Food Loses in the Selected Food Supply Chains

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Abstract

This research belongs to the category of technology assessment which examines socio-economic context of technological progress. In this case, it concerns food security which might be strengthened by reducing food losses at lover stages of the food supply chain (FSC) due to technological improvements. Technologies reducing harvest and postharvest losses exist, however, they are not sufficiently adopted by farmers in developing countries. The paper examines these technologies and discusses factors which stimulate and prevent farmers to innovate their harvest and postharvest practices. These factors include human and financial capital, farm size, risk attitudes, labour availability, credit constraints, land and other property ownership access to commodity markets, social interaction, social capital and institutions. Using literature review it is showed that food supply systems tend to separate to urbanisation or export driven FSC and marginalised rural one. The urban&export FSC tend to adopt modern technologies and often also due to government support providing infrastructure, price guarantee and credit support. In contrast, the poverty and lack of attention of the government prevent small semi-subsistence farmers to improve their performance. But reducing harvest and postharvest losses is critically essential for improving food security of small (semi)subsistence farmers and poor rural households for which cereals and tubers/roots are staple food. Cooperation is needed for both sharing costs of investment in the new technology as well for learning each from the other. In general, farmers need to know, and experience, that a new technology is significantly superior to the existing system, and can provide a secure income. Thus the introduction of a new postharvest technology should use a participatory approach allowing negotiation, conflict mitigation and the creation of consensus among the relevant parties. Technologies for poor farmers should build on the traditional approaches and utilise as much as possible locally available materials.

Keywords: postharvest crop losses, technologies, food supply chain, institutions
JEL Classification: Q13, Q16

1. INTRODUCTION

There are three types of discourses on food waste:

a) on estimating crop/food losses for better storage, marketing and delivery planning;
b) on highlighting the scale of food waste in relation to global malnutrition (moral, economic and sustainability perspective); and
c) on proposing technical solutions in order to control food losses and hence, to increase food supply and to save the environment and the nature.

The latter is the most relevant to this paper, while the publications on the two former provide important information on the context. The "technical solutions" might evoke a bit restrictive concept, in this paper we will understand by them technological and institutional solutions (changes).

Parfitt et al. (2010) distinguishes between food losses and food wastes, arguing that the former relates to early stages of the food supply chain (FSC) and refers to a system which needs investment in infrastructure . In contrast, the term food waste is applied to later stages of the FSC, and generally relates to behaviour of food suppliers and consumers. This study concentrates on harvest and post-harvest crop losses before the raw material reaches processing or shelves in the case of fresh products.

The analysis included losses which occur in the first four stages of the FSC as described in Table 1. The last two stages (3 and 4) cannot always be clearly separated from primary processing and so do the losses.

Table 1 The scope and the structure of crop losses in this paper

	Stage of the FSC	*Examples of food loss characteristics*
1	Harvesting—handling at harvest	Edible crops left in field, ploughed into soil, eaten by birds, rodents; Timing of harvest not optimal: loss in food quality; Crop damaged during harvesting/poor harvesting technique; Out-grades at farm to improve quality of produce
2	Threshing/shelling/chaff separation/ cleaning/ washing	Loss through poor technique
3	Drying/ curing/ cooling, transport and distribution	Poor transport infrastructure; Loss owing to spoiling/bruising
4	Storage	Pests, disease, spillage, contamination, natural drying out of food

Source: Based on Parfitt et al. (2010)

Reduction of food losses is within the mandate of the Food and Agriculture Organization of the United Nations (FAO). In 1974, the first World Food Conference (WFC) identified reduction of post-harvest losses as one of the actions which might significantly contribute to the reduction of world hunger. At this time, post-harvest losses were estimated at 15%, and the proposal settled at the WFC was to reduce them by half by 1985 (Parfitt et al. 2010). Initially, the main focus of the initiated "Special Action Programme for Prevention of Food Losses" was only on reducing losses of durable grain; later (in the 1990s), the scope of work had been broadened to cover roots and tubers, and fresh fruits and vegetables (FFVs).

However, the lack of adoption of effective measures led to no progress in reduction of post-harvest losses. The poor performance of the Special Action Programme can be accounted to the purely technical perception of the food losses problem. Instead, a more holistic approach is needed (Grolleaud 2002). Following this understanding, this paper will not only identify gaps in technology and marketing infrastructure, but will also discuss organizational and institutional imperfections which prevent transfer of knowledge and investment in reducing crop losses effectively anywhere in the world.

This study differentiates three categories of crops: a) grains (cereals and oilseeds), b) roots and tubers and c) fresh fruits and vegetables (FFV). They differ in a number of characteristics (Table 2) of which the degree of perishability is one of the most important from the postharvest losses point of view. On one pole there are grains, on the other pole highly perishable fresh fruits and vegetables, root and tuber crops are in-between. The food supply chains, which include post-harvest technologies and marketing organization and infrastructure, are to large extent determined by product characteristics associated with perishability.

Both quantitative and qualitative food losses are considered in the literature. However, not all weight losses are necessarily food losses, some like respiration and transpiration might be considered as natural, as long as they have no effect on the quality and the opportunity to sell crops. Degradation in quality usually results in impossibility to market such crops. Quality criteria depend on the use of crops and societal/consumer concerns; they include physical and chemical properties, colour, shape, size, nutritional value or absence of microorganisms, toxins and other pollutants (Hensel 2009).

Table 2 Product characteristics relevant to food supply chains and food losses

Categories of crops		*roots and tubers*
	non-perishable (grains)	*perishable food crops (FFV)*
Harvest	Seasonal	seasonal, but possibility of permanent or semi-permanent production
Preliminary treatment	threshing, drying (if needed), cleaning	drying for long term storage, washing, pre-cooling
Fruit	small (below 1 g)	large (5 g - 5 kg)
Product moisture	low	high (50-80%)
Respiratory activity of stored products	low	high, very high
Tissue	hard, good protection	soft, highly vulnerable
Storage	long term (due to seasonality), good natural disposition	rather short term
Losses during storage	mainly from exogenous factors	both endogenous (respiration, transpiration, germination, etc.) and exogenous factors
Direct consumption	rare (need processing)	products for direct consumption

Note: Exogenous factors: pests, insects, rodents, stealing, etc.
Source: Based on Parfitt et al. (2010)

Many authors (e.g. Hensel 2009; Hodges et al. 2010; Parfitt et al. 2010) point out that the nature of food losses and food waste depends on the stage of the development of FSC. Basic characteristics of FSC (without their further differentiation by the above mentioned product groups) are summarized in Table 3. In general, the transition of FSCs goes from traditional semi-subsistence system toward highly integrated global food supply system.

Parfitt et al. 2010 distinguishes three main global drivers of the development of FSC: urbanisation and declining share of the agriculture in GDP, dietary transition and increasing globalization of trade. While dietary transition in developing/transitional countries results from urbanization (change of live style) and growing income, ageing of population is an important factor in developed countries. Hodges et al. 2010 describes that main food losses are due to spillage and biological spoilage in the first stages of the FSCs in developing countries; in contrast, the critical factor for food losses/wastes is in developed counties the growing intolerance of cosmetic defects or deviations from substandard food traits.

The objective of the paper is to discuss the need and effort for improving postharvest technologies in developing countries from the point of view of technology adoption. The paper is structured as follows. After this introduction which provides also scoping of the research we demonstrate the importance of postharvest crop losses in various regions in the world (Paragraph 2). In Paragraph 3 we introduce briefly the conceptual framework. Afterward (Paragraph 4) we will discuss postharvest technologies in various crop food chains and social and economic contexts. Paragraph 5 will be devoted to social capacity to adopt appropriate postharvest technologies and policies. The findings will be summarised in the final paragraph (Paragraph 6).

Table 3 Characterisation of the development stages of food supply chains (FSCs)

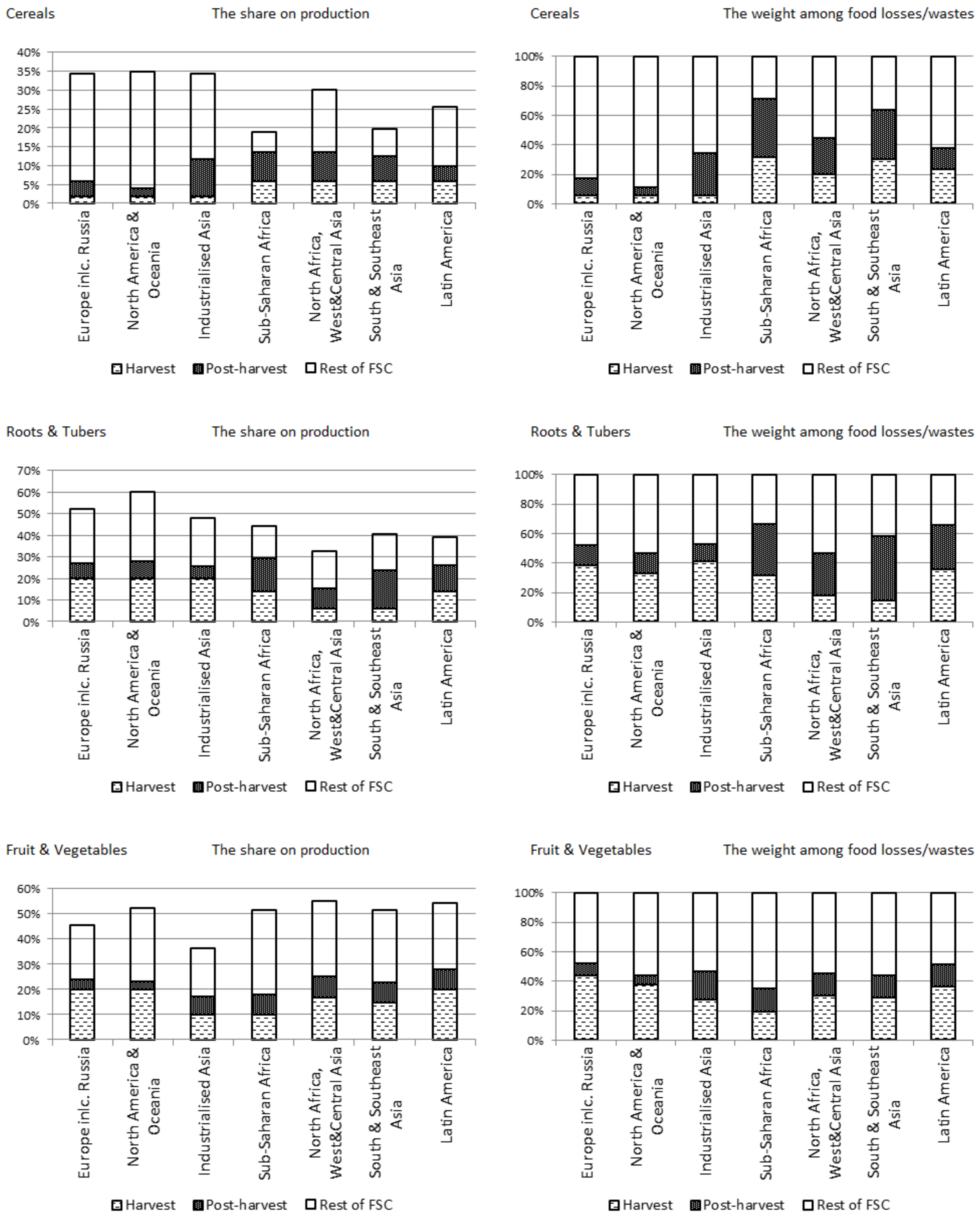
Class of countries	*Developing countries*	*Transitional countries (e.g. BRIC)*	*Developed countries "Northern" FSC*
State of economic development	*Low- income*	*Low- and - middle income*	*Middle and high income*
Type of growers	Smallholders, semi-subsistence farms	Dual farm structure, semi-subsistence farms and larger commercial farms	Medium and larger farms and large commercial farms
Harvesting technology	Traditional, often manual or simple mechanisation	Mechanised harvesting alongside the traditional systems	Harvesting highly mechanised
Post-harvest infrastructure	Traditional threshing, drying, storing, simple mechanisation	Intermediate, i.e. a mixture of sophisticated and traditional technologies	Sophisticated technologies, cold chains
Marketing system	Local markets	Local, urban and increasingly export markets	Centralised (supermarkets), export orientation
Level of vertical integration	Poor integration, many intermediaries supplying urban markets	Vertical coordination, less intermediaries	High vertical integration, even supranational
Quality	Variable quality, no requirements on standards	Variable quality, standards for export markets	Quality and safety standards central to the FSC

Source: Based on Parfitt et al. 2010

2. OVERVIEW OF HARVEST AND POST-HARVEST CROP LOSSES

Most authors agree on the difficulty and rather low reliability of the estimates of post-harvest losses. Measuring what has been lost implies that it is known what was there at the outset and this is usually not the case (Hoddges et al. 2010). Basically, two main approaches are adopted to estimate post-harvest losses: either to actually measure what has been lost or to use questionnaires to collect subjective loss estimates from those who have experienced them. The problem is that this basic methodological information is lost throughout the citations and transcriptions. In addition, some authors (e.g. Gustavsson et al. 2011) add their own assumptions which are based on similarities with other production systems and regions. There are differences among authors (and thus figures) in terms of operations which have been included in post-harvest handling (Grolleaud 1997). As illustrated in Table 4, the ranges of crop losses estimates can be really wide. The variance of estimates depends amongst others on applied methods (authors), year of the survey and other unreported parameters. As noted by Tyler (1982) "postharvest losses may be due to a variety of factors, the importance of which varies from commodity to commodity, from season to season, and to the enormous variety of circumstances under which commodities are grown, harvested, stored, processed and marketed." It is therefore important not only to work with figures that are good estimates at the time and in the situation they are taken but to be aware that at other times and situations the figures will differ.

Figure 1 The importance of harvest and post-harvest crop losses within FSC presented by commodity groups and macro regions



Commodity groups: Cereals: wheat, rice (milled), barley, maize, rye, oats, millet, sorghum, other cereals.

Roots and Tubers: potatoes, sweet potatoes, yams, cassava, other roots.

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.

Source: Based on Gustavsson et al. 2010

The purpose of estimating food losses is also important: if it is for calculations of food availability, all losses should be included; however, if the estimates should guide actions to combat food losses than they should include only avoidable losses. One has to understand that due to mechanical or biological processes (e.g. respiration) some post-harvest losses are unavoidable (Grolleaud 2002). Also social contexts might be important in determining what food loss is and what not (important when subjective judgments are surveyed).

The assessments of post-harvest losses are presented by commodities or groups of commodities, macro regions[1], countries and by climatic and weather conditions. Macro regions refer primarily to various levels of the development of FSCs and their economic environment worldwide, nevertheless, when interpreting the figures one has to take into account also climatic differences.

The importance of harvest and post-harvest losses within the FSC and within overall food losses/wastes in different commodity chains is illustrated with Figure 1 based on Gustavsson et al (2011). The advantage of Gustavsson's study is that it provides "complete" geographical coverage (differentiated by marco regions). The authors, however, do not hide that their estimates are based on various sources and sometimes on their own judgments. A certain level of consistency is guaranteed by using exclusively FAO data on food production and consumption and by assuring balance between production, use and losses at each stage of the FSCs.

There are substantial differences in harvest and post-harvest losses between developed (the three left columns in each graph) and developing and transitional countries. Particularly post-harvest losses are very low (6-14% of all food losses) for all three commodity groups in developed countries, while these might be the most important (up to 44% of all food losses) in less developed regions. This is without doubts due to better post-harvest technologies, particularly storage facilities. However, the temperature and humidity is also an important factor affecting post-harvest losses; these are particularly high for cereals, and root and tuber crops in Sub-Saharan Africa and South and Southeast Asia.

However, this gives only a general picture, because global regions are not homogenous in terms of economic development and climate. Table 4 presents estimates of harvest and post-harvest losses in individual countries (without developed countries). These estimates come from various authors, from various periods, using various methodologies. The figures are often presented as ranges, often very broad ranges. Differences in harvest and post-harvest losses by the level of development (BRIC countries on one hand and LDC on the other hand) are hardly observable. At the bottom of the table, scarce estimates of harvest and post-harvest losses in the three former Soviet Union countries (CIS – the Commonwealth of Independent States) are reported. Also these do not differ from the other countries substantially.

A common observation is that upper ranges of post-harvest losses are pretty high for almost all grains and countries. Although grains are not perishable, substantial part of the high loss figures ought to be accounted to storing. As it will become apparent later, higher storage losses are associated with wet weather (climate), inappropriate post-harvest treatment and poor storage facilities.

Because of lack of consistency in food losses data, it is very difficult to assess the dynamics of post-harvest losses. The loss estimates for Ukraine are a good example. The estimates in Table 4 come from the two surveys (Striewe 1998; Shpychak 1998) conducted in 1998. No later figures are available. However, in the meantime, the post-harvest sector got privatized and new (foreign direct)

[1] Groups of countries of similar climatic, geographical and socio-economic characteristics

investment has reached the sector (Striewe 2011). It is very likely that storage losses dropped accordingly.

Table 4 Harvest and post-harvest losses by countries and commodities

	Country	*Rice*	*Maize*	*Wheat*	*Sorghum*	*Pulses/ oilseeds*	*Roots and tubers*	*FFV*
Africa	*Egypt*	2.50%						
	Sudan	17%		6-19%	6-20%	4-27%		
	Nigeria		10-70%		0 - 40%	5%		50%
	Ghana		7-14%			7-45%	15-60%	10-50%
	Kenia		10-23%				10-20%	30-35%
	Uganda	11%	4-23%			30%		
	Tanzania		20-100%			18%		
Asia	*India*	6%	4-8%	2-5.2%	7.50%	4-5.7%		20-30%
	Pakistan	2-10%	2-7%	5-10%	7%	5-10%		
	Indonesia	6-17%	4%		4%	5%		25%
	Malaysia	17-25%						20%
	Philippines	9-34%						10-50%
	Sri Lanka	10-40%						20-40%
	Thailand	8-14%				10-30%		20-30%
	China	5-23%						10-35%
South America	*Brasil*	1-30%*	15-40%*	15-20%*		15-25%		8-10%
	Paraguay		25%			15%		17-30%
	Bolivia	16%						
	Mexico		10-25%					
	Venezuela		10-25%					
	Dom. Rep.	6,5%	9%					25%
CIS	*Ukraine*		14-32%	14-32%				
	Moldova							5-25%
	Kazakhstan		12-30%	12-30%		30%		

Source: Hensel (2009), Parfitt et al. (2010), Striewe (1998), Shpychak (1998), Maloney (2006), Satybaldin & Grigoruk (2002), Kader (2009)

The "African Postharvest Losses Information System" (APHLIS) addresses the need for a systematic survey of post-harvest losses – particularly for better forecast of food supply in Eastern and Southern Africa. The longest available time series was found for maize and wheat. In spite of high variation, both commodities exhibit a long term decline of losses (the down-sloping trend lines).

The Central Institute of Post-Harvest Engineering and Technology in India reported substantial declines of post-harvest losses by 25% for wheat, 50% for rice, 45% for maize and 40% for pulses between 2004 and 2010 (CIPHET(ICAR) 2010).

3. CONCEPTUAL FRAMEWORK

In the linear model of innovation, technology is assumed to mean a new, scientifically derived, often complex input supplied to farmers by organizations with deep technical expertise. Lot of research as well as practices providing support to the improvement of agricultural production and postharvest treatment was carried out following this concept (e.g. Monge et al. 2008). It also led to the focus on "high technology"[2] inputs for long time ref., hiding the point that a technology is simply the application of scientific knowledge for a certain end. Feder and Umali (1993, 216) define technology as "… a factor that changes the production function and regarding which there exists some uncertainty, whether perceived or objective (or both). The uncertainty diminishes over time through the acquisition of experience and information, and the production function itself may change as adopters become more efficient in the application of the technology."

In this paper we do not look exclusively at right new harvest and postharvest technologies and their diffusion, rather knowledge (and the corresponding equipment) exists but is insufficiently and unevenly adopted by farmers and the other agents in the FSC. Often adopters of modern technologies (with low losses) operate in parallel with traditional ones. The factors most often cited to explain the variability in agricultural technology adoption and its diffusion patterns are those described by Feder, Just, and Zilberman (1985): human and financial capital, farm size, risk impact, attitudes toward and perceptions of risk, family and hired labour, credit constraints, land and other property ownership and formal and informal tenure, and access to commodity markets. Recent studies emphasize the role of other factors like social interaction, social capital and institutions (Katungi 2007, Monge et al. 2008, Horna et al., 2013). All these factors interact with one another in practice, constituting a complex innovation system. In the other words, conceptions of agricultural and rural innovations have moved from a linear view of the farmer as the recipient of externally developed codified knowledge and technological packages disseminated by extension services towards a model in which innovation is conceived as a co-evolutionary learning process occurring in the social networks of an array of actors (Leeuwis and van den Ban 2004, IAASTD 2009).

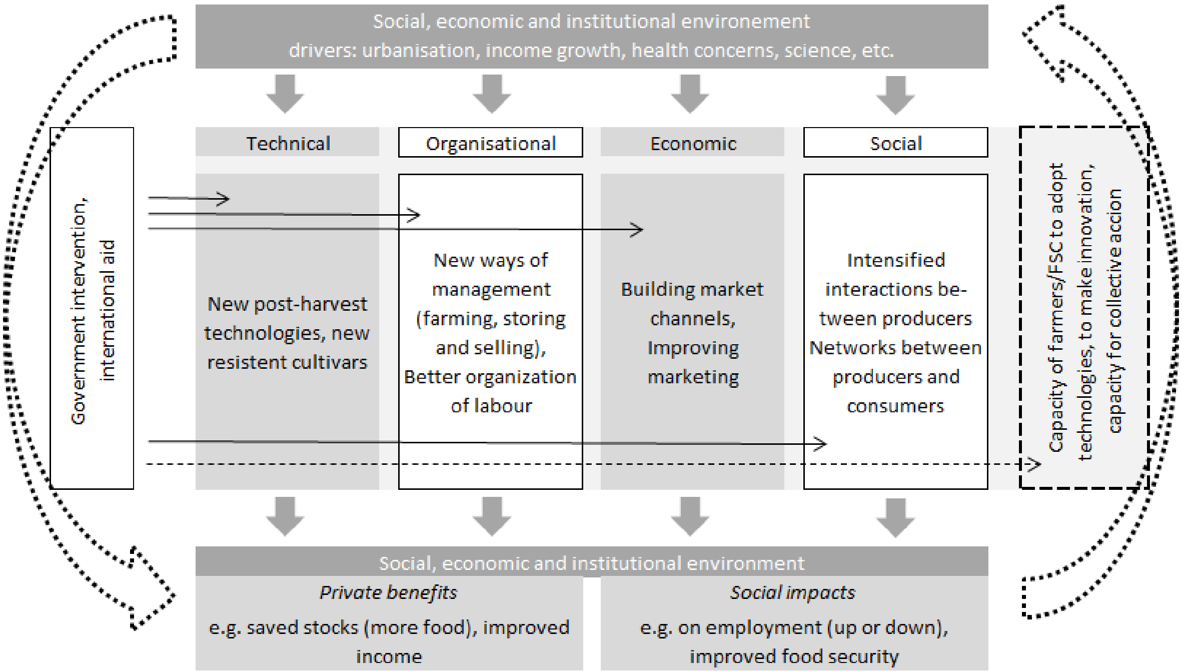
Dockes et al. (2009) distinguish four dimensions/types of innovation: economic, social, organizational and technical innovations. It is illustrated in Figure 2. Although all four innovation types are important for success, their participation (dominance) might vary substantially across agents/ farmers, sectors (production/commodities, postharvest, etc.), regions (see Dockes et al. 2009, Monge et al. 2008). In Figure 2 we also see socio-economic and institutional contexts, government and other interventions and capacity of farmers and FSC agents to adopt/process knowledge/technology. The agents (in the extent of their capacities) interact with the contexts (social and economic environment. The basic engine of the innovation system and thus capacity to adopt appropriate technologies is the learning capacity of the actors including collective learning.

To understand innovation process, one has to look at its dynamics. Knickel et al.(2009) following Rip and Kemp (1998) introduce a concept of innovation cycle where "innovations start with recognizing problems and identifying opportunities, and evolve towards the creation of novelties; in our case it is an adoption of postharvest technology in the specific circumstances of the innovator – a farmer, a down steam agent . They may develop further with niches formation (island where new postharvest technologies are adopted) and lead to changes in market/postharvest regimes. Through diffusion of innovations in wider societal and market networks the political, economic and cultural landscape (FSC) may be transformed. Every stage of innovation is characterized by certain activities, leading actors, innovation forces, configuration of actor networks, and characteristic ways of cooperation and support". As pointed out by Dockes (2009) not all innovations mature in niches or

[2] i.e. driven by science like biotechnology, high yield varieties, sophisticated machinery, etc.

regimes; moreover, our concern is about uneven diffusion, i.e. that some actors (e.g. small farmers, small intermediates) stay aside the "regime".

Figure 2 Innovation system for delivering postharvest improvements



Source: own elaboration based on Dockès et al. (2009), IAASTD (2009)

Figure 2 actually provides a framework for our analysis, particularly in Paragraph 5. It has four elements: analyses of

i) Nature of harvest and postharvest losses and characteristics of available postharvest technologies;

ii) Capacity of Food Supply Chain actors at the low stages (before processing) to innovate, to adopt appropriate technologies reducing crop losses. It includes looking at factors like believes, human capital, farm size, attitudes toward and perceptions of risk, family and hired labour, financial capital and credit constraints and social capital;

iii) The social (networks, local social settings) , economic (market infrastructure, access to credits) and institutional (contracts, standards) environment. It also includes general preconditions for horizontal cooperation and vertical integration in the FSC;

iv) The role of government and other national or international donor organisations (aid programmes, NGOs).

The research is entirely based on literature review. There is plenty of literature on the causes of postharvest losses and postharvest technologies. There is also increasing literature on social, economic and institutional conditions in respect to postharvest systems. There are reports of governmental programmes, information websites (CIPHET, Embrapa, INTA, CGIAR institutes)[3] and critical studies on the involvement of the governments and international aid programmes in improving postharvest processes (e.g. Coulter, 1990). However, there is very little on adoption of postharvest technologies at farm or storage levels. Most of the research on farmers capacity concerns adoption of high yield crops

[3] CIPHET – Central Institute of Post-Harvest Engineering and Technology, India, Embrapa – Empresa Brasileira de Pesquisa Agropecuária, INTA – Instituto Nacional de Tecnología Agropecuaria, Argentina, CGIAR – the Consultative Group on International Agricultural Research and 15 research centres.

or intensification technologies, sometimes also in the opposite direction, i.e. from the point of preserving environment.

4. OPTIONS FOR REDUCING POSTHARVEST LOSSES

Options to reduce losses in the grain sector

Grain harvest and postharvest technologies vary across farming systems and regions. Two technological lines can be distinguished:

i) Modern, which uses combine harvester unifying the two first steps in one, and also cleaning and drying are usually integrated with storing. This set of technologies is largely mechanised and is demanding energy (electricity, fuel) for drying and handling. Grain is stored in bulks in metal or concrete silos. Scale of operations is large; farmers often cooperate horizontally and are fairly integrated with large grain merchants or processors (milling industry).

ii) Traditional, in which all four steps are conducted separately. The share of manual work is high. In many parts of the world, manual harvesting, threshing, winnowing, open sun drying prevail on small farms. Semi-subsistence farmers store their grain in their farmhouse in sacks or bins. The food chain includes several rather small intermediaries storing crop temporarily before transported to mills or large grain elevators (public or private). For better handling, grain is transported and stored in bags.

In practice, there are various transitional forms. Often, the government or a governmental organisation is involved in grain logistic and storing for strategic food security reasons.

Despite the improvements in agro-technology, particularly improvements of the effectiveness and availability of pesticides, harvested grain will still be threatened by biodegradation spoilage mainly due to moulds (e.g. Aspergillus, Penicillium and Fusarium).

Generally, the main R&D stream in postharvest technology for grains aims at reducing crop losses and labour input. Technologies are capital intensive, and in their scale usually suitable for well integrated cereal food chains with large farmers or farmers' cooperatives and big intermediaries. If managed well, the modern system produces very limited grain losses. The main losses due to spillage or mechanical damage of kernels can be attributed to handling and poor maintenance of combine harvesters, transport vehicles, transport belts or fanes. Regular upgrading and good maintenance of machinery and equipment will assure low losses of this type.

In contrast, high harvest and postharvest losses are immanent to poor small semi-subsistent farmers and small intermediaries. These small farmers rely on traditional technologies. Ranges of crop losses (as compiled from various sources, Table 5) are broad; the loss might be high at each postharvest treatment step.

Table 5: The range of grain losses at each postharvest treatment step in developing countries

Threshing	Drying	Parboiling (only rice)	On farm storage	Handling and transport	Central storage
5-13%	1-5%	1-2%	1-15%	3-10%	1-6%

Source: Compilation from various authors: Hensel (2009), Hodges et al. (2010), Parfitt et al. (2010), Rembold et al. (2011)

The traditional threshing of cereals includes a number of methods (FAO 1994, IRRI 2013): by hand, by being trodden underfoot (by humans or animals) or by using a vehicle circulating over cereal bunches as these are thrown on to the threshing area. The associated productivity gains of mechanisation are apparent (manual threshing with 10-30 kg per hour, comparing to 300-2000 kg per hour of the modern thresher). The threshing rate of the modern thresher is higher than 99%, while 1-4% of grains might remain in ears and spilled when manual and by foot method is applied. The traditional cleaning method is winnowing, which uses the wind to remove light elements from the grain.

The traditional ways of threshing and winnowing are gradually replaced by mechanisation: Great contributions comes from international research centres like International Rice Research Institute (IRRI), International Maize and Wheat Improvement Center (CIMMYT), French CIRAD etc. to the development of threshing and cleaning engine powered equipment suitable for small farmers in developing countries. Easy handling and versatility (maize, millet, sorghum, etc.) are necessary preconditions for a successful adoption of these mechanisations (FAO, 1994).

Even if chosen the small one, the modern threshing and cleaning equipment will often greatly exceed the needs of individual farmers in developing countries. Unless the equipment is shared among farmers (either in a cooperative way or commercial way), the spread of the technology is limited; particularly when taking into account cost of \$1000-\$2000. Sharing the threshing equipment requires planning and coordinating harvest and substantial level of social capital.

The efficiency, quality and level of losses vary greatly due to various input and operational factors like cultivars (some new varieties might be difficult for traditional threshing/shelling, FAO, 1994), humidity of input crop which might vary during the day (Asgha 2004), the selection of a beater and the speed of the thresher drum (Peksen et al. 2013). This implies that progress in threshing technology must include beside new machinery also rising knowledge and skill of the operators.

Moisture content is a critical factor for storing, since high moisture content encourages fungal and insect problems, respiration and germination. The simplest traditional method is sunshine thin-layer drying on an open platform or a simple maize crib. On the other pole is a continuous-flow (fuel heated) dryer, usually integrated within the large (central) grain storage. Both the natural and artificial drying systems must be designed to have sufficient capacity to be able to keep pace with the harvest rate, i.e. that it does not hold up the harvest (FAO 1994). The choice depends also on capital and running costs of the system.

The modern grain storage technology uses metal or concrete silos which can be perfectly sealed as well as ventilated if needed. A drying unit is usually part of the storage system. Grain is stored in bulks and the loading and unloading processes are fully mechanised. Moisture and temperature inside the silos is monitored continuously and the system is designed in the way that corrective actions can be taken if needed. However, such technology is investment intensive. The storage capacity is high (although smaller metal bins are also available, see later). Therefore, mostly large farmers invest in such technology. Huge central grain elevators are usually built by large merchants, processors and governmental bodies. In spite of the high investment costs, the cost of grain storage in silos is about 2-4% of the current wheat price[4] (ISU 2013).

In South America, North America, Ukraine or Russia big farmers use large hermetic plastic bags (silo-bags) for storing grain. These silo-bags can hold approximately 200 tonnes of wheat and

[4] In the past before price soaring, it was about 5-10% of the price).

with the available handling equipment it is quite simple to load and unload them. While silo bags provide easy and cheap on farm grain storage (up to 12 months, Bartosik et al. 2008), there might be a problem with the disposal of used bags (Holmes, Springman 2009).

Medium size farmers, groups of farmers (in a village) or smaller intermediaries tend to use warehouses where grain is stored in sacks or bulks. Small farmers in developing countries use traditional storage systems and their improvements. Quite a rich list of storage facilities for small farmers in developing countries is presented in FAO (1994) or in Hayma (2003). The list of more traditional technologies include jute sacks, clay pots, maize cob crib, earthen silo, Burkina silo made of bricks or metal drums, usually disused water or oil tanks. The problem of the traditional storage technologies is that they provide rather poor protection against insects, rodents and water. Improvements include plastic sacks which can be hermetic sealed – a small version of the above mentioned silo-bags. Another example of an improved technology is the Indian Pusa bin, a double-walled silo with a separating layer of plastic sheet between the walls (Hayma 2003). In spite of being considered as expensive, small metal silos were successfully introduces in many places either at village or farm household levels (Anon 1982; Breth 1976; EGSP I and II projects[5]).

Options to reduce losses in the root and tuber sector

Like for cereals, there are traditional and modern technologies of roots and tubers (cassava/manioc, yam, sweet potatoes[6], potatoes) postharvest procedures. Similarly to cereals, roots and tubers are important crop for the subsistence of rural population, but they are also still more demanded by and produced for urban areas and export. This represents an important factor of commercialisation of roots and tubers production. Commercialisation brings with it pressure on productivity and efficiency of crop cultivation as well as postharvest procedures, and thus on modernisation of the production and distribution processes.

Harvest and postharvest losses of roots and tubers can be classified as physiological (caused by the effect of environmental conditions, table 36), pathological (cause by the attack of pathogens, e.g. fungi, bacteria, insects etc.) and endogenous (caused by endogenous processes like respiration, transpiration and sprouting). Of the four mentioned crops, cassava is very difficult to store and therefore is processed quickly after harvest.

Weather extremes, exposition to extreme temperatures (high, low) during pre- and postharvest and rough handling are main factors of physiological losses. They not only reduce the value of the crop due to damaged appearance, but temperature or mechanical injuries can be followed by invasions of pathogens leading in the decay of the attacked crop in the storage. Some weather effects can be hidden having tremendous impact on crop storage e.g. sweet potato asphyxiation, i.e. an excessive carbon dioxide accumulation in tubers. Sweet potatoes that have been asphyxiated may appear healthy for several days or weeks, but if injury was severe, the roots will die and begin decomposing in storage (Edmunds et al. 2007).

The wound type and the level of damage have a big influence on the development of postharvest rots. Scuffs, splits and skin grazes, etc. are entry points for rots (Edmunds et al. 2007; Opara 2003; Meyhoya 2001). Uninjured and cured tubers do not develop postharvest rots (Jobling 2000). The

[5] Effective Grain Storage for Sustainable Livelihoods of African Farmers Project

[6] Yam (Dioscorea sp.), Sweet potato (*Ipomoea batatas*)- which is sometimes called also yam.

damages are caused by harvesting instruments and handling as well as by insects, nematodes (yam) and rodents. Often, the effect of damages does not become evident until several weeks after harvest.

While bacterial rots lead to a rapid decay of tubers and roots, most moulds are also toxical; mycotoxins spread through the rood/tuber and even if the infected part is removed, the rest of the root/tuber is poisonous. Number of authors (e.g. Gnonlonfin et al. 2008) state that, particularly in tropical Africa, the presence of mycotoxins is high in yam and cassava roots as well as in dried chips.

Successful storage starts with high-quality roots/tubers. Traditional harvesting of roots and tubers is done by hand using diggers; simple mechanisation is used for potatoes, sweet potatoes, cassava and some smaller varieties of yam. Advanced mechanisation is used only for potatoes and sweet potatoes, usually, in order to reduce labour intensity in commercial farming systems. In contrast, yam and cassava harvests remain heavily labour intensive also in countries producing these crops for export7 (Bokunga 1999; Opara 2003). The technical constraint to the mechanical harvest of yam and cassava rests in size and distribution of tubers and roots in the soil. The dominance of small-scale farms represents an institutional constraint to the spread of mechanisation in root and tuber production in many developing countries (Opara 2003).

Sorting, i.e. separation of stones, vegetal wastes, cut or rotten tubers/roots, is achieved manually or with efficient sorting machines. Generally, use of water should be avoided before long term storage of tubers/roots, since it increases susceptibility for rotting. Relatively clean tubers sold directly in the local market. However, many urban and export markets require yams, sweet potatoes and potatoes to be washed. Sanitization of yam tubers might be needed (NGMC 2013). Mechanical washing can be used for potatoes and sweet potatoes8 if the produce quantity is large (Meyhuay 2001; Edmunds et al. 2007). Washed tubers/roots must be dried before packaging.

Because of tiny skin and fragility of the root or tuber crops, harvest damages are not fully avoidable, even if the harvest is done by hand. But roots and tubers exhibit self-ability of healing. Curing should be carried out as soon as possible after harvest. Regardless of which crop is to be cured, the roots and tubers must be kept at the right temperature to stimulate skin healing. Further good ventilation should be provided so that oxygen is supplied, and the air around the roots or tubers must be kept moist but without free moisture on the surface.

In many developing countries, roots and tubers are stored and traded without a proper curing treatment. Often the uncured tubers are packed straight into poorly ventilated bags with damp soil still attached to the surface. Then crop is prone to decay and postharvest losses are very high.

Only sufficiently dried and clean crop should be put in the storage. Temperature and humidity must be controlled during storage: There are optimum storage temperatures for each crop ant it must be followed. Respiration of tubers produces heat which is to be conveyed away by ventilation. The forced ventilation (by a fan of sufficient capacity) is often needed to provide more effective heat transfer than can be achieved by natural ventilation. To safeguard the effective heat transfer, the crop should be stored in the way that forced air can reach each tuber. Thus, the type of ventilation and the storage structures (sacks, containers, barns or bulk storage) must be harmonised.

Higher temperature and long storage will lead to sprouting. Sprouting contributes to weight and quality losses as it was pointed out earlier. The use of sprouting inhibitors is recommended for long term storage.

[7] e.g. cassava in Thailand

[8] Clean water is a necessary precondition, some disinfection can be added.

Traditional storage facilities for potatoes, sweet potatoes and yam (field piles, warehouses, yam barns or underground structures) often give little possibility for controlling temperature and humidity and usually provide poor protection against rodents and pests. In contrast, the modern warehouses are usually air conditioned, refrigerated and well protected against insects and rodents. However, these are not affordable for small semi-subsistence farmers. Thus the surplus crop tends to be sold immediately after harvest. Nevertheless, there is still space for the improvement of the traditional technologies and the enhancement of knowledge and skill of small semi-subsistence farmers in order to save most of the harvest, thus reducing losses. It involves improvements of pre-harvest and harvest techniques, curing and rodents and insect protection of storage facilities with materials largely available to small farmers (Meyhuay 2001; Opara 2003). The use of simple evaporatively cooled structures (ECS) to lower temperatures inside a store has been tested. According to Fuglie (1999), average losses after three months of storage were by 60% lower comparing to traditional farmers' clamps. However, ECS involves some construction and maintenance costs and thus the acceptance of the technology by farmers depends on whether the benefits from lower losses and higher prices are sufficient to offset these costs.

Options to reduce losses in the Fresh Fruits and Vegetables sector

Although fruits and vegetables cannot be considered as staple food, they are, nevertheless, important sources of essential minerals and vitamins in the human diet. Some fruit and vegetable produce is immediately processed (canned, pickled, frozen)[9]; in this case there is very little space for postharvest losses. There are four main causes of postharvest losses in the area of fresh fruits and vegetables (FFV) (FAO 1989; Gross et al. 2004):

i) It is typical for fruits and vegetables that biological processes like ripening continue after harvest at relatively high speed. Thus crop spoils if it is not consumed immediately;
ii) Mechanical damage during harvest , transport and handing, damaged crop might be more prone to pests (e.g. mould attack);
iii) Bacterial and fungal infestation during the late vegetation period or harvest handling causing consequent spoilage. The propensity of some crops (e.g. strawberries or mango) to this type of spoilage is particularly high;
iv) Storage linked damages (chilling or freezing injuries, too high CO_2 concentration, etc.)

Technologies to address the first three causes include: (a) appropriate biological or chemical protection of crops at field/orchard before harvesting; (b) timely harvest, using appropriate harvest methods based on manual picking-up, choosing appropriate and clean containers and the discipline of worker harvesting the crop; (c) cooling down the crop often together with controlling availability of oxygen in order to slow down ripening and other biological processes, (d) appropriate packaging and (e) careful, refrigerated and timely transport. Actually, these points (a) to (e) more or less represent stages in a sequential process of FFV production and distribution which is called cold chain. Failure at the preceding stage will almost inevitably cause losses in the following steps. During the process, high hygiene standards must be fulfilled. In contrast, the fourth type of damage results from the effort to prolong the storage life of crops by applying the cold chain technology. It includes chilling and freezing injuries, CO_2 injuries, etc.

[9] Dried fruits are usually added to fresh produce.

The cold chain technology includes many attributes which must be adjusted to individual crops, because various fruits and vegetables are differently sensitive to the parameters like relative humidity, temperature, atmosphere composition etc.. It holds not only between crops, but also it concerns crop varieties. Produce is usually cooled to its storage temperature in special facilities designed to rapidly remove produce heat. Gross et al. (2004) present four (pre-)cooling technologies: (1) Forced-air cooling is the most commonly used for many fruits and fruit-type vegetables; (2) Hydro-cooling; (3) Vacuum-cooling is usually applied to leafy vegetables; (4) Room cooling is used for a few commodities, such as citrus or onion. The need or extent of pre-cooling can be significantly reduced if the crop is collected early morning, or if it stays in the open air overnight. Transport cooling in refrigerated ships and containers is used for products in areas with no cooling infrastructure, such as bananas.

We can distinguish two modes of storage atmosphere: regular air/atmosphere (RA) and controlled atmosphere (CA). Controlled atmosphere storage involves reducing oxygen and increasing carbon dioxide in the air composition: O_2 from 21% to less than 8%[10], CO_2 from 0.03% to values ranging between 1% and 3%) in order to inhibit the ripening process. Atmospheric modification should be considered as a supplement to maintenance of optimum ranges of temperature and relative humidity. A similar principle is applied in the Modified Atmosphere Packaging (MAP), which reduces transmission of gasses between the inner and outer atmosphere.

Alternatively, chemicals can be used to delay ripening and sprouting (My Agriculture Information Bank, 2011). A productive method of inhibiting fruit ripening is to inhibit ethylene perception by gassing the molecules with 1-methylcyclopropene (1-MCP)[11].

Fungal spoilage during postharvest and storage represents serious economic losses to producers. Thus, only sound, intact fruits and vegetables should be stored or used for processed fruit products. Gentle and sanitary handling of the fruit during harvest and in storage and processing facilities is essential for reducing fungal decay and mycotoxin production in fruits. Generally, the refrigerated storage and controlled atmosphere reduce development of fungi and mycotoxin production (Gross et al. 2004). Additional protection against fungi and mycotoxins includes postharvest fungicidal treatment, ozonification and washing fruits and vegetables in water with hypochlorite or diluted ozone. .

Exceeding the range of safe values of temperature and gas concentrations, the stored crop will be injured (chilling, freezing injury, high CO_2 injury, too low oxygen concentration injury). Too rapid chilling or long exposition to chilling stress leads to tissue weakening, biochemical alterations and cellular dysfunctions. Often, injured products that are chilled will still look sound when remaining in low temperatures; symptoms of chilling injury become evident in a short time after they are removed to warmer temperatures (Gross et al. 2004).

Another disorder linked to long term storage is scald (apples, pears), a damage and death within fruit skin. It only occurs after relatively long periods of storage. Early in storage, fruit accumulate a chemical called alpha-farnesene; which is oxidized to a group of fruit skin toxic compounds gradually accumulated as long as the fruit are kept in storage. Some cultivars are more susceptible to scald; also

[10] 1-3% is referred to as Ultra Low Oxygen (ULO); Dynamic Controlled Atmosphere storage allows going below 1% O2 concentration being constantly adjusted on the basis of the fruit's respiratory activity.

[11] 1-MCP is sold commercially as SmartFresh and is approved and accepted for use in more than 34 countries (including the EU and the USA).

hot weather in the late growing period contributes to the excessive development of alpha-farnesene (Postharvest Information Network 2010).

The overall benefit of the cold chain technology in reducing postharvest losses of FFV can be illustrated by comparing the refrigerated storage capacity with the postharvest losses: In developed countries where refrigerated storage capacity per capita is 10 times higher than in developing countries, the losses are substantial lower (15% comparing to 40% in developing countries, IIR 2011). The lack of cold chain in developing countries is particularly worrying if we take into account that increasing proportion of their inhabitants live in big urban agglomerations.

5. INSTITUTIONAL AND OTHER SOCIO-ECONOMIC ASPECTS

Harvest and postharvest losses are affected by a number of natural and socio-economic factors (Table 6). These natural and socio-economic factors constitute the environment in which harvest and post-harvest technologies are developed and adopted. Commodities and their production, postharvest systems and actors in the FSC are differently sensitive to this environment and its changes. Because of the limited control over the natural factors (particularly climate and weather), technologies tend to adopt to them reducing as much as possible their negative impacts. Natural factors like sunshine, wind or relatively stable temperature and humidity underground are usually effectively exploited in the traditional postharvest technologies. Further, crop vulnerability to weather condition in the production and post-harvest processes is particularly important in the context of the current climate change. More frequent adverse weather events damage or destroy crops and create unfavourable conditions for the post-harvest treatment which eventually lead to high food losses. In addition, the need for changing farming and post-harvest practices results from new cultivars which bring obvious benefits like high yields, pest resistance or better nutritional and taste properties, but might also have other physical and biological properties (e.g. tougher ears, tiny skin etc.). The other factor pressing on farming practices is increasing environmental concern of the public: This limits for example the use of pesticides, puts pressure on using water, recycling water and plastics.

Table 6: Factors affecting harvest and post-harvest losses

Natural	*Socio-economic*
Weather and climatic conditions	Agricultural practices in the pre-harvest phase
Spread of pests (bacterial, fungal, insect, rodents)	Applied harvest and postharvest technologies
	Transport infrastructure
Physical and biological (pest resistance) characteristics of crop varieties	Human factor / knowledge & skills / cognitive capacity / social networks / collective learning
Endogenous biological processes (respiration, transpiration, ripening etc.)	Scale of farming
	Integration of FSC
	Economics of production and postharvest practices (productivity, farm income, efficiency)
	Institutional and policy factors (legal framework, property rights, capacity for cooperation, etc.)

Source: Own classification

It follows from the commodity sections that harvest and postharvest technologies must be harmonised on farms and in the commodity chain if losses are to be reduced. These harmonised modern technologies exist, and not only at large scale[12] . Such harmonisation rests in understanding the biological, technical and socioeconomic process and in the coordination of human activities in the growing, harvest and postharvest phases.

Cereal, potato and sweet potato harvest and postharvest can be largely mechanised, labour requirements have declined significantly over the last decades. Harvest of yam, cassava and fruits and vegetables remains largely labour intensive. The postharvest treatment of most crops tends to be organised on farms particularly in developing countries. The great efficiency of the mechanisation attracts interest of farmers even in countries where labour is cheap and abundant (Ethiopian ATA 2013). Another motivation for postharvest mechanisation is increasing requirement of quality standard when crop is sold on the market (FAO 1994). Cooperative postharvest facilities can be found in many developing countries, nevertheless there is large space for encouraging more farmers to establish or to join cooperative. There are also commercial storages, usually owned and organised by large merchants, processors or by the government. In general, there are benefits of scale and therefore, modern technologies tend to be adopted by large businesses. Modern technologies require a certain degree of integration within the food chain because postharvest operations depend also on the final use of the crop. In addition, investment costs are rather high and assets specific (particularly for roots and tubers and for fruits and vegetables), thus good links to market are necessary (preferably long term contracts). Storing crop enables producers to market their production when prices are good. In contrast, small farmers who do not have suitable storage facilities must often sell their surplus production immediately after harvest.

It was indicated that traditional technologies do not provide sufficient protection of stored crops, and therefore, the losses are high. On the other hand, good technologies are available and there is increasing offer of such which in their scale fit to the needs of small farmers – especial in grains and tubers. Changing storage technology depends on many factors. Subsistence farmers (who have very limited cash) will always find buying storage equipment as less preferable than making it from locally available materials like straw, wood, bamboo, reeds, mud, bricks, cow dung etc. It was showed that adding some industrial materials for low cost (e.g. plastic foil) might allow poor farmers to buid suitable storage facilities. Farmers might, however, lack knowledge and confidence that new technology will really reduce losses significantly.

It is not only the storage facility and equipment which will solve the problem of crop losses. It will also require improved organisation and management and new skills: farmer/actors must assure that the moisture content of grain is sufficiently low, that crop put in the storage place is clean and healthy; Disinfection of the storage, suitable storage structures including containers are needed; Continuous monitoring and control of temperature, humidity, air circulation and atmosphere in the storage are required. Small commercial farmers might need flexible postharvest and storage facilities, since the crop and volume of harvest vary from year to year and also the time for which grain or tubers are kept on the farm before selling might be highly variable. Thus these farmers will be reluctant to invest in a technology which might provide good and save long term storage but for high (investment) cost. As already mentioned, shared warehouses, silos or refrigerated and controlled atmosphere storages (at village level or in a cooperative of producers) might be an option, but there must be a commitment of all participating farmers to assure quality and safety standards of their crops put in the

[12] There are many small growers (even part-time farmers) often organized in marketing cooperatives in developed countries who produce, store and sell quality crop to local markets. .

joint storage. In other words, sufficient social capital for such a collective action is needed (Flap and Volker 2004).

Another option is to bring harvested grain or tubers as soon as possible to the large modern well operated storages (central storages). Indian cereal storage system represents rather successful case in this respect (e.g. Naik, Kaushic 2011). Price guarantee makes the flow of grain to storages easy. Moreover, the participating agencies provide cleaning, handling and transportation, procurement and distribution, disinfection services, fumigation services and other ancillary activities, i.e. safety and security, insurance, standardization and documentation (India Agronet 2009). The weakness of the Indian cereal system is (according to Singh, 2010) that (a) it is entirely oriented on food security of urban areas, while rural areas, and in particular very small farmers, might be short in grain, (b) in order to cope with increasing production (stimulated by governmental subsidies – price guarantee) the storehouses do not conduct according to the recommended ("scientific") practices and a lot of grain is spoiled.

Small Indian farmers can also deliver their potato crop to "scientific" storages and they can receive easy marketing credit against the stored produce (AGMARKETNET). The system is similar to the system for cereals, however, relying more on private storages. Because storage rents are administratively fixed on one side and potato prices highly volatile, the system performance is rather variable. The fixed storage rents discourage private investors (Dahiya et al. 1996) and price risk discourages farmers to use these storage facilities (Fuglie 1999).

International development assistance programmes has tended to support 'modern' capital-intensive systems (Coulter 1991): silos/elevators against warehouse or bulks against sacks. There are however warning cases that such investment plans paid little attention to local conditions resulting in low or no effect (eg. Pakistan, Coulter 1991, or Millig Corporation of Tanzania, FAO 1994).

Postharvest technology, its development and adoption, depends also on the wholesale and retail sectors and consumers. This can be well illustrated on the fresh fruits and vegetables sector. Reefs (2010) describes differences between the traditional FFV marketing systems and the modern one. In the developed countries, FFV are produced on large farms, or farms associated in marketing cooperatives. The FFV supply chain exhibits strong vertical relationships. The consumption is rather continuous (also due to the availability given by the international trade). Under these circumstances, farmers and their cooperatives are ready to invest in postharvest technology. In contrast, traditional systems rely on small farmers and several levels of rather small intermediaries. Although the system is able to deliver FFV in the urban areas, it provides little incentives and guarantee for the investment in postharvest technology. This however is needed in order to reduce losses. Transport is almost entirely in ambient trucks and roads can be very congested and poorly maintained in some areas. Cold stores (if any) are often multi-user with owners providing a service. Various fruits and vegetables might meet in one storage room with adverse effects each on the other.

Solutions for decreasing postharvest losses might offer an integrated approach from "seed to supermarket shelf" (Hewett 2006). Actually, cold chain can function only as fully implemented, i.e. refrigerated storage – refrigerated transport – refrigerated retail store. Reardon and Minten (2011) argue that recent rapid development of private supermarket chains in India (annual growth by 49%) might represent the necessary power able to transform gradually the whole supply chain in the near future. These retailers concentrate on the needs of the growing middle class whose diet has changed in favour of fruits and vegetables over last 20 years. According to Reardon and Minten (2011), supermarkets, by their push on the supply chain, can stimulate vertical integration which will have capacity to provide a framework for private investment in the FFV cold chain. They call this process top-down revolution in the food supply chain. Perhaps we can generalize it for the other two commodity chains too.

6. CONCLUSIONS

The historical experience of actors of the FCS is insufficient because new cultivars, inputs and mechanisation as well as imported pests entered in the traditional systems. Also the scale of demand for food has increased due to urbanisation. New knowledge – harvest and postharvest technologies - is needed. Yet formal education of majority of farmers in developing countries is limited[13]. It puts pressure on the information and knowledge diffusion mechanism. New ways of information dissemination, education and training are needed in order to maintain and to enhance the innovation capacity of the actors. Rogers (1995), Foster, Rosenzweig (1995), Collier (1998) argue for a critical role of social networks for learning, knowledge acquirement and technology adoption among small semi-commercial farms. Further, farmers, FSC actors need to be involved in the technology development – actually should be innovators who experiment with the new knowledge and eventually adopt the new technology. The results of Sambodo (2009) suggested that semi-commercial farmers need to know, and confirm, that a new technology is significantly superior to the existing system, and can provide a secure income. The introduction of a new technology should use a participatory approach allowing negotiation, conflict mitigation and the creation of consensus among the relevant parties. (see also Kitinoja 2011)

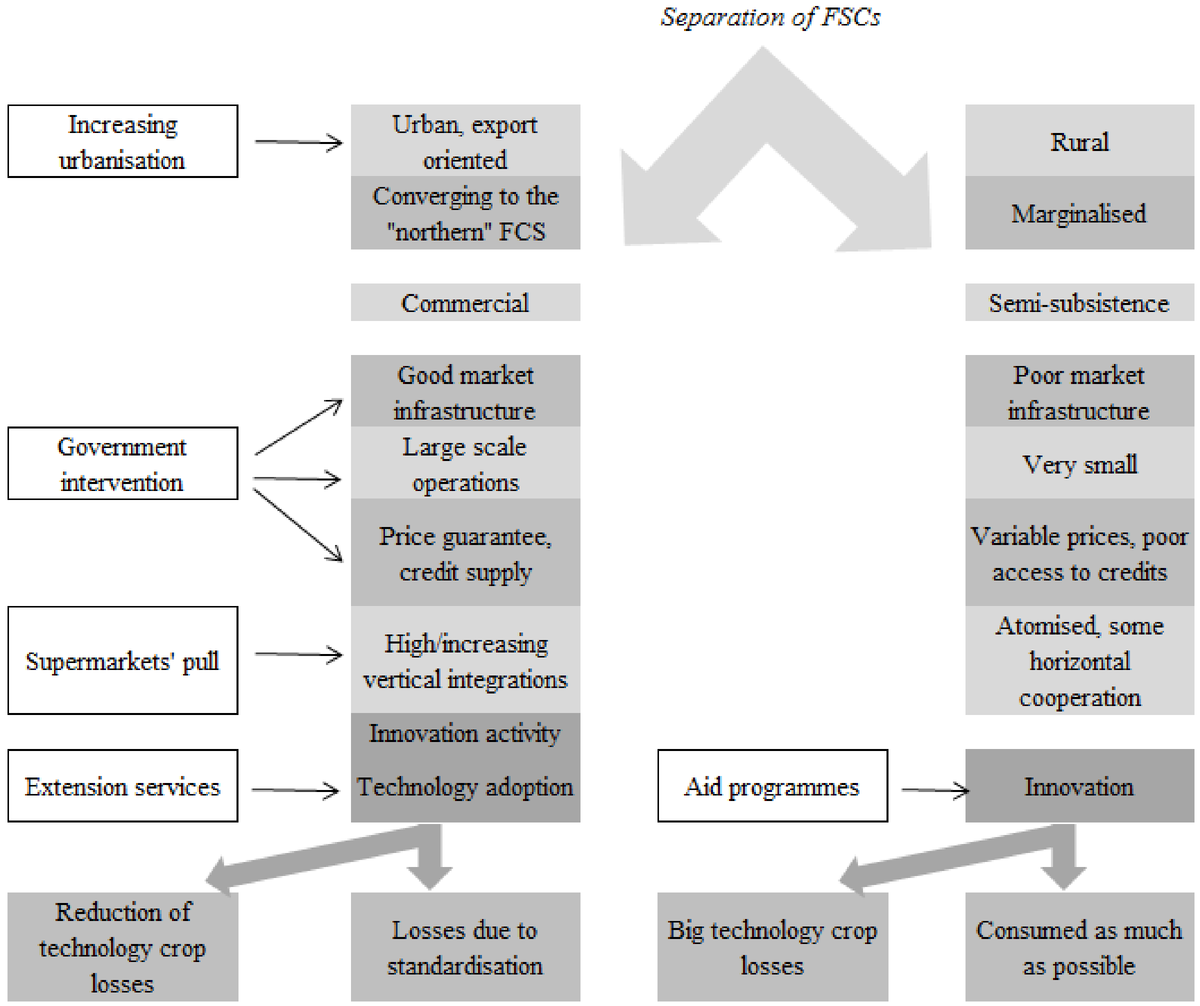
It is more or less clear that not all farmers/FSC actors in developing countries will be able to cope with the knowledge requirements and requirements for standardisation and safety procedures, even if an effective extension service is established and available. In addition, vertical integration as well as investment costs will require growing in size which under property rights restrictions in many countries will be achievable only by horizontal cooperation. This will require social capital and taking risk in pooling financial capital and profit. Thus it is very likely that the crop sector modernisation will go hand by hand with structural change which might result in a separation of the progressive urban oriented food chain and marginalised rural semi-subsistence farming (Figure 3).

The poverty of farmers represents a constraint to the spread of mechanisation and advanced technologies in the crop production, harvest and postharvest process. Often such farms are not integrated in markets; there are many intermediaries and the system is largely inefficient. In contrast, urban and export oriented FSCs are pulled by growing demand in centres of high (growing) income and exhibit significant vertical integration. They converge to the FSC of Europe or Northern America ("Northern" FSCs).

Policies are often biased toward the urban & export oriented FSCs (Singh, 2010, Reordan, Minten, 2011) because of their importance (also political) in the urbanising countries like India or the food exporting countries like Brazil or Argentina. As pointed out earlier, the governments invest in infrastructure and provide incentives for farmers to join them by guaranteeing prices, regulating terms of contracts and providing supports to credits. This is positively reflected in the adoption of modern postharvest technologies. While losses due to poor technology decline, new phenomenon appears – part of the crop is lost due to not reaching the standards.

[13] E.g. 5.8 years on average in Uganda (Katungi, 2007)

Figure 3 The separation of Food Supply Chains (FSCs) in developing countries



Source: own elaboration

Hodges et al. (2010) following World Bank (2010) argues that some of the improvements for reducing postharvest losses in least developed (marginalised rural) regions will need to take the form of public 'goods' including market organisation and infrastructure such as the development of networks of all-weather feeder roads so that crops can get to market, a problem especially acute in Africa.

Past experience shows that the support system for improving postharvest processes cannot be exclusively technically focused (see also Parfitt et al. 2010; Kitinoja et al. 2011); in contrary, more types of intervention are needed: "institutional" providing effective rules, knowledge transfer support, improved access to credits and often direct market intervention providing stabilisation through temporary storage of surpluses. A specific and well-targeted policy intervention may also be needed to accommodate the diversity in the farmers' ways of learning and making decisions (Sambodo 2009). In spite of the importance of urban and export markets, these interventions should not miss rural markets. Reducing harvest and postharvest losses is essential for improving food security of small (semi)subsistence farmers and poor rural households for which cereals and tubers/roots are staple food.

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REFERENCES

APHLIS (2013) African Postharvest Losses Information System http://www.erails.net/FARA/aphlis/aphlis/Home/ ; accessed on January 5, 2013

Agha, S.K., Oad, F.C., Siddiqui, M.H. (2004): Grain Losses of Wheat as Affected by Threshing Timings. International Journal of Agriculture and Biology 6 (6), 1170–1171

Anon. (1982): Como construir y user un silo metalico simple (How to construct and use a simple metal silo). FAO Project PFL/BOL/001, Working Doc. 1/1982.

Bartosik, R., Rodríguez, J., Cardoso, L., (2008). Storage of corn, wheat soybean and sunflower in hermetic plastic bags. In: Maier, D., Goldsmith, P. (Eds), Proceedings of the International Grain Quality and Technology Congress, 15-18 July 2008, Chicago, Illinois, USA

Breth, S (1976). Asian farmers can adopt Guatemala's low cost metal silos. Mod. Agric. Ind.Asia (Philippines), April 1976

Bokanga, M. (1999) Cassava: Post-Harvest Operation in Postharvest Compendium. FAO: Rome. http://www.fao.org/inpho/inpho-post-harvest-compendium/en/

CIPHET(ICAR) (2010): Estimation of Quantitative Harvest and Post-harvest Losses of Major Agricultural Produce in India. All India Coordinated Research Project on Post-harvest Technology. Ludhiana.

Collier, P. (1998) Social Capital and Poverty. World Bank Social Capital Initiative. Working paper No. 4

Coleman T, Udry, C. (2001) Social Learning in Networks: The Adoption of New Agricultural Technologies in Ghana. American Journal of Agricultural Economics, Vol. 83, 668-732

Dahiya, P.S., Khatana, V.S., Ilagantileke, S.G., Dabas, J.P.S. (1996): Potato storage patterns and practices in Meerut district, Western Uttar Pradesh, India. Working Paper (CIP). no. 1997-2.

Dockès, A., C., Rantanen, M., Bourdin, D., Tisenkopfs, T. and Guidi, F. (2009) Processes, organization and networks in Knickel, K., Tisenkopf, T., Peters, S. eds. Innovation processes in agriculture and rural development Results of a cross-national analysis of the situation in seven countries, research gaps and recommendations. Final reprt of the IN-SIGHT project. http://www.insightproject.net/files/IN-SIGHT_final_report.pdf

Edmunds, B., Boyette, M., Clark, C., Ferrin, D., Smith, T., Holmes, G. (2003): Postharvest Handling of Sweet Potatoes. North Caroline Cooperative Extension; pp.55

FAO (Food and Agriculture Organization of the United Nations) (2010): FAO/World Bank workshop on reducing post-harvest losses in grain supply chains in Africa – Lessons Learned and Practical Guidelines. 18-19 March 2010. http://typo3.fao.org/fileadmin/user_upload/ags/publications/FAO_WB_ph_web.pdf

Farina, M. M. Q. (2001) Challenges for Brazil's Food Industry in the Context of Globalisation and Mercosur Consolidation. International Food and Agribusiness Managemnt Review, 2(3/4), 315-330.

Feder, G and Umali, D.L. (1993). The adoption of agricultural innovations: A Review. Technological Forecasting and Social Change, 43, 215-239.

Feder, G., Just, R.J., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A Survey. Economic Development and Cultural Change, 33(2), 255-98.

Flap, H and B. Völker. Creation and returns of social capital: a new research program. London ; New York: Routledge. 2004.

Foster, A., Rosenzweig, M. (1995) Learning by Doing and Learning from Others, Human Capital and Technological Change in Agriculture. Political Economy 103, 1176-1209

Fuglie, K.O. (1999): Economics of Potato Storage: Case Studies. Paper presented at the Symposium on Potato Storage, Processing and Marketing Global Conference on Potato New Delhi, India, December 7-9.

Gnonlonfin, G.J., Hell, K., Fandohan, P., Siame, A.B. (2008): Mycoflora and natural occurrence of aflatoxins and fumonisin B1 in cassava and yam chips from Benin, West Africa. Int. J. Food Microbiology 122(1-2), 140-147.

Gowda, N.K.S., Swamy, H.V.L.N., Mahajan, P. (2013): Recent Advances for Control, Counteraction and Amelioration of Potential Aflatoxins in Animal Feeds. In: Mehdi Razzaghi-Abyaneh (ed.): Aflatoxins - Recent Advances and Future Prospects, Chapter 6, 129-140.Grolleaud, M. (2002): Post-harvest Losses: Discovering the Full Story. Rome: FAO. Available from: http://www.fao. org/docrep/004/ac301e/ac301e00.HTM

Gross, K., Yi Wang, Ch., Saltveit, M. (2004): The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. Agricultural Hand book No. 66, USDA ARS; http://www.ba.ars.usda.gov/hb66/contents.html

Gustavsson J., Cederberg, CH. van Otterdijk, R., Meybeck, A. (2011): Global food losses and food waste. A study conducted for the International Congress SAVE FOOD! at Interpack2011 Düsseldorf, Germany, Rome: FAO.

Hayma, J. (2003): The storage of tropical agricultural products. Agrodok 31. Agromisa Foundation, Wageningen.

Hensel, O. (2009) Welchen Beitrag kann die Forschung im Bereich der Nacherntetechnologie zur Lösung des Welternährungsproblems leisten? (What can be a contribution of research in the area of Post-harvest technologies for the solution of the World nutrition problem?) , a study in the Framework of the Project “Forschung zur Lösung des Welternährungsproblems – Ansatzpunkte, Strategien, Umsetzung (Research for the solution of the World nutrition problem – challenges, strategies, actions)”, TAB

Hewett EW (2006) An overview of preharvest factors influencing postharvest quality of horticultural products. Int. J. Postharvest Technol. Innov. 1:4-15.

Hodges, R.J., Buzby, J.C. and Bennett, B. (2010) Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. The Journal of Agricultural Science, 149 (S1). pp. 37-45.

Horna D., Zambrano, P.,Falck-Zepeda, J. eds. (2013) Socioeconomic considerations in biosafety decision-making: methods and implementation, IFPRI, pp. 211. DOI: http://dx.doi.org/10.2499/9780896292079

Holmes, B.J., Springman, R. (2009): Recycling silo-bags and other agricultural plastics. University of Wisconsin Extension, Cooperative Extension Publishing, A3875.

IAASTD (2009) Agriculture at the Crossroad. International Assessment of Agricultural Knowledge, Science and Technology for Development, Global Report. http://www.unep.org/dewa/agassessment/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Global%20Report%20(English).pdf

Jobling, J. (2000): Potatoes: Handle with care. Sydney Postharvest Laboratory Information Sheet. http://www.postharvest.com.au/Potatoes.PDF (also in Good Fruit and Vegetables magazine 11(4) Melbourne, Australia, 34 - 35).

Leeuwis, C., Van den Ban, A. (2004) Communication for Rural Innovation: Rethinking Agricultural Extension. Blackwell Publishing, pp. 428.

Kader A., A. (2009) Postharvest Losses of Fruits and Vegetables in Developing Countries: A Review of the Literature. http://ucce.ucdavis.edu/files/datastore/234-1479.pdf

Katungi, E., M. (2007) Social Capital and technology Adoption on Small Farms: The Case of Banana Production Technology in Uganda. PhD. Thesis, University of Pretoria,

Kitinoja, L., Saran S., Roy S., K., Kader, A., A. (2011) Postharvest technology for developing countries: challenges and opportunities in research, outreach and advocacy. J Sci Food Agric; 91: 597–603

Knickel, K., Tiesenkopfs, T., Brunori, G. (2009) Innovation processes in agriculture and rural development: the IN-SIGHT project. In Knickel, K., Tisenkopf, T., Peters, S. eds. Innovation processes in agriculture and rural development Results of a cross-national analysis of the situation in seven countries, research gaps and recommendations. Final reprt of the IN-SIGHT project. http://www.insightproject.net/files/IN-SIGHT_final_report.pdf

Kohli, P. (2008) Fruits and Vegetables Post-Harvest Care: The Basics. Crosstree Techno-visors. http://www.crosstree.info/Documents/Care%20of%20F%20n%20V.pdf

Maloney,B. (2010) Post-harvest handling guide for Moldovan peaches and nectarines. USAID. Pp 43.

Manrique, K. (2004) Las deficiencias en postcosecha en la cadena productor-consumidor de la papa en el Peru. INCOPA, Proyecto Papa Andina, Centro Internacional de la papa Lima-Perú, 16 p.

Meyhuay, M. (2001): Potatoes: Post-Harvest Operation in Postharvest Compendium. Rome: FAO. http://www.fao.org/inpho/inpho-post-harvest-compendium/en/

Monge, M., Hartwich, F., Halgi, D. (2008) How Change Agents and Social Capital Influence the Adoption of Innovations among Small Farmers Evidence from Social Networks in Rural Bolivia. Discussion Paper 00761., IFPRI, pp. 68.

Opara, L.U. (2003): Yams: Post-Harvest Operation in Postharvest Compendium. Rome: FAO. http://www.fao.org/inpho/inpho-post-harvest-compendium/en/

Parfitt, J., Barthel, M. and Macnaughton, S. (2010) Food waste within food supply chains: quantification and potential for change to 2050. Phil. Trans. R. Soc. B (2010) 365, 3065–3081

Pekşen, E., Koyuncu, T., Artık, C., Sessiz, A., Pınar, Y. (2013): Seed Viability and Yield of Chickpea (Cicer arietinum) Cultivars Threshed by Different Types of Beaters and Concaves. Int. J. Agric. Biol. 15, 76–82

Rangi, D. (2010) Support farmers to cut crop losses. Science and Development Network. http://www.scidev.net/en/opinions/support-farmers-to-cut-crop-losses.html

Reardon, T., Minten, B. (2011) The Quiet Revolution in India's Food Supply Chains. IFPRI Discussion Paper 01115.

Rembold, F., Hodges, R, Bernard, M, Knipschild H., and Léo, O. (2011) The African Postharvest Losses Information System (APHLIS), JRC Technical Report EUR 24712 EN.

Rip, A. and Kemp, R. (1998). Technological change, in: S. Rayner and E. Malone (eds): Human choices and climate change, Vol. 2. Batelle, Columbus, Ohio.

Rogers, E., M. (1995) Diffusion of Innovation. New York. The Free Press

Rolle, R. S. (2006) Improving postharvest management and marketing in the Asia-Pacific region: issues and challenges. In (Rolle ed.) Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region. Asian Productivity Organization (APO) and FAO, ISBN: 92-833-7051-1.

Sambodo, L. (2009) The Decision Making Processes of Semi-commercial Farmers: A Case Study of Technology Adoption in Indonesia. VDM Verlag Dr. Müller, pp. 376

Satybaldin, L. Grigoruk V. (2002) Post-harvest sector in Central Asia Region sub-regional summary report. Regional Workshop on Post-Harvest in Central Asia and the Caucasus: 2002. Almaty, Kazakhstan, http://www.egfar.org/documents/regional-workshop-post-harvest-central-asia-and-caucasus-summary-report

Shpychak, O. (1998): Analyses and Proposals to Improve Grain Market in Ukraine for 1998-2005. Research Report of the Department for Infrastructure and Prices of the Institute for Agricultural Economics, Kiev.

Striewe, L. (1998) Grain and Oilseed Marketing in Ukraine. CPER occasional paper No 5. Kiev, Ukraine

Striewe, L (2011) Expert View: Agricultural Sector. http://blog.chamber.ua/2011/04/expert-view-agricultural-sector-ludwig-striewe

Tyler, P. S. (1982). Misconception of food losses. Food and Nutrition Bulletin 4 (2). Available from: http://www.unu.edu/Unupress/food/8F042e/8F042E05.htm (verified 11 January 2011).

World Bank (2006). Enhancing Agricultural Innovation: How to go Beyond the Strengthening of Research Systems. Washington, DC: The World Bank

World Bank (2009). Reshaping Economic Geography. Washington, DC: The World Bank.

World Bank (2010). Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. Washington, DC: The World Bank