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ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

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To cite this article: Hans J M van Grinsven *et al* 2015 *Environ. Res. Lett.* **10** 025002

Environmental Research Letters

CrossMark

OPEN ACCESS

RECEIVED
6 June 2014

ACCEPTED FOR PUBLICATION
8 January 2015

PUBLISHED
26 January 2015

LETTER

Potential of extensification of European agriculture for a more sustainable food system, focusing on nitrogen

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Keywords: external costs, sustainable intensification, fertilizer, livestock density, nitrogen pollution, agriculture

Supplementary material for this article is available online

Abstract

Most global strategies for future food security focus on sustainable intensification of production of food and involve increased use of nitrogen fertilizer and manure. The external costs of current high nitrogen (N) losses from agriculture in the European Union, are 0.3–1.9% of gross domestic product (GDP) in 2008. We explore the potential of sustainable extensification for agriculture in the EU and The Netherlands by analysing cases and scenario studies focusing on reducing N inputs and livestock densities. Benefits of extensification are higher local biodiversity and less environmental pollution and therefore less external costs for society. Extensification also has risks such as a reduction of yields and therewith a decrease of the GDP and farm income and a smaller contribution to the global food production, and potentially an i0ncrease of global demand for land. We demonstrate favourable examples of extensification. Reducing the N fertilization rate for winter wheat in Northwest Europe to 25–30% below current N recommendations accounts for the external N cost, but requires action to compensate for a reduction in crop yield by 10–20%. Dutch dairy and pig farmers changing to less intensive production maintain or even improve farm income by price premiums on their products, and/or by savings on external inputs. A scenario reducing the Dutch pig and poultry sector by 50%, the dairy sector by 20% and synthetic N fertilizer use by 40% lowers annual N pollution costs by 0.2–2.2 billion euro (40%). This benefit compensates for the loss of GDP in the primary sector but not in the supply and processing chain. A 2030 scenario for the EU27 reducing consumption and production of animal products by 50% (demitarean diet) reduces N pollution by 10% and benefits human health. This diet allows the EU27 to become a food exporter, while reducing land demand outside Europe in 2030 by more than 100 million hectares (2%), which more than compensates increased land demand when changing to organic farming. We conclude that in Europe extensification of agriculture is sustainable when combined with adjusted diets and externalization of environmental costs to food prices.

1. Introduction

1.1. Changing demands on food production systems

Until now food production kept pace with population growth, despite the worries by Malthus, Attenborough and many others during the last centuries. Increased use of synthetic fertilizer has been a major driver in increasing crop yields. Agricultural policies has kept and still keeps focus on increasing agricultural productivity by increasing external inputs, both in the developing and the developed world. In the developing economies agriculture is a dominant economic sector, in some African countries contributing up to 50% to the gross domestic product (GDP), while in developed countries it generally is less than 5% (World Bank 2014). In some developed countries the agro- and food sector is still a dominant sector. For example, in The Netherlands agricultural production and innovation has always been a major basis for the national economy with an agro–food sector contributing 20% to the export of products and 10% to GDP (Eurostat 2014).

Together with the enormous boost in global agricultural production and land productivity and the associated improvement of human nutrition and well-being, the efficiency of the use of critical natural resources, like biodiversity, phosphate and fossil fuel in the global food production system (the system that feeds the global population), has decreased and impacts on environment, climate and human health have increased. The efficiency in terms of what eventually is consumed per use of these resources decreased because of (i) food waste and losses in the whole chain, which currently reach 30–40% (Gustavson *et al* 2011), (ii) increased production and consumption of animal products, but also (iii) the increased use of agricultural land for the production of luxurious products, such as tea, coffee, sugar, etc. Food production currently contributes about 25% to all GHG emissions (Vermeulen *et al* 2012), is responsible for 60% of loss of land based biodiversity (inferred from Ten Brink 2010) and is the major source of global eutrophication (Sutton *et al* 2013).

The increasing world population in combination with a more affluent diet is projected to demand an increase in crop production of 50% and in livestock production of 70% by 2050 (FAO 2012). According to Tilman *et al* (2011), most likely the food industry even has to double their productivity to satisfy people's demand by 2050. The larger part of the increase of demand for cereals would be to feed livestock to meet the increase in diets rich in animal protein. Many projections indicate that such an increase can be met by yield gap closure (e.g. Foley *et al* 2011, Mueller *et al* 2012). However, currently the annual yield increase for staple food crops is slowing down at the global scale (Grassini *et al* 2013). This will lead to expansion of agriculture area (notably in developing countries). For the first time since 1980 harvested areas for wheat and corn have started to increase (Grassini *et al* 2013). This increase in part was caused by increased demand for biofuels. This land extension is a direct threat to biodiversity (Alkemade *et al* 2009, Van Vuuren 2012). Without additional efforts, current agricultural practices also will increase global emissions of greenhouse gasses and lead to higher losses of nitrogen and phosphorus to the environment (Tilman *et al* 2011, Garnett and Godfray 2012). The main challenge is therefore to guarantee future food security, while reducing environmental pollution and biodiversity loss (Sutton *et al* 2013).

1.2. Sustainable intensification and sustainable extensification

Currently, there is an ongoing debate in society on how to accommodate increasing demand for livestock products and global food security for a larger and wealthier population with more sustainable agriculture (Lang and Heasman 2004, Roberts 2008). Leading scientists and politicians hold contrasting views on the potential contribution of intensification and extensification of agriculture and of changing diets to a more sustainable food system. Here we define: Sustainable intensification of agriculture by: *Maintaining or increasing food production per hectare without compromising the environment and depleting natural resources. This objective generally translates to increasing external inputs, such as nitrogen (N), while decreasing resource losses to the environment*; we define sustainable extensification of agriculture by: *Decreasing the depletion of natural resources and the environmental impacts while limiting the decrease of food production per hectare. This objective translates to reducing external inputs, such as N, and livestock densities while minimizing food loss.*

Agriculture and food include crops and animal products. Both sustainable intensification and extensification require improved management of nutrients, such as nitrogen and phosphorus, but also water, pesticides, seed, plant and livestock diversity and by that increase resource efficiencies. While both strategies focus on agricultural production, they have implications for natural resource efficiencies of food processing and consumption. Sustainable intensification with increased food production provides more room for resource demanding food choices, with a larger share of animal products, and for food loss in retail and consumption to satisfy consumer preferences. When accompanied by decreasing food production, sustainable extensification asks for less resource demanding food choices, different diets and minimizing food wastes.

Sustainable intensification appears to be a good strategy for improving food security in areas where there is a large yield gap, such as in Africa (Garnett and Godfray 2012), under the condition that smallholders profit from it. According to Phalan *et al* (2011), intensification is also the best global strategy to spare land and halt biodiversity loss. The current dominant strategy for closure of crop yield gaps is intensification of land use by the combination of increasing external inputs and use of high yielding crop and animal varieties (van Grinsven *et al* 2014). This form of intensification may be regarded as unsustainable in view of risks for the environment, such as soil degradation and losses of nutrients and pesticides which pose threats for biodiversity and human health (e.g. Garnett *et al* 2013, Sutton *et al* 2011). These threats are particularly manifest in countries or regions where current inputs are already high. In situations with current low crop yields and low levels of fertilization, as in various regions in Africa, the external cost of land extension for increased crop production would likely outweigh cost of intensification for biodiversity and health, but many African small holder farmers lack resources to purchase fertilizers, pesticides and technology. For

Europe sustainable intensification is currently the dominant strategy to improve food security given the small potential to increase the area of agricultural land. In view of concerns about nutrient losses to air and water, one could, however, hypothesize that sustainable extensification could also be a strategy for Europe to meet both the global and regional demand for food and biodiversity.

A necessary condition for both strategies would be to maintain farm income and in the case of the many poor smallholder farmers, to increase income. While extensification holds the risk of loss of income because of reduced yield (at constant market prices), intensification holds the risk of income loss due to a decrease of commodity prices combined with increased cost of fertilizers, pesticides, seeds, machinery etc. Intensification and extensification can create both risks and opportunities for biodiversity, farmers and consumers in different parts of the world. The challenge is to find the optimal combination of intensification and extensification of agricultural production in various parts of the world that reduce risks of environmental pollution and resource depletion in both areas of extensification and of intensification, while increasing the net global production of food. Achieving this optimal combination is facilitated by a globally operating food system with intensive shipping of agricultural products and resources over the globe (Galloway *et al* 2007). Therefore in Europe and particularly The Netherlands, there is room for improving the balance between food production and environmental pressure.

1.3. Characteristics of low input/organic farming and impacts on crop yield

Key to sustainable intensification is closing the yield and harvest gap while minimizing losses of nutrients and pesticides to the environment. The yield gap is the difference between the highest possible yield using best management and all the technology and inputs available relative to the current yield (Foley *et al* 2011), whereas the harvest gap is the difference between current and maximum cropping frequency (Ray and Foley 2013). Yield gaps depend on crop type, genotype, management and also on regional edaphic physical and environmental conditions (van Grinsven *et al* 2014). Yield gaps are largest for poorly managed and low input farms. For the developed agricultural countries the yield gaps are largest for organic production methods and amount up to 20–30% (De Ponti *et al* 2012, Seufert *et al* 2012, Ponisio *et al* 2015). A problem is to establish good reference cases, both for organic and conventional methods and yield gaps therefore show a large range with several organic farms even showing higher yields than conventional farms. The global harvest gap is estimated at 57% (Ray and Foley 2013), as compared to a global yield gap of 45 to 70% for major cereals (Mueller *et al* 2012). While there is huge potential to close the harvest gap in the tropics, the harvest gap in European countries is generally less than 10%.

Organic agriculture is a case of extensification not allowing inputs like synthetic fertilizers and pesticides, nor allowing the use of genetically modified organisms (GMOs). There is no consensus on the relative contribution of various factors to the yield gap between organic and conventional production methods, but lack of nitrogen fertilizer is claimed to be an important reason (Smil 2002). Most agricultural systems are nitrogen limited and therefore nitrogen is important when closing the yield gap. Both conventional and organic systems show nitrogen leakages. Although organic farmers are forced to better manage nutrients, they may occasionally overuse organic sources of N to boost production of valuable crops, in case there is ample availability of nitrogen from N fixing crops, external manure or compost. The main argument against organic farming is that the amount of naturally available nitrogen, including biological nitrogen fixation, is not sufficient to sustain and increase production to feed the world. Smil (2002) estimates that synthetic nitrogen fertilizer feeds about 40% of the world population, Erisman *et al* (2008) estimated that nitrogen fertilizers fed 48% of the world's population in 2008. Arable organic systems depend on N-fixing crops and animal manure to provide nutrients, which would mean that effectively about one third of the available arable land would not be available to directly produce food (Schröder and Sørensen 2011). Estimates of the yield gap between conventional and organic cultivation of cereals of 20 to 40% by Seufert *et al* (2012) and De Ponti *et al* (2012). This yield gap reflects the combined effect of the use of synthetic fertilizer, pesticides, GMO and improved management of nutrients, soils and crops. This implies that the effect of synthetic N fertilizer on cereal yields would be less than 40%. Ponisio *et al* (2015) found a yield gap of 9% between organic and conventional treatments when N inputs were similar, and a gap of 30% when taking into account the effect of higher N input in conventional systems. This implies that by adopting practices from organic agriculture the effect of synthetic N fertilizer on global yields could be reduced to 20% and much more people can be fed by agriculture without synthetic N fertilizer than the 50% estimated by Smil (2002) and Erisman *et al* (2008).

The challenge for both conventional and organic systems is to use nitrogen/nutrients and other resources, such as water, as efficiently as possible. Organic farming focuses on what it can do using the natural processes to increase the production of quality food, with sustainable soil management in a clean environment (e.g. Tomich *et al* 2011). Strict organic production systems demand sophisticated management skills to conserve nutrients and control pests and diseases. Organic arable agriculture typically requires more drought resistance systems with higher soil organic matter and more biodiversity. The organic system forces the community to create resilient systems while boosting production, in that sense aiming for sustainable intensification, as is the case in conventional systems (e.g. Mäder *et al* 2002). Conventional farms using best management practices to reduce external input and to control disease, aim for the same with similar results (Oenema *et al* 2011). Conventional farming also depends on manure to maintain organic carbon in the soil, especially when crop residues are not returned to the field. However, intensification through conventional farming has shown a reduction in soil quality and increased concern about resistance of pests and diseases against antibiotics and pesticides.

1.4. Scope and objective

The objective of this paper is to identify and clarify some key issues in the debate on the potential of sustainable intensification and extensification for meeting future demands on local and global food systems in terms of

1. implications of extensification and improved animal welfare in dairy and pig farming for farm income, environment and nutrient use efficiency.
2. The optimal N intensity at regional (national/European) scale accounting for external costs of adverse N impacts and the consequence of extensification (a decrease of N inputs) for farm income and the added value of agricultural sector.
3. Consequence of extensification on yield loss in Europe and its effect on global food security and land use.

For this assessment we reviewed literature and scenario studies and used field and farm data of examples of extensification in dairy and pig production in The Netherlands for illustration.

2. Examples of sustainable extensification in The Netherland and their impacts on crop yields, animal welfare, income and environment

2.1. Impacts of low input organic dairy farming in The Netherlands on milk yields and farm income

Milk yield data for organic and conventional dairy farming suggest a smaller yield gap than for arable farming (Offerman and Nieberg 2000). Dairy farming systems based on grazing are more suitable for extensification than arable systems because the net export of minerals embedded in dairy products per hectare is lower than in arable systems and because of efficient recycling of manure N. Furthermore, as a perennial crop, grassland is more efficient in conserving nutrients and organic matter than arable crops. Several authors, among which Alan Savory is perhaps the most prominent (Holecheck *et al* 2000), have suggested that rapid rotation grazing is more resource efficient than continuous/season long grazing systems. Holecheck *et al* (2000) could not find proof of superior functioning of rapid rotation grazing in semi-arid regions in the USA and Mexico, in terms of forage production, resource (water and nutrients) efficiency and financial return. In spite of this lack of proof, rapid rotation grazing is becoming increasingly popular in intensive systems in countries with maritime climates like New Zealand, Ireland and also The Netherlands. Resource efficiency would increase due to a combination of deeper rooting and an increase of effective photosynthesizing area. In addition the fatty acid composition and antioxidant content of meat and milk from grass fed systems are more favourable for human health than from grain fed systems (Daley *et al* 2010). The downside of the system is the increased demand for labour.

Peer reviewed information on environmental and economic performance of extensive dairy farming applying strip grazing, which is a form of rapid rotational grazing, is scarce. Provisional data for two organic farms with no use of synthetic fertilizer and applying rapid rotation grazing show an annual milk production per hectare of land used for feed is 10 000 L as compared to 13 000 L for conventional Dutch dairy. Milk production per cow is 30–40% less than for conventional but production life of cows is longer. The income of both farms is higher than for conventional farms, and is representative for the larger population of 50 dairy farms applying low input and intensive grazing and 300 organic dairy farms in The Netherlands. More information is provided in supplementary material.

2.2. Impact of improved animal welfare pig production systems in The Netherlands on farm income

The welfare of pigs is a concern in all steps of the production system, from breeding to slaughter, creating extensive discomfort and health problems for the pigs during fattening in confined housing (Marchant-Forde 2009). Pig welfare can be greatly improved by allowing more space and bedding material, like straw, at modest increase of production costs (Bornett *et al* 2003, Tuyttens 2005). A system of improved welfare was developed by the Dutch organization for animal protection, in cooperation with the pig meat processing industry and retail (Dierenbescherming 2014). This Dutch system likely will have implications for the pig supply chain in Europe because more than half of Dutch pork production is exported to surrounding countries with consumers having similar preferences as Dutch consumers. Pigs raised under the one and two star welfare production system have a 25%, respectively 50% increase of floor space and are supplied with distraction material and bedding material. Because systems with improved welfare do not require major adjustment of housing, conventional pig farmers changing to this system create extra living space by decreasing their livestock number. This will have an immediate negative effect on their fixed costs per unit of production. Additional production costs in this system include costs for bedding material, additional fuel for heating in winter (because a smaller stock produces less body heat) and loss of discount on feed and other material in view of the smaller stock.

In The Netherlands the share of sales of pork from fattening systems with increased welfare in 2013 was nearly 30% (Bakker 2014). Extensification measures in pig production are decreasing livestock numbers and extending the finishing period for the purpose of improving welfare and to comply with conditions for a price bonus. Average Dutch consumers are willing to pay up to a 10% bonus for improved animal welfare (Carabain and Spitz 2012), and increasingly buy one star pork. In 2012 about 15% of pork consumption in The Netherlands was produced on farms with increased welfare systems. Production costs for pig farmers in The Netherlands providing 25% more floor space and distraction material are about 6% higher than in a conventional system. For systems with 50% more floor space additional costs are about 25%, mainly due to increased feed requirements. When there would be a massive change to this system, total production of pig manure would decrease, which could increase the price that arable farmers are willing to pay for this manure and by that even decrease the cost of manure disposal per pig for the pig farmer. Systems with improved welfare and a smaller livestock maintain or can even improve farm income in view of the price premium and possible savings on manure disposal. More detail is provided in supplementary material.

2.3. Impacts of improved nutrient cycling approaches in The Netherlands on farm income and environment

Several dairy farms in The Netherlands aim at reducing their environmental impact by improving the internal nutrient cycle (INC) on their farm by innovative farm management approaches. INC farms, focus on optimizing use of on-farm available resources, including nutrients from manure and home-grown feed production, thus reducing purchased feed and fertilizer, while maintaining a sufficient income in the long term (Van Hees *et al* 2009). Nitrate concentrations in the upper groundwater at INC farms are relatively low compared to dairy farms with regular farming practices on similar soils (e.g. Sonneveld *et al* 2010) and soil organic matter contents are relatively high (e.g. Van Apeldoorn *et al* 2011). Furthermore, N losses through ammonia volatilization are lower when application takes place under the same approach as conventional farming (e.g. Sonneveld *et al* 2008). Recently, Dolman *et al* (2014) showed that INC farms had a lower non-renewable energy use per kg FPCM (fat-and-protein-corrected milk), higher soil organic carbon content and received higher annual payments for agri-environmental measures, whereas economic and other environmental, societal indicators were not significantly different. De Boer *et al* (2012) showed that at landscape level the calculated N losses to air and water were on average 5–10% lower when INC farming would be implemented for the whole region. More detail is provided in supplementary material.

3. Effects of extensification of agricultural sector on environment, economic welfare and food security for The Netherlands and Europe

3.1. Effects of extensification of the Dutch livestock sector on external cost and economic welfare

The Dutch livestock sector is perhaps the most intensive in the world and simultaneously the most efficient livestock sector regarding feed conversion and environmental emissions per unit of livestock product. Dutch citizens are concerned about the quality of the local environment and effects related to ammonia and manure, about the impacts in South America of large import of soy product for feed, about zoonotic diseases particularly after the recent outbreak of Q-fever, about biodiversity loss and about animal welfare. Most of these problems are inextricably related to intensification by modern industrial scale livestock farming. To assess the consequences of extensification for environment and economy a scenario with 50% reduction of pig and poultry livestock, 20% reduction of dairy livestock and 40% reduction of the use of synthetic N fertilizer was analysed (van Grinsven *et al* 2012). Calculation of external costs was limited to nitrogen emissions and based on the unit cost approach, as described in van Grinsven et al (2013). The extensification scenario reduces N-fertilizer use by 42%, N-excretion by 35%, ammonia emission by 37% and nitrate leaching by 58%. In this scenario there would be no exceedance of the 50 mg L^{-1} EU standard for nitrate (NO_3) in the upper groundwater, also in sandy soils, and The Netherlands would comply with the EU Nitrates Directive. Furthermore, current exceedance of critical N-deposition loads on more than 60% of the Dutch area of nature would decrease. Ammonia emissions from agricultural sources contribute about 30% to the mean N deposition of 22 kgN ha^{-1}. The emission reduction in the extensification scenario therefore would lower deposition by about 10% and decrease the area with exceedance of critical loads from 60% to an area between 20 and 40%.

The benefits for society of reducing of N emissions were quantified by the decrease of the external cost of nitrogen pollution. These costs decreased by 0.2 to 2.2

billion euro, a decrease of 40% relative to 2008. External costs estimates of N pollution are highly uncertain in view of various problems in valuation of impacts (van Grinsven et al 2013). The decrease of external cost outweighs the loss of added value of 0.6 billion euro in the primary production, but not the loss of added value of 2.5 billion euro in the full supply and processing chain. One possibility to create net benefits is to transfer the reduction of external cost of agricultural product to price premiums, as for organic products. External N costs considerably offset the benefits of N fertilization for crop yields, and by that current N recommendations in Europe, which are based on what is economically optimal for farmers. van Grinsven et al (2013) estimated that the N rate for winter wheat in Northwest Europe for creating the highest societal benefits is about 50 kg ha^{-1} (25–30%) lower than the economic optimum for the farmers (for more detail see supplementary material).

3.2. Global and regional effects of extensification of agricultural production

As productive land is running short, land extension to compensate for productivity loss will include the taking of less productive land. This implies that the relative increase in land demand due to a transition to less intensive systems will exceed the relative decrease in land productivity, provided that food demands increase as predicted by FAO (2012). Important factors determining the impact of extensification scenario's in the affluent regions on land use and food production are:

1. yield gap between conventional and more extensive and/or organic agriculture.
2. The effect of the increase of the share of extensive (organic) production methods on crop and food waste.
3. The change in food choice by consumers shifting to products from more extensive, or, ultimately organic products.
4. The regional correlation between the increase of the share of extensive (organic) production in total production and the increase of the share of alternative consumers of these products.

A common criticism to the option of saving biodiversity by extensification of agricultural production in Europe, or affluent countries in general, is that this will increase the demand for land in view of yield loss per hectare. A transition to, for example, organic farming in the USA or the EU might create a food security problem if not combined with limiting food waste and a transition to diets that require less land or resources in general. Such diets often infer consuming less animal products, but also less prepared food and with less sugar (Brandt *et al* 2011). Consumers shifting to organic products will indeed tend to consume less animal product for both ethical and economic reasons (Honkanen *et al* 2006), usually going along with a much healthier lifestyle (Kesse-Guyot *et al* 2013). Because of the more labour intensive production methods, a food basket of organic products in the USA typically is 50% more expensive than of conventional products (Brown and Sperow 2005).

Westhoek *et al* (2011) analysed effects of scenarios in 2030 assessing effects of low input farming, as well as of dietary changes and increased use efficiencies (for more detail see supplementary material). A partial shift to organic production in the EU27 would hardly increase arable land use in EU27, but it would increase land use in the rest of the world (RoW) by 16 mln ha. A demitarean diet, with a 50% reduction of livestock products, only leads to small changes in land demand for feed crops (−6 mln ha) and food crops (+4 mln ha) in the EU27. However, the major effect would be a large reduction in land demand in the RoW both for food crops (47 mln ha) and for grassland and fodder crops (60 mln ha), compensating more than six times the increased land demand for organic farming. In this scenario the EU would become a net exporter of cereals. A shift to a healthy diet, following WHO recommendations for consumption of red meat and saturated fats, would have a similar impact on global land use and in the EU27 as the demitarean diet. These results show that diets in the EU27 that are good for health also demand less land. Clearly this type of diet change would have large economic impacts on the livestock sector, on farms, and the feed and meat processing industry, and on the environmental and societal costs (Westhoek *et al* 2014). In summary, this study shows that the slight increase in land that is needed when changing to organic production can be more than compensated by dietary changes and improved efficiencies.

4. Discussion and conclusion

Pressure on the global food system is increasing because of increasing population, more affluent diets, stagnating increase in global crop productivity and increasing environmental pollution, notably for nitrogen. For building a more sustainable future food system both a strategy towards intensification and extensification of agricultural production holds risk and opportunities. The combination of extensification and decreasing food wastes and changing diets with less animal products have large benefits for both the environment and human health. Less consumption of animal products can greatly reduce common and increasing public health concerns about food related cardiovascular disease, cancers, obesity and diabetes. The last two health problems, however, are also related to a general overconsumption of calories and lack of physical exercise (McAllister *et al* 2009). However,

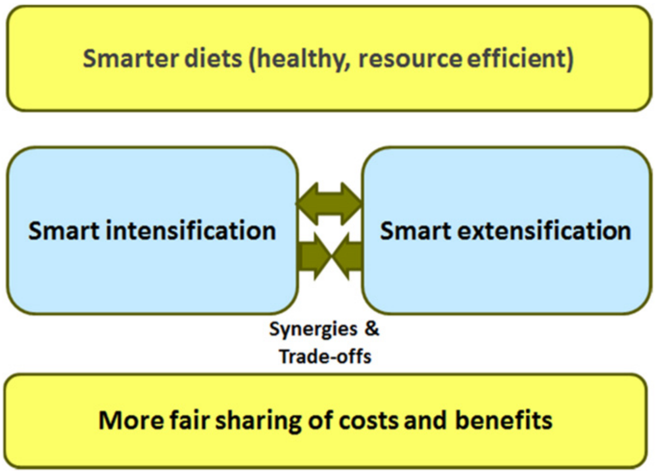

Figure 1. Schematic overview of directions for making the global food system more sustainable: (1) there is no single solution, but rather multiple directions, (2) whether and when intensification or extensification is the right solution depends on where you are in the world; (3) key issues for success are interventions in current food choices and market driven sharing of revenues and costs of food production and consumption (adapted from Westhoek *et al* 2011).

governments appear to be reluctant to promote diets with less animal products. Experiments with introducing a tax on unhealthy consumption in Denmark in 2011 were not successful (Smed 2012). Important conditions for a general adjustment towards healthier and less resource demanding diets are increasing public awareness and agreements with food industry and retail to adjust marketing and labelling of food items which may not fit in a healthy diet.

Extensification has the risk of loss of farm income, but there are various opportunities to compensate for this loss. In The Netherland there are convincing examples of dairy farmers and pig farmers changing to less extensive production with lower stocking densities who can maintain or even improve farm income by price premiums on their product, and by savings on external inputs. But to go beyond niche solutions, establishing adequate and stable price premiums requires more cooperation between the various stakeholders in the food chain, particularly those in processing and retail. Currently, primary producers are 'squeezed' between the market power of suppliers, processers and retail, in part due to a lack of organization. Although a fair proportion of primary production sectors in the EU is organized in cooperatives (e.g. cereals 35%, dairy over 50%, pork 25%) these cooperatives increasingly act similarly to normal multinationals, focusing on cost price reduction rather than sustainability (Bijman *et al* 2012). An important step is to create premium certificates for intermediate production systems and products between conventional and more sustainable products with regard to animal welfare and the use of chemical inputs (Paarlberg 2013). Modest and targeted inputs of synthetic fertilizer, pesticides and antibiotics are very effective to increase average productivity of land and animals reduce risks of loss of production and farm income in individual years. Theoretically, the cumulative premium for extensification should not exceed the conservative estimates of reduction of external costs of environmental pollution. As reduction of external costs is a public concern, government should play a more pronounced role in communicating the need for price premiums for food products from less polluting and also less resource demanding production systems.

Extensification and intensification are not silver bullets but examples of various possible strategies to create a more sustainable food system (Garnett and Godfray 2012). Sustainable intensification may be the way forward in regions with low crop yields, and may be the best option for efficient production of staple food. Both intensification and extensification are not sustainable without a more integrated view on how to change to healthier and more resource sparing diets, reduction of food wastes and on fairer sharing of costs and benefits of food production between players in the food chain. All these possible strategies not only create opportunities to increase sustainability and synergy but also creates risks of trade-offs, and need 'smart' operationalization to make progress (figure 1). In essence the food system should be demand driven which makes the consumer the primary agent of change. But to play this role, consumers in affluent countries need to regain their sovereignty in the food system by making informed choices on the food they buy. Currently the majority of consumers is not very well informed and interested and rely on NGOs and government to make the food system more sustainable.

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