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'Mind the Gap': Reducing Waste and Losses in the Food Supply Chain

One oft-neglected strategy to improve food availability is the simple act of reducing waste. Inefficiencies across the entire food supply chain – from 'farm to fork' – result in significant food losses in both developing and developed countries. As much as 30 per cent of all food grown worldwide may be lost or wasted before and after it reaches the consumer. Reducing such waste could help moderate the amount of increase in food production that is needed to meet growing food demand, which would alleviate the pressure on resources and help lower greenhouse gas emissions. This NTS Insight argues that, given its significant direct and indirect benefits, the reducing of food waste warrants urgent attention from policymakers, the private sector and non-governmental actors.

By Margarita Escaler and Paul Teng.

Food losses and waste in fresh vegetables at a wholesale market outside Kunming, Yunnan Province, China.

Credit: Paul Teng, NTU/NIE.

Introduction

Feeding a projected population of 9 billion people sustainably and equitably by 2050 will be an unprecedented challenge for humankind and will require a multifaceted and integrated global strategy. The strategy of increasing food production is only one among many needed to meet this challenge. One simple, achievable, but often overlooked, way of improving food availability is through reducing food waste. Inefficiencies across the entire food supply chain – from 'farm to fork' – result in significant food losses in both developing and developed countries that could otherwise help relieve some of the pressure to intensify agriculture. Estimates suggest that as much as 30 per cent of all food grown worldwide may be lost or wasted before and after it

Food Security 2011 (ICAFS).

reaches the consumer. Some have even placed the figure as high as 50 per cent (Lundqvist et al., 2008).

A recent UK-government commissioned report projects that if the current global estimate of 30 per cent waste is assumed, halving the total amount of waste by 2050, which is considered to be a realistic target, could reduce the food required by 2050 by an amount approximately equal to 25 per cent of today's production (Foresight, 2011). This would lessen the pressure on the resources required for food production. It would also have positive environmental effects, including lower greenhouse gas emissions, reduced water stress and decreased levels of soil degradation. With food waste reduction offering such important direct and indirect benefits, it has to be given priority and urgent attention by governments, the donor community, the private sector and non-governmental organisations (NGOs).

This NTS Insight looks at the causes of food waste, focusing on post-harvest losses, and examines the drivers of food losses in developing, transitional and developed countries. The trends influencing post-harvest losses – urbanisation, changing consumption patterns and the globalisation of trade – are also discussed. Then, drawing on the analysis of food-waste causes and trends and on examples of successful projects around the world, this NTS Insight suggests some strategies for reducing food waste that may be pursued by governments, the private sector as well as non-governmental entities.

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Food Losses in the Food Supply Chain

Food loss or waste is generally defined as: edible material intended for human consumption, arising at any point in the food supply chain that is instead discarded, lost, degraded or consumed by pests between harvest and reaching the consumer (FAO, 1981). Food is lost or wasted at all stages of the food chain, from production on the farm or pond, to the food being served on a plate, and the causes of the losses are varied (see Table 1).

Unfortunately, the accurate quantification of food waste remains a challenge. There is a dearth of data on food waste at all stages of the food supply chain; and estimates from diverse systems and during different growing seasons vary widely (Foresight, 2011). Agricultural systems and their associated food supply chains contain many intervening human variables that cannot be easily controlled for in research design, as well as external factors that may influence loss estimates (Parfitt and Barthel, 2010). Modern food supply chains in higher income countries lend themselves more readily to analysis than those in developing countries. This is because in low income countries, the nature of their food supply chains is less formal, and thus harder to define.

Table 1: Causes and characteristics of food waste or losses at different points of the food supply chain.

Stage	Causes and characteristics of food waste and losses
Production / Pre-harvest	• Poor cultural practices. • Poor choice of crop varieties. • Pest and disease damage. • Ecological and soil conditions. • Poor water management. • Physiological and mechanical damage.
Harvesting	• Edible crops are left in the field, ploughed into the soil and/or eaten by birds/rodents. • Timing of harvest is not optimal. • Poor harvesting technique. • Out-grades at farm to improve quality of produce or meet quality standards.
Threshing	• Poor technique.
Drying Transport, distribution	• Poor transport infrastructure. • Spoiling/bruising.
Storage	• Pest and disease. • Spillage. • Contamination. • Natural drying out of food.

Processing	• Physical, mechanical or physiological damage. • Inefficiencies. • Poorly trained workers. • Inappropriate technologies.
Product Evaluation quality control	• Product discarded due to out-grades in the supply chain. • Destructive testing.
Packaging weighing, labelling, sealing	• Inappropriate or poorly sealed packaging. • Grain spillage from sacks. • Attack by rodents.
Marketing	• Damage and spoilage during transport. • Poor handling in wet market. • Lack of cooling or cold storage facilities.
Consumer over- or inappropriate purchasing, storage, preparation, portioning, cooking	• Buying more than is needed. • Plate scrapings, and surplus food which has been cooked and not used. • Poor storage or stock management in the home. • Poor food preparation techniques. • Food is discarded in packaging due to confusion over 'best before' and 'use by' dates.
End of Life disposal of food waste	• Food waste that is discarded may be separately treated, fed to livestock/poultry, or mixed with other wastes and landfilled.

Source: Adapted from Parfitt and Barthel (2010).

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Pre-harvest Losses

Pre-harvest losses may be caused by both abiotic (e.g., water, temperature, soil nutrients) and biotic (e.g., weeds; animal pests; pathogens such as fungi, bacteria and viruses) factors leading to reduced crop performance and thus lower actual yield than the site-specific attainable yield.[1] To date, most of the comprehensive studies on pre-harvest losses have focused on crop losses due to biotic factors. Oerke (2006) provides estimates for the potential and actual losses for wheat, rice, maize, potato, soybean and cotton between 2001 and 2003 for 19 regions as well as the global total. The total global potential loss due to pests varied from about 50 per cent for wheat to more than 80 per cent for cotton. On the other hand, actual losses were estimated to be 26 to 29 per cent for soybean, wheat and cotton; and 31, 37 and 40 per cent for maize, rice and potatoes respectively. Overall, weeds caused the highest potential loss (34 per cent), with animal pests and pathogens being less important (losses of 18 and 16 per cent respectively) although regional differences were evident due to cropping intensity, climatic conditions and cropping systems. In tropical and subtropical areas, high temperatures and heavy rainfall often favour the development of pests. Similarly, an increased site-specific yield potential of crops resulting from higher-yielding varieties, improved water and soil management, fertilisation and other cultivation techniques is often associated with higher vulnerability to pest attack, especially by fungal pathogens which favour high-plant-density environments and nutrient-rich plant tissue (Oerke, 2006). Studies have shown that it is possible to characterise typologies of potential losses based on the type of crop production system, thereby implying proactive interventions (Savary et al., 2006). While pre-harvest losses due to pests are of significant economic importance, the primary focus of this review is on post-harvest losses.

Post-harvest Losses in Developing Countries

In many low income countries, most of the rural poor rely on short food-supply chains with limited post-harvest infrastructure and technologies, resulting in substantial food losses after harvest. Something as simple as crop storage remains extremely inadequate in developing countries. While the Green Revolution in the 1960s and 1970s brought in new crop varieties, machinery, pesticides, fertilisers and other inputs that boosted yields dramatically, more basic innovations such as grain stores, drying equipment, fruit crates, cold storage and other essential post-harvest technologies were largely neglected.

The data available for rice post-harvest losses based on field surveys are quite extensive (they represent the 'best case' compared to data for other crops). Post-harvest loss estimates from selected Asian, African and South American countries typically range from 10 to 25 per

cent, with 13 to 15 per cent quoted as the Asian average. However, there has been a tendency to overestimate post-harvest grain losses in developing countries, due partly to taking extreme values rather than averages (Parfitt and Barthel, 2010).

The losses for perishable crops such as fresh fruit and vegetables are, by their nature, higher than for grains. Estimates for Egypt, Venezuela and a number of Asian countries typically range from 30 to 40 per cent (Foresight, 2011). Sri Lanka reportedly loses fruit and vegetables at an annual rate of 40 to 60 per cent, or 270,000 tonnes, an amount worth approximately USD100 million. It has been suggested that a significant proportion of this loss could be eliminated through relatively simple measures (WorldWatch Institute, 2011). India faces similar problems on a much larger scale. While India is one of the largest agricultural producers in the world, it has only a 1 to 1.5 per cent share of the global food trade and only processes around 2 per cent of its produce, compared to some developed countries that process 60 to 70 per cent. Estimates suggest that 35 to 40 per cent of India's fruit and vegetables go to waste, due mainly to the lack of cold chains, and poor harvesting techniques with loss implications for more extended supply chains. Globally, it has been estimated that approximately one-third of all fresh fruit and vegetables is lost before it reaches consumers (Kader, 2005).

Fish and shellfish are also highly perishable. Poor harvest techniques and post-harvest handling combined with a lack of cold storage result in significant loss in quality, or in some cases, complete spoilage. According to the Food and Agriculture Organization of the United Nations (FAO, 2005), post-harvest losses in small-scale fisheries can be among the highest in the entire food system, and spoilage losses alone are estimated at 10–12 million tonnes per year, about 10 per cent of total aquatic production.

Poor storage infrastructure can also have adverse effects on grain quality. In Zambia, one study found that 96 per cent of stored maize samples contained fumonisins, toxins produced by fungi (Kankolongo et al., 2009). A fifth of the samples also contained up to 10 times the government's recommended safe limit for aflatoxins, also produced by fungi. When consumed, aflatoxins can inhibit growth in children and livestock, and cause cancer. As high as 98 per cent of people in several African countries have aflatoxins in their blood, in concentrations sometimes many times higher than that allowed in the European Union and the US. This is caused almost exclusively by eating mouldy food (Kankolongo et al., 2009).

Improper storage after harvest can lead to the growth of toxin-producing fungi. The Fusarium fungus seen here produces a toxin known as fumonisin.

Credit: Thomas Lumpkin/CIMMYT.

Post-harvest Losses in Developed Countries

In contrast to low income countries where the majority of food losses generally occur on and near the farm, most food losses in higher income countries occur beyond the farm-gate, with greater amounts at the consumer than at the retail level. The widespread adoption of mechanisation and cold chain technologies and the presence of sound infrastructure have kept on-farm post-harvest losses lower than those in developing countries. For example, grain losses can be as low as 0.07 to 2.81 per cent in developed countries (Smil, 2004). However, post-harvest losses for perishable crops still occur in these countries. Losses in the US are estimated to be 2 to 23 per cent, depending on the commodity, with an overall average of 12 per cent (Kader, 2005). A tentative estimate from the UK suggests losses of 9 per cent but this does not take into consideration produce that might be left in the field after failing to meet cosmetic or quality criteria (Garnett, 2006).

Although the centralised processing of food, a feature of modern industrialised food supply chains, leads to better resource efficiency and less waste, losses at this level and at the retail level can still be substantial in high income countries. Approximately 22 per cent of the total UK food and drink waste of 16 million tonnes per year is associated with food processing, distribution and retail (Foresight, 2011). The food and drink manufacturing and processing sectors produce an estimated 20 per cent or 3.2 million tonnes of food waste per year. At the retail and distribution stage, losses are less at 2.6 per cent (0.37 million tonnes) of total food waste. In the US, the Department of Agriculture found that annual supermarket losses for 2005 and 2006 averaged 11.4 per cent for fresh fruit, 9.7 per cent for fresh vegetables, and 4.5 per cent for fresh meat, poultry and seafood (Buzby et al., 2009). In general, losses during food processing, distribution and retail consist of by-products and unsold prepared food products.

Food waste at the consumer, including household, level in developed countries has also seen significant growth over the years (Foresight, 2011). Due to food being relatively cheap in such countries, the proportion of disposable income spent on it has declined over the years, especially among the more affluent. The relatively low cost of food, a growing appetite for more perishable food items of high quality, and the trend for more modern, convenient lifestyles provide little incentive for people in high income countries to reduce food waste. Declining food preparation and handling skills and a poor understanding of 'best before' or 'use-by' dates applied to food products have also resulted in perfectly good food being thrown away.

The changes seen in the UK is a good example of the increasing scale of food waste as countries become more developed and affluent.

Studies before World War II showed that between 1 and 3 per cent of food was wasted in the home (Cathcart and Murray, 1939). This had grown to 6 per cent in 1982, depending on the season (Osner, 1982), and by 2008, as much as 25 per cent of purchased food was found to be wasted in the home (WRAP, 2009). In other high income countries, the scale of consumer food waste has been found to be similar. Studies have found household waste ranging from 8 to 11 per cent in the Netherlands; to 15 to 25 per cent in the US and Australia; and 26 to 27 per cent in South Korea (Kantor et al., 1997; Jones, 2005; Morgan, 2009; Yoon and Lim, 2005; Thönissen, 2009). In contrast to developing countries where food losses are likely to be overestimated, consumer food waste in high income countries is probably underestimated as food waste that is composted in the home, fed to pets or poured down the drain have been excluded.

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Water and Carbon Footprint of Food Waste

The nourishment and financial costs are not the only impacts of food waste. The water and energy used to grow and process foods are also wasted. Food is the number one reason for water use. According to a recent report by the UK's Waste & Resources Action Programme (WRAP) and the WWF, the water footprint of avoidable and possible avoidable food waste is 6,200 million cubic metres per year, representing nearly 6 per cent of all water requirements in the UK. In per capita terms, this is 243 litres per person per day, approximately one and a half times the daily average household water use in the UK (WRAP and WWF, 2011). The products with the largest share of the water footprint of UK household food waste are beef, cocoa products, rice, poultry and wheat. As a large part (71 per cent) of the avoidable food waste in the UK is from imported products, most of the 'virtual water' wasted occurs outside the UK.

The study also found that avoidable food waste is responsible for greenhouse gas emissions of 20 million tonnes carbon dioxide (CO_2) equivalent per year. Avoidable food waste represents approximately 3 per cent of the UK's domestic greenhouse gas emissions, with further emissions from overseas components of the supply chain. In contrast to the water footprint, approximately two-thirds of emissions associated with food waste occur within the UK. These emissions, which occur throughout a product's life cycle, from raw materials through to production (or service provision), distribution, consumer use and disposal/recycling, are equivalent to that produced by over 7 million cars per year. The most significant contributors to avoidable carbon emissions are milk waste, coffee waste and wheat products (bread, cake, etc.).

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Global Trends Influencing Post-harvest Losses

While the primary drivers of post-harvest losses in both developing and developed countries have been discussed above, there are other global trends that influence food losses (Parfitt et al., 2010). First is the rapid urbanisation and contraction of the agricultural sector currently taking place in many countries. The last five decades have seen a significant shift from the countryside to the cities. Farmers are leaving their fields and heading to the city in search of better livelihoods. A majority of the world's population now reside in cities. It is projected that by 2050, two-thirds of humanity or 6 billion people will be living in towns and cities compared to only 32 per cent in 1960. This growing phenomenon has created the need for extended food supply chains to feed urban populations. More food will have to be transported over larger distances to reach cities, necessitating improvements in roads, transportation, storage and marketing infrastructure to avoid additional losses. How these extended supply chains keep pace with urbanisation has obvious implications for food waste globally.

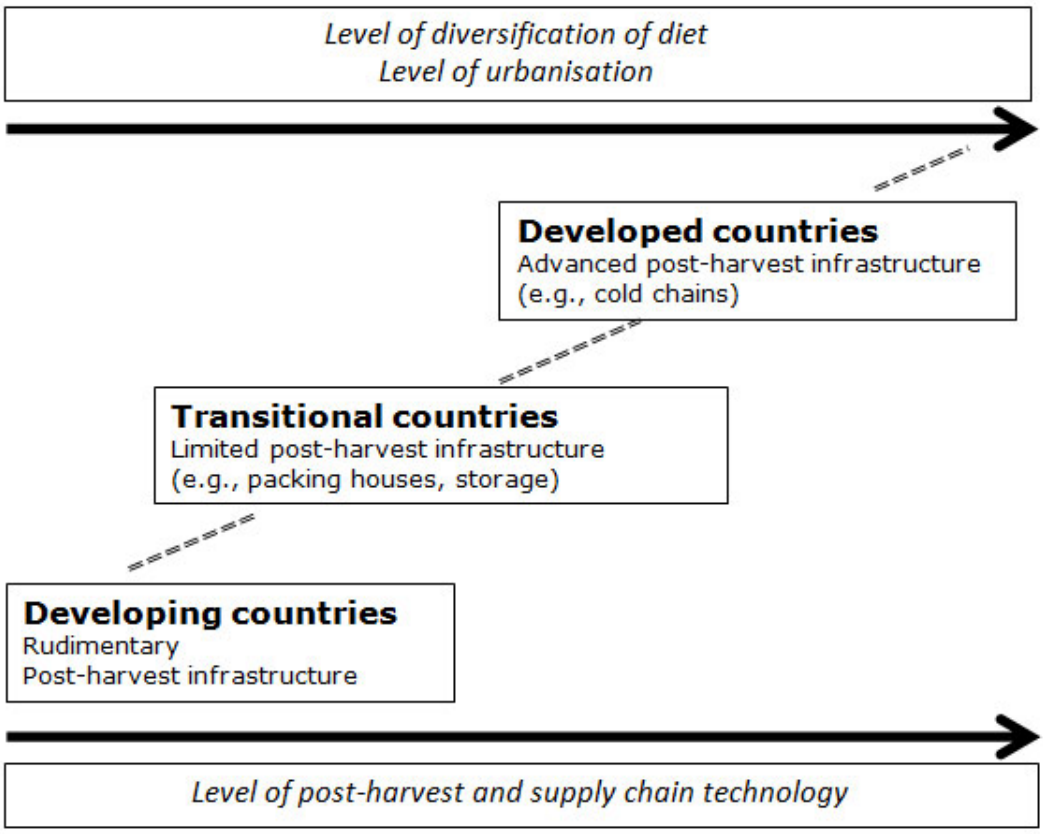
The second trend is the change in food consumption patterns. Increasing urbanisation in combination with income growth, particularly in transitional economies such as Brazil, Russia, India and China, has resulted in the acceleration of the diversification of diets into fresh fruit and vegetables, dairy, meat and fish and a decline in consumption of starchy food staples (Parfitt et al., 2010). This shift towards more perishable, shorter shelf-life items is associated with greater food waste coupled with higher demands placed on agriculture in terms of land and inputs to production (Lundqvist et al., 2008).

The third trend is the increased globalisation of trade. Linked to trade liberalisation and globalisation is the rapid growth of supermarkets – often multinational chains operating across many countries – in many transitional countries. Supermarkets are becoming the dominant intermediary between farmers and consumers. They are displacing traditional retailers in many countries in Africa, Asia and Latin America and are becoming the main vehicle for delivering diversified diets for the growing middle classes and the urban poor. Associated with this supermarket revolution is the requirement to meet the quality and safety standards of consumers, as well as volume and timeliness demands of local and export markets, all of which have implications for food waste along the food supply chain. For example, overproduction or over-ordering in the food manufacturing sector often occurs in response to inaccurate demand forecasting by retailers, thus further increasing food waste.

To reflect these important global drivers, Parfitt et al. (2010) consider post-harvest losses along a technological-economic gradient, from 'developing' to 'transitional' and 'developed'. As developing countries move up the economic ladder, the level of their post-harvest infrastructure and supply chain technology increases and the nature of their food losses changes. With rudimentary post-harvest infrastructure, the majority of food losses occur near the farm whereas in countries with more advanced infrastructure, more and more of the food losses occur at the retail and consumer levels. Thus, the richer a country becomes, the more voluntary the nature of its food loss.

Figure 1 provides an overview of the development of post-harvest infrastructure along this gradient.

Figure 1: Development of post-harvest infrastructure in relation to stages of economic development.



Source: Parfitt et al. (2010:3067).

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Strategies to Reduce Losses

Developing Countries

The post-harvest systems of developing countries are in dire need of considerable investment to create more formal markets and improve their performance to a point where post-harvest losses can be substantially reduced (Hodges et al., 2011). For example, governments need to develop all-weather feeder roads so that crops can get to market. Suitable market institutions need to be developed and promoted by the government, while leaving room for subsequent private sector involvement, to enable marketing groups and individuals to best respond to market demand. For example, in Malaysia, the Ministry of Agriculture and Agro-based Industry set up the Federal Agricultural Marketing Authority (FAMA) to help small farmers market perishables such as fruit and vegetables to domestic as well as export markets. Marketing cooperatives, which are particularly relevant for developing countries where farm sizes are small, should be encouraged among producers of major commodities in important production areas (Kader, 2005). Such organisations provide central accumulation points for the harvested commodity; undertake purchasing of harvesting and packing supplies and materials in quantity; provide for proper preparation for market and storage when needed; facilitate transportation to markets and act as a common selling unit for the members. Transitional economies are also now investing heavily in the kind of cold chains used by industrialised countries, despite the high energy requirements. India, where 35 to 40 per cent of all of its fruit and vegetables go to waste, has recently provided incentives and capital subsidies for the establishment of warehousing and cold storage facilities.

As markets depend on a consistent supply of better-quality produce, farmers must be able to respond to the demand. This can be achieved by adopting innovative technologies and approaches to reduce post-harvest losses and ensure product quality. The interventions can be quick and cost-effective ones. Even without the introduction of capital-intensive Western-style infrastructure, there is a great deal that smallholders can do to prevent serious damage to their harvests and improve their quality. For example, an FAO project in Afghanistan and elsewhere dramatically reduced post-harvest losses simply by providing sealed storage drums to grain farmers (FAO, 2008). Another community project in Guinea achieved dramatic reductions in aflatoxin levels in stored groundnuts by training and educating farmers to better handle their harvests (WorldWatch Institute, 2011). Farmers were shown how to sort groundnuts by hand, eliminating any that were mouldy or damaged. Instead of being dried on the ground, which can be a source of humidity, groundnuts were dried in the sun on locally produced natural-fibre mats. Rather than using plastic bags for storage, which promotes humidity, natural-fibre jute bags were used. These examples, along with many others like them all over the world, demonstrate that directing resources to training farmers in best practices through outreach and extension efforts can dramatically improve food availability and reduce waste without the need for huge capital

investments. This farmer training has traditionally been the responsibility of government extension services, but increasingly, private companies have organised their own technical support services to ensure appropriate use of their products. Seed companies such as Syngenta and Pioneer have active technical advisory services to ensure that farmers capture value from buying hybrid seeds.

Other low-input approaches include using the abundant solar heat available in tropical and subtropical regions to preserve a greater proportion of locally grown fruits and create other food products from them. Fermentation is another low-input, locally appropriate food preservation method. In Africa, kefir, an acidic, mildly alcoholic milk drink, is produced by the fermentation of milk using a grain-like starter culture. For many producers, this is a much more feasible method of preservation than pasteurisation and refrigerated supply chains (WorldWatch Institute, 2011).

Biotechnology is another tool that can be utilised to address some of the concerns about quality attributes and the biological causes of deterioration of harvested produce (Kader, 2002). Due to there being numerous opportunities to use biotechnology to maintain post-harvest quality and safety of fresh produce, priority should be given to the following goals: (1) to attain and maintain good flavour and nutritional quality to meet consumer demands and encourage greater consumption of fresh fruit and vegetables; (2) to introduce resistance to physiological disorders and/or decay-causing pathogens in order to reduce the use of chemicals and delay rotting; and (3) to modify the surface structure and/or composition of some commodities to reduce their microbial contamination potential. The biotechnology R&D required to meet these goals is currently being done in public- as well as private-sector research organisations.

Developed Countries

While the developing world would benefit from greater investment in post-harvest infrastructure, extension services and agricultural technologies to prevent accidental losses, developed countries should rein in their indifference when it comes to food.

Initiatives aimed at raising awareness of food-waste issues among consumers, while also making it easier for them not to waste, are paramount (Foresight, 2011). Consumer education campaigns similar to the ones launched by local governments in large cities such as Guangzhou, China, to reduce energy wastage should be implemented. These campaigns must include messages that point to actions that consumers can adopt to reduce food waste and draw attention to cost savings as a result of doing so. There is also a need to review home economics skills and education in schools to improve in-home food storage, preparation and cooking skills, as well as professional practice.

In terms of strategies that could be employed at the retail, manufacturing and food-service-sector level, the following have been proposed by Foresight (2011): productive recycling of surplus food for food redistribution or for use as a component of animal feed or as a source of energy through anaerobic digestion and composting; improvements in demand forecasting through the expanded use of information technology in food supply chains; and the development and use of cheap, mass-produced sensor technology that can detect spoilage in certain perishable foods. The last approach has the potential to replace some of the current date marks (e.g., ‘best before’ and ‘use-by’ dates) and provide a more accurate indicator of freshness of spoilage, which could help reduce waste.

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Conclusion

The UN projects that world population will grow from its current 6.8 billion, to 9.1 billion in 2050. Feeding this larger, more urban and increasingly affluent population will require agricultural production to grow by 70 per cent (FAO, 2009). This huge increase in demand will not be achieved through a ‘business as usual’ approach which focuses on the more obvious solution, increasing food production. This is particularly so given the fact that the resources for producing food are becoming increasingly scarce. Reducing food losses by addressing inefficiencies across the entire food supply chain must thus be an essential component of any strategy to make more food available without increasing the burden on our natural environment. Regrettably, this is an area that has been neglected over the years. Less than 5 per cent of funding for horticultural research and extension has been allocated to post-harvest issues over the past 20 years, as the historical focus has been on increasing production (Kitinoja et al., 2011). Though the emphasis in the 1990s moved to marketing and more recently to value-chain development, still, internet searches show that less than 1 in 2,000 agricultural projects undertaken globally have centred on fresh-produce handling and marketing.

With post-harvest issues having been largely ignored, a firm evidence base from which to assess global food waste is lacking (Parfitt et al., 2010). Much of the data on losses have not been collected systematically and updated; some of the data are from 30 years ago. In addition, there has not been much research on the impact of food waste in transitional countries such as Brazil, Russia, India and China, where food consumption patterns are changing dramatically. Therefore, there is an urgent need for more quantitative research providing loss estimates for the food supply chains of developing countries and the rapidly evolving transitional countries. Parfitt et al. (2010) argue that without such evidence, discussions on the potential for reducing global food waste as a contribution to feeding 9 billion by 2050 will remain largely rhetorical and measuring progress against any global reduction target almost impossible.

During 1970–1980, the FAO sponsored a two-decade-long Crop Loss Assessment Program, which focused primarily on pre-harvest

losses in developing countries (Teng, 1987). That programme yielded invaluable information which led to the development of Integrated Crop and Pest Management strategies. It is time to revisit the need for coordinated, global programmes similar to the Crop Loss Assessment Program as well as use past experience to tackle the current important issues of pre- and post-harvest losses in the entire supply chain.

Notes

1. The attainable yield is defined as the site-specific technical maximum depending on abiotic growth conditions, which in general is well below the yield potential, a theoretical yield level that cannot be realised under practical growth conditions (Oerke, 2006; Nutter, Jr. et al., 1993).

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About the Centre:

The Centre for Non-Traditional Security (NTS) Studies of the S. Rajaratnam School of International Studies was inaugurated by the Association of Southeast Asian Nations (ASEAN) Secretary-General Dr Surin Pitsuwan in May 2008. The Centre maintains research in the fields of Food Security, Climate Change, Energy Security, Health Security as well as Internal and Cross-Border Conflict. It produces policy-relevant analyses aimed at furthering awareness and building capacity to address NTS issues and challenges in the Asia-Pacific region and beyond. The Centre also provides a platform for scholars and policymakers within and outside Asia to discuss and analyse NTS issues in the region.

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