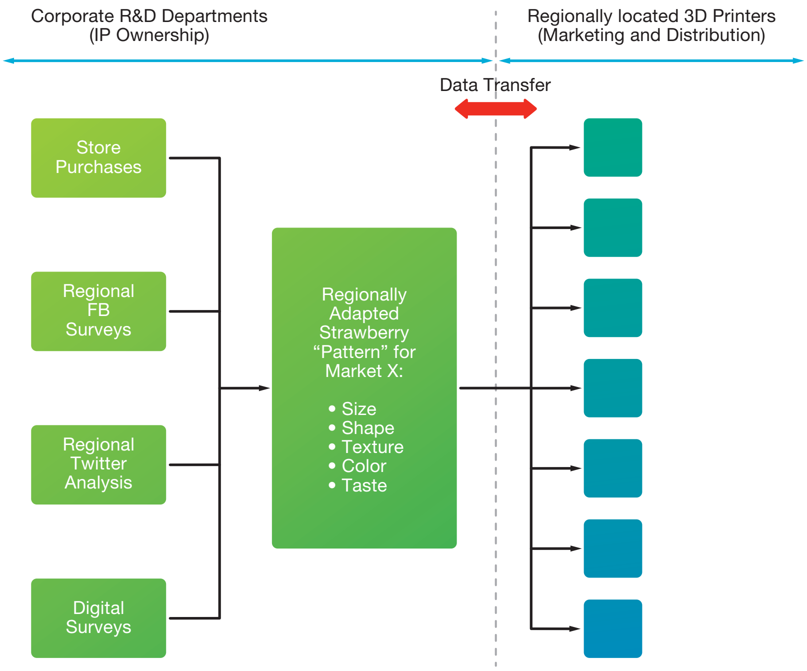
- **Development and modification of seeds to increase yields and increase resistance to pests.**
- **Mapping of fields to provide more 'tailored' watering, sowing, harvesting and other agricultural interventions in farmers' fields.**
- **Use of technologies such as unmanned aerial vehicles (UAVs) to investigate the fields, collect data and analyze the overall progression of crops throughout the season.**
- **Placing sensors onto existing farming equipment, such as tractors, harvesters, etc. that transmit data for analysis in order to improve crop yields.**
- **Combining the above data with weather information, detailed field topography and previous crop performance.**

6.1.4 CREATING NEW TECHNOLOGICAL FOOD SUPPLY CHAINS

Data is, however, taking on a whole new meaning within food supply chains – as the 'data building blocks' of food are unpacked and put to new uses in order to meet the needs of the planet. Examples abound from 'artificial' meat grown in labs, to 3D printing of fruit. Both of these are examples of how food products might be digitally "reconstituted" in aspects ranging from taste, texture, size and shape, to color. In this sense, the food supply chain may become increasingly circular – with companies soliciting input from consumers via social media about, for instance, the 'perfect' strawberry for the tastes of UK consumers, and using 3D printing techniques to deliver that strawberry to market. Effectively, consumers would define the specific market and product on behalf of the companies. This is illustrated in Figure 13.

In addition to enabling the creation of artificial foods, technologies allow end users to bring the food growing process into their homes with the development of home growing kits such as kitchen hydroponic installations.[37] One could conceptualize a localized hydroponic system for one community, similar to the local heating systems used in Scandinavia, as an updated version of an allotment for local communities. Such installations will require ICT in order to coordinate and allot and roster individuals to the allotment.

Figure 13: A Datified Value Chain in Food Production leads to removal of growing altogether



[37] Hyundai's Kitchen Nano Garden, http://www.lovesfoodandart.com/hyundai-kitchen-nano-garden-hydroponic-brilliance/

6.1.5 GIS AND FOOD SUPPLY SYSTEMS

Currently, the mapping technologies used by governments are relatively poor and they do not allow for the detailed mapping of food supply chains. Advanced GIS systems can be applied in order to understand the following:

- **The location of food deserts in order to increase understanding about access to nutritious and sustainable food sources across nations, regions and cities. This will allow governments to better understand policy instruments regarding the use of 'local' products in institutions such as schools, hospitals and other governmental organizations.**[38]
- **The interaction between the food systems and a large variety of other systems such as energy, transport and overall sustainability aims, including the impact of food transport to various locations.**

An understanding of these issues would permit better urban planning, in particular through understanding the role that access to food markets has on other systems. For example, when land prices increase, food markets are often pushed to the peripheries of urban areas. This has a large impact on the accessibility of food for many people who now need to travel further in order to access nutritious food. In addition, moving the food markets to areas with cheaper land prices may increase the amount of traffic – and therefore CO_2 emissions associated with the food system – in a city related to both the transportation and consumption of food.

[38] Access to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences." United States Department of Agriculture Economic Research Service. 2009.

6.1.6 DATA OWNERSHIP IN POST-NATURAL FOOD SYSTEMS

A key concern with the use of digital technologies in food systems is the ownership of data. Just as there is unease about the use and management of personal data surrounding digital consumer technologies, the ownership of data in agriculture is also causing concern. For example, many farmers are concerned about the amount of data that large companies have about their farms due to the data feedback loops from their equipment and their fields. Rival farmers could use this information to increase their crop outputs, for example. There are also strong concerns that the data collected from a large number of farms and farmers will allow companies in possession of that data to manipulate markets for commodities such as corn, wheat etc., all of which are heavily traded internationally.

Beyond the concerns of the ownership of supply-side data in the agricultural economy, there are also issues of ownership on the demand side. If a supermarket, for example, performs a poll by social media to determine the perfect tasting strawberry for the Korean market, who 'owns' that data? A company may be able to use data to create a monopoly over certain food markets through such methods. Who owns the DNA of a pear? Who owns the taste of a strawberry that most people in the UK, Germany, Spain or the USA will buy? As yet, these questions remain largely unanswered – but they are critical issues for the future of the food system if significant numbers of countries decide to transition more fully to a post-natural world.

As mentioned, however, ICT can also be an enabler of a return to more sustainable agricultural practices through providing a localized food system for some foodstuffs.[39]

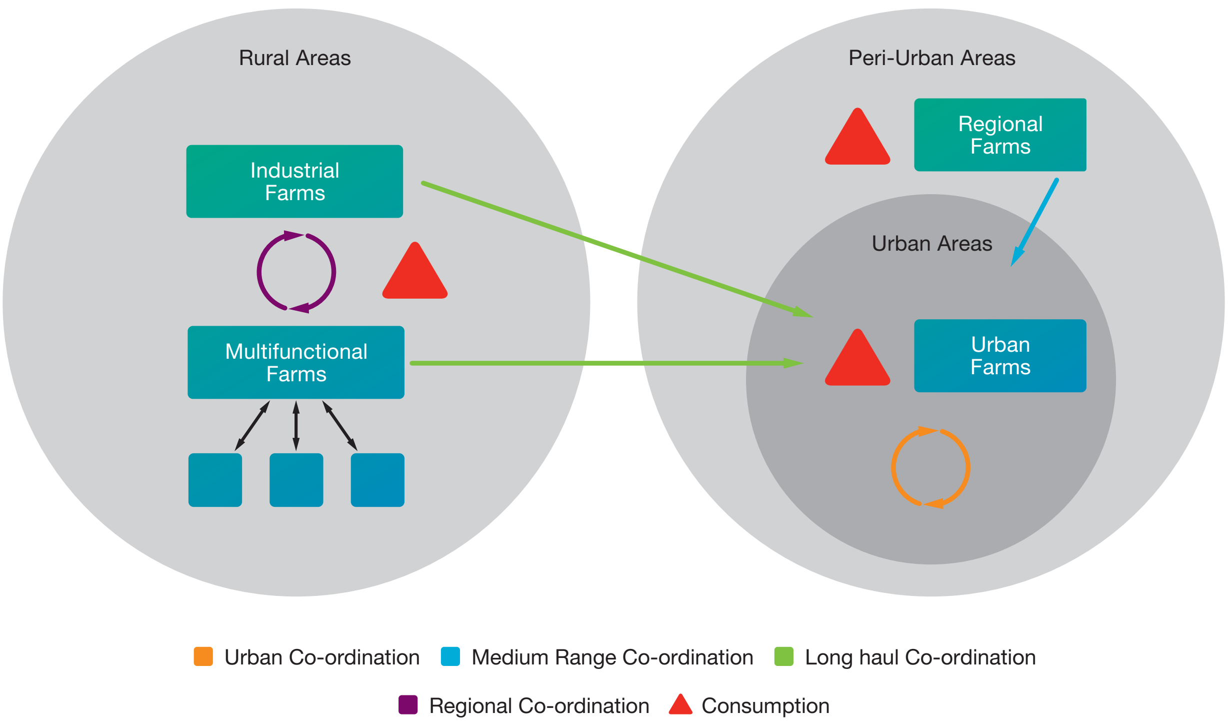
[39] Ensuring localized food production and sustainable agricultural practices does not necessarily mean the end of a globalized food system, but rather the systematic integration of localized production where appropriate. The most likely solution is a combination of both local and global food supplies.

6.2 DIGITAL TECHNOLOGIES IN A RE-TERRITORIALIZED FOOD SYSTEM

While a post natural world will rely heavily on ICT in order to feed 9 billion people, the creation of a re-territorialized food system may depend on a greater number of non-technological factors – requiring increased interaction with, and response to, the behaviors, preferences and agricultural practices within different local areas. In particular, this form of food system requires the creation of 'short' supply chains, which cover multiple individual suppliers across small geographical spaces.

Digital technologies are crucial in the creation of reliable, secure, robust and economically sustainable "short" supply chains. In order to understand this phenomenon, we must first understand the types and forms of coordination that are applicable within the food supply system. The most basic forms of coordination are illustrated in Figure 14.

Figure 14: Forms of Coordination and Consumption within the food system



6.2 DIGITAL TECHNOLOGIES IN A RE-TERRITORIALIZED FOOD SYSTEM

As can be seen, there are a variety of issues that need to be addressed in the coordination around the food system. Firstly, food is grown and produced in a number of different places, not solely in rural areas, but also in peri-urban and urban areas. Within rural areas, there are two main types of farms – industrialized farms and multi-functional farms. Industrialized farms generally produce a small number of crops and rely heavily on the industrial supply chain described in previous sections. Multi-functional farms, by contrast, combine a number of productive activities to produce a wider diversity of products. These products can range from raw produce, such as fresh strawberries, to processed and refined end products, such as strawberry jam. Within peri-urban areas, there are often smaller farms that may be either semi-industrialized or multi-functional but produce smaller quantities and deliver products regionally to nearby cities. Finally, there are a growing number of so-called "urban farms", which take a number of forms from community-based allotments to vertical farms and aquaculture.

Each of these requires different types of coordination mechanisms – enabled by ICT – in order to ensure that these types of farms are able to function as 'going concerns'. Rural farms, for example, need not only long-haul logistics for their take-to-market activities, but also long-haul coordination activities in order to understand when and where the best market price may be obtained for their products. Peri-urban farms, meanwhile, need regional medium-range coordination activities in order to deliver their products to the correct market and customers. Within urban regions, yet another form of coordination is required to enable local logistics and coordination with more granular interactions to ensure that food arrives at the right time and place, in the right quantity and at the best price. Even in short supply chains, it is often necessary to coordinate between rural, peri-urban and urban areas in order to ensure satisfactory supply and delivery to customers in an often highly competitive local market.

We focus our attention on the other forms of farms and the coordination mechanisms required to create short supply chains in the transition towards a sustainable food system.

A short supply chain is one that significantly reduces the number of steps between producer and consumer. It refers to either a short distance or a small number of intermediaries between the production and consumption of the food.[40] A short supply chain covers a broad range of organizational strategies, but some examples are:

> **Farmers' markets,** many of which have started to use social and digital marketing to increase the 'reach' of their message.

> **Food hubs,** many of which are moving to 'virtual' methods of operation, using internet and web technologies to coordinate market exchange between producers and consumers, rather than using farmers' markets as a means to distribute produce.[41]

> **Micro-enterprises** with dynamically organized supply chains, which apply lightweight, often mobile, digital technologies in unique ways in order to coordinate supply and demand and manage business processes.

[40] A short supply chain, therefore, does not need to be local, but reducing the number of hubs within the food systems often means that short supply chains are usually regional.

[41] Food Hub Pioneers Virtual Marketing to Consumers, Hoosier Harvest Market Website is the portal for buyers and sellers. Published on: Jan 31, 2014.

6.2 DIGITAL TECHNOLOGIES IN A RE-TERRITORIALIZED FOOD SYSTEM

Within short supply chains, ICT is critical as a means of coordination between farmers and food producers, both of whom aim to maximize gains from the value they add to the food system. It also offers consumers greater choice in the types of food they have access to through local/regional supply chains. ICT is foundational in connecting those suppliers that wish to participate in short supply chains with one another in order to smooth supply and demand. It allows for the creation of dynamic supply chains – ones that do not require contractual lock-in between supplier and customer but instead allow smaller, local suppliers to participate as and when they are able in a dynamic manner.

The key factor in the ability of small supply chains to break through in today's industry is the significantly lower entry cost for digital technologies. It is perfectly possible to create business process management systems using mobile or cloud technologies, rather than relying on large-scale industrial ICT systems that have traditionally been used in the industrialized food chain. As with most markets, short supply chains raise questions of coordination between suppliers and consumers. While the organizational strategy behind a short supply chain will be different to that of an industrialized food supply chain, the overall business processes remain the same. One significant difference between the food system and other industrial systems is the fact that consumption needs to occur across all locations, rather than mainly in urban or peri-urban areas, as may be the case for other physical products. Although the distribution, consumption and market preferences may differ, a consistent food supply is in equal demand across all areas – urban and rural.

Within all of the coordination scenarios in the creation of short supply chains, there is a strong dependence on the ability of digital technologies to arrange and effectively coordinate business processes across individuals who are not necessarily contractually obliged to one another. Many digital technologies allow for the creation of digital communities of practice as well as strategic networks between individuals. These strategic networks enable people to participate in a short supply chain when they are able – e.g. when they have time or spare product available – but do not obligate them to participate. Through establishing networks with a large number of other like-minded individuals, they are able to coordinate to ensure supply for customers from a variety of regional and local suppliers.

7. CONCLUSIONS

This report has covered the transition to a sustainable food system – one that enables an increased global population to have access to not just food, but nutritious, affordable and sustainable diets. As discussed, there are two main scenarios for the future of the world's food systems:

1. **A post-natural world, where technology is applied to push further beyond traditional agricultural practices.**
2. **A re-territorialized world, where technology is used to support resource conservation across the entire supply chain from supply through to demand, with a particular focus on agroecology.**

Digital technologies have a key role to play in both of these scenarios.

In a post-natural world, digital technologies are applied to create not just increased yields in agriculture, as has previously been the case, but also to create new value chains based completely on data. Industrialized farms will be mapped in ever-greater detail and will rely heavily on a variety of different sensors and digital technologies in order to streamline sowing, watering and harvesting practices. As with many industries, the increased usage of data in farms is not without risks. Ownership and usage of the data in question can become critical issues as large-scale companies use digital technologies to execute greater control over various aspects of the supply chain. Equipment manufacturers and agrochemical companies will be able to control greater sections of supply chains down to a micro level in a manner not previously possible. The execution and regulation of this supply and control will become an increasingly difficult topic for the industry as farmers may have no choice but to comply with the new data-driven agricultural practices or find themselves with limited access to advanced agricultural practices.

In a re-territorialized world, digital technologies are particularly important with regards to coordination mechanisms for knowledge sharing and take-to-market activities. The use of digital technologies allows short supply chains to achieve 'scale' through a variety of mechanisms:

- **Enabling replication of projects within a niche, by bringing about aggregated changes through many small initiatives.**
- **Enabling constituent projects to grow in scale and attract more participants.**
- **Facilitating translation of niche concepts into mainstream settings. The translation process implies a shift in the NM from providing specialties to everyday food.**[42]

The following table summarizes how and where digital technologies might be applied in the two main scenarios in order to transition to sustainable food systems.

[42] Seyfang and Haxeltine, 2012; p. 384.

7. CONCLUSIONS

Table: Role of ICT in Transitioning to Sustainable Food Systems

	Role of ICT in Transitioning to Sustainable Food Systems		
	Post-natural Industrial Supply Chains	New, Digitally-based Supply Chains	Developed Countries
Pre-Planting	GMO seeds, improved resistance to desease, improved resistance to pests, increased yields.	Seeds for kitchen growing systems, hydroponics for mass market.	Exchange of traditional knowledge for the upkeep of soil.
In field	Sensors to detect desease, drones to analyze crops,open data to understand weather pattern, connections between communities to understand desease patterns, etc.	Sensors to detect desease, home-based information systems for growing own food, social and community connection systems.	Smoothing of supply and demand between local suppliers, retailers and consumers.
Production	Transportation: RFID measuring temperature of foodstuffs to reduce waste, finer grained control of supply and demand transport deliveries.	Recipe sharing to reduce waste, details about how to store and keep foodstuffs, 3D-printing of food (fruit), in-vitro production of meats.	Incorporation of short supply chains to reduce waste.
Transportation	Transportation: RFID measuring temperature of foodstuffs to reduce waste, finer grained control of supply and demand transport deliveries.	Transportation: RFID measuring temperature of food stuffs to reduce waste, finer grained control of supply and demand transport deliveries.	Localized transport systems, "ride sharing" for transport of produce.
Marketing	Better information about the product in question for con-sumers.	Better information about the product in question for con-sumers.	Restructuring of supply chains to place control in consumers' hands.

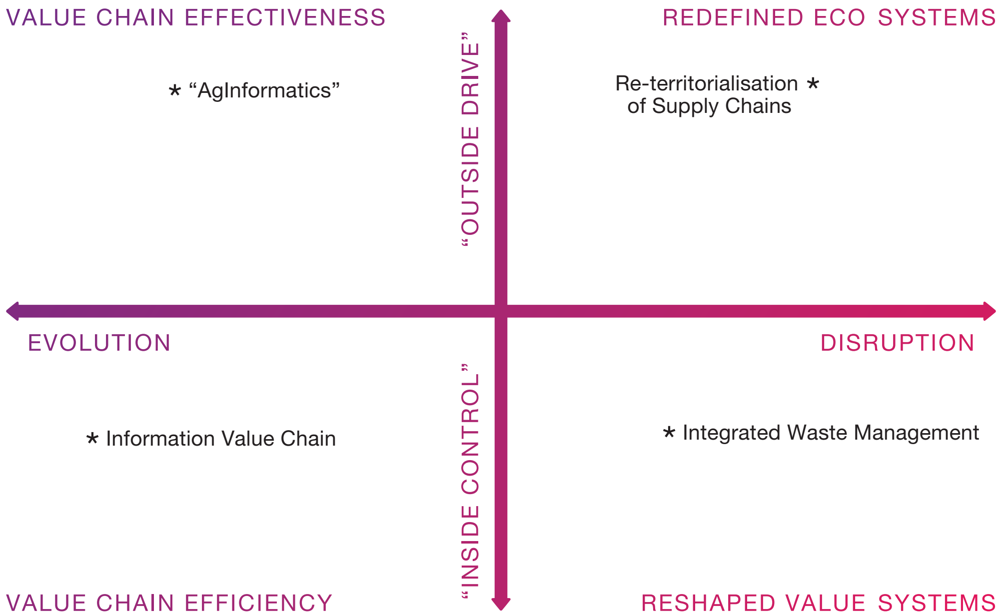
7. CONCLUSIONS

In Figure 15 we position the various forms of interventions that ICT can make within the food and agriculture systems in accordance with their level of disruptiveness to the existing industrial structure as a new landscape emerges around the use of ICT and the structure of the global food chain.

The food and agriculture industries have already experienced some disruption with regards to consumer demand as many consumers demand more local, healthy and sustainably grown food sources. As a result of these demands, ICT has been applied to create new organizational forms that allow end users and suppliers to coordinate with one another to deliver more optimal outcomes. The continued pressure for re-territorialization of food supplies will mean that the drive for new technology solutions required to deliver new organizational structures will continue. As covered in our Retail report, these organizational forms will encompass both the demand and supply side.

Food and agriculture systems are therefore likely to continue the drive towards new technology solutions and organizational forms across the Networked Society.

Figure 15: Matrix of Industrial Disruption in Food and Agriculture



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