Food security impact of global equities

Executive summary

WAGENINGEN
UNIVERSITY & RESEARCH

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1 Wageningen Economic Research; 2 Wageningen Food & Biobased Research
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Dit rapport beschrijft de methodes die zijn ontwikkeld om publiek beschikbare data over de opbrengsten van beursgenoteerde bedrijven uit de verkoop van agrarische technologieën, te koppelen aan het effect van deze technologieën op voedselzekerheid. De methodes zijn ontwikkeld voor kunstmest, zaden, verpakkingen en koeltechnieken. Enkel voor kunstmest kan op basis van publiek beschikbare data de methode algemeen worden toegepast, de andere drie technologieën vereisen aanvullende data of aannames die niet algemeen beschikbaar zijn.

This study describes methodologies that have been developed to assess the food security impact of agricultural technologies supplied by stock exchange companies on the basis of publicly available revenue data. The methods have been developed for fertiliser, improved seeds, cooling and packaging. Given the lack of information on key variables at present it is only possible to apply the method for fertiliser to all companies that sell the technology in their portfolio. For the other three technologies additional information is necessary that is not publicly available.

Key words: impact, investment, agriculture, yield improvement, food loss avoided, food security.

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Preface

UBS manages investment funds for their clients. For one of these funds that invests in shares of stock exchanged companies, UBS's client PGGM would like to measure the impact these companies have on society, so that impact can be included in their investment selection strategy. Several sustainability rating systems of stock exchange companies exist already, but these are mainly based on inputs and processes rather than on impact.

Starting in 2015 Harvard University and City University of New York (CUNY) have developed such impact methodologies for climate/air pollution, health and water. For food security no such impact methodologies are available yet. UBS has asked Wageningen University & Research to develop a methodology that enables them to assess the impact on food security of agricultural technologies supplied by companies, using only publicly available data.

The research was challenging, as this is new research territory and the team had to start from scratch. It was also rewarding insofar as the team has been successful. This report presents the results, the development and application of the methodologies to assess impact on food security. More specifically, it focuses on technologies that have the potential to improve food availability by (1) increasing crop yield and (2) avoiding food losses.

This type of analysis is potentially interesting for pension funds, banks and sustainable asset management companies with an interest in assessing the impact of their assets.

The development of the methodologies has benefitted greatly from extensive and inspiring discussions with Dinah Koehler, our client at UBS. In the course of the project we have also had several meetings with colleagues at Harvard University and CUNY who developed the impact methodology for climate/air pollution, health and water. These meetings have been very valuable for our work. A final word of thanks goes to PGGM, especially Piet Klop, for his ceaseless enthusiasm and support for our work.

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Summary

S.1 Key findings

Methodologies are needed to measure societal impact in terms of food security

Our client UBS wants to develop methodologies with which they can assess the impact of agricultural technologies supplied by stock exchange companies on several sustainability issues. Such methodologies have been developed for climate/air pollution, health and water, but not yet for food security. The methods need to be developed on the basis of publicly available revenue data.

Converting revenue data to additional food or food loss avoided - a good start

This report presents the development and application of methodologies to assess the impact of agricultural technology suppliers on food security. It focuses on technologies that have the potential to improve food availability, one of the four elements of food security, by (1) increasing crop yield and (2) reducing food losses. The technologies covered are the use of fertiliser and of improved seeds for increasing crop yield; for reducing food loss the technologies are cooling and packaging.

For both yield and food loss a logical framework was established to assess the impact of the technologies on yield increase (fertiliser and improved seeds) or food loss avoided (cooling and packaging), using publicly available information only. The framework makes it theoretically possible to calculate *conversion factors* that convert company revenue as stated in the FactSet Revere database into additional food production or food loss avoided, which can be converted to additional number of people being possibly supplied with their daily diet.

Application of methodology limited to fertiliser due to lack of publicly available information

Given the lack of publicly available information on key variables at present, this last step - linking the revenue of any company selling the specific technology to impact indicators through so-called conversion factors - is not yet feasible for three out of the four technologies included in this research. It is only possible to apply the method for fertiliser to all companies in their portfolio that sell the technology. For the other technologies additional information that is not publicly available is necessary.

S.2 Complementary results

Food and nutrition security is a multidimensional issue; food availability is only one dimension

Both indicators, yield increase and food loss avoided, mainly measure an increase in available food. In general, more food should in theory lead to more people (possibly) being fed and hence more food security. However, the food and nutrition status of an individual or household is determined also by access to food, for which income is the main driver, by the use of the food and by the stability of the food and nutrition status. We also focus on national food availability only and therefore do not correct for trade. It is not unlikely that exports of one country contribute to the food security in another country.

Impact on food availability will depend on (correct) adoption by farmers

Regarding farming technologies, in addition to availability, adoption rates are equally important since yields will not rise without the acceptance and correct application by farmers. This is also the case for the food loss related technologies. This was outside the scope of the project, but could be an important improvement of the current methodology.

S.3 Method

Eight-stage approach to estimate impact of fertiliser on food availability

To establish the link between technology sales of a company (revenues) and the final impact on improved food availability, we need to follow an eight-step approach:

- Stage 1.Estimate deliveries of fertiliser/seed in volume terms by country and crop
- Stage 2. Estimate the yield response function by country and crop
- Stage 3. Estimate the increase in yield that can be attributed to the use of the technology
- Stage 4. Estimate the increase in crop production that can be attributed to the company
- Stage 5. Correct for exports and other uses than food consumption
- Stage 6. Convert to raw energy equivalent
- Stage 7. Express in people potentially being fed
- Stage 8. Aggregate results

Five steps to estimate the impact of cooling and packaging on food loss

A new formula is developed that calculates the food loss avoided by selling a specific technology within a specific country. This requires five steps:

1. Select the technology;
2. Find companies selling the technology in the relevant country/region;
3. Identify the stage in the supply chain where the technology is (regularly) applied;
4. Determine per country the reduction of food loss attributable to the use of the technology at hand;
5. Normalise the outcome.

1 Setting the scene

Setting the scene

1.1 Why do we need this study?

Measuring societal impact of stock exchange companies
UBS manages investment funds for their clients like PGGM. For one of these funds that invests in shares of stock exchange companies, PGGM would like to measure the impact these companies have on society so that impact can be included in their investment selection strategy. Several sustainability rating systems of stock exchange companies exist, but these are mainly based on inputs and processes rather than on impact.

Methodologies are needed to measure societal impact in terms of food security
UBS wants to develop a methodology with which they can assess the impact of agricultural technology suppliers on several sustainability issues. For climate/air pollution, health and water, such methodologies have been developed (Vorösmarty et al., 2018), but for food security this methodology has not yet been developed.

The overall goal for this research project is to develop science-based methodologies to assess the food security impact of agricultural technologies supplied by stock exchange companies. The methodology needs to be based on publicly available revenue data as compiled in the FactSet Revere database. It should enable UBS to link the revenue of any company selling the specific technology to impact indicators through so-called *conversion factors*. Ranking companies based on the impact realised is not the objective of the methodology. Given the range of products in the food sector, at the request of the client the focus in this research is on vegetable production.

Before discussing the methodology, we need to take a closer look at what food security is and what indicators could be used to measure (a change) in food security.

1.2 Food security – a complex issue

Food and nutrition security is a multidimensional issue
The FAO defines food security as a situation 'when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'. The four pillars of food security are availability, access, use and stability. The nutritional dimension is integral to the concept of food security (FAO, 2009), hence we use the term food and nutrition security (FNS).

Food availability, access and use determine the <u>food and nutrition status</u> of an individual or household
Availability refers to the extent to which food is within reach, both in terms of quantity and quality, and is largely determined by food supply. Though a necessary condition, food availability does not guarantee food access, for which households must have sufficient resources to acquire appropriate foods. Finally, even if sufficient and nutritious food is both available and accessible to the household, intra-household distribution of food, dietary preferences and individual health status will determine food use or a person's actual dietary intake and the ability to absorb nutrients (Cockx et al., 2017).

Vulnerability and resilience determine the *stability* of FNS
Next to the food and nutrition status, regarded as the first dimension of FNS, the second major dimension of FNS is the *stability* of the food and nutrition status. This is determined by a household's vulnerability to negative shocks, and their resilience or capacity to cope with these shocks. Reducing vulnerability and building resilience however, often go hand in hand.

FNS is largely determined outside the scope of an individual
Although in the end FNS is clearly an individual-specific outcome, many of its drivers (causes) are outside the scope of the individual. Both the status and

the stability of FNS are affected by a range of determinants at different levels (from individual and household level to regional, national and global level) and a wide array of micro- and macro-level policies (Cockx et al., 2017). Indicators of FNS covering the different dimensions are needed in order to generate information about the current absolute and relative status and evolution of FNS, the causes of change in FNS, possible actions and their impacts in the short and long term (Gerber et al., 2017).

Prevalence of food insecurity highest in Less Developed Countries

The Food Security Risk Index map of 2013 (Figure 1.1) shows that the extreme and high risks of food insecurity can be found in countries like Somalia, DR Congo, Haiti, Burundi, Chad, Ethiopia, Eritrea, Afghanistan, South Sudan and Comoros. These are also the countries that are on the UN list of Less Developed Countries (UN Committee for Development Policy, March 2018).

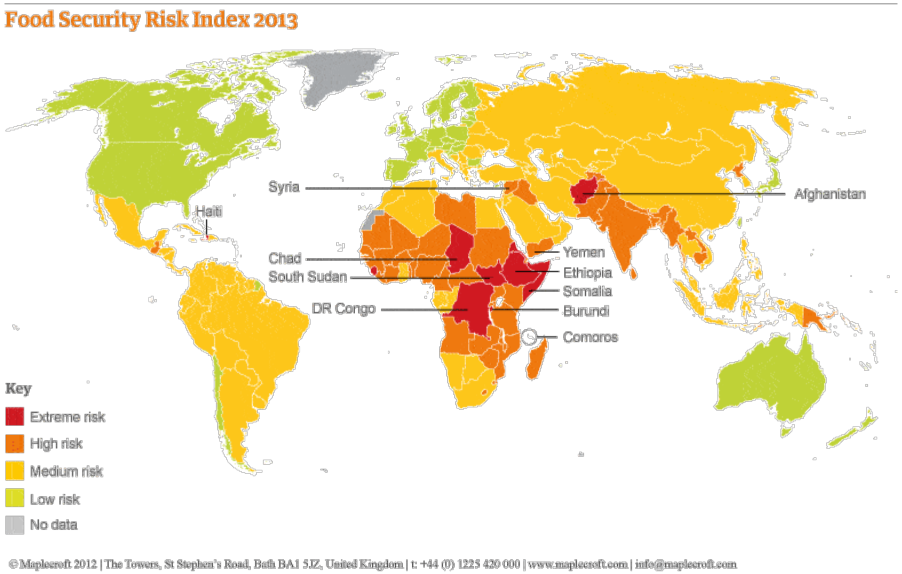

Figure 1.1 Food Security Risk Index 2013 (Maplecroft, 2012. https://www.theguardian.com/global-development/graphic/2012/oct/10/food-security-risk-index-map)

1.3 Focus in this project on yield and food loss

Food availability is the key focus

Our work for UBS focuses on two aspects related to FNS: agricultural yield improvement and food loss avoided. Both aspects relate to the availability of food. Other important determinants of food security are not taken into consideration, rendering our approach a partial one. It should therefore be seen as a starting point. This is also illustrated by Figure 1.2, which depicts the different linkages in our food system.

Food systems offer a way to better understand the complexity of FNS

The food system has become increasingly complex, with longer value chains and an increasing number of actors involved at different stages (Berkum and Dengerink, 2017). In order to address these complexities, the concept of food systems has been developed. A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes (HLPE, 2017).

Feedback mechanisms in the food system are not taken into account

By focusing on just two indicators (yield improvement and food loss avoided), we also do not account for the relations and feedback mechanisms between the different elements, as depicted in Figure 1.2. For example, increasing agricultural yield can be positive for food availability in the short term; if this increase impacts the production capacity in the long term because of insufficient attention for environmental effects – like soil erosion – this will limit the productive potential in the long term. Another example is the possible trade-off between land used for food and land used for feed.

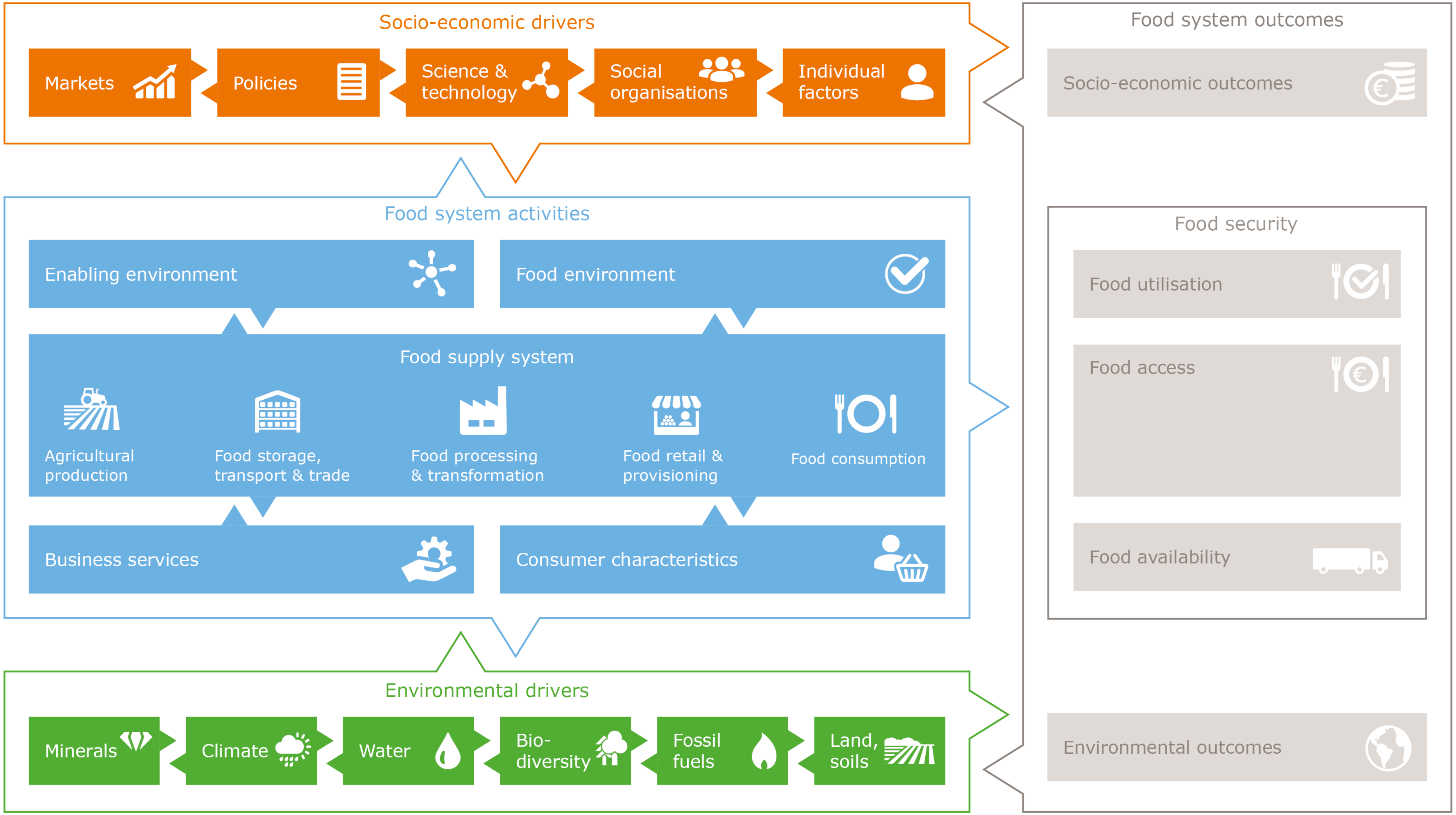

Figure 1.2 An illustration of the food system concept
Source: Berkum and Dengerink, 2017.

1.4 Rationale to focus on yield improvement and food loss

The focus is yield improvement in cereal production; essential to meet growing food demand

Global population is projected to rise from its current level of 7.6bn in 2017 to 9.8bn by 2050 and to 11.2bn by 2100 (United Nations 2017). In order to meet the growing demand for food, cereal production (e.g. maize, rice and wheat, which make up around 40% of the global diet) (Khoury and Jarvis, 2014), needs to increase by 60–110% (Mueller et al., 2012; Ray et al., 2013). Compounding this issue is the pressure that existing agricultural systems place on the environment. Scenario analysis indicates that continuous population growth and 'business-as-usual' economic development will lead to an expansion of agricultural land, resulting in an increase in greenhouse emissions (Popp et al. 2017) and negatively impacting global biodiversity (Visconti et al. 2015). The challenge of achieving global food security is underscored by SDG2: 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture'. Improving cereals yield is therefore a major step towards improving food availability and we therefore focus the analysis on three cereals - maize, wheat and rice - that form the largest share of the global diet and to which most fertiliser is applied.

Food loss and food waste are other key aspects of the FNS food availability dimension

The High Level Panel of Experts on Food Security and Nutrition (HLPE, 2014) defines food loss and waste (FLW) as follows. 'Food losses (FL) refers to a decrease, at all stages of the food chain prior to the consumer level, in mass, of food that was originally intended for human consumption, regardless of the cause. Food waste (FW) refers to food appropriate for human consumption being discarded or left to spoil at consumer level – regardless of the cause' [1]. Parfitt et al. (2010) refer to food loss as the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. Food loss takes place at production, postharvest and processing stages in the food supply chain. Food loss occurring at the end of the food chain (retail and final consumption) is instead called 'food waste', which implicates retailers' and consumers' behaviour.

Our second key FNS aspect of focus is reduction of food loss in post-harvest and processing stages; essential to increase availability of food

Food loss and waste occur for the larger part in the chain up to the consumer (**Error! Reference source not found.**1.3) (FAO, 2011), especially for countries in Sub-Saharan Africa, North Africa, West and Central Asia, South and Southeast Asia and Latin America. Given the prevalence of food insecurity in less developed countries the focus is on food loss – taking place at the post-harvest and processing stage in the food supply chain - as this a the major problem in these countries. Food loss at the production stage, i.e. during the process of seeding up to harvesting the crop is not included.

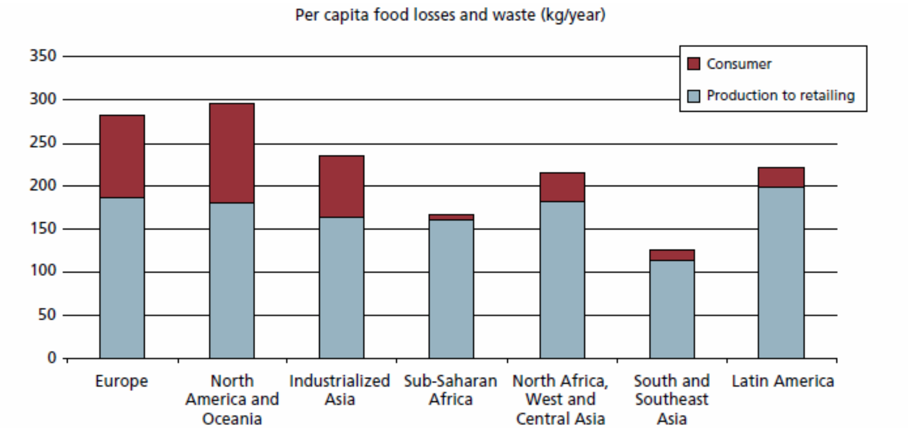

Figure 1.3 Per capita food losses and waste, at consumption and pre-consumption stages, in different regions (FAO, 2011)

[1] These definitions leave open questions regarding recycling. One question is whether food that is recovered to serve another purpose should be regarded as waste? From a food security perspective the answer would be yes, but from a resource use perspective, no. The answer is not so simple and still a matter of debate (Bellemare et al., 2017). In the context of this research recycling is excluded. Furthermore, a lack of a consistent definition is not only limited to loss of quantity but extends also to loss of quality, which is even harder to measure. Whether or not quality loss is included depends on the unit of measurement for FW – while value and calorie includes loss of quality (still edible but nutritionally inferior) of produce, physical quantity (mass or weight) only measures loss of quantity. In the context of this research the decrease of a qualitative attribute of food (nutrition, aspect, etc.) linked to the degradation of the product is excluded.

1.5 Outline of this paper

As indicated the purpose of this study is to develop scientific-based methodologies to assess the food security impact of agricultural technologies supplied by stock exchange companies, using only publicly available revenue data. The research is limited to vegetable production.

As there are multiple agricultural technologies, we start with a description of the key agricultural technologies in place related to yield and food loss avoided respectively. Next, we describe the impact logic used to connect the use of a technology to the impact on the indicator, followed by how in theory the impact could be calculated based on this methodology. The methodology is then illustrated by case studies, which sheds light on the challenges that occur when applying the methodology.
The study concludes with a general discussion on the methodology, the challenges and caveats, as well as on ways to improve the methodology.

Please note that this summary gives a brief overview of the methodology. In two technical annexes, one for the yield indicator and one for the food loss avoided indicator, the methodology and its application is explained in full detail.

Yield improvement

2

Yield improvement

2.1 Identifying key agricultural technologies

Five different types of agricultural technology can be identified

There are many agricultural technologies that determine the yield of the crops of farmers and thus affect the food security situation of a country. We distinguish the following five broad groups of technologies:

1. Technologies that improve plant characteristics, in particular new types of seeds (i.e. improved varieties)
2. Technologies that address water and nutrient supply, the two key factors that limit crop yield when not supplied in sufficient quantities: Irrigation and fertiliser
3. Technologies that address so-called yield-reducing factors, including weeds, pests and diseases: Herbicides, fungicides and herbicides
4. General purpose or enabling technologies: Tractors, cultivators, ploughs, harvesters, etc.
5. Soft technologies, including farm management knowledge, training and extension services.

Agricultural technologies influence FNS, but should be seen within the wider food system

In general, the impact of technologies has been analysed in research focusing on yield gaps. In addition to the availability of technological advances, *adoption rates* are equally important since yields will not rise without the acceptance and correct application by farmers. The farmers attitude towards new knowledge and practices and their willingness to actually apply the technologies need to be taken into account when determining their impact on the yield. Furthermore, it should be noted that other relevant issues prevail when considering technological advances and their impact on yields and hence food security.

First, as elaborated in Chapter 1, food security has several dimensions and we merely take into account the production of crops. More specifically, we focus on cereal crops, thereby neglecting possible (local) varieties that may play a more prominent role in food and nutrient security of a country. In addition, the issue of dependence on imports of technologies, i.e. inputs and solutions, is considered an important point when looking at the stability of the food security situation, which is a function of the respective imports and their delivery to the local farmers in developing countries.

We focus on two key agricultural technologies: fertilisers and seeds

We limit the analysis to two technologies: fertilisers (technologies that address water and nutrient supply) and seeds (technologies that improve plant characteristics). One of the main constraints to agricultural productivity in developing countries is limited fertiliser (Morris et al., 2007). This especially applies to Africa, where average fertiliser use is only eight kilograms per hectare, only 10% of the world's average. For this reason, African countries agreed to increase the access to and use of fertiliser in the 2006 Abuja Declaration. Apart from fertiliser, the development and adoption of improved seeds, as opposed to traditional seed varieties, are also frequently mentioned as a way to increase crop yield (World Bank, 2008). In addition, new types of drought-tolerant varieties are also regarded as an important technology for farmers to adapt to climate change (Rovere et al., 2014).

Figure 2.1 Impact logic

2.2 Impact logic

Agro-companies influence food availability by producing agricultural technologies including seeds and fertilisers

Agro-companies produce agricultural technologies, which are essential for increasing yields and which, in turn, bear heavily on food security through food availability. The impact logic that connects agricultural technologies, such as fertiliser and seeds, to food security is illustrated in Figure 2.1. We adopt the structured approach of Vörösmarty et al. (2018) to define outputs, outcomes and impacts. The elements of this approach are depicted below in Figure 2.1. Starting from the left hand side, companies produce technologies which are then used by farmers to grow cereal crops; this in turn leads to higher yields and finally to food availability, one of the four facets of food security[2].

The key output is delivery of fertilisers and seed

Output in the context of agricultural yields is the distribution of agricultural technologies that affect yields to (small-scale) farmers, in this case fertiliser and seeds. Output can be measured by the units of technology delivered to a defined spatial area (for example Nigeria).

The key outcome is higher yields achieved by (small-scale) farmers using the agricultural technologies

For example, applying fertiliser or improved seeds to grow maize leads to higher yields than would be achieved without these technologies. The quantitative link between the technology and crop yield is called the yield response function. This link depends heavily on spatially explicit variables like the local climate and soil conditions. The response of maize to fertiliser in a dry area with little rain and poor soil will be completely different in a more favourable setting. This suggests that an assessment of the role of a company in advancing food security should incorporate a spatially explicit approach. Of

[2] It is not uncommon to make a distinction between immediate outcome, the adoption of improved technologies; intermediate outcome, improved yield; and ultimate outcome, improved food availability. However we follow the approach of Vörösmarty et al. (2018), who do not make this distinction.

course, the effectiveness of any technology also depends on the user, in this case the farmer. However, a correct appraisal of the technology would not take into account the actual use of the technology but the use for which it was intended.

The key impact relates to food security, in particular food availability/production

Our methodology allows us to establish the link between technology sales and food availability (through an increase in crop yield). However, this by itself does not ensure an improvement in food security. For example, production can be exported and therefore not be available for domestic consumption. It might be possible that the additional production is exported and therefore not available for domestic consumption. Another possibility is that farmers that use fertiliser are large commercial farmers, which are already food secure. Despite these considerations, we suggest that higher yields and higher food production imply greater food security.

The counterfactual of delivering improved technologies is using zero fertilisers and using traditional seeds only

In order to assess the impact of the use of fertiliser and improved seeds on higher yields and food availability, we need to define a baseline, i.e. the yield and food availability if farmers did not have access to these technologies. The baseline for fertiliser is a situation in which farmers do not use (chemical) fertiliser. Naturally, crop yield will be much lower without the application of additional plant nutrients, but there will nonetheless be *some* yield. We use the results of a global crop simulation model to establish the baseline at the country level. The proposed baseline for seeds is the use of traditional varieties, which are also associated with lower yield.

2.3 The methodology applied to fertiliser

Eight-stage approach to estimate the impact of fertiliser on food availability

To establish the link between technology sales of a company (revenues) and the final impact on improved food availability, we need to follow an eight-step approach:

- Stage 1. Estimate fertiliser deliveries in volume terms by country and crop
- Stage 2. Estimate the yield response function by country and crop
- Stage 3. Estimate the increase in yield that can be attributed to fertiliser application
- Stage 4. Estimate the increase in crop production that can be attributed to the company
- Stage 5. Correct for exports and other uses than food consumption
- Stage 6. Convert to raw energy equivalent
- Stage 7. Express in people potentially being fed
- Stage 8. Aggregate results

Using the eight-stage approach to estimate the impact of Yara's fertiliser sale in Brazil

To illustrate the methodology to estimate a fertilisers' contribution to food availability, we used Yara as a case study. Yara belongs to the top five largest fertiliser companies in the world and is active in a large number of developing countries, in particular throughout Africa.

Please note that to do this calculation, we had to make a number of assumptions. All these assumptions are subject to a high level of uncertainty and therefore may bias the final result. The figures presented should therefore be used with caution.

The total impact of Yara on food availability as a result of fertiliser supply is estimated at 62,694m tonnes of cereals

The analysis as described was repeated for all 107 countries in which Yara is active across the three fertiliser types for which we can estimate the impact of food availability. Figure 2.2 depicts the results for additional food (cereals) production in kcal for major regions and the global total that can be attributed to Yara's fertiliser deliveries. The figure shows large differences per crop and region, which are caused by a combination of factors, including differences in regional deliveries of fertiliser, national fertiliser application rates, national yield response rates and kcal content.

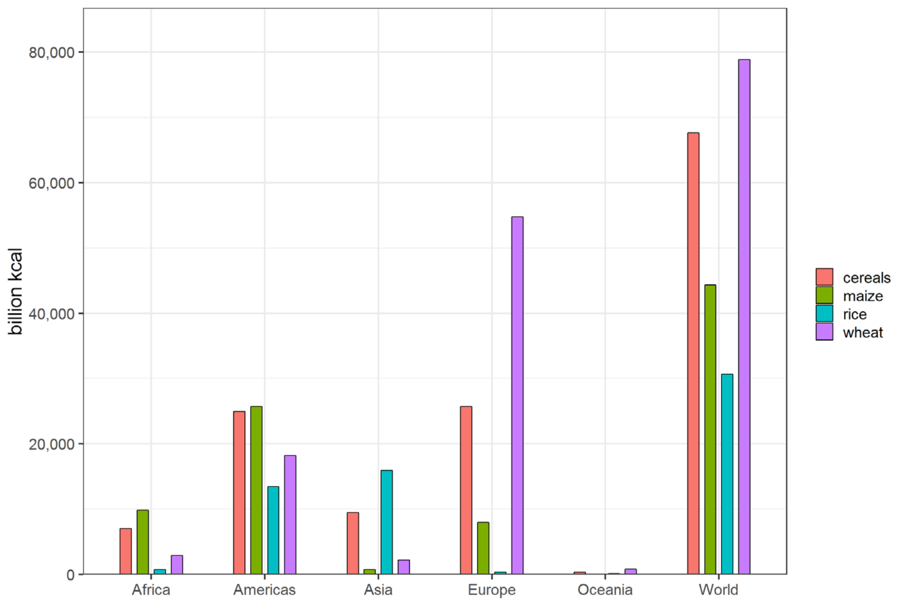

Figure 2.2 Additional food production in kcal attributed to Yara
Note: Cereal production is the total of maize, rice and wheat production.

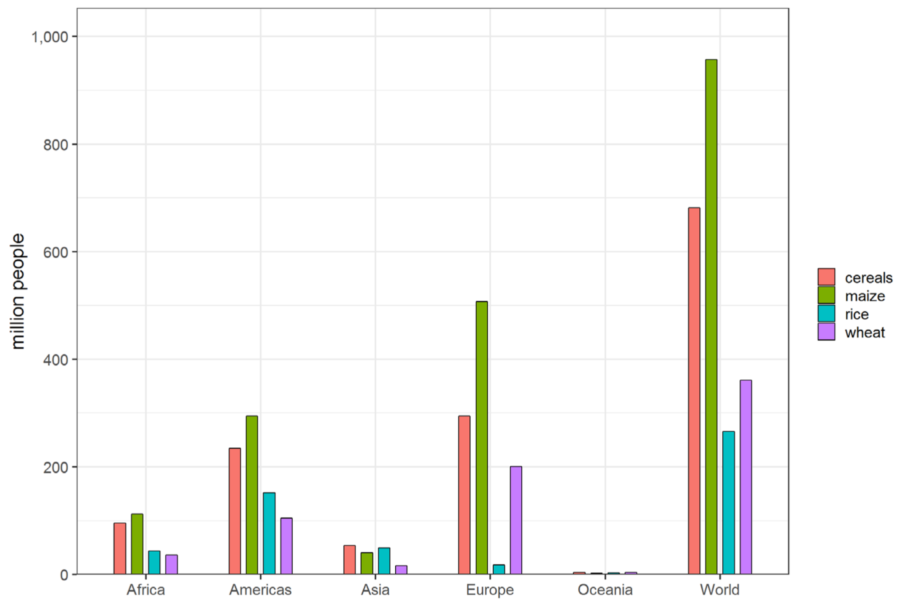

Figure 2.3 Number of people possibly supplied with dietary needs attributed to Yara[3]

The number of people whose dietary needs are filled as a result of fertiliser supplied by Yara is estimated at 659m people

Figure 2.3 shows the number of people whose dietary needs are filled as a result of fertiliser supplied by Yara. It is important to note that it is not possible to aggregate the number of people per crop, as the same people are consuming maize, rice and wheat.

2.4 The methodology applied to seed

The methodology to assess seed companies is similar to the one developed for fertiliser companies. Unfortunately, in contrast to the fertiliser case, essential data to apply the methodology proved impossible to obtain despite considerable efforts to collect the data. For this reason we argue that, given the lack of information on key variables it is not possible at present to properly assess the impact of seed companies on food availability.

[3] The model implicitly assumes that maize, wheat and rice are equally interchangeable in people's diet, which might not be realistic. Nonetheless, it provides a good proxy variable to measure the impact of Yara on total food availability. Also note that, as people consume a mix of maize, wheat and rice, aggregating the number of people per cereal would result in double counting. The cereals value uses the sum of maize, rice and wheat diet shares in the national diet, implicitly assuming that kcal consumption of maize, rice and wheat is perfectly substitutable.


3
Food loss avoided

Food loss avoided

3.1 Agricultural food product groups and supply chain activities

Focus on vegetables and fruits as key sources of food loss
FAO research (FAO, 2013) shows that most of food is lost in the following product groups: vegetables, meat and fruits. Because meat is outside the scope of this research assignment, the relevant food groups to focus on are the fruits and vegetables.

Focus on post-harvest handling and storage
Within the post-harvest food supply chain, i.e. farm to retailer, we can distinguish three 'main types' or clusters of post-harvest activities: post-harvest handling & storage, processing and distribution/transportation. The food loss through the different supply-chain stages for the product group fruit and vegetables is shown below in Figure 3.1. Within the scope of this research the focus is set on post-harvest handling and storage.

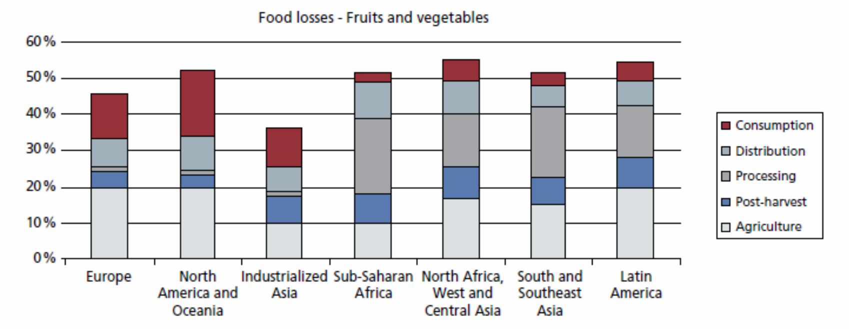

Figure 3.1 Part of the initial production of fruits and vegetables lost or wasted at different stages of the FSC in different regions (FAO, 2011)

3.2 Identifying key agricultural technologies

Focus on cold storage and packaging as key technologies to reduce food waste among fruits and vegetables
Before identifying the key agricultural technologies related to post-harvest food loss for fruits and vegetables, we define the concept 'technology' as follows: '*A technology is an existing physical system that is used directly for preventing loss of a perishable product in the post-harvest phase*'.

It is generally accepted that perishable crops, like fruits and vegetables, should be kept cool to delay the onset of deterioration as long as possible[4]. As shown in Table 3.2, deterioration is often indicative of physical damage. The table also shows that packaging, temperature control and climate control (i.e. controlling mainly relative humidity) are the main technologies leading to less food loss because of mechanical damage/physical damage, physio-biochemical loss/deterioration, microbial spoilage and physical rejection. Because temperature affects relative humidity (the colder the temperature the less moisture the air can hold) temperature or cooling is one of the most relevant steering parameters to control this. Therefore, the focus technologies in this study are cold storage and packaging.

[4] https://postharvest.nri.org/

Table 3.2 From types and causes of food loss to technology

Types	Primary cause	Secondary cause	Main Technology
Mechanical damage / physical damage	Damage, bruising, cracking. Rotting by fungal and bacterial pathogenies is often indicative of physical damage	'Wrong' use or absence of packaging and high temperature and relative humidity during harvest, storage and transport favour the development of post-harvest decay organisms.	Packaging Cold storage / climate control
Physio-biochemical loss / deterioration	Senescence or aging process (unavoidable): Transpiration, respiration, sprouting	Packaging can reduce the aging process providing ventilation to prevent dehydration, temperature rises, et cetera	Packaging
Microbial spoilage or loss	Rotting caused by fungi, bacteria, yeast and moulds	High temperature and relative humidity during harvest, storage and transport favour the development of post-harvest decay organisms.	Cold storage / climate control Cold transportation
Physical rejection or loss	Injury in relation to 'wrong' or absence of refrigerated storage, temperature and relative humidity, composition and proportion of gases in controlled atmosphere storage, type of wrapper or packaging		Packaging Cold storage / climate control

3.3 Impact logic

Agro-companies influence food availability by producing agricultural technologies including cold storage and packaging

Agro-companies produce agricultural technologies which contribute to reducing food loss. The logic that connects these agricultural technologies, such as cold storage and packaging, to food loss avoided is illustrated in Figure 3.3.

The key output is delivery of improved technologies related to storage and packaging

In the framework of the output-outcome-impact proposed by Vörösmarty et al. (2018), we propose that solutions (technology/product/practice) used by a company are the inputs used for producing the final food product (output).

The key outcome is food loss avoided by using improved technologies

Avoided food loss is the outcome of a certain technology that can prevent food loss (by a certain amount or percentage). Different circumstances (products, supply chains, regions) affect the outcome, resulting in different amounts of food loss avoided.

The key impact relates to food security, in particular food availability/production

Defining impact is not easy. While one can argue that food loss impacts multiple dimensions of food security (availability, access, utilisation, stability), the only element this framework allows us to measure is availability. We could accordingly define impact as contribution of the company towards decreasing global food loss (and therefore increasing food availability). Measuring impact according to this definition should consider the food loss situation in the countries of the company's operation, and the market-share of the company in those countries. While the availability of more food due to avoided food loss suggests greater food security, we check whether this link can be made in a rational way for our case studies. **Figure 3.3**3.3 shows the rationale of this technology-driven approach to connect 'causes of food losses' to the company's impact.

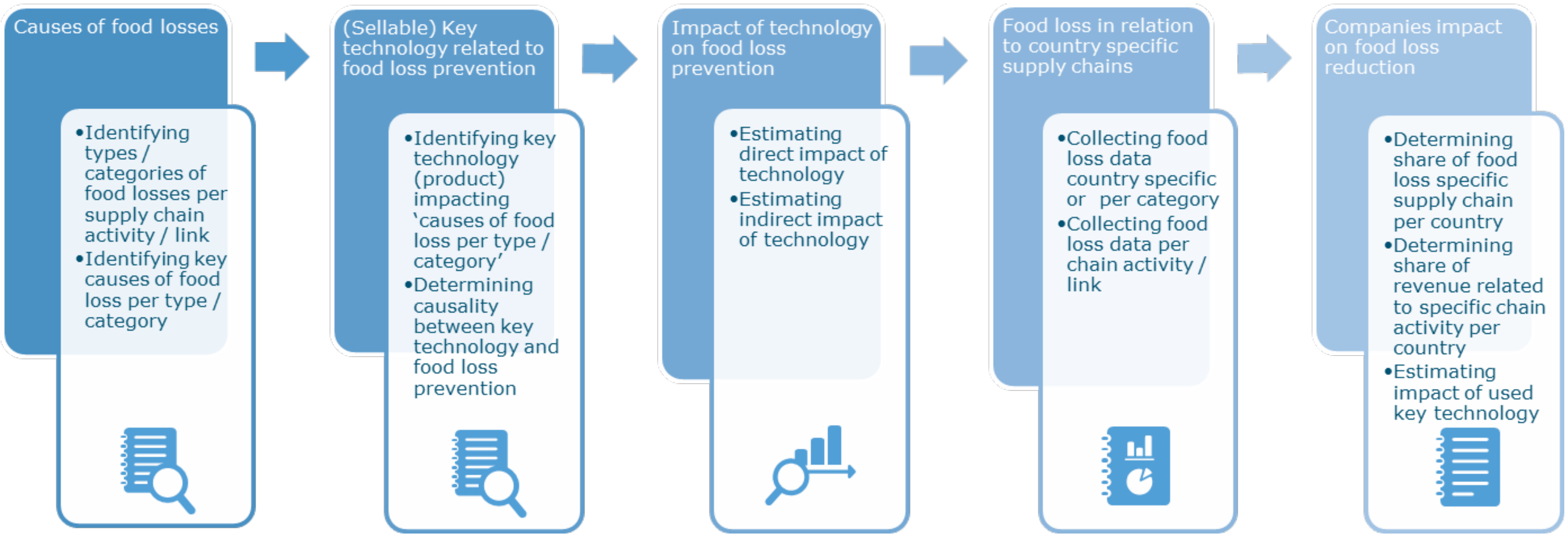

Figure 3.3 Impact logic: from causes of food losses to impact via technology

3.4 The methodology applied to cooling and packaging

The counterfactual of delivering improved cold storage and packaging technologies is not 'zero technology', but a lower level of technology available/applied

To get from improved technology to food loss avoided it is important to define loss reduction by technology. For this, it is necessary to get a clear idea of the specific 'baseline technology' applied in the relevant region/country because this baseline is region- and country-specific. The definition must not only be clear, but also applicable. Therefore, we defined the baseline as the technology that is applied in at least 50% of cases in the supply chain in the specific country or region at the time of comparison. This also means that for some countries or regions the use of technology could be zero in more than 50% of the cases, meaning that for those countries or regions the baseline is zero (i.e. '0-baseline').

Calculating food loss avoided

The basic principle and requirement from the client is to develop a methodology that links food loss avoided to a company's revenues or selling numbers from a specific technology. Based on this idea a new formula has been developed that calculates the food loss avoided by selling a specific technology within a specific country.

This requires five steps:

1. Select the technology
2. Find companies selling the technology in the relevant country/region
3. Identify the stage in the supply chain where the technology is (regularly) applied

4. Determine per country the reduction of food loss attributable to the use of the technology at hand
5. Normalise the outcome

Case study - applying the methodology to Daikin Industries

Daikin Industries, Ltd. is a Japanese multinational air conditioning manufacturing company headquartered in Osaka, Japan. Daikin Industries Ltd serves as a 'test case' for our methodology for cooling. For the case study we zoom in on air conditioning and refrigeration technology used for storage of fruits & vegetables (i.e. in the processing stage of the supply chain of fruits and vegetables) in Kenya.

56,517,225 kg food loss avoided by Daikin in Kenya in the processing stage in the fruits and vegetables sector

Based on the methodology developed we find that 56,517,225 kg food loss is avoided by Daikin in Kenya in the processing stage. Dividing this by the revenue (or sales) of air conditioning and refrigeration technology in Kenya, we find that 7.68 kg food loss is avoided for each USD sales of Daikin in Kenya.

470,000 Kenyans can be fed with the 49,735,158 kg avoided food loss of fruits and vegetables

In Kenya the avoided food loss in fruits and vegetables by Daikin equals 56,517,225 kg. FAOSTAT shows that about 88% of the production is for human consumption in Kenya, which comes down to 49,735,158 kg additional supply of fruits and vegetables.
Based on FAOSTAT the annual Kenyan consumption with respect to fruits and vegetables is about 105 kg. Therefore, approximately 0.47m people can be fed by the avoided food loss of fruits and vegetables. In 2017 Kenya had 47.7m inhabitants, so this number represents approximately 1% of the total population.

Stora Enso was selected as a case study for packaging

Stora Enso was selected as a case study to test the methodology for packaging. The renewable materials company Stora Enso develops and produces solutions based on wood and biomass for a range of industries and applications worldwide, including corrugated packaging.

3,429,903 kg food loss avoided by Stora Enso in Kenya in the processing stage in fruits and vegetables sector

In Kenya the food loss avoided in fruits and vegetables by Stora Enso equals 3,429,903 kg in the processing stage. Dividing this by the revenue (or sales) of packaging technology in Kenya, we find that 0.66 kg food loss is avoided for each USD sales of Stora Enso in Kenya.

29,000 Kenyans can be fed with the 3,018,314 kg avoided food loss of fruits and vegetables

In Kenya the avoided food loss in fruits and vegetables by Stora Enso equals 3,429,903 kg. FAOSTAT shows that about 88% of the production is for human consumption in Kenya, which is 3,018,314 kg additional food supply in fruits and vegetables. Based on FAOSTAT, the annual intake with respect to fruits and vegetables is about 105 kg. Therefore, approximately 0.029m people can be fed by the avoided food loss of fruits and vegetables. In 2017 Kenya had 47.7m inhabitants, so this number represents approximately 0.006% of the total population.

Methodology is not generally applicable based on publicly available data only

UBS has financial data on sales of many companies, and these data are the primary input for our calculations. However, additional information is necessary to apply the methodology in a meaningful way[5]. This additional information has to be provided by the companies or requires expert knowledge, which is not in line with the conditions of our client. Hence, the methodology is not (yet) generally applicable based on public available data only.

[5] To test our methodology, additional assumptions were required based on expert knowledge.

4

Overall discussion and conclusions

Overall discussion and conclusions

Converting revenue data to additional food or food loss avoided (food availability); a good start

This report presents the development and application of methodologies to assess the impact of agricultural technology suppliers on food security. More specifically, it focuses on technologies that have the potential to improve food availability, one of the four elements of food security (FAO, 1996), by (1) increasing crop yield and (2) reducing food losses.

For both yield and food loss a logical framework was established to assess the impact of the technologies on yield increase (fertiliser and improved seed) or food loss avoided (cooling and packaging), using public available information only. The framework makes it theoretically possible to calculate conversion factors that convert company revenue as stated in the FactSet Revere database into additional food production or food loss avoided, which can be converted to additional number of people possibly being supplied with their daily dietary needs.

Given the lack of publicly available information on key variables at present, this last step - linking the revenue of any company selling the specific technology to impact indicators through so-called conversion factors - is not yet feasible for three out of the four technologies included in this research. It is only possible to apply the method for fertiliser to all companies in their portfolio that sell this technology. For the other three technologies additional information that is not publicly available is necessary.

In this project we have come across a number of issues that complicate the actual application of the methodology. This section discusses these drawbacks of and limitations to the use of the conversion factors.

The perfect world versus the real world

Food and nutrition security is a multidimensional issue; food availability is only one dimension

We need to be aware that both indicators, yield increase and food loss avoided, mainly measure an increase in available food. In general, more food should in theory lead to more people (possibly) being fed and hence more food security. However, the food and nutrition status of an individual or household is also determined by access to food, for which income is the main driver (Swinnen, 2016), by the use of the food and by the stability of the food and nutrition status. We also focus on national food availability only and therefore do not correct for trade. It is not unlikely that exports of one country contribute to the food security in another country.

Impact on food availability will depend on (correct) adoption by farmers

Regarding farming technologies, in addition to availability, adoption rates are equally important since yields will not rise without the acceptance and correct application by farmers. This is also the case for the food loss related technologies. This was outside the scope of the project, but could be an important improvement to the current methodology.

Impact on food availability will differ per buyer; data not (yet) available

Finally, agriculture is characterised by different farming systems, including low input and high input types. In developing countries, where food security is most prevalent, the differences between systems can be large, e.g. small subsistence farmers versus large commercial farmers. Adoption of agricultural technologies by large (and probably relatively wealthy) farmers is unlikely to contribute to national food security apart from trickle down effects (e.g. increase in wages and employment, lower food prices), while adoption by small farmers is expected to have much more impact. We cannot quantify these effects without detailed information on the buyers of the technologies.

Side effects not taken into account

Increased use of fertilisers and resulting higher yields may have detrimental effects on the environment
In general, in this project we assume that increasing yields is always beneficial, while in reality this will depend on the type of soil and current level of production. Also, we assume that yield increases due to increased use of fertiliser do not lead to detrimental effects on the environment, like soil depletion or run off/leaching of nutrients, nor do we take into account that production of fertiliser takes a lot of energy. In practice, (arable) farming may use a combination of fertiliser and manure that will deliver the same yield and is more efficient in terms of energy use.

Adoption of improved (hybrid) seeds may be detrimental for the position of farmers and genetic plant diversity
Regarding seeds, improved (hybrid) seeds as compared to traditional seeds with increased tolerance to for instance drought and diseases may lead to less use of plant protection agents, or other inputs like fertiliser or water. On the negative side, the dependency of farmers on external inputs may increase as they can no longer develop or exchange seeds, or save seeds and planting material for the following season. The plant genetic diversity is another issue to take into account.

Negative side effects of cooling and packaging are less prevalent, but do exist in relation to resources required
For cooling and packaging the negative side effects appear to be less pronounced, except for the use of energy and raw materials that is required for different cooling and packaging techniques.

Data availability

Overall the availability of data to develop and apply the methodologies appears to be an issue. Both for the yield and food loss technologies included in this research, the results may be improved if better data could be used. Part of the data are available in the private domain and use of these data depends on the willingness of businesses to share these data.

Limited availability of data on fertiliser deliveries; breakdown into quantity units needed
For yield, fertiliser deliveries per company and per country in quantity units are needed for the calculations. As these data are not directly available for the majority of companies, information from the FactSet Revere database had to be used as a proxy. To convert revenue values into volume, we used the unit values (revenue/volume) of a single company for which fragmented data on deliveries in tonnes were available. It is likely that these values are not representative for other companies, potentially introducing a bias in the conversion.

No availability of data on seed delivery per crop and country; breakdown of Other Agricultural Support Activities in FactSet Revere needed
Essential information was missing on company revenue per crop and per country with respect to seeds. Unlike the fertiliser case, data from the FactSet Revere database could not be used as a proxy, as these data are not specific enough with regard to products and services delivered, covering revenue from both the sales of seeds and other activities. Moreover, it does not provide information on the deliveries by crop, which is essential for assessing the impact on crop yield. A more precise breakdown of the current broad category *Other Agricultural Support Activities* in the FactSet Revere database into sales of seeds is necessary.

Another missing piece of information is up-to-date and detailed data on the difference in yield between improved and traditional seeds, including the lack of a proper baseline for traditional seeds yield to benchmark the improved seeds. In a comprehensive review of recent literature, we did not find robust and systematic research that reports the results of applying improved seeds of different types of crops that are relevant for feeding people in developing countries, including traditional crops and production methods.

For food loss avoided additional data on technology specific application and use is needed
For food loss avoided, data needs relate in particular to the part of the chain where the technology is (regularly) applied, to the costs of applying the technology per unit of food and to the amount of food that can be handled with one unit of the technology. In addition, the categories in the FactSet Revere database are too broad to apply; a more precise breakdown into different techniques sold by a company to avert food loss is necessary to increase the reliability of the outcome.

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