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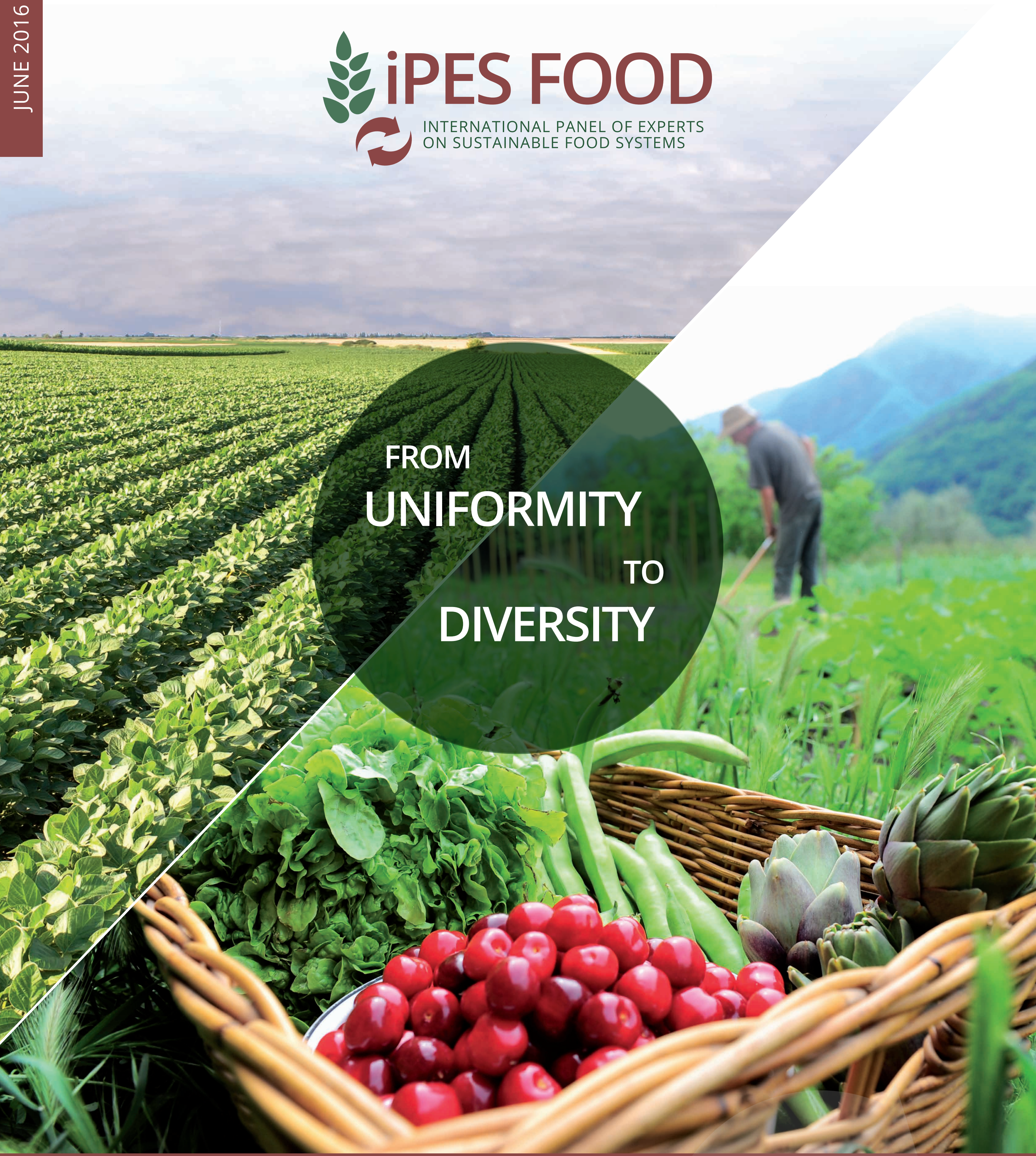

FROM UNIFORMITY TO DIVERSITY

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Key messages

- Today's food and farming systems have succeeded in supplying large volumes of foods to global markets, but are generating negative outcomes on multiple fronts: widespread degradation of land, water and ecosystems; high GHG emissions; biodiversity losses; persistent hunger and micro-nutrient deficiencies alongside the rapid rise of obesity and diet-related diseases; and livelihood stresses for farmers around the world.

- Many of these problems are linked specifically to 'industrial agriculture': the input-intensive crop monocultures and industrial-scale feedlots that now dominate farming landscapes. The uniformity at the heart of these systems, and their reliance on chemical fertilizers, pesticides and preventive use of antibiotics, leads systematically to negative outcomes and vulnerabilities.

- Industrial agriculture and the 'industrial food systems' that have developed around it are locked in place by a series of vicious cycles. For example, the way food systems are currently structured allows value to accrue to a limited number of actors, reinforcing their economic and political power, and thus their ability to influence the governance of food systems.

- Tweaking practices can improve some of the specific outcomes of industrial agriculture, but will not provide long-term solutions to the multiple problems it generates.

- What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes, replacing chemical inputs, optimizing biodiversity and stimulating interactions between different species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods, i.e. 'diversified agroecological systems'.

- There is growing evidence that these systems keep carbon in the ground, support biodiversity, rebuild soil fertility and sustain yields over time, providing a basis for secure farm livelihoods.

- Data shows that these systems can compete with industrial agriculture in terms of total outputs, performing particularly strongly under environmental stress, and delivering production increases in the places where additional food is desperately needed. Diversified agroecological systems can also pave the way for diverse diets and improved health.

- Change is already happening. Industrial food systems are being challenged on multiple fronts, from new forms of cooperation and knowledge-creation to the development of new market relationships that bypass conventional retail circuits.

- Political incentives must be shifted in order for these alternatives to emerge beyond the margins. A series of modest steps can collectively shift the centre of gravity in food systems.

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THE CHALLENGE: SHIFTING THE CENTRE OF GRAVITY IN FOOD SYSTEMS

The evidence in favour of a major transformation of our food systems is now overwhelming. Many influential studies have helped shape our understanding of the perilous situation our food systems are in, from the degradation of ecosystems to the fragility of farmer livelihoods in many parts of the world; from the persistence of hunger and under-nutrition to the rampant growth of obesity and diet-related diseases.

However, few studies have yet to provide a comprehensive view of how alternative food systems, based around fundamentally different agricultural models, perform against the same criteria. Even fewer have mapped out the pathways of transition towards the sustainable food systems of the future.

This report explores the potential for a shift to occur from current food systems, characterized by industrial modes of agriculture, to systems based around *diversified agroecological farming*. It asks what the impacts on food systems would be if diversity, rather than uniformity, were the key imperative. The ecological benefits of such a shift have been widely documented. The key question, and the one asked in this report, is where the trade-offs lie. In other words, could food systems based around diversified agroecological farming succeed where current systems are failing, namely in reconciling concerns such as food security, environmental protection, nutritional adequacy and social equity.

As this report shows, there is much promise in the emerging evidence. The comparison is complex, and the evidence is far from complete. Diversified systems produce diverse outputs, making it difficult to gage their implications for global production volumes of staple crops, and for 'food security' in the narrow terms in which it is often understood[1] (Cloke, 2013). After all, it is not simply a change in agricultural practices that is envisaged here, but fundamentally different farming landscapes and livelihoods, and radically reimagined food systems. This in itself is a key insight: the discrepancy between the potential of diversified agroecological systems to deliver what really matters, and our capacity to measure and value those things. It is no coincidence that one of the key recommendations arising from this report is to develop new ways of measuring success in food systems.

Making the case for changing course is crucial, but so too is mapping out a pathway of transition. Encouragingly, the foundations of this transition are already being laid by farmers, consumers, civil society groups and the many others taking bold and innovative steps to transform food systems around the world. However, the odds are still stacked against those seeking alternatives. As this report describes, industrial agriculture is locked in place by a series of powerful feedback loops extending well beyond the world of farming. Industrial agriculture and industrial food systems have shaped and been shaped by each other. Farmers cannot simply be expected to rethink their production model, nor consumers to radically reorient their purchasing patterns, without a major shift in the incentives running through food systems. The specific steps will differ from setting to setting, and from country to country. However, this report seeks to identify the common leverage points for unleashing this transition.

It is a transition that is applicable to all farming contexts and scales, whether the starting point is highly specialized industrial agriculture, or forms of subsistence farming in poor developing countries. Specialized industrial agriculture

1. A full understanding of food security was established at the 1996 World Food Summit: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

and diversified agroecological farming stand at two ends of a wide spectrum. Agroecology is not a niche for small-scale artisanal farmers in given sectors, nor is it a label to be attained on the basis of specific practices. It is a universal logic for redesigning agricultural systems in ways that maximize biodiversity and stimulate interactions between different plants and species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods. Put simply, it is the opposite of monocultures and their reliance on chemical inputs. It is therefore a broad landing space that can be reached via a variety of pathways and entry points, progressively or in more rapid shifts, as farmers free themselves from the structures of industrial agriculture and refocus their farming systems around a new set of principles.

The majority of farmers currently find themselves somewhere in between the two poles. Many farmers are diversifying their outputs and activities, experimenting with natural pest management, aiming for nutritious, high-quality production and seeking alternative retail circuits, even as they continue to farm primarily on the basis of specialized commodity crops. Rather than encouraging farmers to go a step further, the current incentives in food systems keep farmers locked into the structures and logics of industrial agriculture. The transition envisaged in this report would shift these incentives, thereby empowering farmers to step firmly off the treadmill of industrial agriculture. Only then will the true benefits of diversified agroecological systems be realized.

The type of change considered here would lead to the emergence of what are essentially new food systems with new infrastructures and new sets of power relations, implying the coexistence of two more or less distinct systems for some time to come. That does not mean that we should remain indifferent to the reforms emerging from those at the centre of industrial food systems. The emergence of alternative food systems can and must be complemented by a wholesale shift in mainstream practices, led by those with the power to reform them. Some firms are already engaged on this path. These steps are welcome, insofar as they find ways to complement, and not to derail, a transition that may ultimately redistribute power away from currently dominant actors.

The key is to establish *political* priorities, namely, to support the emergence of alternative systems which are based around fundamentally different logics, and which, over time, generate different and more equitable power relations. Incremental change must not be allowed to divert political attention and political capital away from the more fundamental shift that is urgently needed, and can now be delivered, through a paradigm shift from industrial agriculture to diversified agroecological systems.

Structure of the report :

- Section 1 What are the outcomes of industrial agriculture and diversified agroecological systems?
- Section 2 What is keeping industrial agriculture in place?
- Section 3 How can the balance be shifted in favour of diversified agroecological systems?

THE NEED FOR SYSTEMIC CHANGE

The food systems we inherit in the 21st century represent some of the greatest achievements of human civilization. Paradoxically, they also represent some of the greatest threats to our continued health and prosperity. Contrasted with millennia of subsistence diets for most of the population, today's food systems are a radical success in abundance in many parts of the world. Over the 19th and 20th centuries, major breakthroughs in crop productivity, food processing and distributive capacities drove huge increases in net calorie availability for consumers, bringing more varied diets into reach for those able to access and afford them. Modern food systems also boast impressive achievements in food safety. At the beginning of the 20th century, food poisoning and water contamination were major causes of mortality, even in relatively wealthy regions like Western Europe (Satin, 2007). Improved hygiene, technologies and medicine have all but eradicated these pathologies in the most affluent countries, with middle-income and low-income countries now making major advances.

However, the outcomes of these food systems are poor on many counts, and in many countries and regions of the world. Indeed, the very foundations on which these systems were built are becoming increasingly fragile.

Despite decreases in the percentage of the global population going hungry over recent decades, 795 million people still suffered from hunger in 2015 (FAO et al., 2015). Expanding the lens to take in those who are malnourished, the failures are far starker. In addition to acute hunger, two billion are afflicted by the 'hidden hunger' of micronutrient deficiencies (Bioversity International, 2014), and over 1.9 billion are obese or overweight (WHO, 2015a)[2]. Indeed, one of the greatest paradoxes of our time is the coexistence of the different faces of malnutrition within the same region or even the same household (Graziano da Silva, 2014). Non-communicable diseases (NCDs) associated with imbalanced diets have increased so rapidly as to have overtaken infectious diseases as the number one cause of global mortality (WHO, 2012; Murray et al., 2015). In addition, while food-borne illnesses persist in all types of markets, new scares affecting large numbers of people are emerging in increasingly globalized food markets, threatening to unravel the historical progress on food safety.

The environmental outlook is equally troubling. Today, food systems contribute between 19% and 29% of global anthropogenic greenhouse gas (GHG) emissions (Vermeulen et al., 2012). Upstream of agriculture, major contributions are made by the fossil fuel-intensive production of chemical fertilizer and pesticides (Gilbert, 2012). Downstream, emissions arise from food processing and retail sectors that rely increasingly on abundant synthetic packaging (Murphy-Bokern, 2010) and soaring 'food miles' in order to deliver the highly processed and unseasonal products to which consumers have become accustomed (Schnell, 2013). Meanwhile, 70% of all water withdrawn from aquifers, streams and lakes is used for agriculture - often at unsustainable rates (FAO, 2013). The agricultural sector is responsible for nitrate, phosphorus, pesticide, soil sediment and pathogen pollution in soil and water (Parris, 2011). Furthermore, agricultural systems have contributed significantly to land degradation as well as to the destruction of natural habitats and losses of wild biodiversity around the world (Scherr & McNeely, 2012).

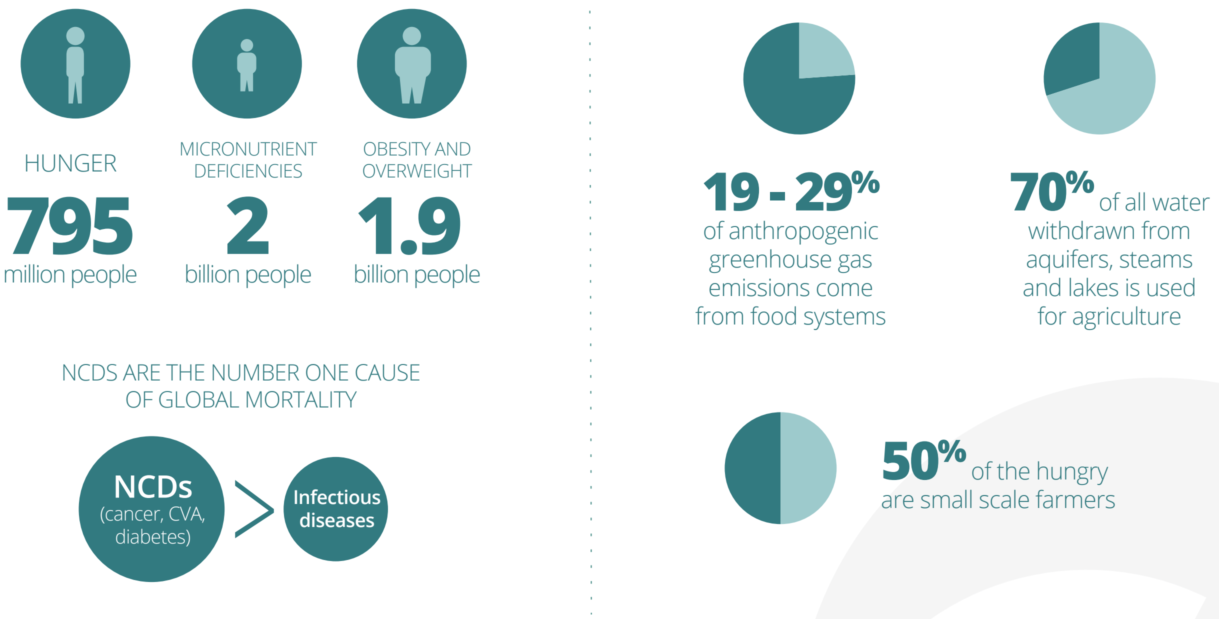
Food systems are also failing food producers themselves. Many small farmers, especially women, struggle to emerge above subsistence level, often lacking access to credit, technical support and markets – or facing the uncer-

2. There are some overlaps between those suffering from hunger, micronutrient deficiencies and overweight and obesity.

tainties of volatile prices on global commodity markets (FAO, 2004). Globalization has brought new challenges in terms of downward price pressures and costly regulatory burdens for farmers. As a result, the world faces the irony of small-scale farming communities making up about 50% of the hungry (WFP, 2015). Even in wealthier countries, farmers continue to face high risks and uncertainties, with farming incomes showing little prospect of rising durably (European Commission, 2014). This leaves many farmers reliant on government subsidies. Meanwhile, labour conditions remain problematic across food systems, from the precarious circumstances facing migrant fruit-pickers to the routine exploitation and under-remuneration of workers in abattoirs, food processing plants and retail outlets (ILO, 2008; ILO, 2015). While food and agriculture generate increasing value for grain traders and global retail giants, decent livelihoods remain out of reach for many of those employed in food systems.

The problems in food systems are deeply interconnected and mutually reinforcing. Some 35% of global cultivated crops depend on pollination (WHO & Secretariat of the Convention on Biological Diversity, 2015). The global decline in insect pollinators – driven in large part by the use of pesticides in agriculture (van Lexmond et al., 2015) – now threatens the very basis of agriculture and its future crop yields. Meanwhile, the livelihoods of many food producers are being pushed to breaking point by climate change and environmental degradation. Nearly one billion people who derive their livelihoods primarily from agriculture are presently living in vulnerable environments, and these are the populations that will bear the brunt of large-scale environmental change in the near future (Fischer et al., 2002). **In other words, modern agriculture is failing to sustain the people and resources on which it relies, and has come to represent an existential threat to itself.**

FIGURE 1 - THE KEY PROBLEMS IN GLOBAL FOOD SYSTEMS



TWO ENDS OF A SPECTRUM: INDUSTRIAL AGRICULTURE AND DIVERSIFIED AGROECOLOGICAL SYSTEMS

The various parts of food systems are clearly interconnected, requiring a holistic analysis of how these systems operate, and an awareness of the power relations running through them (see IPES-Food, 2015). It is nonetheless essential to zoom in on agriculture as a key entry point. In particular, it is crucial to identify the modes of farming that have generated the most negative outcomes, and to explore the potential for a fundamental shift in agriculture to set food systems on a sustainable footing.

It is possible to identify **industrial agriculture** as the dominant logic underpinning agriculture in industrialized countries, and increasingly in transitional economies. It is also the dominant trend in today's agricultural research and development efforts worldwide. In practice, what is referred to as 'conventional' agriculture often corresponds to the industrial model. The negative outcomes proliferating in modern food systems are therefore closely associated with industrial agriculture; the extent of this association, and the potential for improving these outcomes under different agricultural systems, is explored in Section 1.

Alternative visions and organizing principles for agriculture have evolved alongside the industrial model. The terms **diversification and agroecology** capture modes of agriculture that respond to fundamentally different objectives and logics, offering a genuine and holistic alternative to industrial agriculture. This report is focused on exploring the potential for a paradigm shift whereby diversified agroecological systems become the dominant model. The report is therefore structured around three key questions:

- **SECTION 1** What are the outcomes of industrial agriculture and diversified agroecological systems?
- **SECTION 2** What is keeping industrial agriculture in place?
- **SECTION 3** How can the balance be shifted in favour of diversified agroecological systems?

Industrial agriculture and diversified agroecological farming stand at two ends of a wide spectrum, and offer diametrically opposing visions of how to organize farming, particularly in its relationship to ecosystems. While most farmers are currently somewhere in between the two extremes, it is nonetheless important to understand both models in their fullest forms. These models are understood in terms of broad organizing principles as well as the specific practices they entail; many farmers may therefore be operating according to a predominantly industrial logic, even as they adapt some of their practices.

The key characteristics of the two models are described below. It should be noted that this list is not exhaustive, and is limited to the key agricultural/agronomic logics and organizing principles of each system. What these farming systems imply in terms of the broader socio-economic conditions around farming, and what they deliver in terms of outcomes, will be analysed in detail in Section 1.

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[3] 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**. This process must culminate in the adoption of holistic strategies for reintegrating agriculture with the ecosystems

3. Crop rotation is the sequential planting of one crop after another, and is often done to ensure soil health, replacement of nutrients, and reduction of disease.

TABLE 1

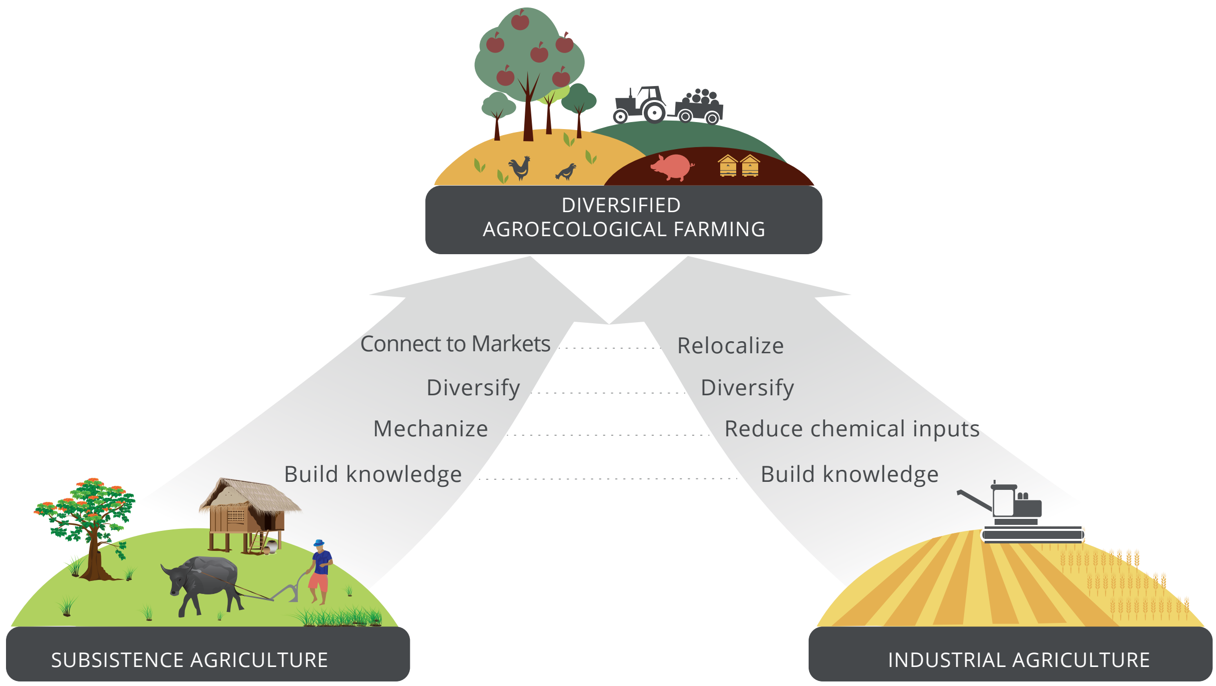
Key characteristics of Specialized Industrial Agriculture and Diversified Agroecological Farming

SPECIALIZED INDUSTRIAL AGRICULTURE	DIVERSIFIED AGROECOLOGICAL FARMING
DEFINITIONS	
Specialization refers to a socio-economic paradigm whereby producers specialize in the production of a single item (or few items) that they are most efficient at producing, or of a single stage of that item's production. **Industrial agriculture** refers to modes of farming that are analogous to industrial processes in their scale and task segregation, and seek to derive productivity gains from specialization (see above) and intensification of production. At various points in the report, 'industrial agriculture' will be used as short-hand to refer to a model which entails and is based around highly-specialized production.	**Diversification** refers to maintaining multiple sources of production, and varying what is produced across farming landscapes and over time. **Agroecology** is understood here as "the science of applying ecological concepts and principles to the design and management of sustainable food systems" (Gliessman, 2007). It encompasses various approaches to maximise biodiversity and stimulate interactions between different plants and species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods. It also represents a social movement; this usage will be specified where relevant.
KEY CHARACTERISTICS	
Crop **monocultures** (or production of a handful of select crops) at the level of farms or landscapes; **Concentrated Animal Feeding Operations** (CAFOs).	**Temporal diversification** (e.g. crop rotation) and **spatial diversification** (e.g. intercropping; mixed farming); diversification employed at various levels, including **plot, farm and landscape**.
Use of **genetically uniform varieties** or breeds selected mainly for high productivity, wide adaptability to favourable environments, and ability to respond to chemical inputs.	Use of wide range of species and less **uniform, locally-adapted varieties/breeds**, based on multiple uses (including traditional uses), cultural preferences, taste, productivity and other criteria.
Vertical and horizontal **segregation** of product chains, e.g. animal feed production and animal rearing in separate farms, value chains and regions.	**Natural** synergies emphasized and **production types integrated** (e.g. mixed crop-livestock-tree farming systems and landscapes).
Highly mechanized, labour-saving production systems.	More **labour-intensive** systems.
Maximization of yield/economic returns from a **single product** or limited number of products.	Maximization of **multiple outputs**.
Intensive use of **external inputs**, e.g. fossil fuel, chemical fertiliser, pesticides and antibiotics.	**Low external inputs**; recycling of waste within **full nutrient cycling** and circular economy approaches.
Production of large volumes of homogenous products for national and international markets, typically within **long value chains**.	Production of a wide range of less homogeneous products often destined for **short value chains**; multiple sources of production, income and livelihood.

on which it relies. The priority here is to establish why this paradigm shift is needed, and what is currently preventing it from occurring.

The spectrum between industrial agriculture and diversified agroecological farming is not the only relevant one, in terms of the changes that are required if agriculture is to respond to the challenges now faced. Models of subsistence farming are still practiced by hundreds of millions of poor farmers in developing countries. As has been widely recognized, there is major scope for increasing the productivity of these systems, and an urgent need to do so. The challenge, therefore, is to ensure that a re-investment in agriculture occurs in the countries and regions where under-performing subsistence farming is currently the norm, and that this investment be oriented towards diversified agroecological systems. In other words, **diversified agroecological systems are considered here to be the alternative toward which both industrial agriculture and subsistence farming can and should evolve**.

FIGURE 2 - TRANSITIONING FROM DIFFERENT STARTING POINTS



01 What are the outcomes of industrial agriculture and diversified agroecological systems?

In this section, the impacts of industrial agriculture (Section 1.a) and diversified agroecological systems (Section 1.b) will be identified on multiple fronts, broadly corresponding to the main areas of concern in modern food systems, and to the criteria that the sustainable food systems of the future will have to meet[4]. These impacts are grouped under the following areas: **Productivity, Environment, Socio-Economic, and Health and Nutrition.**

Three key challenges emerge in conducting this comparison. Firstly, **there are limits to a direct comparison between systems responding to very different logics**. For example, outcomes relating to resilience[5] are a particularly recurrent feature in the literature on diversified agroecological systems. The quest for resilience (e.g. in the face of climate stresses) frequently emerges as the starting point for diversified agroecological farming to be deployed. Therefore, while similar criteria are sought for assessing the two types of systems, and while resilience features in both cases, there is some limited variation between sections 1.a and 1.b in terms of the sub-headings used for grouping data, and how much data is included under each. This variation is essential in order to allow for fundamentally different systems to be understood in their own terms. The question of how we measure success, and the extent to which this skews typical comparisons, is explored in Section 2 of this report.

Flexibility in the terms of analysis is also required in order to account for the **different pathways and channels** that can be taken in order to arrive at the same goals. For example, international trade-based product diversity on one hand, and agricultural diversification on the other, represent fundamentally different channels for reaching the goal of increased dietary diversity. Both must be described in order to paint a full picture of what the opposing systems have to offer and how viably they can achieve this goal.

In other cases, direct comparison is even more difficult to achieve. Diversified systems produce diverse outputs, making it difficult to project the impacts of the envisaged shift on total production volumes of staple crops. This barrier can only be overcome by describing the vision of productivity and food security offered by diversified agroecological systems as fully as possible, and with recourse to a wide range of examples. This question will be revisited in Section 1.c, where conclusions are drawn on the basis of the data comparison.

A second challenge arises in that **much of the available information on agriculture and its impacts is not disaggregated by type of production.** Nonetheless, the analysis in Section 1.a is able to draw on considerable documentation of the specific impacts incurred by staple crop monocultures, export-oriented plan-

4. According to the High Level Panel of Experts (HLPE) of the Committee on World Food Security (CFS), *sustainable food systems* must deliver "food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised" (HLPE, 2014); another key benchmark is *sustainable diets*, characterized by "low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations", and must be "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" (FAO, 2010)

5. Environmental resilience refers to the capacity of an ecosystem to resist and recover from stresses, shocks and disturbances, be they natural events or impacts caused by human activity; Livelihood resilience refers to the ability of people to secure the capabilities, assets and activities required to ensure a decent living, particularly in the face of shocks (e.g. economic crises, environmental disasters).

tations and other manifestations of industrial agriculture. Similarly, Section 1.b includes extensive data that can be specifically attributed to diversifying food production and employing holistic agroecological approaches.

In other cases, data does not concern the two systems in their fullest forms, focusing for example on comparisons of **conventional** versus **organic**[6] systems. In practice, organic farming may often be synonymous with diversified agroecological farming; many 'organic' farmers are likely to have adopted extensive diversification and holistic farm-wide strategies for managing agro-ecosystems, in line with their ambition to depart from the industrial model. However, the organic certification does not carry this guarantee, and also encompasses those using a set of minimum practices for certification and going no further; in some cases it is practiced alongside industrial-style production on the same farm. **Organic/conventional data comparisons will not, therefore, be taken as a direct proxy for the two systems under discussion here, but will be considered highly relevant to the comparison.** In other cases, data refers to specific types of diversified production (e.g. polycultures[7]) which can be used more readily as proxies of the diversified agroecological model described above.

Thirdly, it must be acknowledged that some of the evidence cited below does not concern outcomes in the strictest sense. Evidence on the pathways and mechanisms through which a given system has been observed to function (e.g. the channels through which diversified systems resist environmental shocks) is included in addition to hard data on the impacts of different production systems.

Furthermore, many of the outcomes observed here are influenced by and contingent on a range of other factors (political, institutional etc.). The importance of these intermediary factors, and how difficult it is to extricate them from the modes of agriculture they accompany, is addressed in Section 1.c. As the conclusions in that section will underline, the full capacities of diversified systems will never be fully realized or even be fully identifiable insofar as industrial agriculture – and the edifice surrounding it – dominates the landscape.

6. Organic agriculture is a type of certified farming that must adhere to a set of environmental requirements regarding inputs and practices. A key requirement is non-usage of synthetic inputs (fertilizers/pesticides), although mineral inputs from outside the farm that are mined naturally can be applied. In Europe, organic certification includes requirements for crop rotation.

7. Farms growing crops in polycultures cultivate different plant species in reasonably close proximity in the same field, and vary those species over time. This term is opposed to monoculture where single/similar plant species are grown across large areas with minimum or no rotation.

1.A. OUTCOMES OF SPECIALIZED INDUSTRIAL AGRICULTURE

1.a.i. Productivity outcomes

➔ Yields

Undoubtedly, the greatest positive outcome of industrial agriculture has been the tremendous production increases in several major crops, particularly in the wake of the 'Green Revolution' in the post-war period. By 1970, 20% of the wheat area and 30% of the rice area in low-income countries were planted with **High Yielding Varieties** (HYVs), and by 1990, the share had increased to about 70% for both crops. HYVs were developed to have a high harvest index (grain weight as percentage of total biomass weight) (Guzman et al., 2016; Sánchez-García et al., 2013); to be highly responsive to chemical inputs; to maximize nutrient and water absorption; and to be widely adaptable to favourable production zones.

Spread of high-yielding crop varieties in low-income countries:

- 20% wheat area and 30% rice area by 1970
- 70% wheat and rice area by 1990

The positive effects on yields have been widely recorded. **Between 1961 and 2001, regional per capita food production doubled in Southeast Asia and the Pacific, South Asia, and Latin America and the Caribbean** (McArthur & McCord, 2014). HYVs are considered to have lifted many farmers out of poverty and increased net calorie availability (IFPRI, 2002). Similar increases in the productivity of livestock have also taken place (Thornton, 2010).

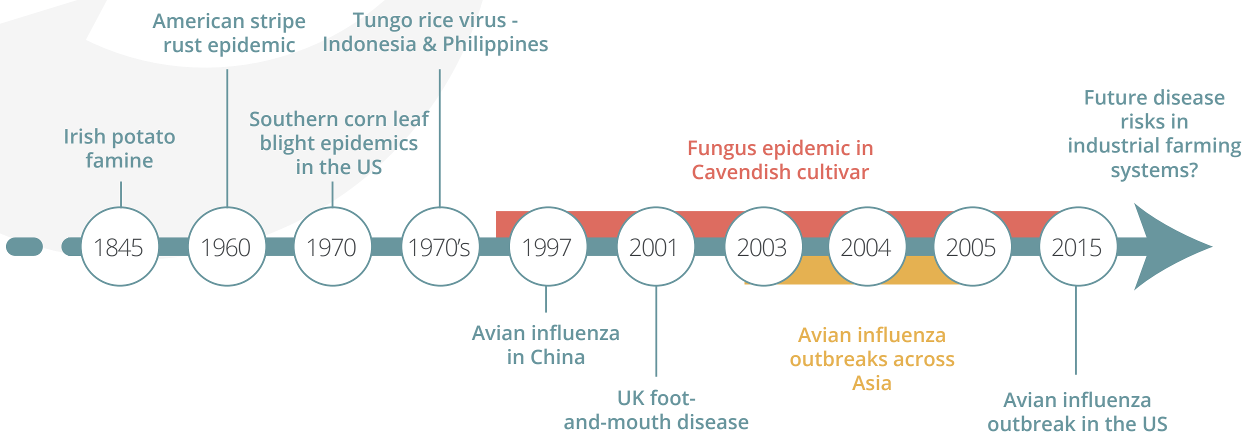
However, **in recent decades, yield increases for key crops in industrial cropping systems have started to plateau** in various regions of the world (e.g. maize in Kansas, rice in Hokkaido, Japan, etc.) (Grassini et al., 2013). A meta-analysis of yield developments around the world from 1961-2008 found that in 24-39% of areas growing maize, rice, wheat and soybean, yields either failed to improve, stagnated after initial gains, or collapsed (Ray et al., 2012). Meanwhile, doubts are emerging over whether high productivity in the livestock sector can be sustained in the future (Wellesley et al., 2015; Thornton, 2010). These phenomena can be attributed to multiple factors, including land degradation, loss of biodiversity and the associated loss of ecosystem functions, as will be further developed in this report (see sub-section below on Resilience and Vulnerability, and Section 1.a.ii on Environmental outcomes).

- Yields failed to improve, stagnated or collapsed in 24-39% of the world's maize, rice, wheat and soybean production zones (1961-2008)

➔ Resilience and Vulnerability

Threats to the productivity of industrial agriculture arise from one of its central characteristics: uniformity. **There are numerous historical examples of vulnerability linked to genetic uniformity in monocultures or industrial scale livestock rearing, resulting in significant economic losses and large-scale suffering.** As these cases show, genetic uniformity has systematically generated vulnerability to epidemics and, more generally, to biotic and abiotic stresses (Scarascia-Mugnozza & Perrino, 2002). Some examples are shown below in Figure 3, including the Great Irish Potato Famine, which started in 1845 (O'Neil, 2010); the American stripe rust epidemic in the 1960s; Southern corn leaf blight in the US (Ullstrup, 1972) and the Tungo rice virus outbreak during the 1970s in Indonesia and the Philippines (Thrupp, 2000, p. 272). In the case of livestock, outbreaks of diseases such as avian influenza (Alexander,

FIGURE 3 - A TIMELINE OF DISEASE OUTBREAKS IN HIGHLY-SPECIALIZED SYSTEMS



2000) and foot-and-mouth disease (FMD) (Gibbens et al., 2001) have spread rapidly among animals in high-density intensive production systems, with more catastrophic epidemics occurring among genetically homogenous populations (Springbett et al., 2003).

While some lessons have been learned from these historical production losses, today's highly specialized agricultural systems remain vulnerable. For example, a new strain of soil fungus affecting plantations of the Cavendish cultivar, accounting for the vast majority of commercial banana plantations, could devastate the banana industry in Latin America, which currently accounts for 80% of the world's multi-billion dollar banana trade (Butler, 2013).

The **mass pesticide usage** associated with the development of specialized large-scale monocropping has engendered risks of its own, with major implications for long-term productivity. The first case of resistance to pesticides was discovered in the 1960s (Gould, 1991). Since then, pests, viruses, fungi, bacteria and weeds have been adapting to chemical pest management faster than ever. **Having recourse to additional chemicals to tackle these resistance problems risks setting in place vicious cycles of further adaptation and resistance** (Pollinis, 2015).

This trend has been increasingly documented with regard to **genetically modified (GM) crops**, and particularly the monocultures associated with the 'Roundup Ready' model of herbicide-tolerant crops and accompanying glyphosate treatments. There are currently some 210 species of herbicide-resistant weeds, many of which can be linked to GM crops (Heap, 2014). The 'treadmill' of increasing pesticide use and increasing resistance not only fails to address the underlying problem of pest resistance and its threat to yields, but also brings mounting costs for farmers (see Section 1.a.iii).

» First case of pesticide resistance found in 1960s
» 210 species of herbicide-resistant weeds now observed

1.a.ii. Environmental outcomes

➔ Land Use

Where land use is concerned, the environmental impacts of industrial agriculture continue to be a subject of controversy. **Positive environmental impacts have been identified on the basis of land being *spared* from becoming cropland**, due to the ability of industrial systems to increase productivity on existing farmland. In Asia, cereal production doubled from 1970 to 1975, with the total cultivated land area increasing by only 4% (IFPRI, 2002). Data suggest that if crop yields had remained constant from 1961 to 2005, an additional 1.761 million hectares of cropland would have been required globally in order to achieve the production levels that were reached at the end of that period; such an increase in land requirements would have triggered deforestation on a much greater scale (Burney et al., 2010).

However, **where land has been brought out of production, the link to high-yielding industrial agriculture is weak** (Kremen, 2015). Few cases could be observed nationally or globally over the 1990-2005 period in which yields increased and cropland declined in tandem; agricultural intensification has not generally led to a country stabilizing or reducing its cropland area (Rudel et al., 2009; Ewers et al., 2009). The predominant experience has been that as productivity has increased, so too has the area under production Rudel et al., 2009).

Furthermore, it should be noted that land sparing is important only insofar as the challenge is framed in terms of limiting the encroachment of cropland into additional areas. For some, this is a distraction from the question of *how* current cropland is used. It should be noted that the 1.761 million hectares supposedly 'spared' between 1961 and 2005 (Burney et al., 2010) is an aggregate figure, meaning that new land is likely to have come into production while other zones were taken out of production – potentially in degraded condition. Land 'spared' from production cannot therefore be assumed to be a haven for biodiversity or sequestering carbon.

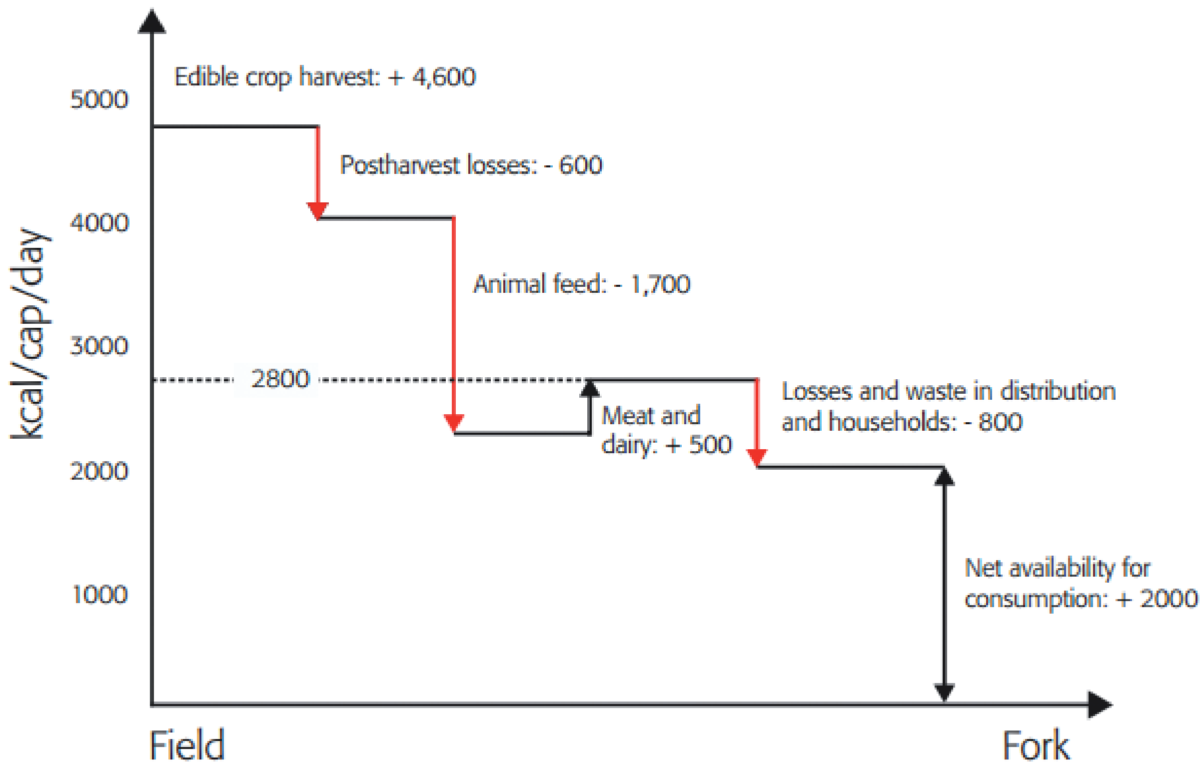
- » Asian cereal production doubled with only 4% increase in land from 1970-1975
- » Without improved yields, 1.76 million hectares of additional cropland would have been required to reach 2005 production levels.
- » The EU's 'virtual land area' is 35 million hectares
- » Most developed countries are net biomass importers

Land sparing arguments also lose relevance when the need for additional crop productivity (either on existing or additional farmland) is called into question. Global food production (and the global cropland it requires) is already theoretically sufficient to feed the planet twice (Lundqvist et al., 2008; Smil, 2001), as Figure 4 explains. The importance of how the question of food security is framed, and the implications for what is prioritized in food systems, will be addressed in Section 2.

A reality of global land use patterns for agriculture, and one potentially obscured by focusing on net land usage, is the growing **outsourcing of food production** in some areas of the world. Facilitated by the specialization of agriculture on regional scales, wealthy countries have been able to shift the land requirements for sustaining their diets – particularly **animal feed supply** - into other parts of the world on a huge scale. For example, the virtual land area required by the European Union (EU) is estimated at 35 million hectares (Witzke & Noleppa, 2010). **Most developed countries are in fact net importers of biomass for human consumption, animal feed and industrial raw materials** (Krausmann et al., 2009).

FIGURE 4 - GLOBAL FOOD PRODUCTION AND LOSSES

This diagram, from Lundqvist et al., 2008, shows the total food calories that would potentially be available for human consumption if losses, waste and the inefficiencies of animal production were removed. This data should be updated to account for current production levels and to include the significant diversion of food crops and cropland to biofuel production since the data was compiled.



➔ Land degradation and soil erosion

As mentioned above, the theoretical land sparing referred to in the above argument is likely to have been offset by rapid land degradation. According to the Food and Agricultural Organization of the United Nations (FAO), by the 1990s, some nine million km2 of land - an area roughly the size of China - was considered to be moderately degraded, with a further 3m km2 in a severely degraded state (Fraser & Rimas, 2011). Although estimates vary, **over 20% of land found on Earth is currently considered as degraded** (UNCCD, 2012). Structural changes in landscapes associated with industrial agriculture are a major source of this degradation, with monocultures and highly mechanized practices linked to cases of historical land degradation. The Dust Bowl in the US in the 1930s is one such example: aggressive tillage across the American Midwest, combined with a period of prolonged drought, led to severe soil erosion and dust storms (Shannon et al., 2015).

Overall, unsustainable practices associated with industrial agriculture remain the largest contributor to land degradation, which continues at an alarming rate of 12 million hectares/year, equivalent to the total agricultural land of the Philippines (ELD Initiative, 2015). Furthermore, it has been estimated that more than

50% of irrigated arable land will be salinized[8] by the year 2050 if current trends continue (Jamil et al., 2011). Therefore, sparing land may be less important than restoring and regenerating degraded land, a question to which industrial systems have yet to provide a convincing answer (Section 1.b.ii covers the regenerative capacities of diversified agroecological systems).

- By 1990s an area of land the size of China was degraded, and an additional 30% was severely degraded
- Over 20% land is now degraded globally
- 12 million hectares of land is degraded annually
- 50% of irrigated cropland will be salinized by 2050 on current trends

➔ Greenhouse gas emissions

As a whole, global food systems generate one-third of all human-caused GHG emissions (Thornton, 2012), with agriculture, forestry, and other land use changes contributing as much as 25% (Smith et al., 2014). Some of the factors contributing most significantly to these emissions are closely associated with industrial modes of farming. **Large-scale deforestation** has been declining in recent years; however, it continues to contribute significantly to GHG emissions and ecosystem degradation in many parts of the world, such as Southeast Asia, primarily to pave the way for large-scale palm oil plantations (NCD Alliance, 2012). Elsewhere, livestock grazing and the production of feed crops have been the main agricultural drivers of deforestation (Garnett, 2014).

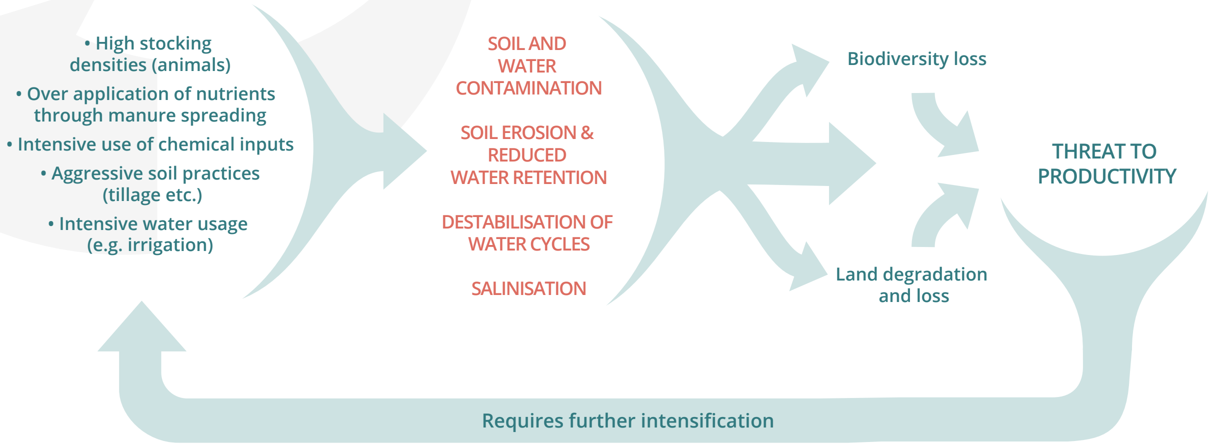
Livestock also makes a significant direct contribution to agricultural GHG emissions, largely through **methane emissions** from cattle. While it is difficult to isolate the contribution of CAFOs and other industrial-style production systems, **it is clear that inefficiencies accrue as animal rearing becomes more disconnected from landscapes and from local feed sources** (Infante & González de Molina, 2013). Typical feed conversion ratios range from 2kg feed per kg of meat in the most efficient animal production systems to as much as 20kg in some beef cattle systems, varying considerably between different animals, farming systems and calculation methods (Garnett et al., 2015). Broadly, net life-cycle emissions from industrial feedlot systems are likely to be considerably higher than those from integrated grassland systems, once carbon sequestration is taken into account (National Trust, 2015).

➔ Water contamination, soil erosion and runoff

Large-scale monocultures and other highly specialized farming systems entail particularly high risks of runoff and soil erosion, leading to widespread contamination of soil and water (Boardman et al., 2003). The **excessive application of nutrients** (particularly nitrate and phosphate) has increased with the intensification of agriculture and the increase in livestock stocking rates, resulting in severe water pollution. Estuarine and coastal agricultural nutrient pollution has damaged marine life, including commercial fisheries in coastal waters (Parris, 2011; Bouraoui & Grizzetti, 2014). Similar impacts from phosphorous runoff have been observed on Lake Erie, shutting down public water supplies (Chung, 2014). Furthermore, **'dead zones' are increasingly being observed at the mouths of river systems**, as a result of fertilizer and pesticide runoff. One example is runoff from the Mississippi River Delta – down-

8. Salinization refers to the phenomenon of increasing salt content in soils, resulting in disturbance of water cycles (e.g. through irrigation practices) and other factors. Salinization prevents plant roots from absorbing water, with the effect of lowering yields and further degrading the soil.

FIGURE 5 - VICIOUS CYCLES OF SOIL AND WATER DEGRADATION IN INDUSTRIAL SYSTEMS



stream from the US 'corn belt' – into the Gulf of Mexico (Pimentel et al., 2005).

Large-scale industrial feedlots generate huge amounts of waste in specific geographical areas. In France, the development and spread of algal blooms on the north-western coastline has been linked to the increase of nitrogen from manure applications. This is associated with the rise of intensive livestock farming in this region (Ministère Français de Agriculture et al., 2012). Similarly, CAFOs in the US generate approximately 500 million tons of manure per year, or three times the amount of annual human sanitary waste (Schwarzer et al., 2012). **When insufficient land is available for safe manure disposal, runoff and leaching of waste into surface and groundwater occurs,** especially in the pig, poultry and dairy sectors (Parris, 2011). This can have multiple negative consequences, including the development and spread of bacteria, representing a potential source of faecal cross contamination. Overall, industrial animal production systems pollute more ground- and surface-water than grass-fed systems (Mekonnen & Hoekstra, 2012).

It should be recalled that livestock manure can be a positive contributor to soil fertility and land management in more extensive mixed farming systems[9] (see Section 1.b); it is the concentration of huge quantities of livestock waste in given areas that converts it into a negative environmental impact in industrial systems.

➔ Water usage

Because of the poorer soil structure in industrial agricultural systems and long periods of bare soil, **water runoff is greater and water retention lower**, thereby requiring more water for irrigation (Gomez et al., 2009; Zuazo et al., 2009). Animal products from industrial-style CAFOs have a larger blue and grey water footprint[10] than produce originating from grazing systems (Mekonnen & Hoekstra, 2012). **Large scale irrigation** in highly-specialized

9. Mixed farming combines plant production with animal or aquacultural production.

10. Water footprint refers to the water that is taken out of its cycle or that has been polluted at different stages. Blue water refers to fresh, surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers. Green water refers to precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation, before evaporating or transpiring through plants.

cropping zones, such as the US Midwest (Scanlon et al., 2012) or Rajasthan in India (Rodell et al., 2009), is also over-exploiting aquifers, with water tables being depleted at alarming rates. Estimates suggest that 30-50% of pre-development groundwater reserves from the Ogallala aquifer, which provides around 30% of US irrigation needs, have already been mined (Kromm, 2000; Chadhuri et al., 2014).

» Manure from US CAFOs is three times the volume of annual human sanitary waste

➔ Erosion of genetic pool

By definition, industrial agriculture significantly reduces agrobiodiversity by employing a reduced range of animal breeds and plant varieties. Furthermore, **the erosion of entire production systems has occurred alongside the mass production of a handful of staple crops**: 'underutilized' or minor crop species such as indigenous leafy vegetables, small-grained African cereals, legumes, wild fruits and tree crops are disappearing in the face of competition with industrially produced varieties of rice, maize and wheat (Jacobsen et al., 2013).

For livestock, a few highly productive breeds adapted to industrial production systems have now replaced most local breeds across the world (Groeneveld et al., 2010). FAO's Global Databank for Animal Genetic Resources for Food and Agriculture contains 7616 livestock breeds. 6536 of these are purely local breeds, meaning that they are found in only one country. Of this total, 20% are classified as at risk. Between 2001 and 2007, 62 breeds became extinct – amounting to the loss of almost one breed per month (FAO, 2007). While these approaches respond to short-term productivity objectives, they entail a general reduction in practical applications of genetic diversity, potentially limiting the genetic pool available to future generations of farmers, and limiting the options in terms of adapting to changing environments (Vigouroux et al., 2011). **The implications of this genetic erosion could be huge, given the unpredictability of future stresses.**

FIGURE 6 - GENETIC EROSION OF LIVESTOCK BREEDS

➔ Wild biodiversity and ecosystem functioning

Industrial agriculture has also had significant impacts on wild biodiversity, jeopardizing the ability of farming systems to deliver crucial ecosystem services (Wood et al., 2000; Luck et al., 2003; Duffy, 2009). Biodiversity loss is the domain in which the world has moved furthest beyond what could be considered a safe *operating space* (Steffen et al., 2015), according to the Planetary Boundaries concept developed by the Stockholm Resilience Centre (Rockström et al., 2009).

A **worldwide loss of pollinators is now occurring**, and is closely linked to agricultural intensification, habitat fragmentation and the use of agrochemicals (Potts et al., 2010), particularly neonicotinoids (Bonmatin et al., 2014; van Lexmond et al., 2015). Populations of bees, flies, moths, bats and birds provide significant pollination and pest control services to crops. According to the Millennium Ecosystem Assessment (2005), the presence of pollinators tends to be significantly lower in monocultures than in fields containing diverse forage and nesting sites. The economic value of pollination is approximately 9.5% (€153 billion) of the value of global agricultural production for human food (Gallai et al., 2009).

» Biodiversity is domain in which world is operating furthest beyond 'safe operating space'
» Economic value of pollination is nearly 10% value of global food production

1.a.iii. Socio-economic outcomes

➔ Income

Industrial farming with highly input-responsive varieties has been shown to increase yields (see section 1.a.i); broadly, this has translated into positive income effects for farmers. However, the **high costs of chemical inputs** on which these systems rely reduces profit margins and often requires access to credit and risk-based insurance. It also contributes to the need for public support; in the EU and the US, the various subsidies received by farmers represent a significant share of their income (Merckx & Pereira, 2015; European Commission – EU FADN, 2011). **Overall, the economic situation of farmers in industrial farming systems, even highly-subsidized ones, remains precarious.** In the US, farm sector profitability is forecast to decline for the third straight year, falling by as much as 3%; if this occurs, net farm income in 2016 would reach its lowest levels since 2002 (USDA, 2016c).

Furthermore, there may be issues of selection bias in comparisons reporting positive income effects from the adoption of industrial agriculture. Given the up-front costs (e.g. inputs, land), those producing in the industrial model are likely to be among the biggest, best-resourced and most-capitalized farms to start with.

This is particularly pertinent when it comes to GM crops, often grown in highly-specialized large-scale monocultures of maize or soybean. A recent meta-study suggested positive yield and income effects for farmers growing GM crops (Klümper & Qaim, 2014). However, critics have argued that only the largest and most profitable farms are able to bear the costs in the first place (Heinemann, 2014; Quist et al., 2013). **The conditions required in order for positive yield and income effects to be recorded – and costs to be recovered – are thus likely to be unviable for many small-scale farmers around the world.** Indeed, this has also been observed in terms of the unequal spread of benefits from the crop breeding advances of the Green Revolution. To date, HYVs have not benefited the poorest small-scale farmers, or those without access to irrigation (IFPRI, 2002).

> US farm income forecasts 2016:
> - Third straight year of decline
> - Lowest level since 2002

➔ Employment rates

The two systems under consideration here have clearly divergent impacts in terms of employment. As will be described in Section 2, one of the key drivers of industrial agriculture has been an **increase in the relative cost of labour**. This has incentivized the use of labour-saving technologies and the search for increasing economies of scale. Indeed, **on-farm employment has steadily decreased over recent decades**, particularly in North America, Europe and Australia, on the back of the shift towards larger and increasingly specialized farms (Bowman and Zilberman, 2013; Australian Bureau of Statistics, 2012; Statistics Canada, 2014; US EPA, 2013; Eurostat, 2015). For example, agricultural labour in the EU decreased by 24.9% between 2000 and 2009 (Eurostat, 2010).

Fast-moving innovations in '**precision agriculture**'[11] – particularly data-driven developments based on geospatial positioning and satellite imagery technologies – may mean further decreases in the labour force as highly-specialized farms seek to upgrade. An Australian study has shown that precision farming requires less hired labour on grain farms (Robertson et al., 2007).

Reduced labour requirements are generally considered to be a major advantage of industrial agriculture, particularly when success is framed in terms of delivering overall economic efficiencies, i.e. by freeing up labour for higher-value sectors of the economy (Timmer, 2015). Indeed, the specialization paradigm fundamentally relies on structural transformation, whereby labour and capital are able to transit from one sector of the economy to another. However, there are major question marks regarding the extent to which this shift can continue to occur, and whether it genuinely brings economic efficiencies.

While workers can transit easily in particularly strong labour markets, in many countries **those pushed out of agriculture do not find decent alternative employment in other sectors** (Oya & Pontara, 2015). In the modern highly globalized economy, services jobs constantly shift to lower-cost locations, often leaving rural out-migrants in precarious situations in city slums (Murray Li, 2009). Furthermore, those exiting agriculture are not only landless workers. The changing patterns of land use associated with industrial export-led agriculture – including as a result of land acquisition or 'land grabs' – have been identified as driving an exodus of previously self-sufficient peasants to the cities (Gendron & Audet, 2012).

Furthermore, **reductions in farm labour may not be efficient in the longer-term if they entail a loss of knowledge**, which may become increasingly important in a context of rising environmental and pest stresses. For example, herbicide-tolerant GM cropping systems that promise labour-saving, simplified forms of crop management are now facing major issues of weed resistance (Bonny, 2011; Quist et

11. Precision agriculture/farming refers to a type of farm management practice that involves the use of technology (GPS, communication technology, etc.) to optimize field-level management, enhance agricultural performance through better use of inputs, and improve the ability to predict and mitigate environmental risks. It is also referred to as satellite farming or site-specific crop management.

al., 2013). This can require farmers to invest in additional GM traits and additional pesticides (Quist et al., 2013). Where these approaches fail, a return to labour-intensive practices such as hand weeding may be needed.

➔ Employment conditions

Employment conditions are highly dependent on the protections in place in a given country, and how well they are applied. The spread of industrial agriculture has occurred alongside general advances in labour rights and protections in many parts of the world. **In some cases, the process of agricultural industrialization has brought specific benefits for workers.** For example, in a recent US study, improvements in labour conditions were observed on larger and more industrialized farms with the capital to invest in modernizing their facilities and automating some tasks. Milk parlour modernization was shown to improve the ergonomic conditions of work for labourers, particularly on large-scale farms; however, here and elsewhere, improved conditions did not accrue evenly to all workers (Harrison & Getz, 2014).

Improvements in labour conditions have been less impressive in the highly-specialized plantations that dominate the farming landscape in many tropical countries. Globally, 60% of child labour continues to occur in the agricultural sector (ILO, 2010). Forms of forced, bonded and slave labour, as well as dangerous and inhumane working conditions, have been found on plantations (Potts et al., 2014; Monsalve Suárez & Emanuelli, 2009). **Serious human rights violations**, including **forced child labour** and the **prohibition of labour unions**, have occurred on palm oil and sugarcane plantations in the Philippines and India (Monsalve Suárez & Emanuelli, 2009). Where women are employed on plantations, they are often engaged in physically demanding tasks to respond to labour shortages, such as harvesting cane or participating in planting, weeding and fertilizing (García, 2006).

In some cases, the promised quantity and quality of jobs on plantations has failed to materialize: in Latin America, large-scale land acquisition for soy, palm oil, maize etc. has failed to create as many jobs as promised, with '**livelihoods replaced by informal jobs**' (Gereña & Burgos, 2014). Indeed, large-scale plantations often rely on the labour of poorly-paid seasonal workers who are left without income and employment between peak seasons.

Furthermore, seasonal farm labourers – often migrants – are routinely denied the rights and protections of other workers. In the US, migrant workers, mostly from Latin America, endure "endemic poverty, poor health outcomes, and squalor living conditions" on tobacco and other monoculture farms, and in farm labour camps (Benson, 2008; Holmes, 2013). Many migrant labourers are engaged in what have been referred to as '**three D' jobs**: the work is considered "**dirty, dangerous, and difficult**" (Schenker, 2011). These types of employment are often highly precarious, menial and present a high risk of repetitive strain injury.

- 60% of global child labour occurs on farms
- 'Three-D' jobs on plantations: dirty, dangerous and difficult

➔ Trade and export orientation

Highly-specialized industrial agriculture and export orientation have reinforced each other over time; the global division of labour into specialized production zones has yielded large volumes of tradable commodities, facilitating the global agricultural trade which, in turn, has created further incentives for specialized, export-oriented farming (see Section 2, Lock-in 2: Export orientation). For countries and regions following this path, **agricultural export commodities have developed into an essential source of income, employment, and government revenues**. In particular, export revenues provide an essential source of foreign exchange for many countries, allowing them to import a range of products, from consumer items to essential healthcare machinery and infrastructural materials that cannot be or are not produced domestically.

Export orientation has, nonetheless, generated risks, not only for the specialized exporters, but for all farmers affected by the policies put in place to accompany and facilitate agricultural commodity exports. Although only about 23% of global food production is traded internationally (D'Odorico et al., 2014), the opportunities presented by export cropping have often led to policies being put in place to support further expansion of the export sector – sometimes at the expense of other concerns (see Section 2, Lock-in 2: Export Orientation). For some groups of farmers, the benefits of export agriculture have remained theoretical: small producers in developing countries have often struggled to compete in the face of restrictive regulations, high food safety and quality standards, and the other requirements of international trade (Steinfeld et al., 2006; van der Meer, 2006; Lee et al., 2012).

Highly specialized export zones have also tended to bring macroeconomic risks. The countries depending most heavily on agricultural commodity exports are commonly low-income countries (FAO, 2004). Reliance on a handful of commodities as the main means of participating in global trade can lead to major vulnerabilities by **exposing an economy to price shocks** (UNCTAD, 2013). In some cases, price volatility has been found to increase in proportion to the specialization of production (Bellora & Bourgeon, 2014). Commodity-induced '**international poverty traps**' have thus been identified where the poor have few resources to fall back on and **no durable route out of poverty**, whilst deep underlying developmental issues are ignored (UNCTAD, 2002; UNCTAD, 2013).

Critics of the theory of comparative advantage have in fact attacked it as a self-fulfilling prophecy; the countries and regions that specialize in higher-value industrial products are able to benefit from a range of spin-off effects and innovation in high-value sectors, unlike those confining themselves to raw commodity production (Cypher & Dietz, 1998; Sachs, 1992). The experiences of many Latin American and African countries suggest that those integrating into the world economy as '**commodity supply regions**' are likely to remain stuck in this role, with their prosperity contingent on access to rich country markets and terms of trade for their commodities (Wade, 2003).

➔ Hunger and Food Security

The production increases delivered by an increasingly industrialized agricultural sector over the last half century, and particularly the crop breeding advances of the Green Revolution, have led to **significant reductions in the number, and especially in the percentage, of hungry people in the world** (IFPRI, 2015). However, progress has been highly uneven between the different regions of the world. While industrial agriculture has undoubtedly raised net calorie availability on global markets, almost 800 million people still suffer chronic hunger.

Hunger is often concentrated in poor countries where agriculture has not yet been industrialized on a significant scale. As indicated at the outset of this report, reinvesting in agriculture in order to move communities out of subsistence farming is just as important as the transition from industrial to agroecological modes of production. However, the global advance of export-oriented industrial agriculture, and the **rapid shifts in competitiveness** this has entailed, has also played its part in overhauling and destabilizing food supply patterns – even in countries where small-scale, traditional and subsistence agriculture still dominate. Having been a net food exporter in 1970, the African continent had become a net food importer with a $22bn agricultural trade deficit by the end of the decade (FAO, 2011). Those transitioning fast towards the industrial model have also experienced new tensions in regard to food security, with **export opportunities sometimes prioritized above domestic needs**; this is seen to have occurred in regard to Mexico's integration into North American markets (González, 2014).

Meanwhile, the general switch towards specialized, export-oriented systems has eroded the **enterprise diversification** that previously underpinned the farming economy, causing a gradual loss of local food distribution systems (Gliessman, 2007). In many places, these localized systems have been replaced by global supply and distribution chains, and the structures of mass retail. However, **this has not occurred everywhere, and not evenly, leaving some populations with limited access to food**, even as net food production has risen in the same regions and countries (the specific nutritional impacts of changing modes of food production are covered in Section 1.a.iv).

> » African continent went from being net food exporter in 1970 to net food importer with $22bn trade deficit by end of the decade.

➔ Competition for land

Given that industrial agriculture is typically geared towards producing for global markets, it tends to increase the competition for resources between populations with vastly different purchasing power. **In poor rural regions, land may be the only resource on which poor communities can rely**. However, the net economic value yielded by this land is always likely to be greater when it is linked to wealthier consumers in the global North through specialized export commodity production. Indeed, large-scale land purchases have generally been undertaken for the purposes of setting up export-oriented plantations, e.g. to produce feedstock for biofuels (Grain, 2011; Lambin & Meyfroids, 2011), or on behalf of foreign governments (via sovereign wealth funds) in order to secure import supply chains for a given food commodity.

This has been the case for much of the new wave of large-scale land acquisitions that have proliferated in the wake of the 2007-2008 global food price spikes (Cotula et al., 2009; McMichael, 2012). Generally, there is a huge distance between where the products obtained are consumed (urban zones and wealthy nations) and the zones where the land is obtained (rural zones in tropical regions), with negative impacts afflicting the poorest in those zones (Lambin & Meyfroidt, 2011). All such impacts depend on the protections granted to local communities and existing land uses; however, **large-scale farmland acquisition generally occurs in areas with an abundance of land and weak governance structures**, as well as neglect of social and environmental issues (World Bank, 2011).

While benefits can accrue to local populations, and while attempts have been made to regulate these transactions, the economic mismatch tends to be overpowering, yielding favourable arrangements for international investors, insufficient compensation of local communities, and widespread social conflicts. The expansion of industrial monocultures has thus resulted in a large number of **land conflicts**, sometimes involving entire communities and often resulting in **forced evictions** (Monsalve Suárez & Emanuelli, 2009). In many cases, farmland acquisition for high-value export crops provides insufficient compensation for local people (Deininger & Byerlee, 2011).

Furthermore, **large-scale land transactions often disrupt social networks, exclude local people from the decision-making process and result in protests or clashes**, particularly when job creation and other benefits are lower than promised (Richards, 2013). These pressures have been particularly acute in Africa (Cotula, 2012) and Southeast Asia (Hall, 2011).

In Guatemala, Paraguay and Colombia, expanding oil palm, soy and maize monocultures are displacing local communities and negatively affecting traditional livelihoods. In these cases, corporate social responsibility and codes of self-regulation have failed to soften the blow (Guereña & Burgos, 2014). In other cases, 'land grabs' have led to the abuse of sacred sites (Richards, 2013).

➔ Cultural erosion

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). In some contexts, cultural erosion is seen to have occurred through the loss of native seed varieties adapted to local growing conditions and tastes, and the **loss of traditional knowledge** associated with them (Amekawa, 2011).

In addition, some of the cultural impacts of industrial agriculture have accrued disproportionately to women. **The general shift from traditional food crops to high-value cash crops has been associated with men taking control of land, water and productive resources at the expense of women** (Monsalve Suárez & Emanuelli, 2009). In many cultures, women have traditionally been the keepers of deep knowledge of the plants, animals and ecological processes around them. The erosion of biodiversity driven forward by industrial agriculture has therefore had specific impacts for women as food producers and caregivers, including a loss of knowledge related to seeds, food processing and cooking (Parmentier, 2014).

1a.iv. Nutrition and health outcomes

➔ Dietary Diversity

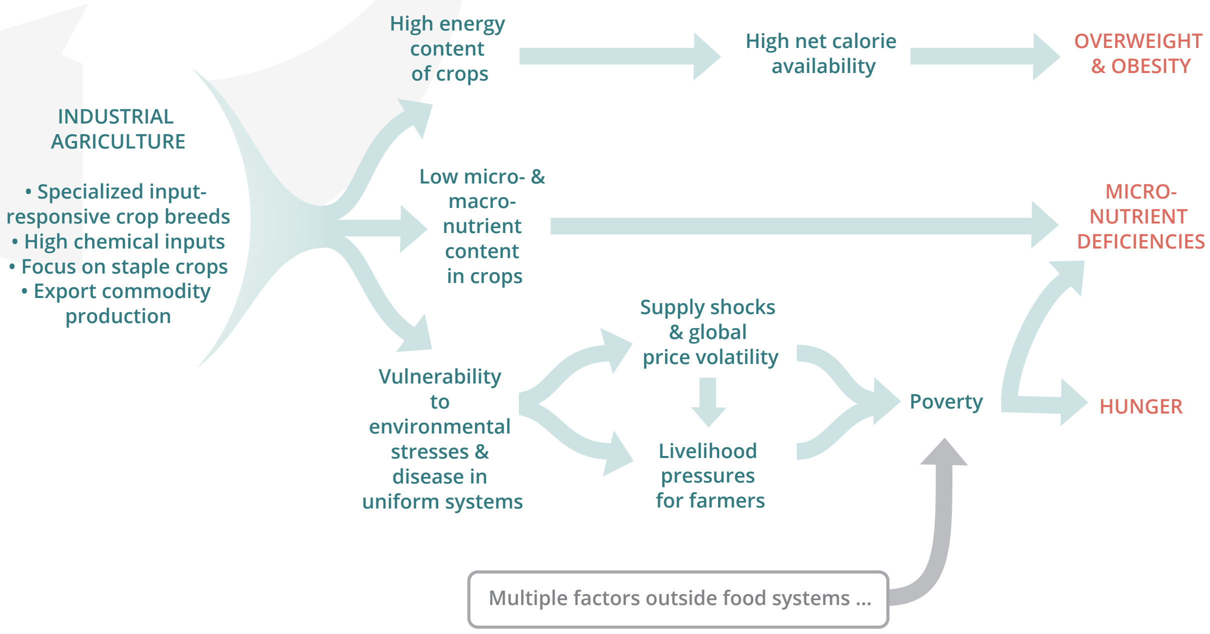
The benefits of a more diverse diet are now widely recognized. A diverse and balanced diet can ensure exposure to a broader set of nutrients and non-nutrients which have antioxidant, anti-cancer and other beneficial properties (Fanzo et al. (eds), 2013). Furthermore, the association between the diversity of a child's diet and his/her nutritional status operates independently of other socio-economic factors (Arimond & Ruel, 2004). There is a strong link between a low monthly Diet Diversity Score and underweight among children under two (Fanzo et al., 2011).

The question, therefore, is how this dietary diversity can be achieved. The pathway offered by industrial agriculture is through highly specialized and productive agriculture around the world, combined with well-functioning trading systems that allow a variety of different foodstuffs to be accessible to consumers in a given place. The viability of this channel is of course contingent on people's ability to access this array of foods. To date, **the diversity of produce delivered by international trade has mainly benefited wealthy consumers in high-income countries**, while poor people in low-income countries continue to be unable to afford the diversity available on these markets (Sibhatu et al., 2015).

- 7000 plants used as food by humans
- Rice, maize and wheat make up more than 50% of plant-based food intake

Furthermore, the focus of research and policy programmes on improving the productivity of industrial agriculture, i.e. focusing on a limited number of input-responsive staple crop varieties and livestock breeds, has been to the detriment of a wider variety of traditional foods. As a result, **poorer populations have struggled either to access interna-**

FIGURE 7 - HOW MALNUTRITION PERSISTS IN INDUSTRIAL SYSTEMS



tionally traded products, or to obtain a diverse diet on the basis of local traditional foods. In many places, traditional diets have effectively been eroded. On a global level, of the 7,000 plants that have been used as food by humans, just three of them - rice, maize and wheat - provide more than 50% of the world's plant-derived food energy intake (FAO, 1995). Wheat, rice, maize and other ubiquitous crop commodities were among those with the greatest gains in both relative and absolute abundance in national per capita food supplies over the past 50 years (Khoury et al., 2014).

In some cases, the general trend has been compounded by government policies with an explicit focus on monocropping of staple crops. For example, since 2009, the Rwandan government has promoted the monocropping of modern, selected varieties together with input intensification. This initiative has been so pervasive that intercropping and crop diversity have declined substantially in recent years, falling from 9-11 crops per farm to 3-4, with potentially highly negative consequences for household dietary diversity (Isaacs, 2014; Snapp & Fischer, 2014).

➔ Nutrient content of crops

The rise of industrial agriculture has also had impacts on the nutrient content of foods. Indeed, agricultural policies that promote specialization in **energy-rich staple cereals** have resulted in a decline in consumption of **pulses** and other **minor crops** with high nutritional value (Hawkes, 2007; DeFries, 2015). For many years, Indian agricultural policies favoured specialization in major cereal production through crop-specific subsidies, with the effect of exacerbating micronutrient deficiencies (World Bank, 2006). In general, cash crop production – sometimes for non-food purposes – helps to push out more diverse food cropping at the expense of nutritionally-important foodstuffs. For example, tobacco farming is considered to have displaced vegetables and pulses in Bangladesh, as well as cassava, millet and sweet potatoes in Kenya (Lecours et al., 2012).

While recent efforts to '**biofortify**' staple crops have led to improved content of specific nutrients, this has not compensated for the **general decrease in nutritional density** of modern varieties of staple crops. Indeed, the specialization of agricultural systems has also had negative impacts on this front (AFSSA, 2003; Barański et al., 2014). Breeding programs for the major crops have focused mainly on productivity increases by altering plant height or disease resistance (Tadele & Assefa, 2012), resulting in varieties that are rich in energy but have a lower content of various macro- and micronutrients (Jones et al., 2014). This has been exacerbated by soils lacking nutrients and minerals for plants to take up or animals to consume, due to the land and soil degradation often associated with industrial specialized systems (see Section 1.a.ii).

As a result, the theoretical diversification of diets facilitated by industrial agriculture and global trade has not managed to remedy the problem of micronutrient deficiencies, which continues to undermine the health status and development of over two billion people (Hunt, 2005; Sibhatu et al., 2015). Meanwhile, **the prevalence of energy-rich crops and foodstuffs continues to be a major factor in the explosion of overweight, obesity, and the associated health impacts** (Wallinga, 2010). Overweight and obesity, primarily through their contribution to NCDs, have not only incurred huge financial costs to society (Alwan, 2011) but are also responsible for the biggest increases in mortality rates over recent years (WHO, 2009), predominantly in low and middle income countries (WHO, 2015b).

- Declining consumption of pulses and minor crops
- Staples/cash crops pushing out traditional foods
- General decrease in nutrition density of foods

➔ Agrochemical exposure

Heavy use of agrochemicals, strongly associated with industrial cropping systems, also has impacts on human health. **Pesticide exposure has been linked to increased incidence of Alzheimer's disease, asthma, birth defects, cancer, learning and developmental disorders, Parkinson's disease and sterility** (Owens et al., 2010; Ye et al., 2013). Studies in developed countries show that annual acute pesticide poisoning affects nearly one in every 5000 agricultural workers (Thundiyil et al., 2008). Those living close to plantations have also been placed at risk. In Costa Rica, children living close to banana plantations were found to be exposed to high levels of insecticides which may impact their health (van Wendel de Joode et al., 2012).

In Southern Spain, the organochlorine pesticide exposure linked to **intensive greenhouse agriculture** is associated with breast cancer, cryptorchidism and a greater prevalence of type 2 diabetes, among other pathologies (Arrebola et al., 2013). Similar problems have been observed in other Mediterranean countries such as Tunisia (Arrebola et al., 2015). The recent meta-study from the International Agency for Research on Cancer on **glyphosate**, a herbicide long considered safe, confirmed it as 'probably carcinogenic' (WHO, 2016). **Pesticide residues in food** constitute a further health risk, particularly in countries where there is no reliable control of these residues.

➔ Zoonotic diseases and antibiotic resistance

The intensification of livestock farming and the genetic homogenization of some animal populations are linked to the emergence of zoonotic diseases such as avian influenza and the Nipah virus (Jones et al., 2013), with implications for human health. Furthermore, the widespread **preventive use of antibiotics** in industrial animal production systems has exacerbated the problem of bacterial resistance to antibiotics; this represents a significant health risk for humans confronted with pathogens that have accumulated resistance to virtually all existing antibiotics (Roy Chowdhury et al., 2014; Carlet et al., 2012).

Disease risks have been exacerbated by other practices associated with highly-specialized and intensive livestock supply chains. For example, the frequent transportation of animals over long distances has generated increased risks in terms of disease (Liverani et al., 2013). Meanwhile, the use of meat and bone meals in intensive livestock production has led to repeated problems of bovine spongiform encephalopathy (BSE) and the human health related risk of Creutzfeldt-Jakob disease (Roels et al., 2001).

1.B. OUTCOMES OF DIVERSIFIED AGROECOLOGICAL SYSTEMS

1.b.i. Productivity outcomes

➔ Yields

There have been relatively few comprehensive, long-term studies comparing the productivity of industrial systems with that of highly diversified agroecological systems. Most studies that have been undertaken use small samples and short time periods, while comparing only some aspects of diversified agroecological systems with industrial agriculture. Studies have typically compared organic agriculture with convention agriculture in developed countries, finding that crop yields per hectare of a target crop are slightly lower in organic systems. For example, a 2007 study with a global dataset of 293 examples found that on average, in developed countries, organic systems produced 8% lower yields than conventional agriculture. However, the same study found that in developing countries, organic systems outperformed conventional farms by as much as 80% (Badgley et al., 2007). Similarly, a review of 286 projects in 57 developing countries, found that farmers had increased agricultural productivity by an average of 79% by adopting "resource-conserving" agriculture (Pretty et al., 2006).

Furthermore, evidence has recently become available on a thirty-year comparison of organic corn and soybean with conventional production in tilled systems in the US, finding equivalent yields on average, and higher yields for organic in drought years (Rodale Institute, 2015). Similar results were obtained in a 10-year experiment with wheat (Rodale Institute, 2015).

Comparisons are increasingly favourable to diversified systems when total outputs are compared, rather than specific crop yields. Studies on grassland have shown that total output productivity increases with the number of species grown in association and over time (Tilman et al., 2001). Other grassland studies have shown that multispecies assemblages[12] produced 15% higher outputs than monocultures on average (Prieto et al., 2015). Mixtures have also been shown to produce 1.7 times more harvested biomass on average than single species monocultures and to be 79% more productive than the average monoculture (Cardinale et al., 2008). It has also been shown that less land is required to produce in polycultures than to produce the same amount in monocultures, making yield per area higher in polycultures (Prieto et al., 2015; Picasso et al. 2008; Cardinale et al. 2008; Francis, 1986). For some, the signs are promising enough to suggest that in Africa, applying farming methods focused on diversity, mixed farming and participatory plant breeding could in fact double food production in periods of 3-10 years (Pretty et al., 2011).

2007 meta-study of organic yields relative to conventional:

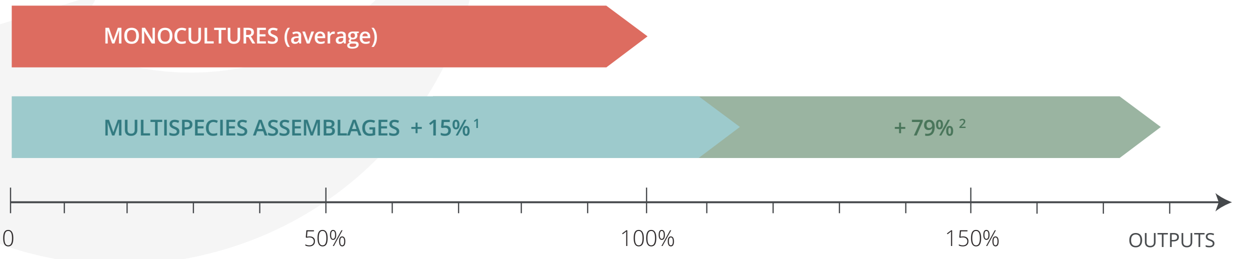
- -8% in developed countries
- +80% in developing countries

➔ Ecosystem Resilience

While long-term yield comparisons of like-for-like cropping systems may be lacking, there is ample evidence to suggest that diversified agroecological farming systems (including silvopastoral and agroforestry systems) can deliver stable outputs over time. Indeed, **these systems are often geared towards securing and stabilizing agro-ecosystems to enable them to remain productive over time, rather than maximizing short-term yields of a specific crop**. As outlined in the In-

12. Mixtures or multispecies assemblages are forms of intensive polyculture production: different species can be combined on the same plot, as well as different varieties of the same plant species, in ways that allow the direct interaction between the members of the mixtures.

FIGURE 8 - THE PRODUCTIVITY OF DIVERSIFIED GRASSLAND SYSTEMS



1. Data from Prieto et al., 2015
2. Data from Cardinale et al., 2008

troduction, many of the world's farmers live in regions where **climate stresses** are already present, making resilience a daily necessity. Traditional farmers often live on marginal land where climate change is predicted to have a significant impact; 60% of the food consumed around the world comes from smallholder agriculture in developing countries where crop diversity is key for the resilience of farming systems (ICRISAT, 2015). More and more studies are demonstrating that diversification-based models are enabling farmers to build resilience and to remain productive in the face of these threats (Folke et al., 2002; Holt-Giménez, 2002; IAASTD, 2009; Lin, 2011; Tirado & Cotter, 2010; Rosset et al., 2011; Pretty et al., 2011; Mijatović et al., 2013; Altieri et al., 2015; Rodale Institute, 2015).

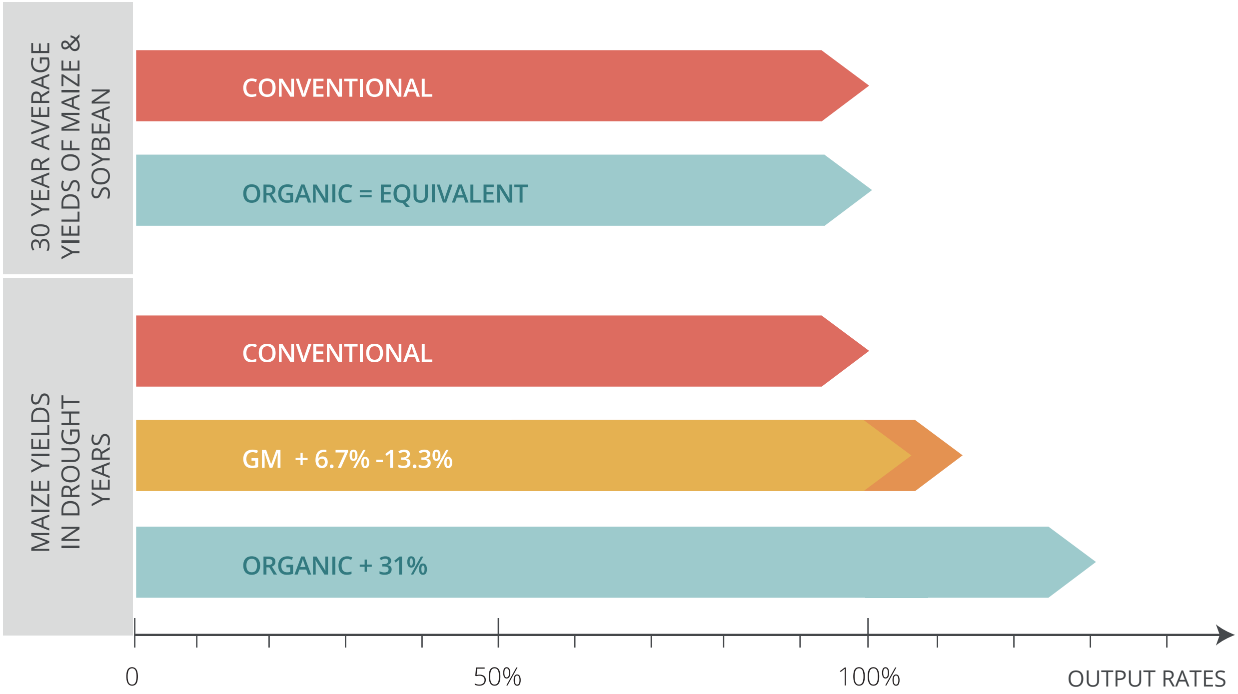
» 60% food consumed around the world comes from smallholder agriculture in developing countries

Biodiversity often plays a key role in delivering resilience, acting as a buffer against environmental and economic risks, and enabling adaptation to changing climate and land use conditions (Mijatović et al., 2013). In some cases, traditional practices centred on agrobiodiversity have been revived because, under changing agro-ecological conditions, they exhibit higher productivity than conventional agricultural methods (Mijatović et al., 2013). Livestock fodder production in managed grasslands has been shown to stand up to environmental stress in diversified systems, with taxonomic (inter-species) and genetic (intra-species) diversity playing different and complementary roles (Prieto et al. 2015).

The 30-year comparisons mentioned above showed particularly favourable performance for organic systems in the face of environmental stress: **organic corn yields were 31% higher than conventional yields in years of drought**; by way of comparison, GM crops adapted for drought tolerance only outperformed conventional plantings by 6.7% to 13.3% (Rodale institute, 2015). Meanwhile, a comparative analysis of agro-ecosystem dynamics in Sweden and Tanzania found that diversified agroecological practices facilitated adaptation to changing conditions (Tengö & Belfrage, 2004).

Diversified agroecological systems have also shown the capacity to respond to extreme environmental shocks in ways that **limit losses** and **enable recovery** (Mijatović et al., 2013; Altieri et al., 2015; Holt-Giménez 2002; Lin, 2011; Rosset et al., 2011). For example, a study of 181 communities of smallholders across Nicaragua after Hurricane Mitch found that farming plots cropped with simple agroecological methods, including rock bunds or dikes, green

FIGURE 9 - PRODUCTIVITY AND RESILIENCE IN ORGANIC FARMING SYSTEMS



Data from Rodale Institute, 2015

manure, crop rotation, and the incorporation of stubble, ditches, terraces, barriers, mulch, legumes and trees, retained on average 40% more topsoil, higher field moisture, and suffered less erosion compared to conventional farms. As a result, the agroecological plots lost 18% less arable land to landslides than conventional plots and had 69% less gully erosion (Holt- Giménez, 2002). Similarly, practices such as terrace bunds, cover crops and agro-forestry were found to deliver greater resilience to the effects of Hurricane Mitch in other parts of Central America (Tirado & Cotter, 2010).

→ Pest management through agrobiodiversity

Some specific applications of agrobiodiversity have shown the capacity to sustain and improve outputs through improved pest management (Nicholls & Altieri, 2004). For example, push-pull systems of pest and weed management[13] used in Kenya have succeeded in doubling maize yields and milk production by 'pushing' away pests from corn by interplanting Desmodium (used as a fodder for livestock) and simultaneously 'pulling' them towards plots of Napier grass (which secretes a sticky gum that traps insects) (Khan et al., 2011).

13 Push-pull systems are integrated pest, weed and soil management systems. For example, In mixed cereal–livestock farming systems, stem-borers are attracted to Napier grass (pull), and are repelled from the main cereal crop (push) using a repellent legume, Desmodium, that is intercropped with the cereal crop. Desmodium root exudates also control the parasitic striga weed by causing abortive germination. In addition, desmodium improves soil fertility through nitrogen fixation, natural mulching, improved biomass and control of erosion. Both companion plants provide high value animal fodder, facilitating milk production and diversifying farmers' income sources.

In mixed farming systems, pest management improvements have been achieved on the basis of rich synergies between different species. One such example is the rice-duck systems found throughout Asia, whereby ducks eat weeds, weed seeds, insects and pests, reducing the need for manual weeding, while duck droppings provide plant nutrients. This system delivered a 20% increase in rice outputs in Bangladesh in less than five years (Van Mele et al., 2005). Meanwhile, experiments in perennial polycultures have shown that weed biomass decreases exponentially as the number of cultivated species increases (Picasso et al., 2008).

» Doubling of maize and milk yields in push-pull systems (Kenya)
» 20% increase in rice outputs in rice-duck systems (Bangladesh)

1.b.ii. Environmental outcomes

➔ GHG emissions & resource efficiency

Diversified and less intensive systems can deliver major GHG savings and increases in resource efficiency, particularly when a life-cycle analysis approach is taken. **Agroecological systems that seek to improve soils and maintain vegetative cover have huge potential for carbon sequestration** (Aguilera et al., 2013). Indeed, these systems are designed in order for natural synergies to take the place of **GHG-intensive external inputs**. Farming without synthetic fertilizers and pesticides is an important factor in reducing emissions, while the use of organic matter enables carbon sequestration in the soil. GHG emissions from organic fruit tree orchards in Spain have been estimated to be on average 56% lower than conventional orchards on an area basis, and 39 % lower on a product basis (Aguilera et al., 2014).

Resource efficiency (in terms of water, light, nutrients and land) is also maximized and waste reduced in farming systems that integrate a variety of species and production types (Gliessmann, 2007; Altieri et al., 2012), as well as in organic farming (Alonso & Guzmán, 2010). In polycultures, potential energy and resources are distributed efficiently between plants that have different root structures and distribution in the soil (Prieto et al., 2015). **Small farms using agroecological techniques may be two to four times more energy-efficient than large conventional farms**, in terms of total energy input/output ratios (Chappell & Lavalle, 2001).

➔ Water efficiency and usage

Less input-intensive and more diversified farming systems have also shown clear benefits in water management. Diversified agroecological systems can increase water use efficiency through a combination of **local water catch-**

ment systems, improved soil capacity for **water absorption and retention, lower run-off**, and **soil cover** that reduces evaporation (Gomez et al., 2009; Zuazo et al., 2009). In a recent study in the US, water volumes percolating through soil were 15-20% higher in organic systems featuring long rotation and leguminous cover crops, relative to conventional systems, with more groundwater recharge and less run-off (Rodale institute, 2015). Water efficiency can differ greatly between different livestock production models; grazing-based systems have a smaller blue- and grey-water footprint than industrial systems (Mekonnen & Hoekstra, 2012).

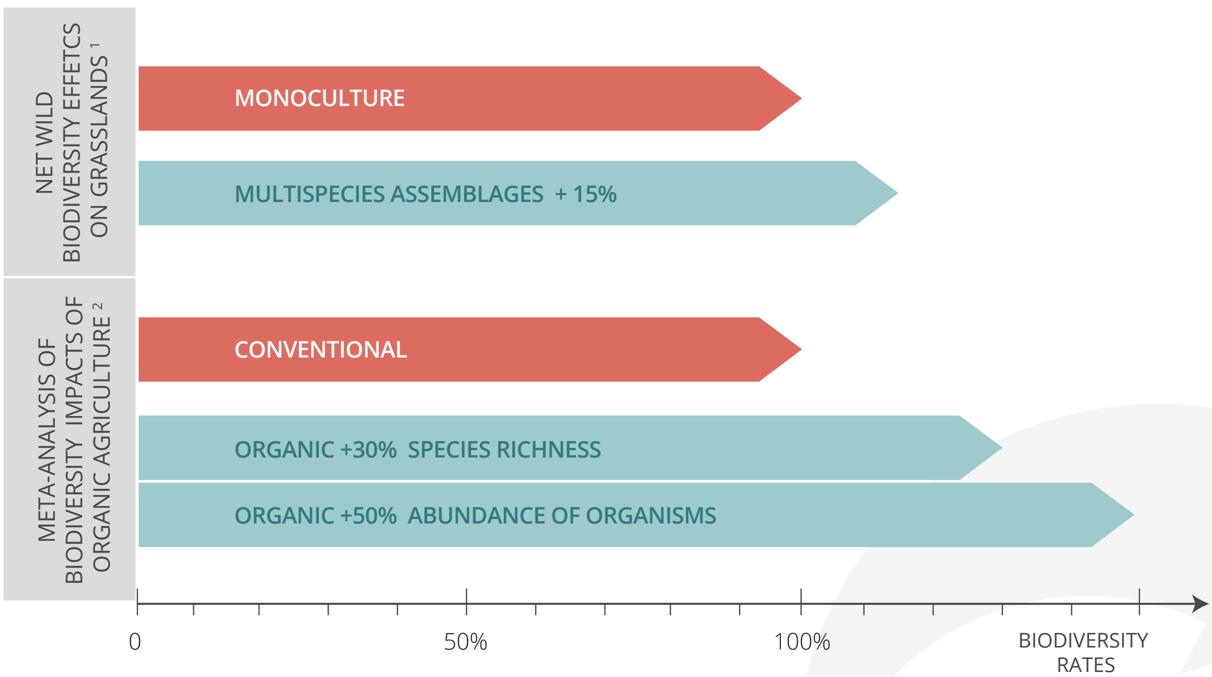
➔ Wild Biodiversity

Diverse agricultural landscapes sustain wild biodiversity in the surrounding ecosystems (Scherr & McNeely, 2008; Altieri & Nicholls, 2004); heterogeneous agricultural landscapes retain tree cover and provide complementary habitats (Harvey et al., 2008). Experiments with multispecies assemblages have shown positive net biodiversity effects, with a 15% average increase relative to monocultures (Prieto et al., 2015). A meta-analysis in 2005 found that organic farms have approximately 30% higher species richness and 50% higher abundance of organisms than conventional farms, though wide variation exists between different studies (Bengtsson et al., 2005). A more recent study found that species richness was on average 10.5% higher in organic than non-organic production fields, with organic delivering the highest relative gains (around +45%) in intensive arable fields (Schneider et al., 2014).

➔ Ecosystem services

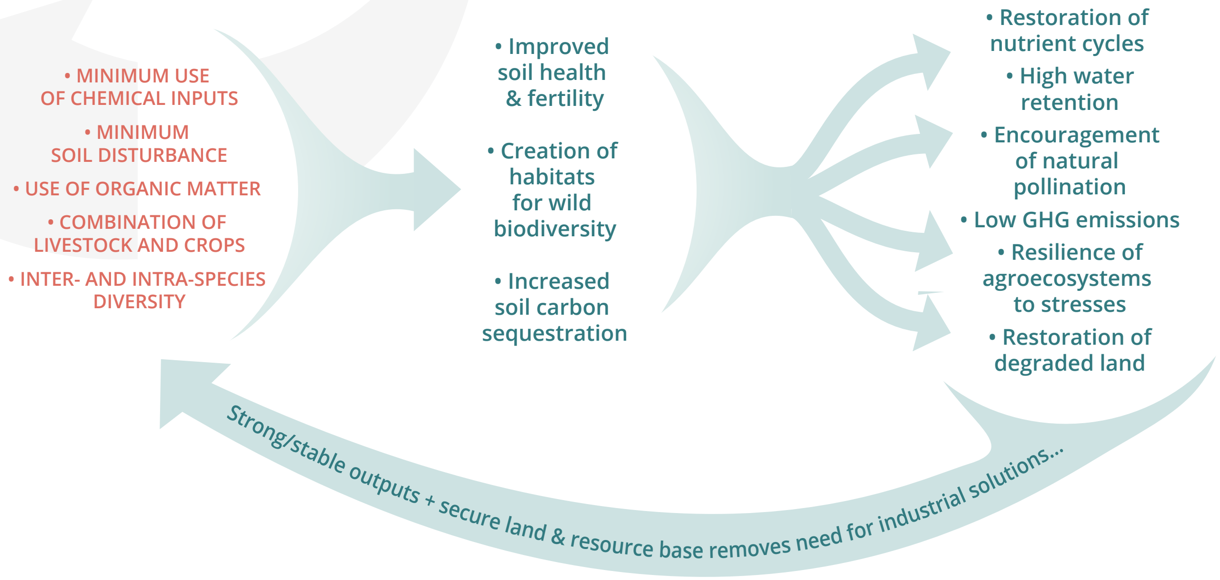
The rich biodiversity in diversified agroecological systems (see above) has a series of positive knock-on effects, contributing to the delivery of crucial ecosystem services – and outperforming conventional systems in this regard (Milder et al., 2014). This is largely thanks to the number

FIGURE 10 - BOOSTING BIODIVERSITY IN ALTERNATIVE SYSTEMS



1. Data from Prieto et al., 2015
2. Data from Bengtsson et al., 2005

FIGURE 11 - VIRTUOUS CIRCLES OF ECOSYSTEM HEALTH IN DIVERSIFIED AGROECOLOGICAL SYSTEMS



of species and the diversity of functions they carry out, particularly in grassland systems (Kremen & Miles, 2012; Prieto et al., 2015). Diversified cropping systems create a variety of microclimates which are occupied by a range of beneficial organisms (predators, parasites, pollinators and soil fauna), providing valuable environmental services and supporting entire agroecosystems (Altieri & Nicholls, 2004).

Meanwhile, crop rotation has beneficial effects on the soil, reducing the threat of pests and diseases (Pelligrini & Tasciotti, 2014). Reduced use of chemical inputs also contributes to positive impacts in terms of water quality and carbon content in soils, as well as micronutrient storage and availability for plants (Rodale Institute, 2015). Mixed crop–livestock systems are particularly promising in terms of ecosystem services, given that animal manure can be utilized to enhance soil health, fertility and carbon sequestration (Russelle et al., 2007).

Diversified agroecological systems do not only have the capacity to improve land management; they can also help to restore previously degraded land. In 2015, the International Year of Soils, FAO highlighted the great potential of diversified agroecological systems to reverse soil degradation, restore degraded land and rebuild soil fertility (FAO, 2015a). The various microclimates and beneficial organisms that thrive in diversified systems help to rebuild soil fertility (Gliessman, 2007) and contribute to the rehabilitation of degraded land (Snapp & Pound, 2011). Successful agroecological restoration of savannah ecosystems, with a focus is on restoring ecological balances, has been observed in Ghana (Badejo, 1998).

The benefits of ecosystem services do not only accrue to farmers. Agroecological systems can provide ecosystem services to communities downstream, such as improved water quality, or prevention of flooding. These benefits are particularly strong when agroecological farming is combined with integrated landscape management approaches that bring farmers together with other actors, and ensure the necessary connectivity for species movement and water flows over a given territory (Estrada-Carmona et al., 2014; Thaxton et al., 2015; Scherr & McNeely, 2008).

1.b.iii. Socio-economic outcomes

➔ Income and Livelihoods

Diversified agroecological farming strategies are not only based around building resilient environments, but often more resilient livelihoods. Diversification is crucial for livelihood resilience (IIED, 2011); **risk is a daily reality for many farmers around the world, and crop and livestock diversification is seen as a form of self-insurance**, allowing income to be stabilized in the face of crop failure or loss of livestock or other risks (Gliessman, 2007; Johnston et al., 1995). Crop diversification strategies are pursued around the world for that very purpose (Papademetriou & Dent, 2001).

Furthermore, **diversified systems can help reduce the risks that come with variable yields and seasonal shortages**. For example, crop diversification provides more opportunities for continued production year-round (Powell et al., 2015).

Meanwhile, diversified agroecological systems can reduce the economic risks associated with natural disasters: as outlined in Section 1.b.i, crop diversification has emerged as an effective strategy in areas that are vulnerable to **natural disasters** such as hurricanes and floods (FAO, 2013b).

Additionally, the production of organic fertilizers on-farm in agroecological systems reduces farmers' reliance on costly external inputs. This, in turn, makes smallholders less dependent on local retailers and moneylenders (De Schutter, 2011). In particular, the reduced capital requirements and reduced reliance on external inputs has the potential to benefit women farmers, who often have lower incomes and poor access to credit, and encounter greater difficulties in accessing subsidies (Curtis, 2012; Parmentier, 2014; De Schutter, 2010). However, it must be recalled that reduced dependency on inputs does not tackle the root causes of gender inequality in the rural world.

Studies are increasingly yielding data on the positive impacts of diversified systems on income and livelihoods. An eight-country study found that the number of crops that a given farm produces is positively correlated to household income, as well as dietary diversity (Pelligrini and Tasciotti, 2014) (see 1.b.iv for more on dietary outcomes). A Dutch study also concluded that mixed farming systems can lead to a 25% higher labour income/ha without increased environmental pollution (Bos & Van De Ven, 1999).

More comprehensive data is available concerning the income and livelihood benefits of **organic farming**; a study covering 55 crops grown on five continents over 40 years found that **despite lower yields, organic agriculture was significantly more profitable** (22–35%) than conventional agriculture. Indeed, many farmers have converted to certified organic farming systems in order to capture **high-value markets and premiums**, through 20-24% higher benefit/cost ratios than conventional agriculture (Crowder & Reganold, 2015; Reganold & Wachter, 2016).

Small farmer revenues have been increased by 15-60% in Costa Rican organic production systems supported by regional cooperatives and situated within an integrated landscape management project focused on biodiversity conservation (Scherr & McNeely, 2008).

40-year, 5-continent study of organic v conventional :

- +22-35% profitability
- +20-24% benefit/cost ratios

➔ Knowledge, autonomy and capacity to adapt

Environmental and livelihood resilience depends on the ability of farmers to adapt to changing circumstances. Agroecology is seen to build social capital and the capacity to adapt through the process of acting independently and retaining control over how resources are used (Pretty & Smith, 2004; Chambers, 1983). Moreover, organizations and social movements for rural peoples are increasingly using agroecology as a platform for defending rural spaces in the face of threats from agribusiness and other private actors (Rosset & Martínez-Torres, 2012).

The capacity to retain traditions and traditional knowledge also appears to go hand in hand with the practice of agricultural diversity. On the whole, communities, cultures and countries able to maintain their own traditional food systems are better at conserving the crop varieties and animal breeds underpinning local specialties (Johns et al., 2013). These **local foods** come with **locally-adapted knowledge** that is otherwise lost; in recent years, the reintroduction of traditional crop varieties has helped revive traditional agroecological knowledge and practices (IIED, 2011).

➔ Employment

As described in Section 1.a.iii, industrial agriculture and diversified agroecological systems have clearly divergent impacts on employment. **Agroecological systems are more labour-intensive, especially during their launch period**, due to the complexity of managing different plants and animals on the farm, and recycling the waste produced (Ajayi et al., 2009; Herren et al., 2012; Bowman & Zilberman, 2013). When short supply chains are envisaged, this further increases employment opportunities; it has been estimated that organic agriculture can provide 30% more jobs per hectare than conventional farming, with **on-farm processing and direct marketing** playing a key part in driving the demand for additional labour (Soil Association, 2006). Diversified farms also spread the need for labour more evenly throughout the year, allowing for **full-time employment** of farm labourers. While data is still sparse in this area, farms departing from the industrial model may be conducive to more pleasant working conditions; a study from the UK found that migrant workers on organic farms were happier than their counterparts working on conventional farms (Cross et al., 2008).

1.b.iv. Nutrition and health outcomes

➔ Dietary diversity

As described in Section 1.a.iv, dietary diversity brings major health benefits. There is growing evidence to suggest that diversified farming can facilitate diverse diets among producer households without relying on the intermediary of international trade. However, intermediary factors (e.g. education, income, general health status) are particularly important when it comes to dietary patterns and associated nutritional outcomes (see Section 1.c).

Some of the emerging evidence suggests that agricultural diversity does translate into dietary diversity at the farm household level and beyond. A special issue of the Journal of Development Studies on "Farm-Level Pathways to Improved Nutritional Status" has brought evidence to light showing that diversity in household agricultural production has direct and important linkages with dietary diversity and nutrition (Carletto et al., 2015; Kumar et al., 2015; Shively et al., 2015). A number of studies have now found links between agricultural diversity and diversity of nutrient intake in various regions (Herforth, 2010; Oyarzun et al., 2013; Torheim et al., 2004; Remans et al., 2011; Jones et al., 2014). In general, mixed farming systems provide a range of foods with different nutritional elements to the farming household and those accessing the produce on local markets (Johns et al., 2013). In addition, other studies have shown agrobiodiversity to contribute to human nutrition by increasing dietary diversity and quality (Powell et al., 2015; Pelligrini & Tasciotti, 2014).

Agricultural diversity has been linked specifically to **increased consumption of a range of key nutritional elements** often missing in diets based around staple cereal crops. The consumption of legumes, fruits and vegetables was found to be strongly associated with greater farm diversity in Malawi (Jones et al., 2014). Adopting diversified cropping systems and micronutrient-rich varieties has been shown to help improve the intake of both macro- and micronutrients (Welch & Graham, 2005).

Polycultures and mixed crop-livestock farming systems help to ensure that key nutrients are available throughout the year, allowing food to be saved for dry periods, and therefore providing protein during hunger gaps (Jones et al., 2014; Remans et al., 2011). Integration of livestock into farming systems, such as dairy cattle, pigs and poultry, also provides a source of protein for the family, as well as a means of fertilizing soils (Smith et al., 2013); so does the incorporation of fish, shrimp and other aquatic resources into farm systems, e.g. in irrigated rice fields and fish ponds.

In some cases, improved health outcomes have been observed in relation to diversified food production and its dietary benefits. A recent cluster-randomized controlled trial of a homestead food production program in Burkina Faso documented statistically significant positive effects of diversified farming on child nutrition outcomes in terms of wasting, diarrhoea and anaemia (Olney et al., 2015). Meanwhile, NGOs in Bangladesh have promoted home gardening and small livestock production on the basis that children from homes with gardens were less likely to suffer night blindness, linked to vitamin A deficiency (Talukder et al., 2000).

Channels of improved nutrition via diversification:

- Increased availability of legumes, fruits and vegetables
- Year-round availability of key nutrients
- Protein availability in mixed crop-livestock systems

➔ Toxicity, nutrients and beneficial compounds

A significant health benefit of diversified agro-ecological systems is the reduced exposure to pesticides and other harmful chemicals used in agriculture (Reganold & Wachter, 2016). Meanwhile, **health-giving qualities have been identified in foods not treated with chemical pesticides**. For example, concentrations of a range of **antioxidants** such as polyphenols have been found to be substantially higher in organic crops/organic crop-based foods which have not been sprayed with pesticides. Many of these compounds have been linked to a reduced risk of chronic diseases (Barański et al., 2014). Polyphenol intakes have also been associated with decreased mortality (Zamora-Ros et al., 2013). A recent systematic literature review concluded that both organic milk and meat contain around 50% more beneficial **omega-3 fatty acids** than their conventional equivalents (Średnicka-Tober et al., 2016a; Średnicka-Tober et al., 2016b).

Health benefits observed in organic foods:

» Reduced pesticide risks

» More antioxidants

» +50% omega3 in organic meat and milk.

1.C. CONCLUSIONS ON THE OUTCOMES OF SPECIALIZED INDUSTRIAL AGRICULTURE AND DIVERSIFIED AGROECOLOGICAL SYSTEMS

What emerges clearly from the comparison is that diversified agroecological systems have huge potential to improve on the outcomes of industrial agriculture. It is also clear that these outcomes are mediated by a range of factors extending well beyond the realm of agriculture. For example, it is *political support* for specialized commodity crops and *insufficient social safety* nets that expose certain populations to the vulnerabilities of export-oriented agriculture; it is *lacking environmental and health regulations* that allow CAFOs to pollute water sources and generate antibiotic resistance; it is absent *lacking labour protections* that allow abuses to continue on tropical plantations.

However, these cannot be viewed as *exogenous* factors. Industrial agriculture requires certain institutional, political and market arrangements in order to flourish, and those arrangements systematically lead to an industrial mode of agriculture. For example, the political imperative of export-led agriculture could not exist without the development of highly-specialized commodity cropping, and vice versa.

Similarly, the environmental impacts of chemical inputs can be mitigated by improved practices, but cannot be taken out of the picture: the intensive use of synthetic fertilizers and pesticides is part and parcel of industrial agriculture, and is integral to its design.

Moreover, **the opportunities generated by industrial agriculture accrue to specific sets of actors, who are able to translate that economic power into political power**, thus ensuring that institutional arrangements continue to favour this form of agriculture. In other words, industrial agriculture shapes and is shaped by industrial food systems. Understanding these feedback loops, and how they work to keep *industrial agriculture* and industrial food systems in place, is the subject of Section 2.

In this light, the outcomes described in Section 1.a are the systematic outcomes of industrial agriculture, not accidental side-effects. These outcomes are facilitated and shaped by institutional, political and market arrangements that are themselves a manifestation of industrial agriculture. Specific regulations and policies do of course shift between different settings, with the capacity to somewhat mitigate the outcomes. However, a set of core dynamics always exists alongside industrial systems.

As the evidence in this section has shown, the negative impacts of these systems are multiple and mutually reinforcing. Industrial agriculture's weaknesses are its core characteristics: the principles of **specialization** and **uniformity** around which it is organized, and the **reliance on chemical inputs** as a means of managing agro-ecosystems.

For every increase in productivity achieved on this basis, there is a price to be paid sooner or later, locally or further afield, directly or indirectly, by those practicing industrial agriculture or by others facing its fallout. This price may come in the shape of disease vulnerability, yield stagnation, environmental degradation or the ratcheting up to breaking point of economic pressures on farmers – with the outcomes often reinforcing one another.

It is clear, therefore, that industrial agriculture does not and cannot reconcile the multiple concerns of sustainable food systems. **Food and farming systems can be reformed, but only by moving away from an industrial orientation and organization.** Tweaking industrial systems will only improve single outcomes, while leaving untouched the dynamics and power relations that reproduce the same problems over time. A fundamental reorientation of agriculture, particularly in its relationship with ecosystems, is required in order to break these cycles.

Based on the evidence described in Section 1.b, diversified agroecological systems can provide that fundamental reorientation in a way that improves multiple outcomes.

The evidence in regard to the environmental benefits of these systems is overwhelming, from **increases in wild biodiversity** to the improvement of soil health and fertility and water retention. In particular, the capacity of diversified agroecological systems to **restore degraded land** and to **keep carbon in the ground** is unparalleled by any other options on the table.

GHG emissions can be somewhat mitigated by efforts to apply chemical inputs more sparingly, or to reduce tillage, within industrial systems. However, the promise of such approaches pales in comparison with the potential of fundamentally redesigning agriculture around diversification and agroecology in ways that re-invest soils with the capacity to sequester carbon.

Land may theoretically be 'spared' (i.e. taken/kept out of production) in industrial agricultural systems (see Section 1.a.ii). However, the environmental benefits of such a trend are highly speculative. Whether or not ecosystem services can actually be delivered depends on the condition of the land coming out of production; meanwhile, there are major question marks about whether these pockets of biodiversity could compensate for the ecological degradation (particularly the decline in pollinators) on remaining land as it continues to be farmed in industrial – and increasingly intensive – ways.

These risks and trade-offs are rendered unnecessary by diversified agroecological systems, which nurture the environment in holistic ways, rebuilding biodiversity and rehabilitating degraded land.

Furthermore, **it is the reintegration of agriculture with healthy ecosystems and sustainable land management that holds the key to a range of other positive outcomes, from strong and stable outputs to secure farm livelihoods.** These pathways are not hypothetical. A growing body of evidence is demonstrating the capacity of these systems to intensify production (e.g. in densely inter-cropped farming systems) in ways that nurture, rather than degrade, ecosystems. There is also extensive evidence regarding the capacity of diversified systems to deliver resilience in the face of environmental stresses.

The picture is far from complete. The existing evidence does not provide comprehensive insights into all farming systems, sectors and contexts. **More evidence is required on whether and to what extent diversified agroecological systems can improve farm working conditions**, even in less regulated environments where labour abuses have blighted agriculture so systematically.

It will also be crucial to see whether these systems can match the improvements of working conditions now being observed in some ultra-modernized industrial farms. Where these improvements are specific to industrial-style holdings, it will be important to consider the alternative forms of workplace improvement offered by diversified agroecological systems – or to acknowledge potential trade-offs on this front. To date, the situation has been insufficiently documented.

The picture is also incomplete in terms of other socio-economic impacts. Much of the evidence on income and livelihoods in diversified systems concerns small-scale farming in developing countries, where the quest for livelihood diversification and livelihood resilience has always been a necessity, and where traditional practices that overlap with agroecology have often been drawn upon.

Meanwhile, the evidence from developed countries is currently reliant on comparisons between organic systems and the predominant industrial systems. These provide valid – and highly promising - insights into the productivity and resilience of diversified, low external input systems. However, there are limits in using organic agriculture as a proxy for fully diversified agroecological systems (see introduction to Section 1).

The picture is particularly complex in terms of **food security** at the macro-level, given the different ways of measuring it, and the highly divergent pathways to achieving it. What we do know is that **where diversified systems raise productivity, they do so durably, and in the places where additional food is desperately needed.** The limits of this comparison (and indeed any such comparison) are clearest on this point; diversified systems produce diverse and changing outputs, making it difficult to make meaningful projections in terms of net availability of specific crops.

However, in the absence of such comparisons, it should not be assumed that no longer prioritizing the production of staple cereal crops for global markets will jeopardize 'food security'. As will be explored in Section 2, the tendency to frame food security in terms of 'feeding the world' (i.e. net volumes of commodities on global markets) is itself a reflection of the systemic and self-reinforcing logic running through industrial food systems – and does not necessarily reflect what matters in terms of improving the lives of the food insecure.

The capacity of diversified agroecological systems to deliver food security is only unproven in that the pathway these systems offer to food security has not yet had the chance to prove itself on a larger scale. **These systems have not yet been adopted widely enough to show their full impacts, nor have they been able to benefit from significant investments and an enabling environment in which to fulfil their full potential.** It should not be forgotten that where diversified agroecological farming systems are emerging, they are swimming against the tide. As the following sections will show, the context and the incentives in which agriculture operates are very much aligned to and symbiotic with the industrial agricultural model. It is therefore doubly impressive to see these alternative systems emerge, and to be able to observe such positive outcomes, on the basis of so little support and funding (Pretty, 2006). And it is doubly difficult to get a full picture of what *diversified agroecological food systems* would look like in their entirety. Indeed, the experimental, decentralized, knowledge-intensive nature of agroecological developments suggests that the positive impacts already observed are only just the beginning.

Additional research is also required on the **process of transition** itself. In particular, more must be known about the challenges that might be encountered for the most industrialized cereal monocultures in shifting towards diversified agroecological systems, the timeframes for equivalent productivity to be recovered, and the economic implications for farmers in this transitional period. The many emerging research projects in this field are therefore to be welcomed. Case studies are currently being gathered by IPES-Food in order to identify the specific pathways of transition to agroecology being undertaken by individual farms and farming communities in a range of contexts (IPES-Food, forthcoming).

These unknowns should not hold back the case for change. If incomplete evidence on the potential of alternatives were enough to justify a 'wait and see' approach, food systems would never change: only one system can be predominant and show its full potential at any one time. Industrial agriculture has occupied this privileged position for decades, and has failed to provide a recipe for sustainable food systems. On the basis of the evidence gathered here, **there may be no greater risk than sticking with industrial agriculture and the systematic problems it generates**. This strategy is riskier the longer it goes on, as the pressures on ecosystems are ratcheted up to breaking point, threatening even the high yields these systems were designed to deliver.

A shift to diversified agroecological systems is not without its challenges. However, we know enough to suggest that a fundamental shift in this direction is likely to be the only way to set food systems on sustainable footing. We also know enough about the inter-connections in food systems to be confident that steps in this direction are likely to be mutually-reinforcing, and to generate food systems which, in turn, deepen the incentives for diversified agroecological farming to continue to thrive, and are highly responsive to ensuring that productivity, health, environmental sustainability and other concerns are continually reconciled.

It is the task of Section 3.a to identify where and in what forms these alternative food systems are already taking shape, and in Section 3.b to trace out what can be done to support their emergence and to shift the balance in their favour. However, before doing so, it is crucial to understand the precise ways in which industrial agriculture is currently held in place.

TABLE 2

Glossary of terms for Sections 1.a and 1.b

Crop rotation is the sequential planting of one crop after another, and is often done to ensure soil health, replacement of nutrients, and reduction of disease.

Ecosystem services are the advantages that humans can derive from ecosystems. They cover different types of benefits: provisions (food, raw material, etc.), regulation of systems (climate, waste water treatment, etc.), support (e.g. habitat for wild biodiversity), and culture (tourism, leisure).

Environmental resilience refers to the capacity of an ecosystem to resist and recover from stresses, shocks and disturbances, be they natural events or impacts caused by human activity.

Inter-cropping is the simultaneous planting of two or more crops in the same field at the same time in ways that permit interaction between the crops.

Livelihood resilience refers to the ability of people to secure the capabilities, assets and activities required to ensure a decent living, particularly in the face of shocks (e.g. economic crises, environmental disasters).

Mixed farming combines plant production with animal or aquacultural production.

Mixtures or multispecies assemblages are forms of intensive polyculture production: different species can be combined on the same plot, as well as different varieties of the same plant species, in ways that allow direct interaction between the different varieties/species.

Nutrient cycling refers to organic and inorganic matter being returned to the production of living matter, a process that occurs through a series of pathways whereby matter is decomposed into mineral nutrients.

Organic agriculture is a type of certified farming that must adhere to a set of environmental requirements regarding inputs and practices. A key requirement is non-usage of synthetic inputs (fertilisers/pesticides), although mineral inputs from outside the farm that are mined naturally can be applied. In Europe, organic certification includes requirements for crop rotation.

Polycultures refer to the cultivation of different plant species in reasonably close proximity in the same field, with variation over time. This term is opposed to monoculture where single/similar plant species are grown across large areas with minimum or no rotation.

Precision agriculture/farming refers to a type of farm management practice that involves the use of technology (GPS, communication technology, etc.) to optimize field-level management, enhance agricultural performance through better use of inputs, and improve the ability to predict and mitigate environmental risks. It is also referred to as satellite farming or site-specific crop management.

Salinization refers to the phenomenon of increasing salt content in soils, resulting in disturbance of water cycles (e.g. through irrigation practices) and other factors. Salinization prevents plant roots from absorbing water, with the effect of lowering yields and further degrading the soil.

Water footprint refers to the water that is taken out of its cycle or that has been polluted at different stages. **Blue water:** Fresh, surface and groundwater, in other words, the water in freshwater lakes, rivers and aquifers; **Green water:** The precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation, before evaporating or transpiring through plants; **Grey water:** is polluted water (e.g. by agrochemicals) and wastewater generated in households or office buildings (excluding water with faecal contamination).

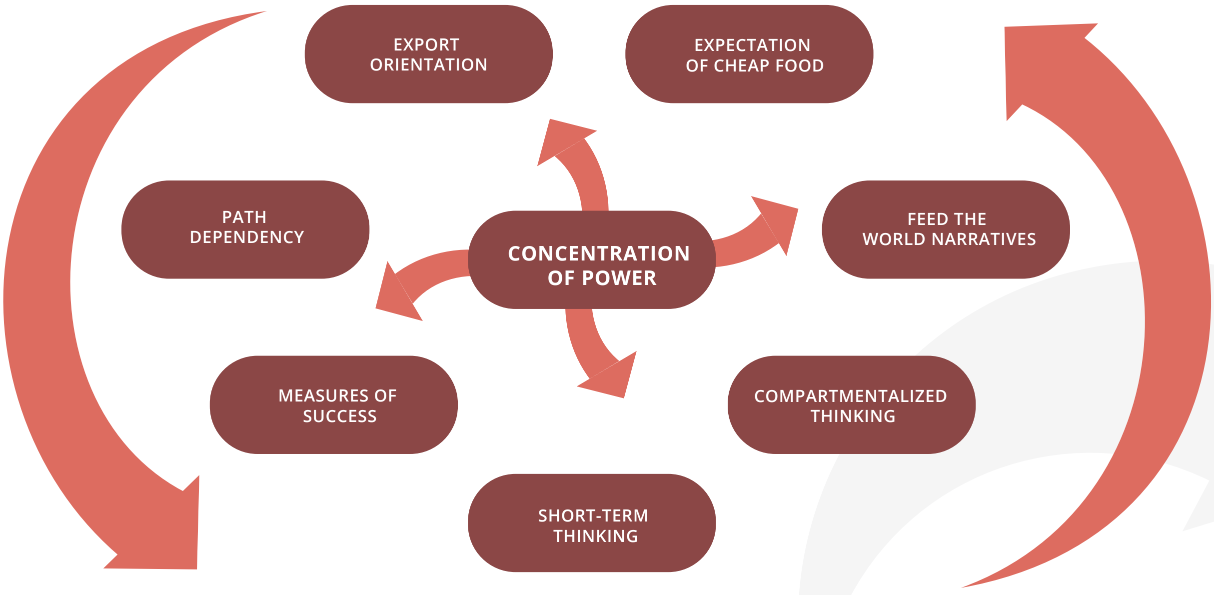
02 What is keeping industrial agriculture in place?

The analysis in Section 1 has shown that diversified agroecological systems have major potential to improve on the multiple negative impacts of the specialized, industrial production systems that dominate modern agriculture. However, **this raises the question of *why* systems with such potential to deliver benefits to farmers and to society have not been taken up more widely**. To answer this, we must understand the context in which farmers, communities, regions and countries are opting for industrial modes of production.

As indicated in Section 1.c, industrial agriculture and *industrial food systems* are symbiotic. Furthermore, food and farming systems have developed alongside and in tandem with broader developments in transport, energy, finance, and the manufacturing sectors whose productivity has been contingent on the outflow of labour and capital from agriculture. It is therefore impossible to provide an exhaustive list of the factors contributing to the development of industrial agriculture, or to define clear cause and effect; neither is it easy to separate out what is exogenous technological development and spontaneous market evolution from what is politically driven.

However, it is possible to identify the specific focal points around which industrial food systems now revolve, and the vicious cycles keeping them in place. The eight 'lock-ins' described below are the key mechanisms locking industrial agriculture in place, regardless of its outcomes; it is these cycles that will need to be broken if a transition towards diversified, agroecological systems is to be achieved. Some of these 'lock-ins' relate to the **political structures** governing food systems, some concern the way **agricultural markets** are organized, and others represent **conceptual barriers** around the way questions are framed. Each represents a vicious cycle locking in industrial agriculture, as well as a potential entry point for change (see Section 3.b).

FIGURE 12 - THE EIGHT KEY LOCK-INS OF INDUSTRIAL AGRICULTURE



LOCK-IN 1: PATH DEPENDENCY

Industrial agriculture has become self-reinforcing through the investments it requires and the need to see a return on those investments. The specific skills, training, equipment, networks and retail relationships that industrial agriculture requires are costly to obtain, and may no longer be relevant if a farmer shifts to a fundamentally different mode of production. In particular, the decision to specialize has often gone hand in hand with investment in scaling up farm operations. **Specialized industrial agriculture may in fact *require* large-scale farming in order to spread the costs of production** (e.g. specialized farm machinery and chemical inputs) over a sufficient production base. Diversifying production is not impossible on large-scale farms. However, the economics of scaling up generally entails decisions (e.g. shedding labour/hectare, investing in machinery for mass cultivation of specific crops) that make any production system other than highly-specialized industrial agriculture increasingly unlikely.

Market signals have long suggested industrialization, specialization and large-scale farming to be the most profitable pathways. Long-term trends in the costs of two key factors of production – labour and energy – have supported this shift. Recent decades have seen an **increase in the relative price of labour**, including in transitional economies (Das & N'Diaye, 2013). The rising cost of employing farm workers has acted as an incentive to accelerate large-scale mechanization, drive up farm sizes and increase specialization (Bowman & Zilberman, 2013). **Energy prices have also supported this trend.** In the post-World War II period, the cheap price of fossil energy allowed agriculture greater access to mechanization, as well as to chemical fertilizers and pesticides, thereby facilitating industrial modes of production (UNEP, 2012). These factors are by no means static, with energy prices recently showing considerable volatility. Nor are they purely market-driven. For example, subsidies for fossil energy and for specific energy-intensive agricultural inputs (e.g. fertilizer) have played a major role in making industrial agriculture economically viable (Pimentel & Pimentel, 2007; Gliessman et al., 1998, 2002).

Industrial agriculture encouraged by:

- High labour costs
- Low energy costs

Several incentives in food systems have supported large-scale farming in particular. For example, **agricultural research outputs are often 'scale-positive'** in the sense that they are geared towards and more readily available to large-scale farmers who have better access to information, resources and credit (Tollens & Tavernier, 2006). Meanwhile, **agricultural subsidies**, e.g. in Europe, have tended to favour large-scale production and specialization of farming (Couturier, 2005), with payments increasing per hectare under the EU Common Agricultural Policy (CAP). In other cases, seed and intellectual property legislation has also been geared towards the interests of large-scale farms. Incentives emanating from the **retail sector** have also cemented the preference for large-scale farming: mass retailers often require bulk supply contracts which cannot realistically be met by individual smaller farms, and prefer to deal with fewer and larger producers (Hazell et al., 2007).

A web of interlocking market and political incentives tailored to large-scale farming therefore offer de facto support to industrial modes of production. These incentives reinforce the already strong path dependencies generated by the need to recoup the considerable up-front investments in industrial agriculture. Farmers are effectively locked into this pathway, even as the negative outcomes of industrial agriculture start to multiply, and even as the quest to recoup those investments in the face of narrow profit margins requires them to continually intensify their production.

LOCK-IN 2: EXPORT ORIENTATION

Export orientation via:

- Agriculture policies
- Trade policies
- Development policies
- Energy policies

International trade produces a variety of impacts in food systems that vary dramatically over time, between different regions and different population groups, often setting in motion fundamental shifts in the structure of a region or country's economy. **Trade agreements** often overlap with a host of **domestic policies** with the capacity to mitigate (positively or negatively) the impacts of international trade. Assessing the overall impacts of trade is therefore a vast undertaking, with case-by-case assessment required in order to determine the impacts of specific steps to liberalize trade in given regions.

It is outside the remit of this report to perform such an assessment. However, the increasing orientation of agriculture towards international trade must be addressed as a key element locking industrial agriculture in place. **New opportunities for trade have been a key cause and effect of the specialization and industrialization of agriculture.**

By the end of the 19th century, improvements in water and rail transportation, as well as refrigeration technologies, meant that surplus crops and livestock were no longer confined to local markets and could be sold internationally (Mazoyer & Roudart, 2006). It also meant that individual farms no longer needed to produce their own fodder for raising animals. In turn, this freed up land that could be used to specialize in commercial crops (Mazoyer & Roudart, 2006).

By reducing the plurality of activities carried out on a given farm, production could focus in on a narrower spectrum of crops and livestock that farmers in a given region were particularly suited towards producing, while allowing farmers to produce at competitive costs, based on the resources at hand. Distribution and retail infrastructures have evolved alongside these developments, making it ever easier to sell agricultural products in foreign markets; supermarkets and other mass retailers have brought economies of scale to bear, rendering international transport costs non-prohibitive (Lawrence & Dixon, 2015).

However, by the end of the 20th century, **expanding and enhancing the opportunities for trade had become a political imperative in itself.** Increasing urbanization has led governments to prioritize the provision of cheap and abundant food for urban centres. This '**urban bias**' has guided agriculture and trade policies for decades (Lipton, 1977; Masters et al., 2013).

Increasingly, a preference for global commodity chains has been reflected in the structure of agricultural subsidies. **Subsidization of large-scale commodity crop agriculture** is now common in middle- and high-income countries (Herren et al., 2012). This preference is clear in the government support programmes in the US (Carolan, 2013), where policies keep soy and corn prices artificially low, acting as an incentive for grain-fed and often **import-dependent livestock systems** over grass-fed livestock (Schoonover & Muller, 2006).

Another example can be found in India, where government programmes exercise a preference for staple crops such as rice, maize and wheat (Kaushal & Muchomba, 2015). In many cases, policies have been shaped around global animal feed supply chains, whose final outputs (meat and dairy products) often do not reach consumers in the countries producing the feedstock (Sharma, 2014).

Measures arising from a host of different policy areas have further incentivized export agriculture. During the 1980s, a significant share of **agricultural development aid** was focused on export-oriented production of commodities rice, wheat, sugar and maize (Lines, 2008). More recently, policies for the **global expansion of biofuel production** have led to the expansion of biofuel commodities (Banse et al., 2011), often for export markets. Meanwhile, generous subsidies and support have helped to make **fossil energy** cheap and abundant over the second half of the 20th century, facilitating the relatively inexpensive transport of agricultural goods over long distances (Leach, 1992). The various incentives for export orientation have continued to multiply, even in the face of commodity price volatility and potentially harmful impacts for farmers (see Section 1.a.iii).

While '**comparative advantage**' (e.g. climate, soil conditions) underpins the ability to specialize, a myriad of political incentives have undoubtedly worked to enhance these advantages in food systems and ensure continual expansion of export crops. As a result, farmers across entire regions have received clear signals to specialize and supply specific commodities to global markets. Vast homogenous systems such as the 'corn belt' in the US Midwest cannot be attributed to farmers individually choosing to specialize on the basis of inherent geographical advantages.

In some cases, regional specialization runs fully counter to resource endowments: California's acreage of water-intensive almond crops recently expanded in the midst of a drought (CDFA & USDA, 2015). Favourable market infrastructures (e.g. post-harvest storage, retail outlets) – often supported through a mix of public and private investment - have also played a part in consolidating regional production patterns. However, it is political measures such as agricultural subsidies and water-drawing rights for farmers that allow a particular comparative advantage to be developed, maintained and enhanced over time.

Food systems have thus become reliant on and centred around export agriculture, even though many people around the world do not benefit directly from it. The share of food traded internationally has increased over recent decades – from 15% in 1986 to 23% in 2009 (D'Odorico et al., 2014) – but most food consumed around the world does not cross international borders. Despite this, trade plays a disproportionate role in specific supply chains (e.g. meat and dairy), specific distribution and retail circuits (e.g. for processed foods requiring undifferentiated commodity ingredients), and thus in the eating habits of those relying on these systems (see Lock-in 3: The expectation of cheap food).

Due to macroeconomic dependencies, the export economy has also become increasingly important over time: countries benefitting from agricultural commodity exports have come to rely on this source of foreign exchange to import increasing arrays of industrial and consumer goods, or to import other foodstuffs. Export orientation is therefore locked into modern food systems, acting as one of the major drivers of highly-specialized and industrial modes of agriculture.

Share of food traded internationally:

» 15% in 1986
» 23% in 2009

LOCK-IN 3: THE EXPECTATION OF CHEAP FOOD

Diets, modes of consumption and consumer expectations have evolved in parallel with the emergence of industrial agriculture, influenced by a range of factors that collectively shape modern lifestyles. Like international trade, evolutions in food consumption represent a vast area that can only be touched on here. New consumer and retail imperatives are multifaceted, arising from trends that are often independent from evolutions in agriculture, and in some cases representing major entry points for change in food systems.

However, what is of interest here are the feedback loops that have formed between industrial agriculture and **specific evolutions in food retail and consumption habits** over recent decades. In particular, attention must be paid to the development of **mass food retailing** and its implications for agriculture.

In an ever-increasing number of countries, **developments in the technologies and infrastructures of food retail and distribution have played a major role in facilitating consumer access to a new wealth of choice**. Refrigeration technology and sophisticated transport and distribution infrastructures have allowed a variety of foods to be available year-round to consumers with access to supermarkets and other well-stocked retail outlets. Meanwhile, fruit and vegetable varieties have been developed to retain their freshness and avoid spoilage over long journeys (Cocetta, 2014). Increasingly efficient methods of processing have also brought down the costs of producing many non-perishable, highly-processed food products and brought them to increasing numbers of consumers.

The product ranges and retail infrastructures that characterize modern food systems are not intrinsically linked to industrial agriculture, but have developed alongside and in relation to it. Indeed, **mass retailers have increasingly relied on the cheap and flexible supply of uniform commodities that industrial agriculture is uniquely positioned to provide**. For example, the processed foods now prevalent in many countries are principally based on staple crops such as maize, soybean and wheat, for which large quantities of uniform quality are demanded by the processing industry.

Processed foods raise demand for:

- Large volumes of uniform commodities
- Undifferentiated vegetable oils
- Corn-based sweeteners

Furthermore, many of these products are rich in added sugar and saturated fats, most commonly obtained from undifferentiated vegetable oils (Popkin et al., 2012). **Palm oil**, which is relatively inexpensive, currently accounts for more than 30% of global vegetable oil production (Carlson et al., 2013). Another commonly consumed ingredient in processed foods is **high fructose corn syrup** (HFCS), employed as a sweetener (Truax et al., 2011). The production of HFCS has been a major driver in the expansion of highly specialized, industrialized production of genetically uniform corn (Miller & Spoolman, 2011).

These trends have been compounded by the way mass retailing is organized. The rise of processed foods has itself been facilitated by the growth of supermarkets (Reardon et al., 2003; Gomez & Ricketts, 2013), where these foodstuffs are often marketed at low prices relative to other products. Furthermore, **the quality and safety standards** imposed by supermarkets and other mass retailers often require costs and **levels of standardization** that can be difficult for individual small-scale producers to meet, particularly in low-income countries, and therefore, supermarket chains prefer to deal with fewer and larger producers (Hazell et al., 2007).

Rising demand for animal proteins is another key feature in the evolution of consumption patterns, with major implications for how agriculture is organized. The increasing demand for meat is generally being met through the growth of industrial livestock production, based around a few highly specialized breeds (Thornton, 2010). This trend has also driven higher demand for grains to feed animals (UNCTAD, 2013), reinforcing highly specialized feed production systems. For instance, **the spread of soybean monocultures has been driven by the demands of an expanding global meat industry**, as well as demand for soybean by- and co-products (e.g. oil) for food and non-food purposes (Ash et al., 2006).

Several factors are converging to lock in these trends where they already exist, and to embed them in new locations where purchasing power and consumer habits are converging with Western norms. Firstly, **consumers have become accustomed to cheap abundant food**, both at retail outlets and in fast-food restaurants, and have adapted their household budgets to this new normality. For example, in 2014 the share of household spending dedicated to food fell as low as 11.4% in the US (6% at home and 5.4% outside the home) (USDA, 2016a).

The relative devaluation of food has gone hand in hand with **major food waste** in industrialized countries, reaching around 19% at the household level (Gustavsson et al., 2011). Consumers in wealthy countries have duly become accustomed to spending the vast majority of their income on other items, from essential living costs (e.g. rents) to the luxury items (e.g. consumer technology) that have become widespread.

» Food accounts for 11.4% of US household spending
» 19% of food wasted at household level in wealthy countries

Secondly, consumers have become increasingly disconnected and disengaged from food systems. This disconnection has been observed on three levels: **physical** (between the urban zones where most people live and the rural zones where food is produced); **economic** (more intermediaries between consumers and farmers, with a greater share of value moving up the supply chain at the expense of farmers); and **cognitive** (decreasing knowledge of how food is produced and processed) (Bricas et al., 2013). As a result, **the fact that food choices have implications for farming systems has become less obvious and less important in the hierarchy of daily concerns**.

A vicious circle is therefore firmly in place. Retail practices are unlikely to change insofar as consumers continue to expect the same products at the same prices, and insofar as industrial agriculture continues to provide that flow of cheap commodities. Alternative retail circuits are now resurgent in some places (see Section 3.a), but for many farmers, the increasingly dominant and consolidated mass retail circuits continue to be the only viable outlet for selling their produce. In this context, farmers have had little choice other than to further specialize and industrialize their production, in order to supply large volumes of specific commodities at low costs.

LOCK-IN 4: COMPARTMENTALIZED THINKING

Industrial agriculture is also locked in place by the highly compartmentalized structures that govern the setting of priorities in **politics, research and business**.

Raising the productivity of a narrow range of crop and livestock breeds became the central priority of many policy and research programmes over the course of the 20th century. The first chemical fertilizers were developed in the mid-19th century, paving the way for further scientific advances in crop productivity that would characterize the next 100 years (Nene, 2012). Wealthy countries benefitted from these developments and experienced huge productivity gains.

In the post-war period, efforts were stepped up to spread these advances to developing regions of the world. The 'Green Revolution', that followed saw major successes in raising productivity, focused around breeding crops with high responsiveness to external inputs and wide applicability. In the mid-60s, the International Rice Research Institute (IRRI) was established to carry out research on improved rice varieties; as a result, IR-8 ('Miracle Rice') was adopted by numerous Asian countries. The International Maize and Wheat Improvement Center was also established around the same period; in 1971, donor countries and a number of foundations came together to form the Consultative Group for International Agricultural Research (CGIAR) in order to support these and other specialized research centres. The successful new varieties were marketed and distributed around the world, contributing to the dramatic increases in the productivity of key staple crops documented in Section 1.a.i.

However, 'Green Revolution' thinking continues to dominate and to generate the same type of solutions, even as the need to reconcile productivity growth with other concerns has been increasingly recognized. Its legacy is particularly visible in the compartmentalized agronomic/crop-productivity and yield focus of modern agricultural research. Most agricultural colleges have developed siloed structures in which different disciplines do not interact closely (O'Brien et al., 2013). Classical agricultural research and education systems have thus evolved with little attention to the complex interactions between the natural environment and human society that underpin food systems (Francis et al., 2003). This is exemplified by the high proportion of doctoral and post-doctoral research topics in highly specialized fields of biotechnology as compared to research on agroecology; in general, a large number of academics focus their research on the industrial model of agriculture (Francis et al., 2004). These educational systems therefore act as a roadblock against alternative models and systemic approaches (Bammer, 2005).

Green Revolution thinking:

- Input-responsive crops
- Wide applicability > localized approaches
- Staple crop breeding > minor species
- Technological innovation > social innovation
- Value chain approach > horizontal knowledge-building

The **gradual privatization of agricultural research** has reinforced these trends. In many countries, public sector agricultural research has been scaled back over recent decades, alongside measures to reinforce intellectual property protections that favour private sector research and development (R&D), such as trade secrets, plant breeders' rights and patents (King et al., 2012). The parallel rise in private investment has focused on those commodities for which there is a large enough market to secure a significant return on investment (Piesse & Thirtle, 2010). In this context, minor species and traditional crop varieties have been neglected (Rahman, 2009).

The shift towards private sector priority-setting has been particularly acute in universities. Over the last 30 years, government funding cuts have strained higher education and agricultural research budgets, with private funding often filling the void (Muscio et al., 2013). **This leads researchers to follow the agendas set by private sector funders.** What remains of public sector research has largely supported this agenda, continuing to focus on a **small number of tradable crops** (Jacobsen et al., 2013), and often focusing on **technological innovation** (particularly for input-responsive crop breeding) to drive productivity increases. For example, the European Commission has supported projects on GM crops in the order of €300m since the beginning of the Bio-Molecular Engineering Programme (European Union, 2010).

Similar trends have been observed in transitional economies such as Brazil, China and India, which now account for 25% of global public agricultural R&D spending (IFPRI, 2012). Developing countries have also seen an increase in private agricultural R&D over recent years, with a similar focus on a narrow range of crop and livestock breeds and technologies; this has occurred alongside the development of large-scale, capital-intensive farm operations mirroring farming systems in industrialized countries (Naseem et al., 2010).

Compartmentalized approaches focused around the various specialized agricultural sectors are also visible in how knowledge and training are transmitted to farmers. Sectoral or **value chain approaches**, such as the '*interprofessions agricoles*' in France, have taken root in many countries (Agriculture Ministry of France, 2011), with extension services geared towards **sharing knowledge and facilitating exchange vertically**, i.e. in relation to a particular product chain.

Policy-making structures have also become highly compartmentalized and ill-equipped to respond to the cross-cutting challenges in food systems. For example, discussions around CAP reform are notoriously dominated by agricultural constituencies, with the European Commission's Directorate-General for Agriculture and the European Parliament's Agriculture Committee occupying privileged positions procedurally. This siloed approach is increasingly out of sync with the broader set of priorities to which these policies claim to be responding, such as providing **public goods** or delivering **food security**. The European Commission's in-house research service has now echoed civil society groups in requesting the creation of a cross-sectoral taskforce for food and the environment in order to break the silo effect surrounding the CAP (Maggio et al., 2015). Similarly compartmentalized approaches have been identified in the US, where scientists and civil society groups have encouraged the government to develop agricultural policies in tandem with other policy areas, and in relation to a broader set of objectives (Union of Concerned Scientists, 2015a).

The compartmentalization in research, policy and farm industry structures is mutually reinforcing. **The agricultural policies made in isolation depend on the knowledge emanating from the corresponding agricultural silo of the research world.** Agricultural sector bodies are organized to convey this knowledge to farmers, who in turn rely on agricultural subsidies and other political support measures geared towards raising crop productivity and net production.

As a result, concerns related to agricultural productivity – and the associated budgets – are isolated from other competing priorities. This occurs even as emerging bodies of knowledge (e.g. on agro-ecosystem resilience) call into question purely agronomic approaches focused on increasing yields of staple crops under optimal conditions. The compartmentalized structures that worked so well to support the productivity increases of the Green Revolution are therefore proving slow or unable to adapt to the interconnected challenges now facing food systems.

LOCK-IN 5: SHORT-TERM THINKING

Industrial agriculture has emerged due to significant political support on various fronts, and in tandem with major private investments to raise agricultural productivity, particularly via crop breeding (see Lock-ins 1-4). These constituencies are thus invested in the agricultural sector, and have a strong interest in continuing to support it.

However, their interests are bound by the unforgiving timeframes of political and business cycles, **pushing short-term solutions** to the forefront and keeping these actors firmly wedded to existing systems – even as they generate increasing problems.

Short-term thinking is most visible in the electoral cycles governing the policy sphere. **Politicians seeking re-election are unlikely to espouse policies whose rewards will not materialize within the same electoral cycle.** This places an emphasis on tweaking current frameworks rather than engaging in fundamental reform. Even at the EU level, where timeframes are longer and the political accountability of certain actors (e.g. the European Commission) is less explicitly linked to elections, reform efforts have been modest. Successive rounds of CAP reform have been aimed at stemming the decline in farm numbers and the outflow of agricultural labour, rather than addressing the root causes of these problems (Buckwell, 2015). These reforms have been undertaken in the knowledge that many of those receiving subsidies are unlikely to innovate or shift their practices (Haniotis, 2016).

Other actors in political processes, for example the elected representatives of agricultural pressure groups, are also likely to be seeking to deliver immediate benefits to those who have elected them and to whom they will shortly be looking for re-election.

Meanwhile, it is well established that **short-term bottom line results** are the main considerations and motivations for investors, thereby limiting the ability of large traded companies to invest significantly in long-term changes.

Short-term concerns are particularly prevalent in the retail sector, where mass retailers are bound by the expectations they have nurtured among consumers: for **cheap, varied food year-round** (see Lock-in 3: The expectation of cheap food). In this context, supermarkets have often dictated which crops should be grown based on short-term commercial considerations (Thresh, 2006), creating pressures for all farmers – particularly those attempting to nurture long-term natural synergies within diversified agroecological systems.

As outlined in Section 1.b, diversified agroecological systems offer major benefits for farmers and society. However, the advantages will not be immediately visible, given the time needed to rebuild soil health and fertility, to increase biodiversity in production systems, and to reap the full benefits of enhanced resilience.

Undertaking this shift clearly brings economic risks for farmers, at least during the transitional period. Current political and business approaches, bounded by short-term cycles, are ill-adapted to provide the long-term support that would be needed to support this transition. The requirement of many food systems actors for immediate results is therefore a key factor in locking in current systems and preventing the spread of diversified agroecological farming.

Short-term thinking in response to:

- Electoral cycles
- Shareholder returns in traded companies
- Retail imperatives

LOCK-IN 6: 'FEED THE WORLD' NARRATIVES

Delivering food security by increasing **total food production** has been one of the key motivations for pursuing industrial agriculture. Public policies have often made this objective explicit, particularly in the post-war period, and have advocated a pathway of extreme specialization in order to achieve it. For example, in 1963 the US Department of Agriculture wrote: "Over the long term the Nation will be better off and its resources will be most productively used if the bulk of each product is produced in those areas and on those farms that have the greatest income advantage in producing it" (Johnson & Parsons, 1963).

Policies were therefore devised in order to increase the production of major commodities, as a condition for achieving food security (Duncan, 2015). This type of thinking underpinned several generations of agricultural policies, often taking the shape of programmes to support **increased production of commodity crops**, and complementary policies to **increase agricultural trade flows** (see Lock-in 2: Trade and export orientation).

The vision underlying these policies is of industrial agriculture 'feeding the world', i.e. **food security understood in terms of delivering sufficient net calories at the global level**. As outlined in Section 1.a.iii, productivity has grown impressively in industrial systems, but this has not translated into global food security by any measure: 795 million people still suffered from hunger in 2015 (FAO et al., 2015b), with two billion afflicted by the 'hidden hunger' of micronutrient deficiencies (Bioversity International, 2014).

Meanwhile, there has been increasing recognition that hunger is fundamentally a distributional question tied to poverty, social exclusion and other factors affecting access to and utilization of food (WHO, 2008; World Bank, 2010; FAO, 2015; Sen, 1981). This has led to a growing understanding that increases in productivity have to occur predominantly within developing countries if they are to have an impact on food and nutrition security, particularly among the poorest (Piesse & Thirtle, 2010; Pretty et al., 2011).

Narratives about feeding the *world* have nonetheless continued to be propagated, especially in the wake of the food price spikes of 2007-2008 and the newfound urgency associated with questions of food security (Wise, 2015). Eye-catching statistics relating to net production levels for achieving future food security have been regularly highlighted, including FAO's projection that global agricultural production will have to increase by 60% by 2050 to satisfy food and feed demands (FAO, 2013a). **Narratives about feeding the world have duly been built around figures such as these, not least by agribusiness firms.** Citing a global population of nine billion in 2050, Monsanto argues: "To feed everyone, we'll need to double the amount of food we currently produce" (Monsanto, 2015); Cargill identifies the need for a "boost in global food production to meet the world's growing demand" (Cargill, 2015).

These narratives claim that the same systems and same actors driving the Green Revolution-style productivity increases of the past must remain at centre stage. However, the prescriptions have been nuanced to integrate new imperatives.

For example, ecological concerns have been reconciled with food security imperatives through now common terms such as '**sustainable intensification**' or 'climate smart agriculture'. The approaches advocated under these banners often involve significant steps to reduce the environmental impacts of industrial agriculture, e.g. by reducing the use of chemical inputs.

However, **these visions tend to address specific food systems outcomes in isolation, and thus avoid fundamentally reappraising in-**

dustrial agriculture and its self-reinforcing problems. The 'sustainable intensification' approach is often focused on sparing further land from entering production (see for example James, 2014), suggesting that reducing net agricultural land usage to a given global threshold is key. As shown in Section 1, this downplays the huge potential of diversified agroecological systems to regenerate existing farmland and sequester carbon, and therefore risks drawing attention away from the need to fundamentally rethink production systems on current cropland.

In other cases, productivity-focused narratives have been adjusted to emphasize concerns about social equity. Here too, there has often been too little attention to the root causes of problems in food systems. For example, the G8's 'New Alliance for Food Security and Nutrition', a development scheme launched in 2012 to deliver food security, declares a focus on improving the livelihoods of smallholder farmers. However, **integrating smallholders into agribusiness-led global supply chains as outgrowers** remains the primary mode of action (McKeon, 2014); this bypasses questions about price volatility and declining terms of trade for commodity export cropping zones (see Section 1.a.iii), as well as ignoring the **livelihood stresses** and **power imbalances** that are often exacerbated in these types of arrangements (De Schutter, 2011).

The failure to consider other pathways, e.g. supporting agroecology, or to consult broadly with civil society and farming groups in defining this pathway to food security, was heavily criticized in a recent European Parliament opinion on the G8 New Alliance (European Parliament, 2016).

Where the focus on productivity has been broadened to take in nutritional concerns – from a '**food and nutrition security**' lens – the root causes of deficiencies have often been left unaddressed. In many development schemes and research programmes, the focus has been placed on single nutrients through **supplementation, fortification and biofortification**, with little emphasis on durably improving people's access to a diverse diet (Frison et al., 2006; Burchi et al., 2011).

'Feed the world' narratives fail to address:

- Problems of poverty and access
- Social equity and power relations
- Root causes of insufficient diets
- *Where* and by *whom* additional food must be produced
- Interconnections between food systems problems

These narratives rightly underline the need to think about food security. However, they do so in ways that deflect attention away from the failings of industrial agriculture. **These narratives continue to ignore the question of *where* and *by whom* additional food must be produced.** The framing of the debate around 'feeding the world' pre-disposes us to approach the question in terms of net production volumes of mainly energy-rich, nutrition-poor crop commodities.

As a result, crucial questions are side-lined, e.g. how farming livelihoods will be secured; how additional food will reach the poor in the parts of the world where food insecurity is greatest; how to provide healthy, diverse diets; or how to improve equity and social well-being. These narratives clearly constitute an important lock-in. How big an impact they have depends on the power and visibility their proponents are able to bring to bear, underlining the importance of how power is distributed in food systems (see Lock-in 8: Concentration of power).

LOCK-IN 7: MEASURES OF SUCCESS

As indicated in Lock-in 6, industrial agriculture and the quest to 'feed the world' go hand in hand. The ways in which success is measured in food systems often corresponds to the same imperatives – and constitutes another key factor locking in industrial agriculture. Measuring and benchmarking success is crucial in determining how well agricultural systems are functioning, and how effective specific interventions have been. Research funding, development programming and political support for agriculture is often decided on the basis of specific performance indicators. ***Which* indicators are used is therefore crucial.**

The performance of agriculture is often measured in terms of **total yields of specific crops, productivity per worker, and total factor productivity** (total outputs relative to total land and labour inputs). On this basis, the efficiencies of highly-specialized and increasingly large-scale farms have been highlighted by agriculture ministries and global institutions (see for example USDA, 2016b). Furthermore, the analysis of different agricultural systems' viability is generally carried out based on simplistic cost-benefit analysis, which does not incorporate ecological, social and cultural variables, and does not take into account the complexity of systems (Flores & Sarandón, 2004).

Evidence is emerging, particularly in recent long-duration studies, to suggest that diversified agroecological systems can compete well on these fronts, delivering strong and stable yields, and securing income in the process (see Section 1.b). These outcomes are likely to further improve if commensurate support and investment is made available to develop and spread agroecological knowledge (see for example Pretty et al., 2011; De Schutter, 2010).

However, diversified agroecological systems are by definition geared towards producing diverse outputs, some of which are reused on the farm (e.g. fodder for animals). Diversified agroecological systems are also generally focused on **shorter retail circuits** with fewer intermediaries, **fewer input-related transactions**, and **elements of own-consumption**. This means that the economic exchange value of these forms of agriculture tends to be smaller. As such, they are disadvantaged by calculations of specific crop yields per area or per worker, and even by calculations of total factor productivity that do not adequately capture the different outputs and circuits they enter.

Furthermore, the metrics most commonly referred to do not account for the high nutrient content of foods arising from diversified agroecological systems, nor do they capture the vast environmental benefits of diversified agroecological systems. More holistic 'resource efficiency' or 'environmental efficiency' perspectives would be required in order to do so, not only taking output to input ratios into consideration, but also the proportions of desired outputs relative to undesired outputs or impacts (Garnett et al., 2015). As described in Section 1.b.ii, where calculations have been made on the basis of resource efficiency, diversified agroecological systems have performed very favourably.

In light of growing environmental and disease pressures, the ability of diversified systems to recover from extreme shocks and to sustain production under stress conditions should also be reflected in what is measured and considered of importance. Diversified agroecological systems also hold major potential to deliver

Benefits of agroecological systems that are typically under-valued:

- High total outputs
- High nutrient content of outputs
- Resilience to shocks
- Provision of ecosystem services
- High resource efficiency
- Job creation

ecosystem services within and beyond agriculture (e.g. biodiverse habitats, carbon sequestration, water quality, stock of natural capital/assets). These services are yet to be measured and rewarded on a significant scale.

Adequate and nuanced ways to measure the labour effects of agricultural systems are also lacking. Conventional measures of productivity per worker clearly reward labour-saving systems. Relying solely or primarily on these measures means ignoring complexities around the question of labour markets. As described in Section 2.b.i, **the labour intensity of diversified agroecological systems may be a positive in terms of long-term economic development and social cohesion**, particularly if the working conditions prove more favourable than traditional agricultural work (see Sections 1.b.iii and 1.c). The picture painted by typical measures of market efficiency is incomplete. Indeed, markets tend to fail at many tasks that society regards as important, such as poverty reduction, nutritional well-being, food price stability or even employment generation (Timmer, 2015).

Overall, it is clear that current systems will be held in place insofar as these systems continue to be measured in terms of what industrial agriculture is designed to deliver, at the expense of the many other outcomes that really matter in food systems.

Market concentration in multiple sectors:

- 3 companies control 50% of commercial seed market
- 7 companies control nearly 100% of fertilizer sales
- 5 companies share 68% of agrochemical market
- 4 firms account for 97% of private R&D in poultry
- 4 firms control up to 90% of the global grain trade

LOCK-IN 8 : CONCENTRATION OF POWER

Concentration of power in food systems is a lock-in of a different nature: **it is a mechanism that reinforces all of the lock-ins discussed above**. Food systems, in their current forms, allow value to accrue to a limited number of actors, reinforcing their economic and political dominance, and thus their ability to influence the policies, incentives and imperatives guiding those systems.

For example, the centrality of **chemical fertilizer, pesticide** and **input-responsive seeds** in industrial systems allows value to accrue to a handful of dominant agribusiness firms in these highly concentrated sectors. Three companies controlled nearly 50% of the world's commercial seed market in 2007; seven companies control virtually all fertilizer supply; and five companies share 68% of the world's agrochemical market (Renwick et al., 2012). This concentration has led to a drastic reduction of small and medium seed companies, and an even narrower range of varieties being developed.

Similarly, a limited number of companies now dominate R&D in **animal genetics**. In the poultry sector, four firms account for 97% of private R&D, two companies control an estimated 94% of the breeding stock of commercial layers, and the same two supply virtually all of the commercial turkey stocks, with efforts focusing on an increasingly narrow range of breeds. Meanwhile, the top four transnational companies account for two thirds of the total industry R&D for swine and cattle (FOE & HBF, 2014).

Meanwhile, the **commodity export circuits** so integral to these systems (see Lock-in 2: Export orientation) generate considerable value for a handful of multinational companies with the logistical capacity to manage huge commodity flows. Up to 90% of the global grain trade is controlled by four agribusiness firms (Murphy et al., 2011). The emergence of supermarkets and other **large-scale retailers** has concentrated power at another node of the food chain (BASIC, 2014). Not only is power highly concentrated at these different points, but the various interests are closely aligned in terms of the prevailing dynamics they would like to see. Food systems in which uniform crop commodities can be produced and traded on a massive scale are in the economic interests of crop breeders, pesticide manufacturers, grain traders and supermarket retailers alike.

Dominant actors are able to bring their power to bear in various ways. With public sector research fading in its financial clout and its ability to set trajectories (see Lock-in 4: Compartmentalized thinking), input agribusinesses are able to take centre-stage in **framing the problems** (e.g. underlining the global productivity challenge) *and* **providing the solutions** (e.g. new ranges of input-responsive crops and breeds), thus securing demand for their products, while ensuring that power and influence continue to flow their way.

Lobbying policy-makers to ensure favourable policy frameworks is another channel used to exert power. In 2015, agribusiness firms spent more than $130m lobbying US Congress, a figure that exceeds the lobbying efforts of the defence industry and is roughly three times the total lobbying expenditure of organized labour (OpenSecrets, 2016). For example, lobbying efforts by food manufacturers, food producers, and special interest groups helped to ensure that the dietary guidelines adopted by the US Department of Agriculture (USDA) in 2015 deviated substantially from the recommendations the department had commissioned from health and nutrition experts in the Dietary Guidelines Advisory Committee (Watson, 2015).

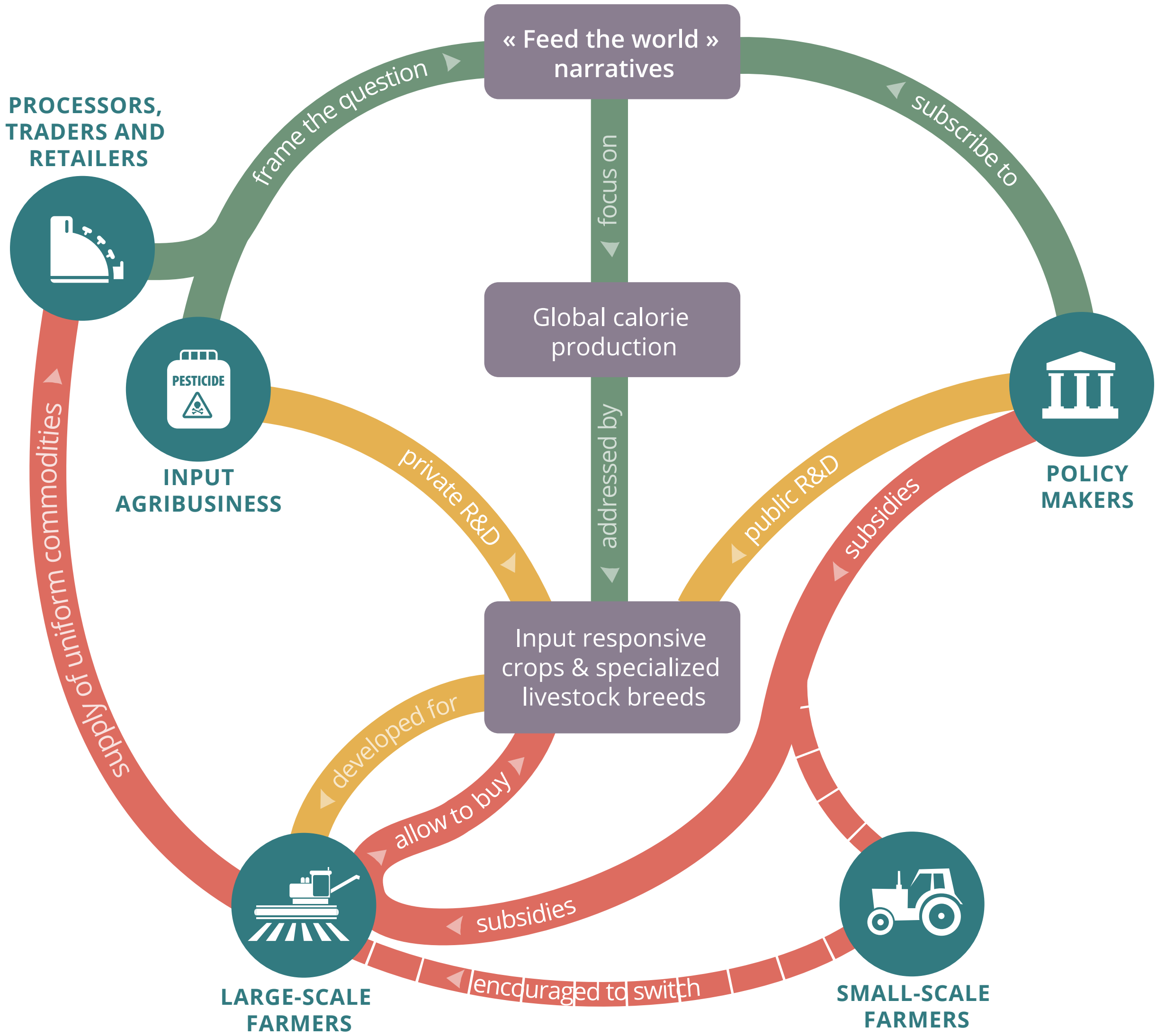
This power can also be brought to bear by **leveraging influence to secure research focuses** – and findings – that are favourable. In 2009, dozens of US scientists wrote anonymously to the Environmental Protection Agency (EPA) to complain about the difficulties conducting independent research on GM crops (Pollack, 2009). In some extreme cases, **campaigns to discredit crop science** researchers whose findings have not been conducive to dominant interests are alleged to have occurred (see for example Waltz, 2009; PR Watch 2015).

Another important channel for bringing this influence to bear is by **co-opting the alternatives**. As seen in Lock-in 6, narratives are a powerful tool in reinforcing industrial agriculture. A prominent variant of food security narratives now insists that we need conventional *and* organic agriculture in order to feed the world (see for example Huffington Post, 2014). Accordingly, organic farming has become an accepted product line for large-scale agribusinesses and a market niche for mainstream retailers – thereby blunting the challenge it might otherwise pose to conventional farming (Jaffee & Howard, 2010).

Agroecology may now face similar risks; it is increasingly referenced in a range of settings, and is regularly conflated with general aspirations to improved sustainability, while only addressing single, often environmental, objectives. For example, fast food chain McDonald's France adopted an 'agroecological strategy' in 2010, featuring, inter alia, promises to "replace conventional phytosanitary products with alternatives where possible" (McDonald's, 2015).

A wholesale transition to diversified agroecological food *and* farming systems does not hold obvious economic interest for the actors to whom power and influence have previously accrued. The alternative model requires **fewer external inputs**, most of which are locally and/or self-produced. Furthermore, in order to deliver the resilience so central to diversified systems (see Section 1.b), a wide variety of **highly locally-adapted seeds** is needed, alongside the ability to reproduce, share and access that base of genetic resources over time. This suggests a much-reduced role for input-responsive varieties of major cereal crops, and therefore few incentives for commercial providers of seeds, fertilizers and pesticides. The global trade and processing industry is also a major potential source of resistance to change, given that alternative models tend to favour local production and **short value chains** that reduce the number of intermediaries.

FIGURE 13 - POWER IMBALANCES IN FOOD SYSTEMS: FRAMING THE QUESTIONS AND PROVIDING THE SOLUTIONS



The mismatch between the potential of agroecology to improve food systems outcomes, and its potential to generate profit for agribusinesses, may explain why it has been so slow to make its way onto the global political agenda. Because of the opposition of certain member countries for many years, it took until September 2014 for FAO to organize its first Symposium on Agroecology for Food Security and Nutrition (see Section 3a). While this development is promising, it is long overdue, and may struggle to emerge further into the mainstream without strong demonstrations of support from governments, foundations and other influential actors – including from the corporate sector.

The self-reinforcing power imbalances in industrial food systems are a major reason why transition is needed. They also underline the extent of the challenge, in terms of overcoming the resistance of dominant actors who have become symbiotic with those systems. As will be explored in Section 3, mainstream actors can play a major role in changing food systems – and in some cases already are. However, ensuring that the necessary wholesale transition towards diversified agroecological food and farming systems is able to take root will require political priorities to be clearly established.

03 How can the balance be shifted in favour of diversified agroecological systems?

3.A. EMERGING OPPORTUNITIES FOR A TRANSITION TO DIVERSIFIED AGROECOLOGICAL SYSTEMS

The vicious cycles identified in Section 2 serve to reinforce industrial agriculture in a number of ways. Nonetheless, **a series of opportunities for change are emerging through the cracks of these systems, laying the foundations for a shift towards diversified agroecological food and farming systems**.

These developments cannot be described exhaustively. In many cases they are grassroots initiatives cropping up in different countries and contexts, and thus taking a variety of forms. However, a series of common trends can be identified in terms of how these initiatives are challenging industrial food systems.

Eight key opportunities for supporting the transition to diversified agroecological systems are therefore identified below. How big an impact these developments can have, and what might be needed to allow them to advance further, is addressed in Section 3.b.

Opportunity 1: Policy incentives for diversification and agroecology

In some parts of the world, governments have started to provide support and incentives for moving away from industrial modes of agriculture. These measures range from baseline diversification requirements to approaches supporting a broader shift in practices. For example:

- The **2013 CAP reforms** have made the EU's direct payments to farmers conditional on some limited crop diversification[14], protection of permanent grassland and the maintenance of Ecological Focus Areas. They have also introduced automatic recognition for organically-certified land.
- After the Soviet Union collapsed, the **Cuban government** began shifting away from a system of chemical input-intensive commodity monocropping. The government has since promoted a transition towards more sustainable means of farming, using agroecology and self-sufficiency as guiding principles, with agroecology now institutionalized by both state and non-state actors (Nelson et al., 2009). Family farms in Cuba practicing agroecological farming occupy 25% of the total arable land, and may account for as much as 65% of the domestic food supply (Rosset et al., 2011; Altieri & Toledo, 2011).
- The **Brazilian National Plan for Agroecology and Organic Production**, involving nine different ministries, is focused on fostering organic and agroecological production as a contribution to sustainable development. The scheme targets increased consumption of healthy food, and looks to achieve this in part by using and conserving traditional plant and animal genetic resources (Brazilian Ministry of Agrarian Development, 2013).

14. The 2013 reform of the CAP introduced a requirement for farmers to cultivate at least two crops when arable land exceeds 10 hectares, and at least three crops when arable land exceeds 30 hectares. The main crop is allowed to cover at most 75% of arable land, and the two main crops at most 95% of the arable area.

Opportunity 2: Building joined-up 'food policies'

Increasingly, efforts are being made to overhaul and integrate the policy processes affecting food systems. These efforts have seen multiple actors (scientists, policy-makers, civil society) and multiple constituencies (health, environment, development etc.) come together in pursuit of joined-up food policy-making. For example:

- Since first emerging in Toronto in 1991, '**food policy councils**' are increasingly being established in cities and municipalities, primarily in the US, Canada and the UK. These forums bring together actors from multiple backgrounds and sectors (food, farming, public health, agri-business, retail, environment, policy, civil society etc.) and allow members to build long term strategies around food-related goals (Toronto Food Policy Council, 2016; Massachusetts Workforce Alliance et al., 2015, Vancouver FPC, 2016; Bristol FPC, 2016; Alaska FPC, 2016).
- In **Brazil**, the National Council for Food and Nutrition Security (CONSEA) is an advisory council designed to bring together a wide range of actors to inform food policies. Representatives from the private sector and civil society make up two thirds of its members, including labour unions, business associations, church groups, professional associations, academics, family farming and indigenous groups. The federal government makes up the remaining third. CONSEA advises the Presidency of Brazil on the formulation of policies to guarantee its human right to adequate and healthy food, and succeeded in having the National Law on Food and Nutrition Security (LOSAN) approved by congress in 2006. Under LOSAN, the country has developed a National Policy on Food and Nutrition Security, and all levels of government (federal, state, and municipal) are to participate in the construction of 'SISAN', a National System for Food and Nutrition Security (CONSEA, 2009).
- In **Thailand**, the National Food Committee Act (2008) created a National Food Committee to serve as the main agency for national food management and to promote cooperation. The Committee was made responsible for assessing and proposing policies on a range of questions including food security, food safety, food quality and food education.
- Building on these types of examples, 2015-2016 has seen calls for more integrated policy-making for food systems within the EU. In 2015, the **European Commission**'s in-house research service requested the creation of a **cross-sectoral taskforce for food and the environment**, in order to develop a Common Food Systems Policy and break the silo effect surrounding the CAP (Maggio et al., 2015). In 2016, IPES-Food joined forces with the cross-party Sustainable Food Systems Group in the European Parliament and other scientific and civil society groups to launch a multi-stakeholder process to develop a 'Common Food Policy' vision for the EU (IPES-Food, 2016).
- In 2015, the **Dutch government** held multi-stakeholder reflections on developing a comprehensive food policy based on recommendations from a report it commissioned from the Netherlands Scientific Council for Government Policy (WRR, 2015).
- The **US 'Plate of the Union'** campaign launched by scientists and civil society groups in 2016 calls for the next president to put a 'national food policy' in place (Union of Concerned Scientists, 2015a).

Opportunity 3: Integrated landscape thinking

There is growing momentum for managing and improving the outcomes of food systems at the landscape or territorial level. The initiatives and partnerships forming around these objectives are starting to lay the foundations for food systems that are diversified at multiple levels (fields, farms, landscapes, regions), are capable of managing resource and waste flows, and ensure healthy ecosystems across territories. For example:

- **Integrated landscape initiatives** involving environmental organizations and farmer learning networks are fast emerging. A study of 87 integrated landscape initiatives in 33 African countries showed that overall, 63% of the projects reported at least one positive outcome in terms of conservation, agriculture, policy, and economic development, while 72% reported positive outcomes in at least three domains (Milder et al., 2014).
- The '**city-region**' is emerging as a key unit for food systems planning and management, drawing on the precedent of environmental planning between cities and the surrounding regions, e.g. to manage watersheds and downstream water quality. The FAO-supported City Region Food Systems Alliance brings together a range of civil society, research-based and local government associations to build knowledge and share practices on managing food systems at the city-region level (FAO & RUAF Foundation, 2015).
- **Urban-rural cooperation** has helped to support the preservation and regeneration of landscapes. In **Japan**, the Ownership System was launched 25 years ago in Yusuhara and now involves thousands of participants in different parts of Japan. It is based on co-operation between rural and urban communities, combines food production with landscape conservation, cultural activities and environmental education, and has allowed culturally-significant rice terrace systems to be maintained (RUAF Foundation, 2015).

Opportunity 4: Agroecology on the global governance agenda

Over recent years, the intergovernmental sphere has become more responsive to the case for wholesale food systems transition and the potential for agroecology to deliver it. This has manifested itself in a range of new intergovernmental processes and assessments:

- In 2005, the **Millennium Ecosystem Assessment** highlighted the alarming degradation of ecosystems and called for changes in agriculture to reduce its impact on the environment (Millennium Ecosystem Assessment, 2005).
- In 2009, the **International Assessment of Agricultural Knowledge, Science and Technology for Development** (IAASTD), a study involving 400 experts from all regions of the world as well as FAO, the World Bank and other international organizations, called for a fundamental paradigm shift in agricultural development and strongly encouraged the development of agroecological science and practice (IAASTD, 2009).
- **FAO** officially and directly addressed agroecology at the International Symposium on Agroecology for Food Security and Nutrition in 2014 (FAO, 2015b). This meeting was followed up by **regional agroecology meetings** in South America, Africa and Asia in 2015. In addition, an International Symposium on Agroecology will be held in China in August 2016; in Europe, a regional meeting is planned towards the end of 2016 in Hungary. According to the FAO's Director General José Graziano da Silva, "agroecology continues to grow, both in science and in policies. It is an approach that will help to address the challenge of ending hunger and malnutrition in all its forms, in the context of the climate change adaptation needed" (FAO, 2014).
- **FAO** has funded **training courses** to build agroecology into its Farmer Field School systems and to train staff involved in community training to expand agroecology networks. Courses for 2016 include Burkina Faso in September and Mozambique in October.
- In 2015, FAO and UNEP launched the **Sustainable Food Systems Programme** (SFSP) as part of the UN 10 Year framework programme on sustainable consumption and production. The SFSP serves as a tool for accelerating the shift to sustainable food systems in both developing and developed countries (UNEP, 2015).

- The contribution of agroecology to reducing soil degradation and increasing food security was acknowledged under the **International Year of Soils 2015**.

Opportunity 5: Integrated food systems science and education

As described in Section 2, the food price spikes of 2007-2008 have underpinned global food security narratives and accompanying investments in raising the productivity of industrial agriculture. Conversely, they have given new impetus to efforts to develop and spread knowledge on building resilience in food systems, often emphasizing the needs of small-scale farmers, especially women, in the face of climate change and volatile international markets (Wise & Murphy, 2012). This has added to the momentum for a shift towards integrated food systems research:

- **Educational structures and programmes** are seeing some evolution towards **systems analysis**, higher-order thinking, and new approaches to collecting, managing, and interpreting data (O'Brien et al., 2013). Many universities have recently opened Food System Centres or Units that tend to break down the traditional silo structures of research.
- **Collaborative research programmes** are forming around agroecology and high-diversity farming systems. An increase in agroecology and food systems curricula has been occurring in North America and Europe (Francis et al., 2012; Jordan et al., 2014; Francis, 2004; Méndez et al., 2013).
- Agroecology is garnering growing support among numerous experts in the **international scientific community** (Wezel et al., 2009). In 2015, a statement signed by over 300 US scientists and experts pushed for greater public investment in research that applies ecological principles and relies on agroecological processes (Union of Concerned Scientists, 2015b).
- The **EU Framework Programme 7** and **Horizon 2020** research programmes include a number of calls based around agroecology, organic farming and conservation agriculture (Lampkin et al., 2015).

Opportunity 6: Peer-to-peer action research

Perhaps of more significance than the modest inroads in mainstream settings, there has been a recent spread of agroecological research through participatory, practical applications. This type of research is allowing for a greater understanding of which techniques are most efficient and best-adapted to local contexts:

- Long-standing **peasant innovation systems**, such as the campesino a campesino movement, are well-placed to develop and spread agroecological knowledge. This movement, launched some 30 years ago in Nicaragua, was born in reaction to top-down approaches to agricultural technology. These peasant networks allow farmers to be empowered as agricultural innovators (Holt-Giménez et al., 2010; Rosset et al., 2011; Sosa et al., 2010).
- **Farmer field schools** are emerging as a powerful tool to spread knowledge. Bringing together groups of farmers to work on topics such as conservation agriculture, organic farming, animal and soil husbandry, and IPM, farmer field schools can act as effective extension services. In some 90 countries these schools have permitted farmers to improve their knowledge, to reduce pesticide use and to shift towards more sustainable livelihoods (Pretty, 2015; FAO et al., 2010).
- An increasing number of model farms with agroecological practices are now being developed with support from a number of f**oundations, NGOs and bilateral donors**, as well as through collaborations between farmers, land managers, researchers and civil society (Méndez et al., 2013; Wolfenson, 2013).

Opportunity 7: Sustainable and healthy sourcing

Concerns about nutrition and diets are gaining ground as a result of the rampant spread of NCDs (WHO, 2013), alongside increasing concerns about the health impacts of pesticides, and growing awareness of the benefits of dietary diversity. In parallel, public awareness about environmental sustainability and equity in food systems has been steadily rising. This has prompted a range of responses that call industrial agriculture into question:

- **Organic food sales** have risen in response to the confluence of demand for healthy and sustainable products: in the US, organic food and beverage sales grew from $1 billion in 1990 to over $39 billion in 2014; nation-wide sales for organic fruits and vegetables alone increased by 11.8% in 2009-2010, despite the global economic slowdown (Organic Trade Association, 2015; Rodale Institute, 2015). By 2013, global organic sales had climbed to $72 billion (FiBL & IFOAM, 2015).
- **Sustainability-compliant** and **Fairtrade schemes** have come to occupy increasing market shares for various (mostly tropical) foodstuffs. Between 2012 and 2013, global sales of Fairtrade products grew by 15%, reaching €5.5 billion (Fairtrade International, 2015).
- **Underutilized crops** are now being recognized for their vitamin and micronutrient content, and thus for their ability to help combat dietary imbalances (Mayes et al., 2012; Kafkas et al., 2006).
- A number of chefs are popularizing and valuing wild, indigenous, ethnic, traditional and diverse foods (Münke et al., 2015).
- Different countries in the global South have established arrangements with smallholder farmers in order to source produce for **home-grown school feeding programmes**. These collaborations have provided opportunities for strengthening local agricultural development (HGSF, 2016).
- In a growing number of municipalities, cities and countries, **public procurement programmes** have been reformed in order to source local, sustainable, ethical and/or healthy food for public canteens (Chandler et al., 2015; De Schutter, 2014). For example, the city of **Copenhagen** has set incremental targets aiming for 90% organic procurement by 2016 (Hultberg & Bergmann Madsen, 2012). In **Brazil**, the 2009 Law on School Feeding includes the procurement of diversified products from local family farms (CONSEA, 2009).

Opportunity 8: Short supply chains

One of the most impressive grassroots developments of recent years has been the emergence of a variety of schemes and initiatives aimed at reducing the distance between producers and consumers. These short supply chain initiatives are emerging fast in a wide range of settings:

- The provision of weekly boxes of fresh local produce (often fruit and vegetables) directly from farmers to consumers is on the rise in many countries in the global North. These boxes are often procured through **group purchasing associations**, referred to as 'AMAPs' in France, 'GASAPs' in Belgium, Community Supported Agriculture (CSA) in the USA and Teikei in Japan etc. (Lagane, 2011). In France, some 250,000 people (almost 1% of the working-age population) currently receive an AMAP box (INSEE, 2015; Assemblée Nationale, 2015).
- The resurgence of farmers' markets, **direct sales** shops and specialized organic shops is also an indicator of the rising demand for short supply chains. In the US, the number of farmers' markets grew by 76% between 2008 and 2014 (USDA, 2014).
- Some of the newest forms of citizen engagement with food production have come in the form of associations for acquiring **shares in agricultural cooperatives,** such as the *Compagnons de la Terre* in Belgium (Les Compagnons de la Terre, 2016).

3B: PATHWAYS OF TRANSITION: RECOMMENDATIONS FOR MOVING TOWARDS DIVERSIFIED AGROECOLOGICAL SYSTEMS

The opportunities for change identified in Section 3.a show that alternatives are emerging through the cracks of industrial food systems. These developments are challenging industrial food systems on multiple fronts, from the forging of new governance mechanisms to the creation of new market relationships that bypass conventional retail circuits and even the development of new narratives. They are also emerging in a variety of geographical settings.

However, these opportunities are not developing far or fast enough. Whether in terms of the composition of agricultural subsidies, the allocation of research budgets or the market share of different retail circuits, the alternatives are still marginal.

The need for a broader shift is urgent: the negative impacts of industrial agriculture, particularly its widespread environmental degradation and GHG emissions (see Section 1.a.ii), are pushing ecosystems ever-closer to dangerous tipping points. In many countries and regions of the world, farming systems now stand at a crossroads. **In the absence of compelling alternatives, the current reinvestment in agriculture in the global South is likely to replicate the pathways of agricultural industrialization that have raised farm productivity in wealthy countries – but at huge costs.** A global convergence towards these norms would make it ever harder to untangle the web of industrial agriculture.

It would also represent a major missed opportunity. Agroecology offers farmers a development pathway that builds on their existing knowledge and on the principles of resilience often central to smallholder systems - particularly those on the front lines of the fight against climate change. Diversified agroecological farming also represents an opportunity to increase access to diverse and nutritious diets on the basis of – and not *in spite of* – what is farmed locally.

The emerging opportunities described in Section 3.a must expand rapidly in order not to go into reverse. The discussion in Section 2 showed that industrial food systems, built around industrial modes of agriculture, are held in place by a set of powerful feedback loops. These loops tend to shut out the alternatives and keep food systems centred on industrial agriculture. The distribution of power is particularly crucial. **New knowledge platforms, new governance frameworks and new retail circuits only hold the potential to drive a transition insofar as they are able to avoid capture and prevent further power accruing to dominant actors** (Lock-in 8).

Strong, deliberate and coherent steps are therefore required to strengthen the emerging opportunities, while simultaneously breaking the vicious cycles that keep industrial agriculture in place.

IPES-Food is able to identify seven key recommendations for supporting the shift towards diversified agroecological systems:

1. **Develop new indicators for sustainable food systems.**
2. **Shift public support towards diversified agroecological production systems.**
3. **Support short circuits & alternative retail infrastructures.**
4. **Use public procurement to support local agroecological produce.**
5. **Strengthen movements that unify diverse constituencies around agroecology.**
6. **Mainstream agroecology and holistic food systems approaches into education and research agendas.**
7. **Develop food planning processes and 'food policies' at all levels.**

These recommendations, which are fleshed out below, identify the various areas in which action would need to be taken in order to shift the balance in food systems. The recommendations are pragmatic, drawing on existing policy tools, seeking to build on existing entry points, and working in combination to target the various lock-ins of industrial agriculture.

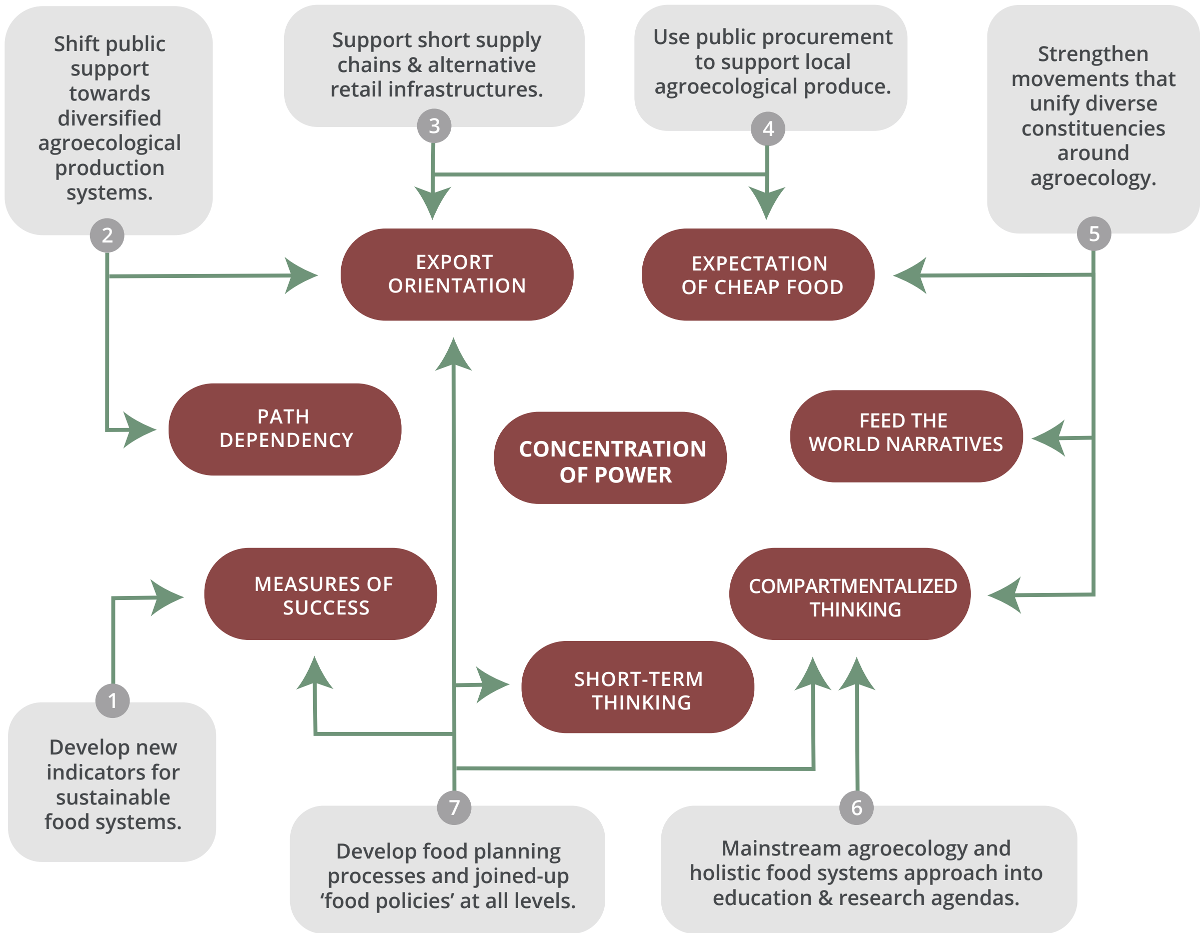
The individual steps are modest and feasible, but collectively they have the potential to shift the centre of gravity in food systems, allowing harmful dependencies to be cut, the agents of change to be empowered, and alliances to be created in favour of change. In other words, **the vicious cycles of industrial agriculture must be replaced with new *virtuous circles***; the various steps in favour of diversified agroecological systems can and must lock each other in, just as current dynamics act to lock them out (see Figure 16).

The seven key recommendations identify the component parts of a joined-up strategy to support the emergence of diversified agroecological systems. However, the specific measures that might be required will vary from country to country and context to context. The most viable and most urgent actions will differ in particular between highly-industrialized commodity-producing regions, and those where smallholder systems and subsistence agriculture are still predominant. The menu of options below each of the key recommendations indicates what shape these measures might take, how they might be achieved, and what various actors can do. This should not be considered an exhaustive list of options for transforming food systems, and nor should it prejudice what is decided within the inclusive democratic processes which are recommended below (see Recommendation 7).

Most of the steps envisaged here concern policy measures, as well as new orientations for farmers, consumers and civil society groups. This does not reflect indifference to what occurs in the agribusiness sector. As indicated at the outset of this report, the emergence of alternative food systems based around agroecology and diversification can and must be complemented by a wholesale shift in practices within the existing infrastructures of global value chains and mass retail, led by those with the power to govern and reform these chains. Some firms are already engaged on this path.

However, given the agenda-setting powers that currently accrue to dominant actors (see Lock-in 8: Concentration of power), **there is a major risk that initiatives to improve mainstream business practices be used to deflect political attention and political capital away from the more fundamental shift that is needed**. Business-led change should be encouraged and expected to continue in parallel, insofar as businesses are willing to aspire towards new norms on multiple fronts and to share power within the food systems of the future. However, **political priorities must be clearly established**, namely, to support the emergence of alternative systems, which are based around fundamentally different logics, and generate different and more equitable power relations over time. Duly, the focus of this report and its recommendations is on supporting the emergence of these alternative systems.

FIGURE 14 - TURNING LOCK-INS INTO ENTRY POINTS FOR CHANGE



Note: Although arrows to 'Concentration of power' (Lock-in 8) are not shown here, all of the recommendations are considered to tackle Lock-in 8, given that it underlies and reinforces all of the other lock-ins.

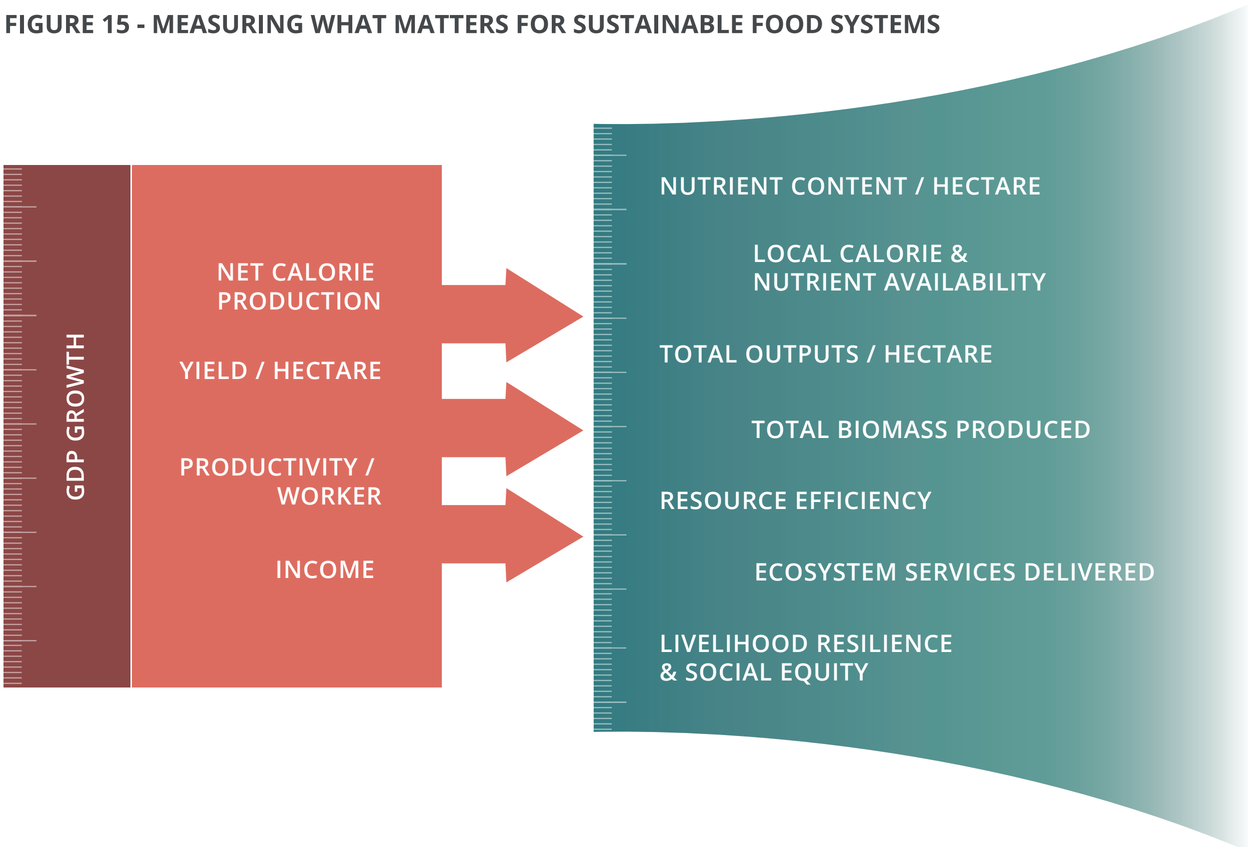
Recommendation 1: Develop new indicators for sustainable food systems.

The benefits of diversified agroecological farming are systematically undervalued by classical measures of agricultural productivity (see Lock-in 7: Measures of success). It is therefore essential to adopt and systematically refer to a broader range of indicators in assessing the performance and success of agriculture and food systems. These indicators should reflect what matters for the longer term and for society at large, i.e. long-term ecosystem health; total resource flows; sustainable interactions between agriculture and the wider economy; the sustainability of output; livelihood resilience; true food and nutrition security; and the economic viability of farms with respect to debt, climate shocks etc. In other words, what are needed are indicators for sustainable food systems. Composite indexes and integrated packages of indicators should therefore be developed, building on current efforts in this regard, and covering measures such as nutritional quality, resource efficiency, impacts on biodiversity, provision of ecosystem services and impacts on livelihoods and equity.

There is major scope to develop these approaches further and to use them systematically in setting food systems priorities:

- **Agricultural development programmes** should be assessed on the basis of how well they perform against a package of sustainable food systems indicators.
- New indicators for sustainable food systems could be used as a **basis for awarding support and subsidies** to farmers (see Recommendation 2).
- '**Full cost accounting**' approaches are currently being developed to capture the positive and negative externalities of different production systems. These approaches should be further developed and linked to policy processes in order to internalize the costs of industrial agriculture and the benefits of diversified agroecological systems.

FIGURE 15 - MEASURING WHAT MATTERS FOR SUSTAINABLE FOOD SYSTEMS



Recommendation 2: Shift public support towards diversified agroecological production systems.

Farmers are often trapped by the path dependencies of industrial agriculture (Lock-in 1: Path dependency), and are dependent on the training, distribution and retail infrastructures of industrial (often export-oriented – Lock-in 2) food systems. Equipping farmers to lead the transition therefore requires steps to cut these dependencies and replace them with new support structures and incentives. In some parts of the world, e.g. the EU and the US, support to farmers comes primarily in the form of agricultural subsidies offering a form of income support/stabilization, often linked to production areas or specific crop commodities. In some cases, incentives to diversify have been introduced (see Opportunity 1).

Building on this basis, governments must ultimately shift all public support away from monocultural production systems, while rewarding the array of positive outcomes in diversified systems. In other contexts, access to land and productive resources may be more important than subsidies in determining which modes of agriculture are able to take hold. The key may thus be to prioritize the needs of those willing and able to practice diversified agroecological farming over competing land uses such as large-scale monocultures. This could mean supporting small-scale farmers to stay on the land and transition to agroecological practices, rather than being incorporated into outgrower schemes or forced to exit agriculture.

Whatever the local context, governments must find measures that allow all farms to diversify and transition towards agroecology. In particular, they must support young people to enter agriculture and adopt agroecological farming – before they are locked into the cycles of industrial agriculture (Lock-in 1: Path dependency).

A range of support measures for farmers could therefore be envisaged, including:

- **Agricultural subsidies** could be incrementally shifted on the basis of new indicators for sustainable food systems (see Recommendation 1), e.g. including premia for managing multi-functional landscapes with a continuum of wild and cultivated species.

- Governments should respect and fully implement the **Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests** adopted at FAO's Committee on World Food Security (CFS) in 2012; stronger support could be provided for customary land rights.

- **Moratoria on large-scale land acquisitions** may be required given the tendency of these purchases to accentuate highly-specialized large-scale agriculture and industrial modes of production; Governments should facilitate access to land for agroecological farming by the next generation.

- Barriers to diversity/diversification arise from a range of policies and regulations that are tailored to the needs of the industrial food system and tend to have very negative effects on peasant and agroecological systems, e.g. national or regional **food safety rules, intellectual property protection legislation**, and **seed legislation**; these barriers may need to be reformed/dismantled and replaced with policies and measures that facilitate the spread of diversified farming systems.

- Specific seed legislation could be developed to support the **exchange of and access to seeds from traditional, often genetically heterogeneous, varieties** through informal/traditional seed systems.

Recommendation 3: Support short supply chains & alternative retail infrastructures.

For farmers to take on the challenge of diversifying their production and shifting to agroecological practices, they need *markets*. Emerging consumer and retail imperatives have brought renewed attention to the conditions under which food is produced, giving farmers an economic incentive to shift production in new directions (Opportunity 7, Opportunity 8).

However, there is a long way to go before this consumer pressure translates into something more than market niches, becoming a genuine counterweight to export-oriented, mass retail-driven supply chains (Lock-in 2) and the cheap food they transmit to consumers (Lock-in 3). In many parts of the world, traditional and informal markets often provide important alternative sales outlets (ROPPA, 2013).

Elsewhere, new initiatives to promote short circuits and direct sales are particularly promising, in that they bypass mass retail circuits that have tended to require and value uniform commodity production. Not all food sold through these circuits is organically-certified, nor is it necessarily tied to diversified agroecological production systems. However, new and more promising incentives do tend to emerge: direct consumer-producer relationships allow a commitment to ecological production to be built and maintained in lieu of formal certification, and often in addition to formally certified standards (e.g. organic). Direct purchasing schemes are also conducive to diversification; receiving a basket of diverse, seasonal foods is often a key selling-point of community supported agriculture schemes.

The balance must now be shifted through actions that bring the incentives – and eventually the costs – of different production systems into line with the benefits they offer to society. Governments should support and promote short circuits in order to make them a viable, accessible and affordable alternative to mass retail outlets. Ways to achieve this could include:

- **Farmers' markets** could be established in multiple neighbourhoods of cities by adapting existing public infrastructures (e.g. town halls) and building new ones (e.g. new covered markets), in addition to support for mobile food markets, in order to facilitate widespread access to local produce.
- **Food policy councils** at the city/municipal level and regional food policy and planning processes (see Recommendation 7) could be used to define priorities in terms of connecting producers and consumers in given regions, e.g. identifying zones with poor availability of fresh food as priority locations for new farmers' markets.
- **Local exchange and trading systems** between farmers could be supported, where exchange systems based around recognition of equal value have traditionally played an important role.
- **More data on the nature and extent of informal markets should be gathered**, in order to provide relevant support.

Recommendation 4: Use public procurement to support local agroecological produce.

Governments should also support markets for the production of diversified agroecological farming systems through food purchasing for school canteens, hospitals and other public institutions, building on the successful examples now proliferating (Opportunity 7). This would help to ensure sales outlets for farmers who diversify their production, while providing fresh, nutritious food and diversified diets for the users of public canteens, particularly schoolchildren. Many national and local governments are already using public procurement to drive improved outcomes in food systems, often by sourcing organic foods. This existing policy tool could be used more systematically and with increasing ambition in order to drive the transition forward; this will be particularly important to support the demand for food produced within these systems while markets develop (see Recommendation 3). Agroecological public procurement could be phased in to various extents and in various ways:

- Agroecological sourcing could be phased in through **staggered targets** at the local and national level, potentially rising fastest for fruits and vegetables, and being revised upwards as supply increases.
- Where labelling/certification schemes do not exist, agroecological production could be identified on the basis of **locally-adapted indicators for sustainable food systems** (see Recommendation 1).
- *Local* procurement, based on a region's diverse seasonal produce, could be favoured and coordinated through **localized food systems planning processes**, e.g. at the city-region level (see Recommendation 7).

Recommendation 5: Strengthen movements that unify diverse constituencies around agroecology.

Many of the most promising developments profiled in Section 3.a are grassroots, bottom-up, farmer- and consumer-led initiatives. Where they are making the biggest inroads, they are doing so by reaching across divides and creating new constituencies of pooled interest. Community-supported agriculture (Opportunity 8) entails a confluence of values across the consumer-producer divide, while some of the most promising opportunities for spreading agroecological knowledge come in the form of intensive collaboration between farmers and researchers (Opportunity 6).

There is scope to further unify these voices and to operationalize their demands. Diversified agroecological systems must find their advocates, and those advocates must find a strong and unified voice which policy-makers will not be able to ignore. Together, these shared messages can powerfully counter the 'feed the world' narratives which currently hold sway (Lock-in 6).

A range of steps could help to facilitate the unification of social movements around diversified agroecological systems:

- Increased support could be provided to **farmers', women's, indigenous and community-based organisations** and social movements which encourage the spread of agroecological practices and advocate for sustainable food systems.
- Support for **diversity fairs, community genebanks and seed banks** is likely to be a crucial element in strengthening social movements and unifying them around diversified, agroecological systems.
- **Rural farmers' organizations** primarily focused on human rights and livelihood issues could forge alliances with civil society groups (including urban-based) through agroecology as a vehicle for environmental and social change.
- The participation and collaboration of diverse civil society groups from the **global North and South in global governance processes and forums** should be facilitated. The CFS could serve as a model of inclusive civil society involvement in terms of recognizing the autonomy and self-organisation of civil society groups, and including small producer organisations.
- **The strong coalitions and narratives already formed around 'food sovereignty'** and opposition to trade liberalization should be built upon; diversified agroecological systems could be further emphasized as a key manifestation of and requirement for 'food sovereignty'.

Recommendation 6: Mainstream agroecology and holistic food systems approaches into education and research agendas.

Improved education on healthy eating in schools from an early age is essential to changing eating habits. At the level of secondary and higher education, changes will be required to provide the necessary skills and approaches to promote the transformation of our food systems, including strengthening systems thinking/approaches, and understanding the true costs of cheap food (Lock-in 3).

Beyond the educational sphere, there are already highly promising opportunities for developing and spreading agroecological knowledge, in the shape of fast-developing food systems research and participatory peer-to-peer approaches (Opportunities 5 and 6).

However, a broader transition is unlikely to occur insofar as the structures for developing and delivering knowledge to farmers remain aligned with industrial systems (Lock-ins 1 and 4). Public research agendas must be redefined around different priorities, and be shaped by and designed to serve a wider range of actors. Over recent decades, private agribusiness firms have been the major investors in agricultural research, and have been most vocal in making the case for investments in raising agricultural productivity. Reinvestment is urgently required, but must be redirected towards equipping farmers to shift their production, rather than further relying on industrial solutions.

Attention is also required to address the complexity of food systems, the need for transdisciplinary approaches, and the integration of traditional, indigenous and peasant knowledge, as well as experiences from all actors of the food web. The new constituencies forming around agroecology (see Recommendation 5) must be as vocal as agribusinesses have been in making the case for new public research imperatives. In particular, the mission of university research should be redefined around the delivery of public goods, with clear rules and transparency in relation to accepting private funding, including public-private partnerships.

Several steps could be envisaged in order to meet these objectives:

- **School curricula** at all levels should include modules that integrate the multiple dimensions of food systems, including hands-on experiential programs such as school gardens, food preparation facilities, and making meals a time for learning as much as for eating.
- Where public research programmes require recapitalization, resources could be freed up and redirected by **increased targeting of agricultural subsidies** (see Recommendation 2).
- **Philanthropic foundations** and other **donors in the environmental and development fields** should be encouraged to prioritize investments in developing and spreading agroecological knowledge, given the huge potential of diversified agroecological systems to deliver positive environmental impacts, including climate mitigation.
- **Research to plug the gaps in current knowledge about agroecology** should be prioritized, such as: studying the **long-term productivity** of diversified agroecological farming and its potential to withstand abiotic and biotic stresses, as well as its resilience in the face of extreme weather events; understanding the linkages between **agrobiodiversity/wild biodiversity and dietary diversity/nutritional outcomes**, including overall dietary quality and positive health outcomes.
- Research programmes could link agriculture with the fields of **ecosystem services and landscape management** (see Recommendation 7) in order to identify the most effective policy and governance models for securing

productive and healthy agro-ecosystems.

- The development of practical, scientifically-grounded **methodologies for measuring sustainable food systems** should be prioritized (see Recommendation 1).

- **Agricultural extension and public health/ sanitary extension services** should be trained to deliver mutually reinforcing messages that promote sustainable food production, improved dietary intakes, and improved sanitation and health.

- **FAO, IFAD, UNEP, WHO** and other relevant UN agencies should adopt a **sustainable food systems** approach in their programmes and strengthen collaboration around it. Following up on its 2014 agroecology symposium, **FAO should progressively mainstream agroecology into all its programming**.

- Research conducted by the **CGIAR** consortium should be substantially reoriented and refocused around diversified agroecological systems and farmer participatory research.

Recommendation 7: Develop food planning processes and 'joined-up food policies' at multiple levels.

None of the changes envisaged above will move far or fast enough while policy processes are constrained by compartmentalized approaches (Lock-in 4) and short-term thinking (Lock-in 5). It is therefore crucial to establish new, more inclusive and more-joined-up processes, responding to the growing proposals for redesigning food policy-making (Opportunity 2). Long-term, cross-party, inter-ministerial planning around food systems – reaching across political boundaries and transcending electoral cycles - should therefore be facilitated. These processes can counter the traditional trade bias in agricultural policymaking (see Lock-in 2: Export orientation), ensuring that global market provisioning in food commodities is reconciled with health, environment and development concerns. New food systems indicators (see Recommendation 1) can be agreed in these food policy fora, and used as a benchmark for the long-term strategies set in place. Building on landscape management and territorial planning initiatives (Opportunity 3), these policies and processes must be organized at the various levels where food systems can be meaningfully planned, and where food security can be meaningfully targeted and understood in terms other than 'feeding the world' (Lock-in 6). Crucially, these forms of food systems planning must be based on broad participation. Taking inspiration from municipal and city-level food policy councils, these processes should reach across constituencies, bringing together agriculture, health, environment and other interest groups with a stake in food systems reform (see Recommendation 5).

These processes could take various shapes and forms, emerging from various entry points:

- **Territorial/landscape management planning**, including at the city-region level, can be used to determine diversification measures on a landscape scale, ensuring connectivity between agrarian spaces and natural vegetation areas, protection of traditional watering systems, etc.

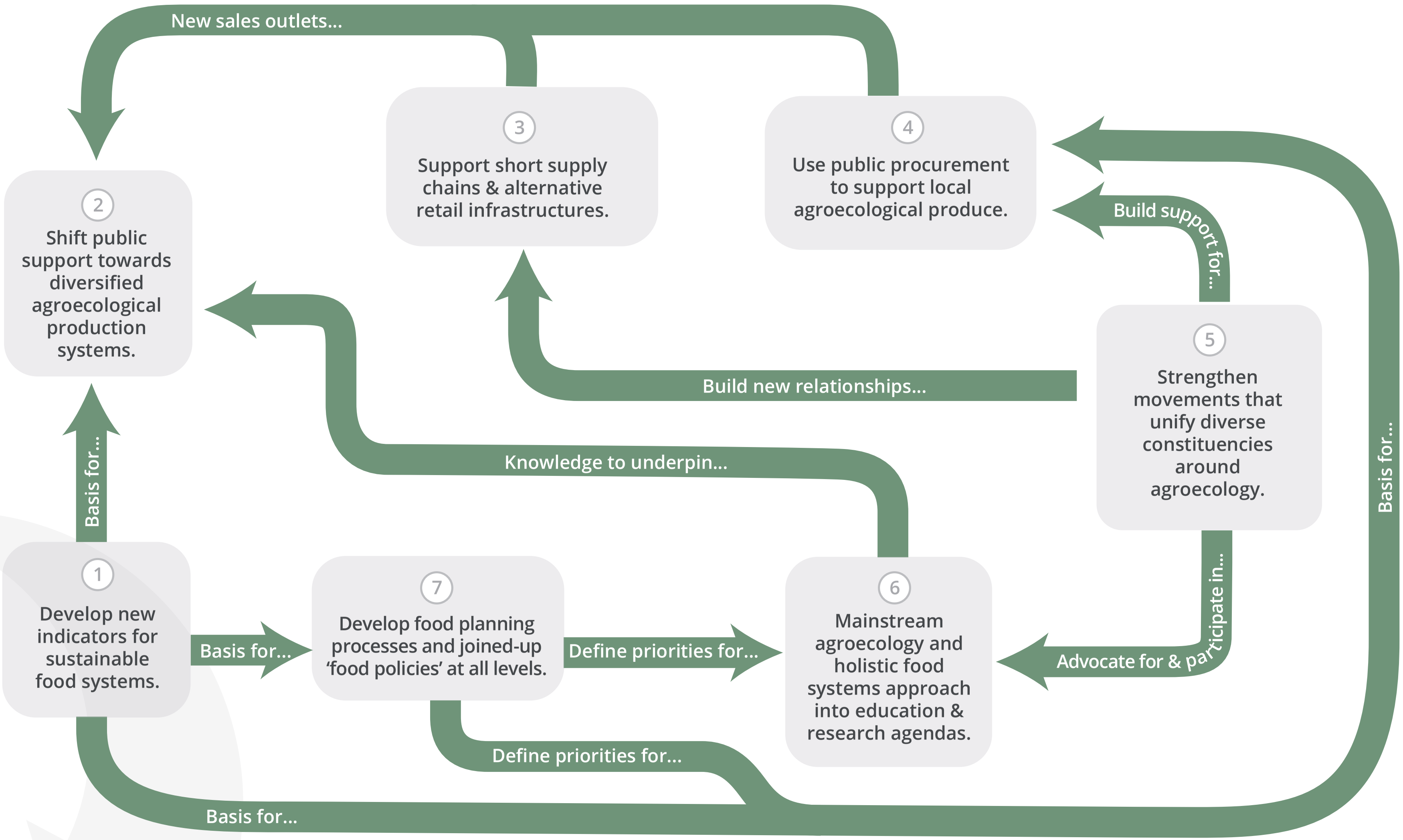
- Territorial management processes can also be used to plan and manage the **integration of animals into diversified landscapes**, including the question of feed strategies that seek to maximize local protein production.

- **Inter-ministerial mechanisms** could be put in place to bring together all relevant ministries (agriculture, environment, health, education), coupled with mechanisms to consult with different stakeholders, potentially as a step towards developing national food policies (see below).

- The processes described above could be brought together in the shape of '**National Food Policies/ National Food Strategies**' where these are yet to be put in place. Such policies/strategies could set long-term goals for food systems, allowing those goals to be informed and monitored by cross-party, inter-ministerial and multi-actor groupings. Scientific and civil society groups should unite with willing political partners in order to create these platforms where they do not yet exist. The process launched by IPES-Food in March 2016, 'Towards a Common Food Policy in the EU', seeks to establish such a process at the EU and European member state levels (IPES-Food, 2016).

- At the global level, the **Committee on World Food Security (CFS)** has a mandate of improving policy coordination, policy coherence and accountability to achieve food security and nutrition and the right to food. Being the foremost inclusive, intergovernmental policy space on these issues, the CFS is well placed to advocate for coherent policies. The CFS should build on its existing policy decisions, particularly those on investing in smallholder agriculture, to strengthen diversified agroecological food systems

FIGURE 16 - CREATING VIRTUOUS CIRCLES TO SUPPORT DIVERSIFIED AGROECOLOGICAL SYSTEMS



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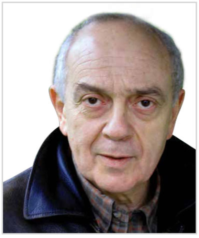
Molly Anderson is a specialist in hunger, food systems, and multi-actor collaborations for sustainability who has led inter-disciplinary academic programmes and participated in regional food system planning.

Million Belay, founder of the MELCA-Ethiopia NGO and the Alliance for Food Sovereignty in Africa (AFSA), is an expert and advocate for forestry conservation, resilience, indigenous livelihoods and food and seed sovereignty.



Claude Fischler has headed major French research institutions and served on national and European-level food safety committees, and has a long track-record of innovative inter-disciplinary research on food and nutrition.

Emile Frison is an expert on conservation and agricultural biodiversity who has headed global research-for-development organisation Bioversity International for ten years, after holding top positions at several global research institutes.

Steve Gliessman founded one of the first formal agroecology programs in the world, and has more than 40 years experience of teaching, research, publishing and production experience in the field of agroecology.

Corinna Hawkes is an expert on food systems nutrition and health who participates in the World Health Organization's Commission on Ending Childhood Obesity and regularly advises governments and international bodies.

Hans Herren is a World Food Prize (1995) and Right Livelihood Award (2013) Laureate, and has managed international agriculture and bio-science research organizations as well as playing a leading role in global scientific assessments.

Phil Howard is an expert in food system changes and the visualization of these trends. He has authored prominent contributions to the public debate on concentration, consolidation and power in food systems.

Martin Khor is Executive Director of the South Centre, an inter-governmental organisation helping to assist developing countries in trade and climate negotiations, and a former director of the Third World Network.

Olivier De Schutter is co-chair of IPES-Food. He served as UN Special Rapporteur on the right to food from May 2008 until May 2014 and was elected to the UN Committee on Economic, Social and Cultural Rights in 2014.

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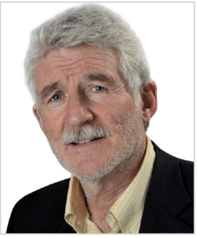

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Executive Summary: http://www.ipes-food.org/images/Reports/UniformityToDiversity_ExecSummary.pdf
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