Study conducted for the
International Congress

SAVE FOOD!

at Interpack2011
Düsseldorf, Germany

GLOBAL FOOD LOSSES AND FOOD WASTE

EXTENT,
CAUSES AND
PREVENTION

FAO
FIAT PANIS

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Simone Morini

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GLOBAL FOOD LOSSES AND FOOD WASTE

EXTENT, CAUSES AND PREVENTION

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Preface

This publication is based on studies carried out from August 2010 to January 2011 by The Swedish Institute for Food and Biotechnology (SIK) on request from the Food and Agriculture Organization of the United Nations (FAO).

The two studies on global food losses (one for high/medium-income countries and one for low income countries) have been carried out to serve as a basis for the international congress Save Food!, 16-17 May 2011, at the international packaging industry fair Interpack2011 in Düsseldorf, Germany. Save Food! has been co-organized by Interpack2011 and FAO. Save Food! aims at awareness raising on global food losses and waste, and on the impact of these on poverty and hunger in the world, as well as on climate change and on the use of natural resources.

The authors would like to thank Lisa Kitinoja, Adel Kader, Felicitas Schneider, Vaclav Smil and Jesper Stage among other researchers who have contributed helpful inputs throughout the project.

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Executive summary

The study highlights the losses occurring along the entire food chain, and makes assessments of their magnitude. Further, it identifies causes of food losses and possible ways of preventing them.

The results of the study suggest that roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year. This inevitably also means that huge amounts of the resources used in food production are used in vain, and that the greenhouse gas emissions caused by production of food that gets lost or wasted are also emissions in vain.

Food is lost or wasted throughout the supply chain, from initial agricultural production down to final household consumption. In medium- and high-income countries food is to a significant extent wasted at the consumption stage, meaning that it is discarded even if it is still suitable for human consumption. Significant losses also occur early in the food supply chains in the industrialized regions. In low-income countries food is lost mostly during the early and middle stages of the food supply chain; much less food is wasted at the consumer level.

Overall, on a per-capita basis, much more food is wasted in the industrialized world than in developing countries. We estimate that the per capita food waste by consumers in Europe and North-America is 95-115 kg/year, while this figure in Sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year.

The causes of food losses and waste in low-income countries are mainly connected to financial, managerial and technical limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging and marketing systems. Given that many smallholder farmers in developing countries live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods.

The food supply chains in developing countries need to be strengthened by, *inter alia*, encouraging small farmers to organize and to diversify and upscale their production and marketing. Investments in infrastructure, transportation, food industries and packaging industries are also required. Both the public and private sectors have a role to play in achieving this.

The causes of food losses and waste in medium/high-income countries mainly relate to consumer behaviour as well as to a lack of coordination between different actors in the supply chain. Farmer-buyer sales agreements may contribute to quantities of farm crops being wasted. Food can be wasted due to quality standards, which reject food items not perfect in shape or appearance. At the consumer level, insufficient purchase planning and expiring 'best-before-dates' also cause large amounts of waste, in combination with the careless attitude of those consumers who can afford to waste food.

Food waste in industrialized countries can be reduced by raising awareness among food industries, retailers and consumers. There is a need to find good and beneficial use for safe food that is presently thrown away.

The study revealed that there are major data gaps in the knowledge of global food loss and waste. Further research in the area is urgent.

Food security is a major concern in large parts of the developing world. Food production must clearly increase significantly to meet the future demands of an increasing and more affluent world population. This study illustrate that one of the first mean to fight imbalances and reduce tensions between the necessary increase in consumption and the challenging increase in production, is to also promote food loss reduction which alone has a considerable potential to increase the efficiency of the whole food chain. In a world with limited natural resources (land, water, energy, fertilizer), and where cost-effective solutions are to be found to produce enough safe and nutritious food for all, reducing food losses should not be a forgotten priority.

1. Introduction

The issue of food losses is of high importance in the efforts to combat hunger, raise income and improve food security in the world's poorest countries. Food losses have an impact on food security for poor people, on food quality and safety, on economic development and on the environment. The exact causes of food losses vary throughout the world and are very much dependent on the specific conditions and local situation in a given country. In broad terms, food losses will be influenced by crop production choices and patterns, internal infrastructure and capacity, marketing chains and channels for distribution, and consumer purchasing and food use practices. Irrespective of the level of economic development and maturity of systems in a country, food losses should be kept to a minimum.

Food losses represent a waste of resources used in production such as land, water, energy and inputs. Producing food that will not be consumed leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced.

Economically avoidable food losses have a direct and negative impact on the income of both farmers and consumers. Given that many smallholders live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods. For poor consumers (food insecure or at-risk households), the priority is clearly to have access to food products that are nutritious, safe and affordable. It is important to note that food insecurity is often more a question of access (purchasing power and prices of food) than a supply problem. Improving the efficiency of the food supply chain could help to bring down the cost of food to the consumer and thus increase access. Given the magnitude of food losses, making profitable investments in reducing losses could be one way of reducing the cost of food. But that would, of course, require that financial gains from reduced losses are not outweighed by their costs.

How much food is lost and wasted in the world today and how can we prevent food losses? Those are questions impossible to give precise answers to, and there is not much ongoing research in the area. This is quite surprising as forecasts suggest that food production must increase significantly to meet future global demand. Insufficient attention appears to be paid to current global food supply chain losses, which are probably substantial.

For the international congress Save Food! at Interpack2011, FAO hired the services of the Swedish Institute for Food and Biotechnology (SIK) to carry out two studies on the extent and effects, as well as causes and prevention of food losses and food waste, one for high/medium-income countries, and one for low-income countries. The two studies highlighted the food losses occurring along food chains, and made assessments of the magnitude of these losses, focussing on quantitative weight losses. They compile, analyze and assemble data and reports produced on the topic of global food loss and waste during recent years. Where information was not available, assessments and assumptions have been made. Results of the two studies are combined in this paper.

2. Methodology

The Swedish Institute for Food and Biotechnology (SIK) has reconstructed mass flows of food aimed to human consumption, from production to consumption, using available data, in order to quantify food losses and wastes.

2.1 DEFINITION OF FOOD LOSSES AND FOOD WASTE

Food losses refer to the decrease in edible food mass throughout the *part of the* supply chain that specifically leads to edible food for human consumption. Food losses take place at production, post-harvest and processing stages in the food supply chain (Parfitt *et al*., 2010). Food losses occuring at the end of the food chain (retail and final consumption) are rather called "food waste", which relates to retailers' and consumers' behavior. (Parfitt *et al*., 2010).

"Food" waste or loss is measured only for products that are directed to human consumption, excluding feed and parts of products which are not edible. Per definition, food losses or waste are the masses of food lost or wasted in *the part of* food chains *leading to* "edible products going to human consumption". Therefore food that was originally meant to human consumption but which fortuity gets out the human food chain is considered as food loss or waste even if it is then directed to a non-food use (feed, bioenergy…). This approach distinguishes "planned" non-food uses to "unplanned" non-food uses, which are hereby accounted under losses.

2.2 TYPES OF FOOD LOSSES/WASTE

Five system boundaries were distinguished in the food supply chains (FSC) of vegetable and animal commodities. Food loss/ waste were estimated for each of these segments of the FSC. The following aspects were considered:

Vegetable commodities and products:
Agricultural production: losses due to mechanical damage and/or spillage during harvest operation (e.g. threshing or fruit picking), crops sorted out post harvest, etc.

Postharvest handling and storage: including losses due to spillage and degradation during handling, storage and transportation between farm and distribution.

Processing: including losses due to spillage and degradation during industrial or domestic processing, e.g. juice production, canning and bread baking. Losses may occur when crops are sorted out if not suitable to process or during washing, peeling, slicing and boiling or during process interruptions and accidental spillage.

Distribution: including losses and waste in the market system, at e.g. wholesale markets, supermarkets, retailers and wet markets.

Consumption: including losses and waste during consumption at the household level.

Animal commodities and products:
Agricultural production: for bovine, pork and poultry meat, losses refer to animal death during breeding. For fish, losses refer to discards during fishing. For milk, losses refer to decreased milk production due to dairy cow sickness (mastitis).

Postharvest handling and storage: for bovine, pork and poultry meat, losses refer to death during transport to slaughter and condemnation at slaughterhouse. For fish, losses refer to spillage and degradation during icing, packaging, storage and transportation after landing. For milk, losses refer to spillage and degradation during transportation between farm and distribution.

Processing: for bovine, pork and poultry meat, losses refer to trimming spillage during slaughtering and additional industrial processing, e.g. sausage production. For fish, losses refer to industrial processing such as canning or smoking. For milk, losses refer to spillage during industrial milk treatment (e.g. pasteurization) and milk processing to, e.g., cheese and yoghurt.

Distribution: includes losses and waste in the market system, at e.g. wholesale markets, supermarkets, retailers and wet markets.

Consumption: includes losses and waste at the household level.

2.3 QUANTIFICATION OF FOOD LOSSES AND WASTE

Physical mass of food produced for human consumption and of food lost and wasted throughout the food supply chain have been quantified, using available data, results from the literature on global food waste and SIK's own assumptions. For each commodity group a mass flows model was used to account for food losses and waste in each step of the commodity's FSC. Model equations are provided in Annex 5.

The production volumes for all commodities (except for oil crops and pulses) were collected from the FAO Statistical Yearbook 2009 (FAOSTAT 2010a). The production volumes for oil crops and pulses were collected from FAO's Food Balance Sheets (FAOSTAT 2010d).

Allocation factors have been applied to determine the part of the produce oriented to human consumption (and not for animal feed). Conversion factors have been applied to determine the edible mass (Annex 2). At each stage of the Food Supply Chain, losses and waste were estimated using FAO's Food Balance Sheets from the year 2007 and results from a thorough literature search on the topic of global food waste. Where there are gaps of knowledge, SIK has made own assumptions and estimations, based on food waste levels in comparable regions, commodity groups and/or steps of the FSC. The figures used are presented in Annex 4. The sources and assumptions behind these estimations are described in detail in the study reports from SIK.

3. Extent of food losses and waste

3.1 FOOD VOLUMES PRODUCED

Figure 1 illustrates the 2007 production volumes of all commodity groups in their primary form, including animal feed products (which are then factored out using allocation factors), in the regions of the world studied. The production volumes were compiled from the FAO Statistical Yearbook 2009, except for the production volumes of oil crops and pulses which were collected from FAO's FBS, 2007.

Meat production in Industrialized Asia was dominated by large pig (around 46 million ton) and chicken (around 12 million ton) production. Meat production in Europe was dominated by pig (around 27 million ton) while it was more diversified in North America and Oceania, with chicken (18 million ton), cattle (16 million ton) and pig (12 million ton).

In developing regions, meat in Latin America was dominated by large cattle (around 15 million ton) and chicken (around 17 million ton) production. Meat produced in South and Southeast Asia mainly consisted of pig (7 million ton) and chicken (9 million ton). Animal production in sub-Saharan Africa mostly consisted of cattle (around 4 million ton) and in North Africa, West and Central Asia it was mostly chicken (around 4 million ton) production.

3.2 EXTENT OF FOOD LOSSES AND WASTE

Roughly one-third of the edible parts of food produced for human consumption, gets lost or wasted globally, which is about 1.3 billion ton per year. Food is wasted throughout the FSC, from initial agricultural production down to final household consumption. In medium- and high-income countries food is to a great extent wasted, meaning that it is thrown away even if it is still suitable for human consumption. Significant food loss and waste do, however, also occur early in the food supply chain. In low-income countries food is mainly lost during the early and middle stages of the food supply chain; much less food is wasted at the consumer level.

Figure 1. Production volumes of each commodity group, per region (million tonnes)

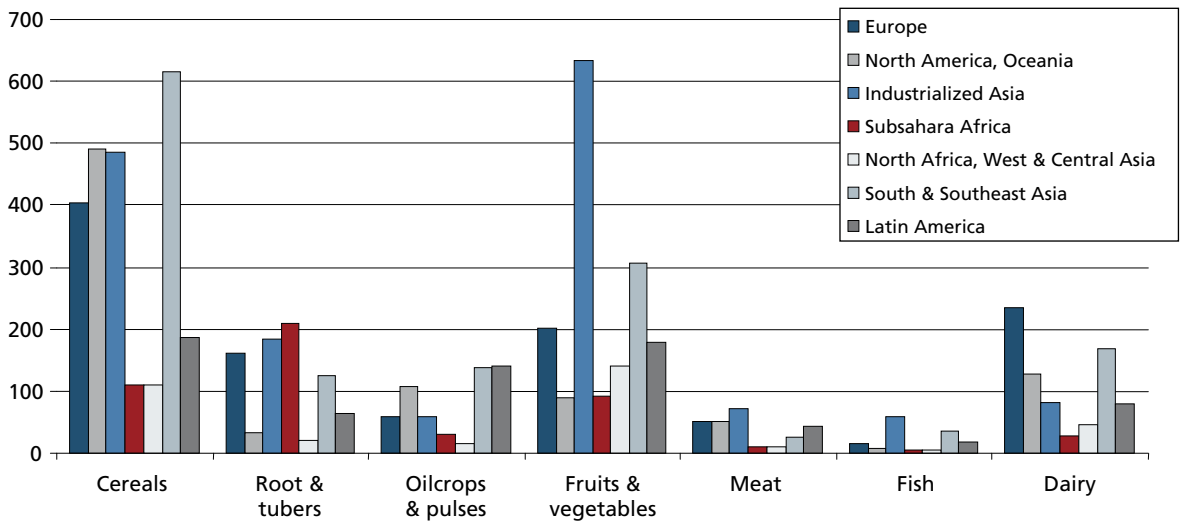


Figure 2. Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions

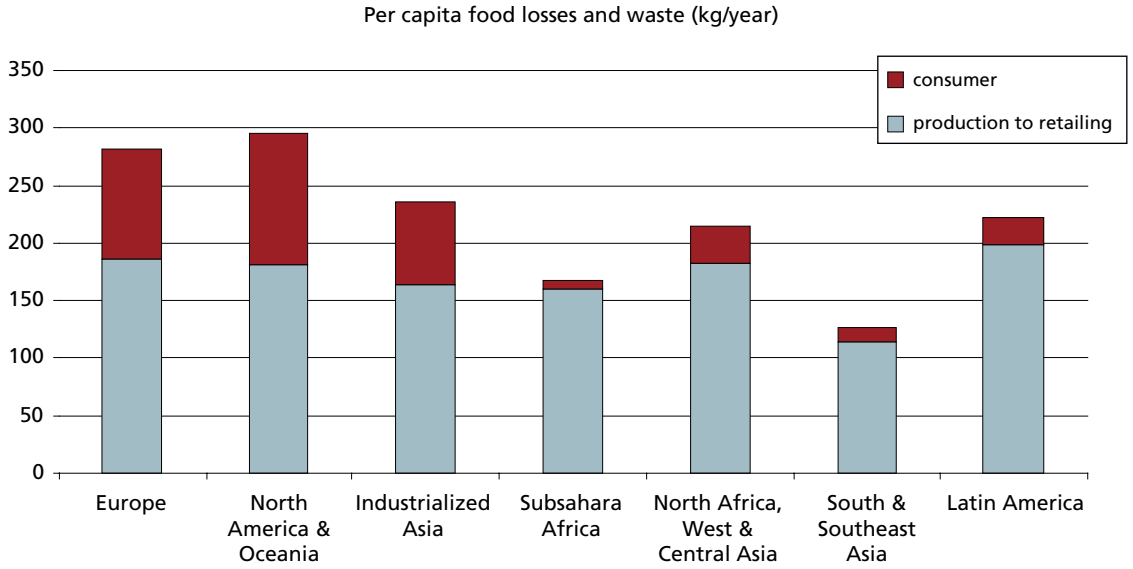


Figure 2 shows that the per capita food loss in Europe and North-America is 280-300 kg/year. In Sub-Saharan Africa and South/Southeast Asia it is 120-170 kg/year. The total per capita production of edible parts of food for human consumption is, in Europe and North-America, about 900 kg/year and, in sub-Saharan Africa and South/Southeast Asia, 460 kg/year.

Per capita food wasted by consumers in Europe and North-America is 95-115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year.

Food losses in industrialized countries are as high as in developing countries, but in developing countries more than 40% of the food losses occur at post harvest and processing levels, while in industrialized countries, more than 40% of the food losses occur at retail and consumer levels. Food waste at consumer level in industrialized countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton).

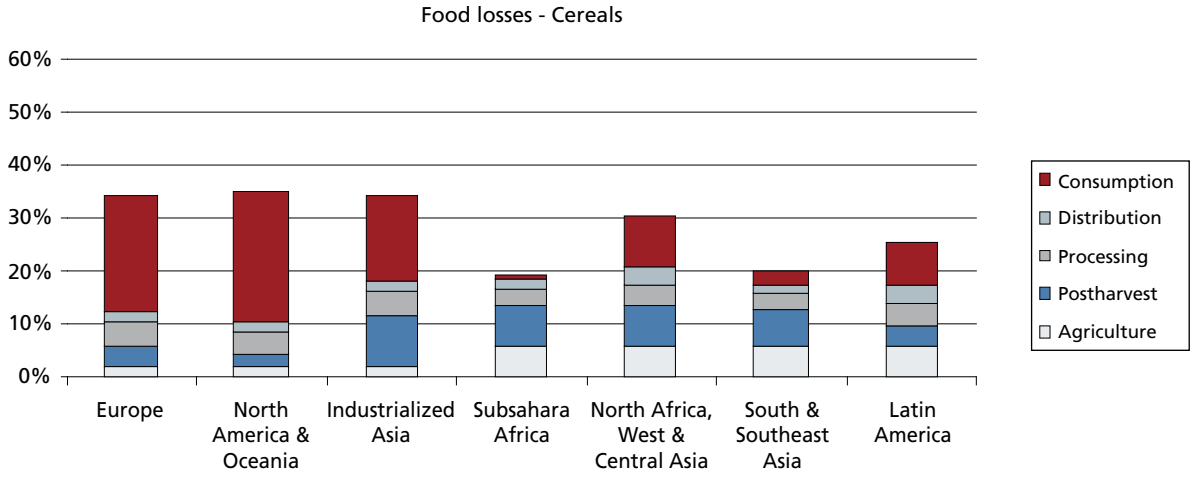
The graphs of the seven commodity groups below show the percentage food losses and waste of the edible parts of food products that were produced for human consumption.

In the case of *cereals* (Figure 3), wheat is the dominant crop supply in medium- and high-income countries, and the consumer phase is the stage with largest losses, between 40-50% of total cereal food waste.

In low-income regions rice is the dominant crop, especially in the highly populated region of South and Southeast Asia. For these regions, agricultural production and postharvest handling and storage are stages in the FSC with relatively high food losses, as opposed to the distribution and consumption levels.

In the *roots and tubers* group (Figure 4), potato (sweet potato in China) is the dominating crop supply in medium- and high-income countries. Results indicate that all three medium- and high-income regions loose the largest volumes during agricultural production. This mainly depends on postharvest crop grading, due to quality standards set by retailers. Food waste at the consumer level is, however, also high.

Figure 3. Part of the initial production lost or wasted, at different FSC stages, for cereals in different regions



Cassava is the dominant supply crop in SSA and LA and potato the dominant crop in North America, West Asia and Central Asia, and South and Southeast Asia. For these regions, agricultural production and postharvest handling and storage are stages in the FSC with relatively high food losses, as opposed to the distribution and consumption levels. One reason for this is that fresh roots and tubers are perishable, which make these products easily damaged during harvest and postharvest activities, especially in the warm and humid climates of many developing countries.

In the *oil crops and pulses* commodity group (Figure 5), sunflower seed and rape seed are the dominating crop supplies in Europe, while soybeans are the dominating crop supply in North America and Oceania and Industrialized Asia. Losses in all medium- and high-income regions are relatively large during agricultural production, contributing waste percentages between 6 and 12% during harvest.

Figure 4. Part of the initial production lost or wasted at different stages of the FSC for root and tuber crops in different region

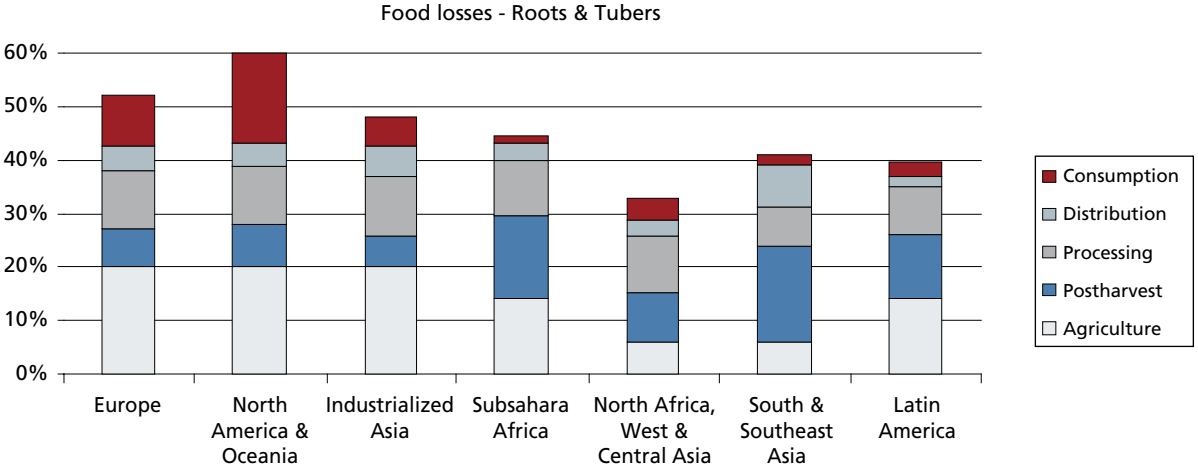
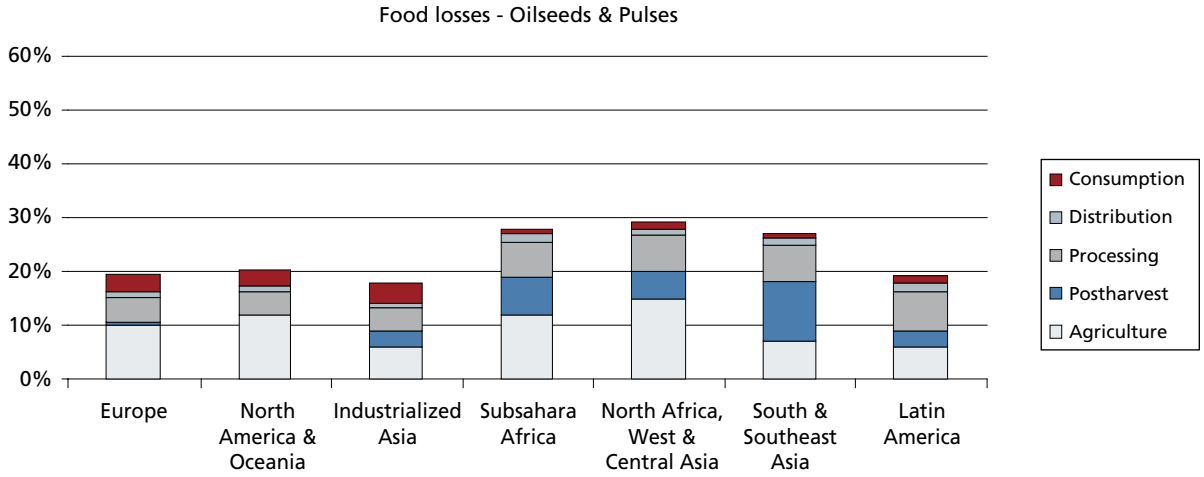


Figure 5. Part of the initial production lost or wasted at different stages in the FSC for oilseeds and pulses in different regions



Groundnut is a dominant oil crop in SSA; soybean and olives in North America, West and Central Asia; soybean and coconut in South and Southeast Asia and soybean in Latin America. Losses in these regions are largest in agricultural production and during postharvest handling and storage. This is, however, also due to the fact that oil crops in the distribution and consumption stages are mainly consumed as vegetable oils, products which are wasted relatively little compared to fresh products.

In the *fruits and vegetables* commodity group (Figure 6), losses in agricultural production dominate for all three industrialized regions, mostly due to postharvest fruit and vegetable grading caused by quality standards set by retailers. Waste at the end of the FSC is also substantial in all three regions, with 15-30% of purchases by mass discarded by consumers.

In developing regions losses in agricultural production dominate total losses throughout the FSC. Losses during postharvest and distribution stages are also severe, which can be explained by deterioration of

Figure 6. Part of the initial production lost or wasted at different stages of the FSC for fruits and vegetables in different regions

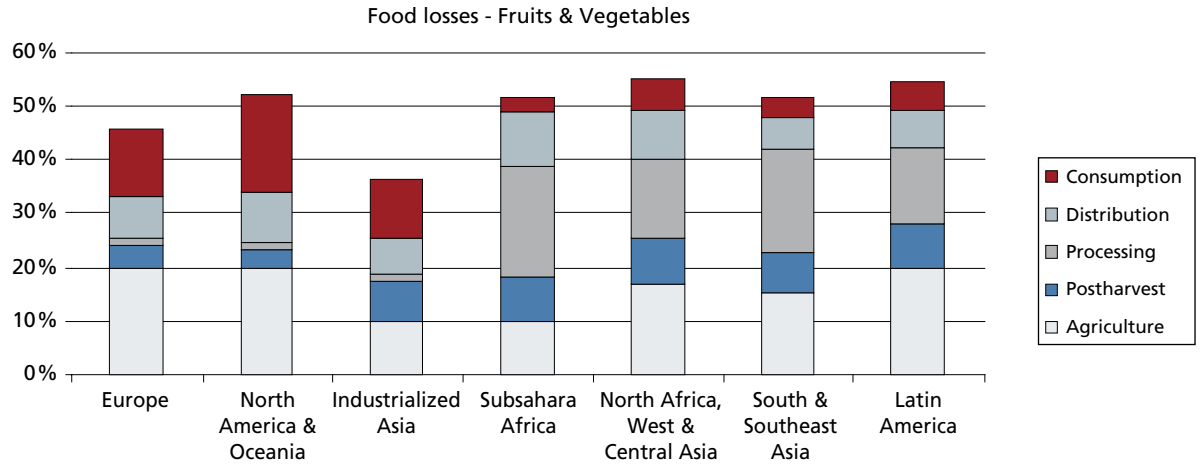
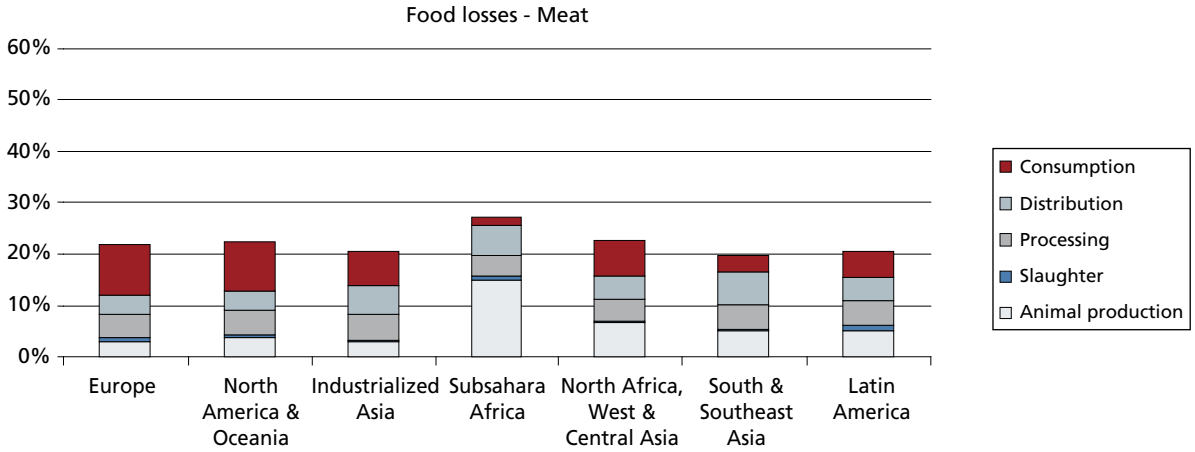


Figure 7. Part of the initial production lost or wasted for meat products at different stages in the FSC in different regions

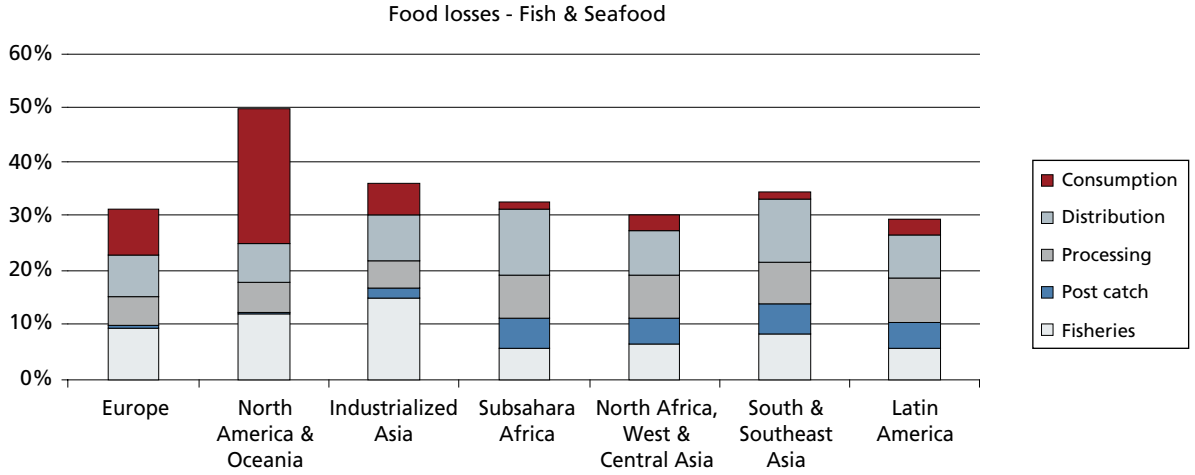


perishable crops in the warm and humid climate of many developing countries as well as by seasonality that leads to unsaleable gluts.

In the case of *meat and meat products* (Figure 7): losses and waste in industrialized regions are most severe at the end of the FSC, explained by a high per capita meat consumption combined with large waste proportions by retailers and consumers, especially in Europe and the U.S. Waste at the consumption level makes up approximately half of total meat losses and waste. The relatively low levels of waste during agricultural production and postharvest handling and storage can be explained by relatively low losses due to animal mortality during breeding and transportation to slaughter.

Losses in all developing regions are distributed quite equally throughout the FSC, but notable is the relatively high losses in agricultural production in SSA. This is explained by high animal mortality, caused by frequent diseases (e.g. pneumonia, digestive diseases and parasites) in livestock breeding.

Figure 8. Part of the initial catchings (fish and seafood harvested) discarded, lost and wasted in different regions and at different stages in the FSC



Box 1. Snapshot case: fish discards

Fish discards as potential human consumption

Discards, the proportion of total catch that is returned to the sea (in most case dead, dying or badly damaged), represent a significant part of the world's marine catches and is generally considered a wasteful misuse of marine resources. The first global assessment was published in 1994 and it identified a total discard of 27 million ton (Alverson *et al*., 1994). The latest global study conducted by FAO in 2005 suggests that discard have dropped to 7.3 million but the figures are not totally comparable. Even if the first was overestimated and the latter underestimated, reductions seem to have been significant. The latest assessment corresponds to a weighted global discard ratio of 8%. However, large variations among fishing methods and regions exist (Kelleher, 2005).

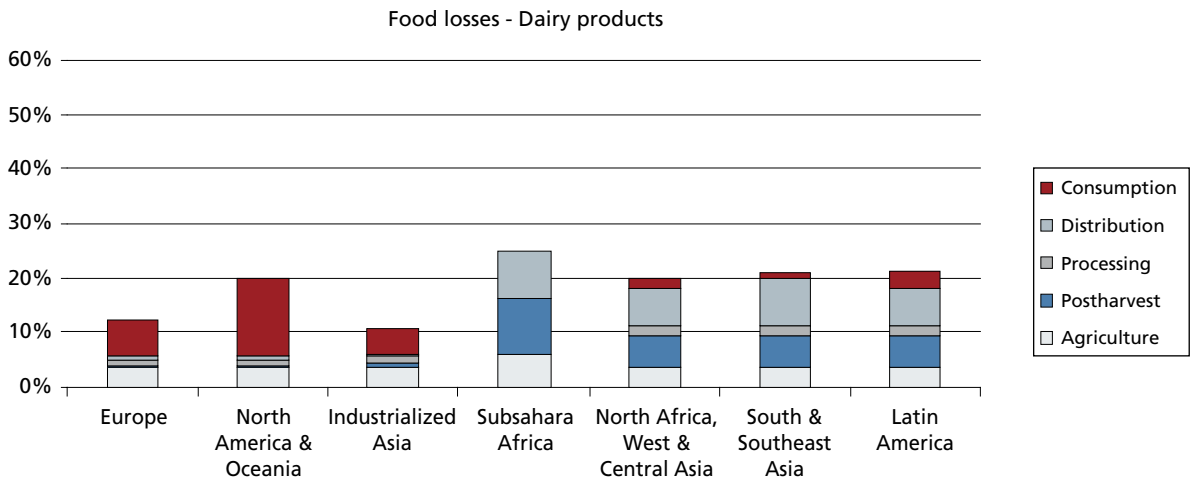
For all three industrialized regions, losses in primary *fish and seafood* (Figure 8) production are significant due to discard rates of between 9-15% of marine catches. A large proportion of purchased fish and seafood is also wasted by consumer households.

In developing countries, losses in primary production mostly depend on discard rates between 6-8% of marine catches. High losses at the distribution level can be explained by high levels of deterioration occurring during fresh fish and seafood distribution.

For *milk* (Figure 9): waste at the consumption level makes up approximately 40-65% of total food waste in all three industrialized regions. Losses in agricultural production are significant since dairy cow illness (mostly mastitis infections) causes an approximate 3-4% decrease in milk yield.

For all developing regions, waste of milk during postharvest handling and storage, as well as at the distribution level, is relatively high.

Figure 9. Part of the initial milk and diary production lost or waisted for each region at different stages in the FSC



4. Causes and prevention of food losses and waste

Food is wasted throughout the FSC, from initial agricultural production down to final household consumption. In medium- and high-income countries food is to a high extent wasted, meaning that it is thrown away, even if it is still suitable for human consumption. Significant food loss and waste do, however, also occur earlier in the food supply chain. In low-income countries food is mostly lost during the production-to-processing stages of the food supply chain.

In industrialized countries food gets lost when production exceeds demand. In order to ensure delivery of agreed quantities while anticipating unpredictable bad weather or pest attacks, farmers sometimes make production plans on the safe side, and end-up producing larger quantities than needed, even if conditions are "average". In the case of having produced more than required, some surplus crops are sold to processors or as animal feed. However, this is often not financially profitable considering lower prices in these sectors compared to those from retailers.

***Prevention**: Communication and cooperation between farmers.* Cooperation among farmers could reduce risk of overproduction by allowing surplus crops from one farm to solve a shortage of crops on another (Stuart, 2009).

In developing countries and, sometimes, developed countries, food may be lost due to premature harvesting. Poor farmers sometimes harvest crops too early due to food deficiency or the desperate need for cash during the second half of the agricultural season. In this way, the food incurs a loss in nutritional and economic value, and may get wasted if it is not suitable for consumption.

***Prevention:** Organizing small farmers and diversifying and upscaling their production and marketing.* Small resource-poor farmers can be organized in groups to produce a variety of significant quantities of cash crops or animals. In this way they can receive credit from agricultural financial institutions or advance payments from buyers of the produce.

Box 2. Snapshot case: *appearance quality* standards

Carrot quality standards, by the supermarket chain Asda

As research for the book 'Waste – understanding the global food scandal' (2009), Tristram Stuart visited several British farms in order to understand how quality standards affect the level of food waste. Among others, Stuart visited M.H. Poskitt Carrots in Yorkshire, a major supplier to the supermarket chain Asda. At the farm, the author was shown large quantities of out-graded carrots, which, having a slight bend, were sent off as animal feed. In the packing house, all carrots passed through photographic sensor machines, searching for aesthetic defects. Carrots that were not bright orange, had a blend or blemish or were broken were swept off into a livestock feed container. As staff at the farm put it: "Asda insist that all carrots should be straight, so customers can peel the full length in one easy stroke" (Stuart, 2009). In total, 25-30% of all carrots handled by M.H. Poskitt Carrots were out-graded. About half of these were rejected due to physical or aesthetic defects, such as being the wrong shape or size; being broken or having a cleft or a blemish.

High 'appearance quality standards' from supermarkets for fresh products lead to food waste. Some produce is rejected by supermarkets at the farm gate due to rigorous quality standards concerning weight, size, shape and appearance of crops. Therefore, large portions of crops never leave the farms. Even though some rejected crops are used as animal feed, the quality standards might divert food originally aimed for human consumption to other uses (Stuart, 2009).

Prevention: *Consumer surveys by supermarkets.* Supermarkets seem convinced that consumers will not buy food which has the 'wrong' weight, size or appearance. Surveys do however show that consumers are willing to buy heterogeneous produce as long as the taste is not affected (Stuart, 2009). Consumers have the power to influence the quality standards. This could be done by questioning them and offering them a broader quality range of products in the retail stores.

Prevention: *Sales closer to consumers.* Selling farm crops closer to consumers without having to pass the strict quality standards set up by supermarkets on weight, size and appearance would possibly reduce the amount of rejected crops. This could be achieved through, e.g., farmers markets and farm shops (Stuart, 2009).

Poor storage facilities and lack of infrastructure cause postharvest food losses in developing countries. Fresh products like fruits, vegetables, meat and fish straight from the farm or after the catch can be spoilt in hot climates due to lack of infrastructure for transportation, storage, cooling and markets (Rolle, 2006; Stuart, 2009).

Prevention: *investment in infrastructure and transportation.* Governments should improve the infrastructure for roads, energy and markets. Subsequently, private sector investments can improve storage and cold chain facilities as well as transportation (Choudhury, 2006).

Unsafe food is not fit for human consumption and therefore is wasted. Failure to comply with minimum food safety standards can lead to food losses and, in extreme cases, impact on the food security status of a country. A range of factors can lead to food being unsafe, such as naturally occurring toxins in food itself, contaminated water, unsafe use of pesticides, and veterinary drug residues. Poor and unhygienic handling and storage conditions, and lack of adequate temperature control, can also cause unsafe food.

Prevention: *develop knowledge and capacity of food chain operators to apply safe food handling practices.* Food chain operators should be skilled and knowledgeable in how to produce safe food. Foods need to

Box 3. Snapshot case: poor postharvest facilities

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Lack of facilities for rice threshing, drying and winnowing, Tajikistan

A farmer winnowing rice in Tursunzade, Tajikistan in 2010. Sun drying exposes rice to rodents and parasites, which may eat or damage the harvested crops. Proper storage facilities are also important in order to reduce the amounts of food lost during postharvest handling and storage.

Box 4. Snapshot case: food safety at risk

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Rickshaws transporting milk in Bangladesh
Rickshaws transporting milk from the countryside to processing plants in Baghabarighat, Bangladesh. Transporting milk in the warm and humid climate of Bangladesh without a proper cold chain may cause milk losses. The rickshaw transportation on narrow and winding roads prolongs the time milk is handled in warm temperatures.

be produced, handled and stored in accordance with food safety standards. This requires the application of good agricultural and good hygienic practices by all food chain operators to ensure that the final food protects the consumer.

'Disposing is cheaper than using or re-using' attitude in industrialized countries leads to food waste. Industrialized food processing lines often carry out trimming to ensure the end product is in the right shape and size. Trimmings, in some cases, could be used for human consumption but are usually disposed of. Food is also lost during processing because of spoilage down the production line. Errors during processing lead to final products with the wrong weight, shape or appearance, or damaged packaging, without affecting the safety, taste or nutritional value of the food. In a standardized production line these products often end up being discarded (Stuart, 2009; SEPA, 2008).

Prevention: *develop markets for 'sub-standard' products.* Both commercial and charity organizations could arrange for the collection and sale or use of discarded 'sub-standard' products that are still safe and of good taste and nutritional value (SEPA 2008).

Box 5. Snapshot case: disposing is cheaper than using or re-using

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French fries production in The Netherlands
During his thesis, D. Somsen interviewed a Dutch french fries producer to better understand the causes of food waste in the french fries production line (Somsen, 2004). The company reported several steps in the production line where raw material was lost and wasted, e.g. during the size reduction in which potatoes are cut into strips. French fries are fragile and easily break when transported during processing as well as when packaged. The unwanted products are sorted out and occasionally end up wasted. In addition to this, some potatoes are sorted out prior to entering the factory, due to damage during loading, transport from producer to factory and/or during storage.

Box 6. Snapshot case: poor market facilities

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Central wholesale market in Pakistan
Central wholesale market in Lahore, Pakistan. These bananas are traded among unsanitary conditions, causing major health hazards since food is handled and piled on the ground close to the gutter. This kind of market environment also causes food waste, since the unsanitary conditions and rough handling cause deterioration of fragile fresh products.

Lack of processing facilities causes high food losses in developing countries. In many situations the food processing industry doesn't have the capacity to process and preserve fresh farm produce to be able to meet the demand. Part of the problem stems from the seasonality of production and the cost of investing in processing facilities that will not be used year-round.

Prevention: *develop contract farming linkages between processors and farmer.* Governments should create a better 'enabling environment' and investment climate, to stimulate the private sector to invest in the food industry and to work more closely with farmers to address supply issues.

Large quantities on display and a wide range of products/ brands in supply lead to food waste in industrialized countries. Retail stores need to order a variety of food types and brands from the same manufacturer to get beneficial prices. Consumers also expect a wide range of products to be available in stores. A wide range of products does, however, increase the likelihood of some of them reaching their "sell-by" date before being sold, and thereby wasted. When shopping, consumers expect store shelves to be well filled. Although certainly beneficial for sales statistics, continually replenished supplies mean that food products close to expiry are often ignored by consumers. This is particularly difficult for small retail stores (SEPA, 2008).

Inadequate market systems cause high food losses in developing countries. To minimize losses, the commodities produced by farmers need to reach the consumers in an efficient way. There are too few wholesale, supermarket and retail facilities providing suitable storage and sales conditions for food products. Wholesale and retail markets in developing countries are often small, overcrowded, unsanitary and lacking cooling equipment (Kader, 2005).

Prevention: *Marketing cooperatives and improved market facilities.* Marketing cooperatives are organizations providing a central point for assembling produce from small farmers and preparing commodities for transportation to markets and other distribution channels. The marketing cooperatives should be able to reduce food losses by increasing the efficiency of these activities. Although the development of wholesale and retail markets should preferably be done by the private sector, local governments and marketing cooperatives can be instrumental in establishing and improving market facilities (Kader, 2005).

Food wasted at consumer level is minimal in developing countries. Poverty and limited household income make it unacceptable to waste food. A contributing factor is that consumers in developing countries generally buy smaller amounts of food products at the time, often just enough for meals on the day of purchase.

Box 7. Snapshot case: public awareness raising

Voluntary initiatives
'Stop Wasting Food' in Denmark give guidance to consumers on how to avoid wasting food by shopping according to daily needs of households, and promotes better household planning and shopping patterns in order to encourage a movement away from impulsive to rational food shopping and consumption patterns

In the UK, the Waste Reduction Action Plan (WRAP) encourages leading retailers, brand owners and their supply chains to identify collaborative approaches towards reducing the amount of food and packaging waste that ends up in the household bin and ultimately in landfill. WRAP aims at reducing packaging waste and consumer food waste by carrying out R&D work, by guidance on best practices and by promotion. WRAP partners with packaging manufacturers, retailers, brands, suppliers, research institutes, universities, design agencies and environmental and design consultants.

Abundance and consumer attitudes lead to high food waste in industrialized countries. Perhaps one of the most important reasons for food waste at the consumption level in rich countries is that people simply can afford to waste food. The amount of available food per person in retail stores and restaurants has increased during the last decades in both the USA and the EU. A lot of restaurants serve buffets at fixed prices, which encourages people to fill their plates with more food than they can actually eat. Retail stores offer large packages and "getting one for free" bargains. Likewise, food manufactures produce oversized ready to eat meals (Stuart, 2009).

Prevention: *Public awareness.* Education on these matters in schools and political initiatives are possible starting points to change people's attitudes towards the current massive food waste.

5. Conclusions

This study has compiled and analyzed a magnitude of data and reports on food losses and waste. Waste levels and waste volumes in each step of the food supply chain were estimated. Causes of and possible ways to prevent food losses and waste in each step of the food supply chain were reported.

Due to lack of sufficient data, many assumptions on food waste levels at foremost the distribution and consumption levels had to be made. Therefore, the results in this study must be interpreted with great caution.

The studies first reveal the major data gaps in available knowledge of global food waste, especially with regard to the quantification of food losses by individual cause, and the cost of food loss prevention. And when data are available, they are often accompanied with major uncertainties.

Further research in the area is urgent, especially considering that food security is a major concern in large parts of the developing world.

While increasing primary food production is paramount to meet the future increase in final demand, tensions between production and access to food can also be reduced by tapping into the potential to reduce food losses. Efficient solutions exist along the whole food chain, for reducing total amounts of food lost and wasted. Actions should not only be directed towards isolated parts of the chain, since what is done (or not done) in one part has effects in others. In low income countries, measures should foremost have a producer perspective, e.g. by improving harvest techniques, farmer education, storage facilities and cooling chains. In industrialized countries on the other hand, solutions at producer and industrial level would only be marginal if consumers continue to waste at current levels. Consumer households need to be informed and change the behavior which causes the current high levels of food waste.

Another point to be stressed is that the food supply chain of today is more and more globalized. Certain food items are produced, transformed and consumed in very different parts of the world. The impact of growing international trade on food losses still has to be better assessed.

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Annex 1. Grouping of world regions

Countries included in world regions 1-3 – Medium/High-income countries.

Region 1: Europe		
Albania	France	Netherlands
Armenia	Georgia	Norway
Austria	Germany	Poland
Azerbaijan	Greece	Portugal
Belarus	Hungary	Romania
Belgium	Iceland	Russian Federation
Bosnia & Herzegovina	Ireland	Serbia
Bulgaria	Italy	Slovakia
Croatia	Latvia	Slovenia
Cyprus	Lithuania	Spain
Czech Republic	Luxemburg	Sweden
Denmark	Macedonia	Switzerland
Estonia	Moldova	Ukraine
Finland	Montenegro	United Kingdom

Region 2: USA, Canada, Oceania	Region 3: Industrialized Asia
Australia	Japan
Canada	China
New Zealand	South Korea
United States of America	

Countries included in world regions 4-7 – Low-income countries.

Region 4 sub-Saharan Africa		Region 5 North Africa, West and Central Asia	Region 6 South and Southeast Asia	Region 7 Latin America
Angola	Liberia	Algeria	Afghanistan	Argentina
Benin	Malawi	Egypt	Bangladesh	Belize
Botswana	Mali	Iraq	Bhutan	Bolivia
Burkina Faso	Mauritania	Israel	Cambodia	Brazil
Burundi	Mozambique	Jordan	India	Chile
Cameroon	Namibia	Kazakhstan	Indonesia	Colombia
Central African Rep	Niger	Kuwait	Iran	Costa Rica
Chad	Nigeria	Kyrgyzstan	Laos	Cuba
Congo-Brazzaville	Rwanda	Lebanon	Malaysia	Dominican Rep
Congo-Kinshasa	Senegal	Libya	Myanmar	Ecuador
Cote d'Ivoire	Sierra Leone	Mongolia	Nepal	El Salvador
Equatorial Guinea	Somalia	Morocco	Pakistan	Guatemala
Eritrea	South Africa	Oman	Philippines	Guyana
Ethiopia	Sudan	Saudi Arabia	Sri Lanka	Haiti
Gabon	Swaziland	Syria	Thailand	Honduras
Gambia	Tanzania	Tajikistan	Vietnam	Jamaica
Ghana	Togo	Tunisia		Mexico
Guinea	Uganda	Turkey		Nicaragua
Guinea-Bissau	Zambia	Turkmenistan		Panama
Kenya	Zimbabwe	Utd Arab Emirates		Paraguay
Lesotho		Uzbekistan		Peru
		Yemen		Suriname
				Uruguay
				Venezuela

Annex 2. Commodity groups

The different commodities addressed are grouped according to FAOSTAT's Food Balance Sheets (http://www.fao.org/corp/statistics/en/):

1. Cereals (excluding beer): wheat, rice (milled), barley, maize, rye, oats, millet, sorghum, other cereals.
2. Roots and Tubers: potatoes, sweet potatoes, cassava, yams, other roots.
3. Oilseeds and Pulses (including nuts): soybeans, groundnuts (shelled), sunflower seeds, rape and mustard seed, cottonseed, coconuts (incl. copra), sesame seed, palm kernels, olives, other oil crops.
4. Fruit and Vegetables (including bananas): oranges and mandarins, lemons and limes, grapefruit, other citrus, bananas, plantains, apples (excl. cider), pineapples, dates, grapes (excl. wine), other fruit, tomatoes, onions, other vegetables.
5. Meat: bovine meat, mutton/goat meat, pig meat, poultry meat, other meat, offals.
6. Fish and seafood: freshwater fish, demersal fish, pelagic fish, other marine fish, crustaceans, other mollusk, cephalopods, other aquatic products, aquatic mammal meat, other aquatic animals, aquatic plants.
7. Dairy products: milk.

Annex 3. Additional references for quantifying food losses/waste

NB.: Conversion factor determines the part of the agricultural product that is edible.
Allocation factor determines the part of the agricultural produce that is allocated for human consumption.
LIC: low-income countries; MHIC: medium/high income countries; FBS: food balance sheets.

Cereals:
*Conversion factors: w*heat, rye = 0.78; maize, millet, sorghum =0.79 (LIC), =0.69 (MHIC); rice = 1; oats, barley, other cereals = 0.78. Source: Wirsenius (2000)

Allocation factors for losses during agricultural production and postharvest handling and storage:
Europe = 0.35; NA&Oce = 0.50; Ind. Asia = 0.60; SSA = 0.75; NA,WA&CA = 0.60; S&SE Asia = 0.67; LA = 0.40.

Roots & Tubers:
Proportion of roots and tubers utilized fresh:
Assumed average proportion of cassava utilized fresh in SSA = 50%. Source: Westby (2002). In LA = 20%. Source: Brabet (1998).

Assumed average proportion of potato utilized fresh in Europe and NA&Oce = 27%. Source: USDA (2010b). In NA,WA&CA = 81%. Source: Potatoes South Africa (2010). In S&SE Asia = 90%. Source: Pendey (2009) and Keijbets (2008). In Ind. Asia = 85%. Source: Keijbets (2008) and FAOSTAT (2010a).

Conversion factors: Peeling by hand = 0.74; Industrial peeling = 0.90. Source: UNICEF (1990), Mattsson (2001).

Oil crops & pulses:
Allocation factors: SSA = 0.63; NA,WA&CA = 0.12; S&SE Asia = 0.63; LA = 0.12 ; Europe = 0.20; NA&Oce = 0.17; Ind. Asia = 0.24. Source: FAOSTAT (2010d)

Fruit & Vegetables:
Proportion of fruit and vegetables utilized fresh:
Assumed average proportion of fruit & vegetables utilized fresh in SSA = 99%. Source: Mungai (2000). In NA,WA&CA = 50%. Source: Guajardo (2008). In S&SE Asia = 95%. Source: FAO (undated). In LA = 50%. Source: Guajardo (2008). In Europe and NA&Oce = 40%. Source: USDA (2010c). In Ind. Asia = 96%. Source: Cheng (2008)

Conversion factors: peeling by hand = 0.8; industrial peeling = 0.75; mean = 0.77. Source: own investigation and UNIDO (2004c)

Fish & Seafood:
Proportion of fish and seafood utilized fresh:
Assumed average proportion of fish & seafood utilized fresh in LIC = 60%; in MHIC = 4 %. Source: FAO (2009)

Conversion factor: Average conversion factor for fish & seafood = 0.5. Source: FAO (1989).

Annex 4. Weight percentages of food losses and waste (in percentage of what enters each step)

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **Europe incl. Russia**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution: Supermarket Retail	Consumption
Cereals	2%	4%	0.5%, 10%	2%	25%
Roots & Tubers	20%	9%	15%	7%	17%
Oilseeds & Pulses	10%	1%	5%	1%	4%
Fruit & Vegetables	20%	5%	2%	10%	19%
Meat	3.1%	0.7%	5%	4%	11%
Fish & Seafood	9.4%	0.5%	6%	9%	11%
Milk	3.5%	0.5%	1.2%	0.5%	7%

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **North America & Oceania**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution: Supermarket Retail	Consumption
Cereals	2%	2%	0.5%, 10%	2%	27%
Roots & Tubers	20%	10%	15%	7%	30%
Oilseeds & Pulses	12%	0%	5%	1%	4%
Fruit & Vegetables	20%	4%	2%	12%	28%
Meat	3.5%	1.0%	5%	4%	11%
Fish & Seafood	12%	0.5%	6%	9%	33%
Milk	3.5%	0.5%	1.2%	0.5%	15%

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **Industrialized Asia**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	2%	10%	0.5%, 10%	2%	20%
Roots & Tubers	20%	7%	15%	9%	10%
Oilseeds & Pulses	6%	3%	5%	1%	4%
Fruit & Vegetables	10%	8%	2%	8%	15%
Meat	2.9%	0.6%	5%	6%	8%
Fish & Seafood	15%	2%	6%	11%	8%
Milk	3.5%	1%	1.2%	0.5%	5%

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **sub-Saharan Africa**.

	Agricultural Production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	6%	8%	3.5%	2%	1%
Roots & Tubers	14%	18%	15%	5%	2%
Oilseeds & Pulses	12%	8%	8%	2%	1%
Fruits & Vegetables	10%	9%	25%	17%	5%
Meat	15%	0.7%	5%	7%	2%
Fish & Seafood	5.7%	6%	9%	15%	2%
Milk	6%	11%	0.1%	10%	0.1%

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **North Africa, West&Central Asia**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	6%	8%	2%, 7%	4%	12%
Roots & Tubers	6%	10%	12%	4%	6%
Oilseeds & Pulses	15%	6%	8%	2%	2%
Fruits & Vegetables	17%	10%	20%	15%	12%
Meat	6.6%	0.2%	5%	5%	8%
Fish & Seafood	6.6%	5%	9%	10%	4%
Milk	3.5%	6%	2%	8%	2%

Estimated/assumed waste percentages for each commodity group in each step of the FSC for **South & Southeast Asia**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption
Cereals	6%	7%	3.5%	2%	3%
Roots & Tubers	6%	19%	10%	11%	3%
Oilseeds & Pulses	7%	12%	8%	2%	1%
Fruits & Vegetables	15%	9%	25%	10%	7%
Meat	5.1%	0.3%	5%	7%	4%
Fish & Seafood	8.2%	6%	9%	15%	2%
Milk	3.5%	6%	2%	10%	1%

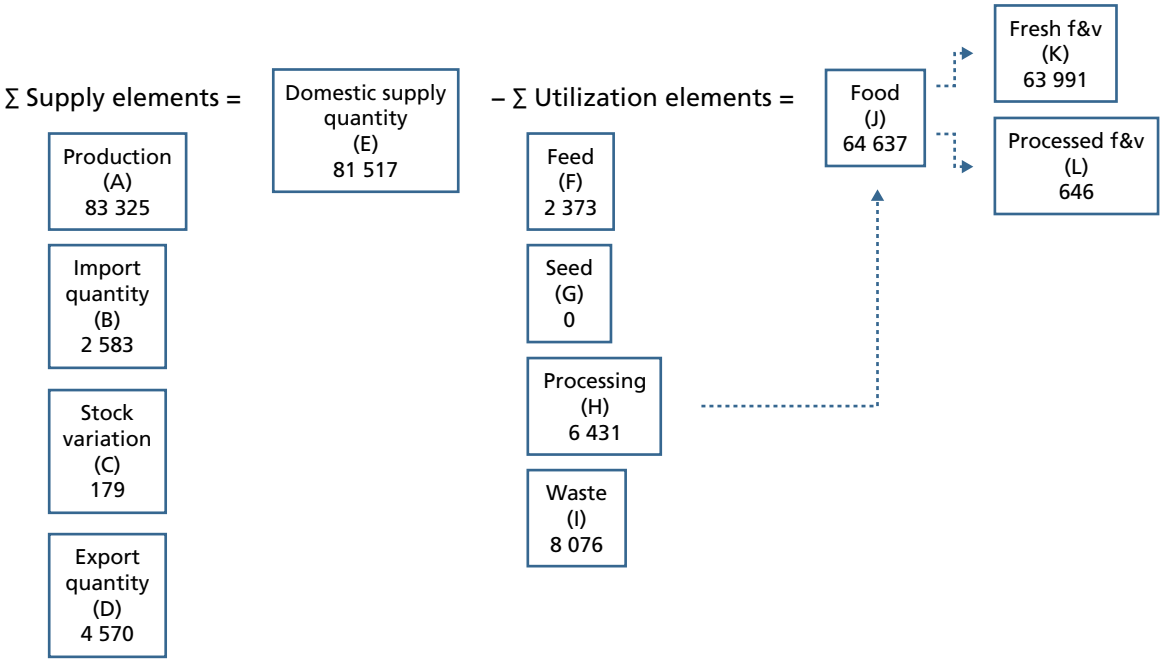
Estimated/assumed waste percentages for each commodity group in each step of the FSC for **Latin America**.

	Agricultural production	Postharvest handling and storage	Processing and packaging	Distribution	Consumption at household level
Cereals	6%	4%	2%, 7%	4%	10%
Roots & Tubers	14%	14%	12%	3%	4%
Oilseeds & Pulses	6%	3%	8%	2%	2%
Fruits & Vegetables	20%	10%	20%	12%	10%
Meat	5.3%	1.1%	5%	5%	6%
Fish & Seafood	5.7%	5%	9%	10%	4%
Milk	3.5%	6%	2%	8%	4%

Annex 5. Example of calculations of food losses and waste

Example: Calculations on losses and waste of fruit and vegetables (F&V) in SSA. The figure below shows the mass flow of total F&V (1000 tons), as presented in the 2007 FBSs for SSA.

Figure 10. Mass flow of total F&V (1000 tons) as presented in the 2007 FBSs for SSA



A+B+C-D=E-(F+G+H+I) = J=K+L

Waste percentage in each step of the FSC:
Agricultural production = 10%
Postharvest handling and storage = 9%
Processing and packaging = 25%
Distribution (fresh F&V) = 17%
Distribution (processed F&V) = 10%
Consumption (fresh F&V) = 5%
Consumption (processed F&V) = 1%

Calculations on primary equivalent F&V losses and waste in each step of the FSC:
Agricultural production: (0.1/(1-0.1))*83 325 = 9 258 = 9.3 mn tonnes
Postharvest handling and storage: 0.09*83 325 = 7 817 = 7.8 mn tonnes
Processing and packaging = 0.25*(646+6 431) = 1 769 = 1.8 mn tonnes
Distribution (fresh F&V): 0.17*63 991 = 10 878 = 11 mn tonnes
Distribution (processed F&V): 0.1*(646+6 431-1 769) = 531 = 0.5 mn tonnes
Consumption (fresh F&V): 0.05*(63 991-10 878) = 2 656 = 2.7 mn tonnes
Consumption (processed F&V): 0.01*(646+6 431-1 769-531) = 48 = 0.05 mn tonnes
Conversion factors: peeling by hand = 0.8; industrial peeling = 0.75; mean = 0.77

Calculations on edible F&V losses and waste in each step of the FSC:
Agricultural production: 9 258*0.77 = 7 129 = 7.1 mn tonnes
Postharvest handling and storage: 7 817*0.77 = 6 019 = 6.0 mn tonnes
Processing and packaging: 1 769*0.75 = 1 327 = 1.3 mn tonnes
Distribution: (10 878*0.8)+(531*0.75) = 9 101 = 9.1 mn tonnes
Consumption: (2 656*0.8)+(48*0.75) = 2 161 = 2.1 mn tonnes

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