IMPROVING METHODS FOR ESTIMATING POST-HARVEST LOSSES

A Review of Methods for Estimating Grain Post-Harvest Losses

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## Acronyms and Abbreviations

<table>
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<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADLS</td>
<td>Administrative Data Liaison Service</td>
</tr>
<tr>
<td>APHLIS</td>
<td>African Postharvest Losses Information System</td>
</tr>
<tr>
<td>ESS</td>
<td>Economic and Social Development Department, Statistics Division</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FLAWIS</td>
<td>Food Loss and Waste Information System</td>
</tr>
<tr>
<td>FLW</td>
<td>Food Loss and Waste</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>NLP</td>
<td>Natural Language Processing</td>
</tr>
<tr>
<td>SAC</td>
<td>Scientific Advisory Committee</td>
</tr>
<tr>
<td>SVM</td>
<td>Standard Volume/Weight Method</td>
</tr>
<tr>
<td>TGM</td>
<td>Thousand Grain Mass Method</td>
</tr>
<tr>
<td>WRI</td>
<td>World Resources Institute</td>
</tr>
</tbody>
</table>
Introduction

Within the framework of the Global Strategy research plan, the research topic, “Improving methods for estimating post-harvest losses” is aimed at developing statistical methods for measuring post-harvest losses. Extensive research has been conducted on post-harvest losses in developing countries across different disciplines, however, a standard methodology for collecting data and estimating those losses has yet to be established in the context of a developing country.

This present report is a review of relevant literature, which includes publications manuals, methodologies and guidelines on estimating post-harvest losses of the Food and Agriculture Organization of the United Nations (FAO), as well as publications by other institutions, international organizations and relevant country experiences on estimating post-harvest losses.

In the review process, 105 documents were processed. This set of documents was divided into two groups. The first group comprised 56 documents that focused on specific topics relating to post-harvest loss assessment studies with their related methods and techniques. The second group comprised 49 documents that covered general post-harvest loss topics. The documents of first group were the main focus of this review, while those in the second group were used for an overall description of the domain and its concepts. Although this was a quite substantial corpus on the topics of food loss and waste, the review is not considered to be exhaustive as only the available literature has been referred to in this report.

A literature review can be viewed as a compilation, classification, and evaluation of what other researchers have written on a particular topic, with its main purpose being the following:

- To put key pieces of work in the context of its contribution to the subject under review;
- To describe, to the extent possible, the relationship of important pieces of work to the others being considered;
• To find novel ways to give meaning, shed some light on any gaps in previous research;
• To show the way forward for further improvement in connection with the issues at hand.

Hence, the objective of this review was not to list as many articles and names as possible nor to try to refer to every piece of literature in the area (an impossible undertaking). Moreover, for the review to be grounded in reality, a thesis statement and a research question (to be answered at the end of the review) are stated below.

One effective and efficient way to dramatically improve on the availability and accessibility of post-harvest loss data is to use a system approach for the collection, processing, analysis and dissemination of such data. This makes it easier to develop guidelines on cost-effective methods to estimate post-harvest losses.

The main research question is the following:

“What are the most appropriate principles, methods, theoretical models and techniques for creating a standard methodology for collecting data and estimating post-harvest losses in a developing country context?”

The domain under review for which suitable measurement techniques are to be investigated comprises a number of elements that dynamically interact with each other. A proper understanding of this complex system is a prerequisite for any attempt to measure it.

Regarding the remainder of the report, the first part contains a careful examination of the domain naming, definitions, concepts, dimensions or categories, and the measures that together highlight and define the essence of the domain. It is followed by a description of assessment techniques and statistical methods. Then, the literature review is summarized to show the gaps, and a framework for collecting data, measuring, and calculating/estimating food losses based on common methodology is broadly outlined. The final proposed system with all the technical details will be described in future technical reports.
Definitions and concepts

2.1. GENERAL DEFINITIONS

In the literature, the domain is mostly referred to as “post-harvest food losses”, “post harvest food losses”, or “postharvest food losses”. The World Resources Institute (WRI), however, refers to it as “food loss and waste” (FLW).

In dealing with the domain, terminology has been a bit imprecise in the past.

In February 2014, FAO released a definitional framework of food loss, as a global reference for stakeholders to use within their context of operations. In essence, the terms and concepts in that FAO definition are:

- Food waste is a part of food loss, however not sharply distinguished; the term “food loss and waste” is nevertheless maintained in regular communication.
- “Intended for human consumption” (already embedded in the Codex definition of “food”).
- Plants and animals produced for food contain “non-food parts”, which are not included in FLW.
- Food redirected to non-food chains (including animal feed) is food loss or waste.
- Quantitative FLW = the mass (kg) reduction.
- Qualitative FLW = reduction of nutritional value, economic value, food safety and/or consumer appreciation.

This definitional framework is by no means counter to the following more detailed and operational definitions found in the literature on food loss assessments studies. The most commonly used terms, based mainly on previous FAO work and Boxall (1986), are the following:
Grain: Used in this review in a broad sense, it refers to cereals and pulses; it includes cereals on the head, ear or cob, and after threshing or shelling, and pulses both shelled and in a pod.

Food: Commodities that people normally eat: the weight of wholesome edible material, measured on a moisture-free basis that would normally be consumed by humans. Inedible portions of the crop, such as stalks, hulls and leaves, are not food. Crops for consumption by animals are not considered food.

Harvest: The act of separating the food material from the site of immediate growth or production.

Post-harvest: The period after separation from the site of immediate growth or production. It begins at cutting and ends when the food enters the mouth. For most post-harvest loss studies, the end point is reached when the grain or grain product is finally prepared for future consumption.

Loss: The measurable decrease of a food grain, which may be quantitative or qualitative.

Damage: The superficial evidence of deterioration, for example, holed or broken grains, from which loss may result.

Grain loss: The loss in weight of food grain that would have been eaten had it remained in the food chain.

Food loss: Any change in the availability, edibility, wholesomeness or quality of food that reduces its value to humans. Food grain losses may either be characterized as direct or indirect.

Direct loss: The disappearance of food by spillage or consumption by insects, rodents and birds.

Indirect loss: The loss caused by a lowering of quality, leading to its rejection as food.

Losses of crop product: Crop products may be lost from the food chain, at any or all of the periods between planting and preparation for immediate consumption. Three general periods have been identified:

(I) Pre-harvest losses: Occur before the harvesting process begins and may be due to such factors as insects, weeds or diseases afflicting crops;
(II) **Harvest losses:** Occur during the harvesting process and may be due to, for example, shattering and shedding of the grain from the ears to the ground;

(III) **Post-harvest losses:** Occur during the post-harvest period.

**Post-production losses:** The combined harvest and post-harvest losses.

**Quality loss:** Local population and concerned traders assess the quality of produce in different ways based on the factors that each specific group considers to be important. In general, quality is assessed and products graded on the basis of appearance, shape, size, and sometimes smell and flavour.

**Nutritional loss:** Reflects the product of the quantitative and qualitative losses; more specifically, it is the loss in terms of nutritional value to the human population concerned. Weight loss during storage, excluding loss of moisture by definition, is a measure of food loss, however, the nutrient loss may be proportionately larger due to selective feeding by pests.

**Loss of seed viability:** Related to the loss in seed germination, which is important because of its effects on future food supplies.

For WRI, “food loss and waste” refers to the edible parts of plants and animals that are produced or harvested for human consumption but are not ultimately consumed by people.

More specifically, “food loss”, refers to food that spills, spoils or incurs an abnormal reduction in quality, such as bruising or wilting. Food loss accordingly is the unintended result of an agricultural process or technical limitation in storage, infrastructure, packaging or marketing. “Food waste”, on the other hand, refers to food that is of good quality and fit for human consumption but that does not get consumed because it is discarded either before or after it spoils. Hence, food waste is the result of negligence or a conscious decision to throw food away.

**Assessment** is the process of gathering information using various methods to systematically gauge the effectiveness of the domain.

**Measurement** is the reproducible procedure of extracting, recording or mapping basic quantitative or qualitative facts about loss situations; reproducible implies that the same procedure applied by any operator under the same circumstances will yield the same outcomes.
**Estimation** is the process by which measured basic data are combined and interpreted; experience and judgment are combined during the process to bear on the factual data.

### 2.2. DIMENSIONS OR CATEGORIES

Dimensions or categories refer to the scope of the various items and their classifications, the geographic locations, the losses/wastes types, the processes/activities, the main actors, the technologies and the factors causing losses/wastes.

#### 2.2.1. FOOD ITEMS AND THEIR CATEGORIZATIONS

In addition to referring to the various commodities by name in the different cross-tabulations, other classifications exist, with the most common being the following the FAO categorization:

<table>
<thead>
<tr>
<th>Cereals</th>
<th>Meat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots and tubers</td>
<td>Fish and seafood</td>
</tr>
<tr>
<td>Fruits and vegetables</td>
<td>Milk and eggs</td>
</tr>
<tr>
<td>Oil seeds, pulses and nuts</td>
<td></td>
</tr>
</tbody>
</table>

Other researchers and authors use categories, such as grains, food-grains (durable) and/or perishable/non-perishable food commodities.

#### 2.2.2. LOCATIONS

Measures of loss/waste can be presented by country using the ISO standard classification of countries or the FAO classification. Other classifications are the following:

<table>
<thead>
<tr>
<th>North America and Oceania</th>
<th>Sub-Saharan Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>Latin America</td>
</tr>
<tr>
<td>Industrialized Asia</td>
<td>South and Southeast Asia</td>
</tr>
<tr>
<td>North Africa, West and Central Asia</td>
<td></td>
</tr>
</tbody>
</table>

or

Developed countries versus developing countries

Within a given country, the information may be broken down by administrative units/subunits or agro-ecological zones.
2.2.3. LOSS / WASTE TYPES
Distinctions are made between loss types as quantitative, qualitative, real, apparent, food, weight, economic, goodwill/reputation and seed.

2.2.4. ACTORS
The actors are the farmers/farming households and other producing entities, as well as the traders, food processors, distributors, warehouse owners, retailers, other intermediaries and the final consumers.

<table>
<thead>
<tr>
<th>Farmer/holder/holding</th>
<th>Processor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trader</td>
<td>Exporter</td>
</tr>
</tbody>
</table>

2.2.5. PROCESSES / ACTIVITIES BY ITEM
These are also known as the various stages of the food value chain, such as levels, steps and stages in the flow of grain. The chain, in general, starts the moment the crops mature in the field/plantation, animals on the farm are ready for slaughter, milk has been extracted from an animal’s udder, aquaculture fish are mature or wild fish are caught in a net. The value chain ends at the moment food products are consumed by people or removed from the food chain. Different ways of depicting the value chain are used, including simply listing the stages by their name, or drawing them in boxes or in pipeline diagrams. It is important to note that the chains vary (number and type of levels) according to the commodity and the type of actor.

For cereals (food-grains, grains and durable), the most common breakdown, which is advocated by FAO, is shown below. At each of these stages, losses may be considered for measurement; the methods for doing that can then be designed and used during measurement studies. This chain does not reach the consumer table (“fork”).

<table>
<thead>
<tr>
<th>Harvesting</th>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stacking and stoooking</td>
<td>Transport</td>
</tr>
<tr>
<td>Threshing/shelling</td>
<td>Processing</td>
</tr>
<tr>
<td>Cleaning/winnowing</td>
<td>Packaging</td>
</tr>
<tr>
<td>Drying</td>
<td>Distribution</td>
</tr>
</tbody>
</table>

2.2.5. A HARVESTING
Harvesting carried out through a manual approach involved cutting the crop and then gathering and bundling it. This operation may also be done in a mechanized way by a harvester. During this stage, losses are mainly the result
of shattering and shedding of grains, with the amount of loss largely dependent upon the date/time of harvesting.

2.2.5.B STACKING AND STOOKING
Immediately after harvest, the produce may be stacked or stooked in the field to make it dry for a variable length of time, depending on farmers’ practices. During this operation, losses that occur may be the result of shedding or scattering.

2.2.5.C THRESHING/SHELLING
During threshing/shelling, the grains are beaten to separate them from the husk (in the case of rice) or from the cob to which they are attached (in the case of maize). This operation can be done manually or mechanically by threshers. Grains may be damaged during this process.

2.2.5.D CLEANING/WINNOWING
Cleaning is carried out by blowing away the chaff from the grain. In so doing, loss may occur as part of the edible grain passes into the chaff. This cleaning operation may be done manually or mechanically (in the latter, the winnower machine may be hand or engine-operated).

2.2.5.E DRYING
During the drying stage, losses may occur in different ways. For example, birds, rodents, insect pests and other vermin may take away or eat crops, such as paddy rice, that are spread out (on a road, or in the yard). The other kind of losses can be attributed to inadequate drying, which makes the grain vulnerable to damage by fungi or a lower proportion of grain recovery during milling.

2.2.5.F STORAGE
Many investigations in the literature have reported that greatest post-harvest losses occur at the storage stage. Notably, storage losses appear to be easier to estimate, as well as to prevent and reduce. Storage may be initiated at the farm level, trader level, retailer level or government warehouse level). The different modes of storage are (a) traditional, (b) intermediate, (c) improved, and (d) modern (steel, concrete for instance). Losses may be caused by insects, mites, rodents and micro-organisms.

2.2.5.G TRANSPORT
Transport operations may occur between the farmer's fields to the threshing floor, from farmer's storage to assembling markets or from assembling markets to possibly foreign markets; all of these operations entail loading and
unloading. During this process, the concept of loss would normally be the weight of grain because of spillage or pilferage.

2.2.5.H PROCESSING

Food grains may undergo different types of processing before being consumed. Rice, for instance, is obtained by dehusking paddy through the processes of pre-cleaning, hulling, husk separation, par-boiling, polishing and glazing. Grains may be broken during these processes.

2.2.5.I PACKAGING

Packaging and handling losses may arise at different stages, such as during transport from farm storage to market storage or at the retail-trade level. Handling can be done in bulk or in bags (gunny, cloth or plastic-lined). Losses may occur, owing to a reduction in weight or rejection because of spoilage as a result of defects in the packaging and handling.

2.2.5.J DISTRIBUTION

At retail levels, grain is mostly handled in gunny bags or sold to customers loose in their own containers. Losses at this level occur during handling or weighing.

Owing to its more general nature, the WRI value chain has a different structure, which is shown below.

<table>
<thead>
<tr>
<th>Production</th>
<th>Distribution and market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling and storage</td>
<td>Consumption</td>
</tr>
<tr>
<td>Processing and packaging</td>
<td></td>
</tr>
</tbody>
</table>

The African Postharvest Losses Information System (APHLIS) uses the following stages for its post-harvest loss profile.

<table>
<thead>
<tr>
<th>Harvesting</th>
<th>Transport to farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform drying</td>
<td>Farm storage</td>
</tr>
<tr>
<td>Threshing and shelling</td>
<td>Transport to market</td>
</tr>
<tr>
<td>Winnowing</td>
<td>Market Storage</td>
</tr>
</tbody>
</table>

This chain is for food grains only and does not include the consumption stage.

There are many other classifications of the value chain. The classifications differ to some extent by commodity (the harvesting of fruits and vegetables for instance do not involve threshing/shelling or winnowing stages). Another example of general classification, for instance, makes reference to the
following stages of the post-harvest process within the value chain of food grains:

<table>
<thead>
<tr>
<th>Production</th>
<th>Loading and unloading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting</td>
<td>Transport (on farm, off farm)</td>
</tr>
<tr>
<td>Threshing/drying/winning</td>
<td>Processing</td>
</tr>
<tr>
<td>Grading and sorting</td>
<td>Storage (on farm, off farm)</td>
</tr>
<tr>
<td>Packaging and Bagging</td>
<td></td>
</tr>
</tbody>
</table>

2.2.6. TECHNOLOGIES, METHODS, TECHNIQUES AND PRACTICES
To effectively carry out the processes/activities within the system, the various actors make use of the different technologies, methods, techniques and practices at their disposal. The technologies, methods, techniques, and practices used vary widely within and between systems driven by, for example, environmental, cultural and socioeconomic factors and availability of resources. Basically, actors are differentiated by the following: the size of their farm (small-scale/communal or large scale/commercial); their use of traditional, modern and high-yielding varieties; their use of insecticides and pesticides; their use of traditional or mechanized equipment, such as tractors, trailers, pumps, trucks, harvesters, combiners and threshers; their use of modern or traditional storage, such as warehouses, silos and bags; their level of training and knowledge; and their use of information technologies and communication to gain a competitive advantage.

2.2.7 FACTORS CAUSING LOSSES/WASTES
The losses within the system and at each stage/step of the value chain are most often attributed to the following group of general level factors:

1. Socioeconomic
2. Biological and/or microbiological
3. Chemical or biochemical
4. Mechanical
5. Environmental

Some of these factors are related to the technologies, methods, techniques, and practices as they are deployed and used by the actors within the system, such as mechanization, agronomic practices and farm management practices. Other factors relate directly to the natural environment, such as insects, vermin, molds, temperature, weather conditions and humidity, or to the socioeconomic environment, such as access to market information. A given combination of any number of these factors may be at work at any given time to influence weight
loss. Since these factors depend on the given stage/step within the value chain and many other variables, very few studies have used them.

APHLIS, for example, has singled out the following factors as those that may vary seasonally or annually and have a strong influence on the losses at various steps in the post-harvest chain. These factors, which are at the heart of the system, constitute the foundation of the post-harvest loss profile.

- Grain marketed within the first three months after harvest (%). According to APHLIS, this grain is expected to have suffered little or no losses in farm storage.
- Rain at harvest. This may affect the grain drying process, increasing the probability of infection of the crops by molds and other fungi.
- Storage duration (months). APHLIS states that the duration of farm storage has a direct effect on how much biodeterioration will occur and that the duration will depend on the size of the harvest and the opportunities of farmers to market grain.
- Larger Grain Borer infestation (a pest that attacks the maize crop). According to APHLIS, in many countries in Sub-Saharan Africa, the Larger Grain Borer is a major pest of farms that store maize, as it afflicts significantly higher losses than the more usual pests (which are already taken into account in the profile figures for storage losses).

The review of the APHLIS methodology will be conducted in a separate technical report. At this stage, it should be pointed out that APHLIS does not conduct field surveys to collect data needed for estimation. Instead, a network of data providers sends the loss information at its disposal to the APHLIS database. So if loss data are available, APHLIS will use it according to its own algorithm to output loss estimates. In such a situation, it is almost impossible to gauge the quality of the loss estimates in terms of statistical variances and biases.

**2.3. MEASURES**

In essence, measures are the numeric variables/indicators that are being investigated/colllected and then estimated and reported on through a proper breakdown by the dimensions/categories previously defined and agreed upon. It is of the utmost importance for any consistent and standard methodology on the domain under study to clearly specify the units of measurement, the measurement techniques and technologies.
Since the publication of the manual entitled “Post harvest grain loss assessment methods: a manual for the evaluation of post harvest losses”, which was compiled by Harris and Lindblad (1978), loss assessment studies have almost exclusively concentrated on the measurement of weight loss.

Before proceeding to the measures definitions, it is advisable to introduce the following additional concepts.

In most FAO approaches, post-harvest loss assessments are usually made on the basis of dry-matter variations, with almost no attention paid to nutritional or financial losses.

FAO defines grain loss for grain that would otherwise have been available as human food as the loss in weight, occurring over a specified period and expressed on a moisture-free basis.

**Moisture content (mc)** is defined as the quantity of free water in a given material. For science, as well as for all intent and purposes, organic material is defined as consisting of dry matter and water. Loss of moisture during grain drying is not considered food loss. A decimal ratio or a percentage is used to define moisture content as the one used by FAO (See Greig and Reeves 1985).

1. **Wet basis (wb)** is the ratio of the weight of water to the total weight of dry matter and water; it is most commonly used in agriculture.

2. **Dry basis (db)** is the ratio of the weight of water to the dry-matter weight.

When moisture content is expressed without information on wb or db, it is assumed that it is on a wet basis.

The following relationships hold between wb and db.

\[
mcwb = \frac{mcdb}{1 + mcdb}
\]

\[
mcdb = \frac{mcwb}{1 - mcwb}
\]

In any discipline, quantifying a problem and its solution can be made easily if measurements are carefully and correctly performed.
In physical sciences, known primary units of measurement are the mass, length, temperature and time. From there, other units used in loss assessment are derived as per the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Symbol</th>
<th>Other units</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight</td>
<td>kilogram</td>
<td>kg</td>
<td>ton (1000 kg)</td>
</tr>
<tr>
<td>time</td>
<td>second</td>
<td>s</td>
<td>minute (min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>hour (h)</td>
</tr>
<tr>
<td>distance</td>
<td>meter</td>
<td>m</td>
<td>kilometer(km)</td>
</tr>
<tr>
<td>temperature</td>
<td>degree Celsius</td>
<td>°C</td>
<td>degree Fahrenheit (°F)</td>
</tr>
<tr>
<td>area</td>
<td>square meter</td>
<td>m²</td>
<td>hectare (ha)</td>
</tr>
<tr>
<td>volume</td>
<td>cubic meter</td>
<td>m³</td>
<td>liter(l)</td>
</tr>
<tr>
<td>force</td>
<td>Newton</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>pressure</td>
<td>Pascal</td>
<td>Pa</td>
<td>Newton/square meter (N/m²)</td>
</tr>
</tbody>
</table>

Weight losses within the system are generally presented in two major ways: (i) an absolute loss being the actual weight of grain (kg or tons being the unit); or (ii) as a relative loss given as a percentage or proportion. APHLIS, for example, presents users with both absolute and relative loss values from production. Moreover, these loss figures are computed at each level/step/stage of the value chain. Calculations are made to estimate post-harvest weight losses of cereal grains by administrative subunits and then aggregated to provide estimates of loss values by region and by country.

In a typical post-harvest loss assessment study, many other quantitative variables are compiled, including, among them, farm areas and production yield, to be used to produce the required percentages/ratios. More detailed information is given in the review of the main post-harvest loss statistical methods that follows.
Methods and techniques for assessing post-harvest losses

3.1. BACKGROUND

Historically, loss assessment studies have been associated with loss reduction/prevention programmes.

The seventh session of the United Nations General Assembly, which convened in 1975, set the goal of a 50 percent reduction of post-harvest losses by 1985.

In 1976, FAO formulated a special action programme, which identified three major constraints on post-harvest loss prevention in developing countries. They were as follow:

1. Lack of information about the amplitude of the losses, the nature of the losses, their causes and the most effective techniques for reducing or preventing them;
2. Lack of infrastructure for implementing loss prevention measures;
3. Lack of investment in food loss prevention.

These events highlighted the need to develop standard and suitable terminology and methodology for the measurement of losses and led to the publication by Harris and Lindblad (1978).

Some of the methods and techniques compiled by Harris and Lindblad (1978) (quite accurate and detailed) were first reviewed by Boxall (1986) over the period 1980-1986, in an attempt to simplify them.
During that period, FAO, in 1980, published the *Assessment and Collection of Data on Post-Harvest Food Grain Losses* manual, which intended to serve as a guide to the statistical methodology for assessing and collecting data on post-harvest food-grain losses using objective measurements coupled with statistical survey sampling techniques. Over the period 1990-2000, researchers improved on the previous methods while using more and more the rapid methods (visual scales and the standard chart, for instance, described above). Compton and Sherington (1998), for instance, devised rapid assessment methods for stored maize cobs in cases in which weight losses were caused by insect pests. From 2000 onward, the APHLIS team project and other researchers have brought forward additional methodological improvements. These improvements were made possible by making the rapid methods work with more modern sampling-based field surveys to provide the data necessary for loss estimations.

In most cases, loss prevention and reduction efforts are undertaken using only part of the post-harvest system. This is done by identifying the most obvious and serious grain loss points in a country's post-harvest food system and then focusing on loss prevention and reduction efforts on those points. Methodologies for measuring post-harvest losses are aimed at providing outcomes that allow the determination of priorities for loss prevention and reduction efforts.

Assessments may be made by surveys (traditional or improved) experimental design studies (field studies or trials) or more recently by using econometric modeling (special cases of machine learning algorithms).

Because of the need to obtain reliable estimates of loss, FAO and other organizations conducted literature reviews in the 1970s to map the extent of available quantitative information on post-harvest losses in cereals. Many examples of very high estimates of unsubstantiated losses were found, of which most of them can be attributed to the ambiguity of the terminology used by their authors. Quoted figures of the type “39 percent for grain losses in Sub-Saharan Africa, or 45 percent for pearl millet losses in Namibia” may not provide an objective view of the real situation. In certain situations, figures provided for certain stages of a stated post-harvest chain have simply been totalled, leading to overestimates. Boxall (1986) gave an illustration along the following example:
How post-harvest losses may be overestimated

<table>
<thead>
<tr>
<th>Chain level</th>
<th>% loss</th>
<th>Weight loss (kg)</th>
<th>Balance (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>----</td>
<td>----</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Harvesting</td>
<td>15</td>
<td>150.00</td>
<td>850.00</td>
</tr>
<tr>
<td>Threshing</td>
<td>10</td>
<td>85.00</td>
<td>765.00</td>
</tr>
<tr>
<td>Drying</td>
<td>5</td>
<td>38.25</td>
<td>726.75</td>
</tr>
<tr>
<td>Transport</td>
<td>5</td>
<td>36.34</td>
<td>690.41</td>
</tr>
<tr>
<td>Storage</td>
<td>10</td>
<td>69.04</td>
<td>621.37</td>
</tr>
<tr>
<td>Processing</td>
<td>10</td>
<td>62.14</td>
<td>559.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>440.77</td>
</tr>
</tbody>
</table>

Source: (Boxall 1986).

If it is wrongly assumed that each loss figure is a percentage of the initial weight of a product, overestimation will ensue. In fact, in the above example, each loss figure is a percentage of the amount remaining in the preceding level of the chain. Hence, the total loss of 55 percent, a simple addition of the losses at different levels, is obviously an overestimation. The correct loss is shown on the weights in the last two columns, namely a 440.77 kg loss from the potential 1,000 kg, or 44.077 percent.

Overestimation can also occur during farm-level storage loss studies when grains are being withdrawn at certain intervals during the storage period. In that case, it is not suffice to record only one loss figure at one point in time during the season and use it as an indication of the overall loss for the year.

In this review, a number of figures have been quoted from the various studies that have been conducted at different levels of the food chain for the various actors and assorted crops in different countries. They cannot all be all enumerated here. To gain further insight, please refer to the bibliography.

Based on results from APHLIS, post-harvest loss figures for cereal grains, in Sub-Saharan Africa are as follows:
It may be of interest to compare and contrast with the following figures provided in from Karnataka, India (Basavaraja, Mahajanashetti and Udagatti 2007, pp 117-126).

**Estimated post-harvest losses at different stages in rice and wheat: 2003-2004**

<table>
<thead>
<tr>
<th>Stages</th>
<th>Rice</th>
<th>Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loss (kg/q)</td>
<td>Loss (%)</td>
</tr>
<tr>
<td>I Farm-level losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvesting</td>
<td>0.40</td>
<td>7.70</td>
</tr>
<tr>
<td>Threshing</td>
<td>0.52</td>
<td>10.02</td>
</tr>
<tr>
<td>Cleaning/winnowing</td>
<td>0.20</td>
<td>3.85</td>
</tr>
<tr>
<td>Drying</td>
<td>0.80</td>
<td>15.41</td>
</tr>
<tr>
<td>Storage</td>
<td>1.20</td>
<td>23.11</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.50</td>
<td>9.63</td>
</tr>
<tr>
<td>Packaging</td>
<td>0.20</td>
<td>3.85</td>
</tr>
<tr>
<td>Total losses at farm level</td>
<td><strong>3.82</strong></td>
<td><strong>73.57</strong></td>
</tr>
<tr>
<td>II Wholesale-level losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>0.12</td>
<td>2.31</td>
</tr>
<tr>
<td>Transit</td>
<td>0.17</td>
<td>3.27</td>
</tr>
<tr>
<td>Total losses at wholesale level</td>
<td><strong>0.29</strong></td>
<td><strong>5.51</strong></td>
</tr>
<tr>
<td>III Processor-level losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>0.01</td>
<td>0.17</td>
</tr>
<tr>
<td>Transit</td>
<td>0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>Grain scattering</td>
<td>0.01</td>
<td>0.10</td>
</tr>
<tr>
<td>Total losses at processor level</td>
<td><strong>0.03</strong></td>
<td><strong>0.42</strong></td>
</tr>
<tr>
<td>IV Retailer-level losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage</td>
<td>0.53</td>
<td>10.21</td>
</tr>
<tr>
<td>Transit</td>
<td>0.32</td>
<td>6.16</td>
</tr>
<tr>
<td>Handling</td>
<td>0.21</td>
<td>4.04</td>
</tr>
<tr>
<td>Total losses at retailer level</td>
<td><strong>1.06</strong></td>
<td><strong>20.42</strong></td>
</tr>
<tr>
<td>Total post-harvest losses</td>
<td><strong>5.19</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>
3.2. TYPES OF LOSS ASSESSMENT STUDIES

3.2.1. GENERAL BASELINE SURVEYS
General baseline surveys are used for preliminary examination of specific problem points and are conducted to expose the most serious grain loss points. They may or may not be randomized, and may include elements of purposive sampling. Properly conducted, these surveys build a better understanding of the post-harvest system, and the causes of losses to be revealed. While they are being conducted, additional relevant available data from other sources, such as administrative records, including, for example, rainfall and temperature, should be collected. These surveys, which are taken prior to the main loss assessment survey, should also provide initial rough expected values of losses.

3.2.2. PROBABILITY SAMPLE SURVEYS
Probability sample surveys are used for the main loss assessment exercise, with the objective to obtain statistically reliable quantitative data at different administrative and agro-ecological units, such as villages, regionally or at the national level. Procedures, such as random sampling (simple, stratified or clustered) with possibly sampling stages, are used. In cases in which the primary sampling units differ widely in size, sampling with probability proportional to size can be used. These operations are costly and require specially trained personnel. Probability sample surveys (both traditional and modern) are best suited for value chain processes, such as harvesting, threshing, drying and processing. They tend to be less suitable for estimating losses during the storage stages of the value chain, during which processes of biological degradation occur.

3.2.3. EXPERIMENTAL DESIGNS – FIELD TRIALS
Field trials are also used for loss assessment studies; they can handle loss comparisons between traditional and improved practices. Storage simulation trials can be conducted at research stations with a high degree of control over the conditions of the experiment; alternative post-harvest production practices can be evaluated to determine their effect on the level of losses, and multivariate analysis is performed using regression models.

Appiah, Guisse and Dartey (2010) used this technique for a study of post-harvest losses of rice from harvesting to milling in Ghana (Ejisu Juabeng district) to provide basic important information regarding the losses.
3.2.4. MULTIVARIATE LINEAR REGRESSION FITTING

Strictly speaking, multivariate linear regression fitting is more of an estimation technique than a type of study; data are collected from surveys and administrative records to create a database to be used to estimate model parameters. At different stages of the food loss value chain, some of the factors causing quantitative and qualitative losses are interrelated. For example, at the storage stage, variables, such as storage structure, moisture content, temperature, relative humidity, insects, mites, rodents, micro-organisms attacks, respiration and other biological processes (independent variables), act together at the same place to impact loss variables (dependent variables). Hence, regression equations can easily be fitted to quantify the relationships between dependent and independent variables. The advantage of doing this is the ability to predict losses in advance so that planners and decision makers can take appropriate measures as early as possible in their decision cycles.

Some of these techniques have been used with some success in studying the factors affecting post-harvest losses in rice and wheat at the farm level in India (see Basavaraja, Mahajanashetti and Udagatti 2007) Taherzadeh and Hojjat (2013) also used a regression model in the Islamic Republic of Iran for a study on post-harvest losses of wheat in the north-western part of the country, which involved combining post-harvest loss survey data with administrative records data.

The ADM Institute for the Prevention of Postharvest Loss is currently conducting initial conceptual work at the University of Illinois to establish a method for evaluating post-harvest loss that is consistent with the econometric modeling approach as described above.

3.3. GENERAL PRINCIPLES OF LOSS ASSESSMENT STUDIES

In the literature, measurement techniques and methodologies are most often presented at each of the main stages of the food loss chain. To assess food grain losses at any of those stages, statisticians have developed a number of techniques based on the following principles:

1. Definition of the population for which loss estimates are to be produced;
2. Construction of a proper sampling frame;
3. Design of proper sampling procedure and measurement technique;
4. Design of the field work organization, data collection tools, data processing and analysis tools;
5. Production and publication of standard errors of the estimated variables to evaluate the quality of the information thus obtained;
6. Breakdown of the loss estimation at various stages into at least three levels: (a) losses at the farm level; (b) losses at the level of the intermediaries, such as grain merchants; and (c) losses at the level of government agencies, such as warehouses.

After the sampling issues are sorted, the data collection techniques as briefly described below are implemented and appropriate estimation procedures are devised to obtain average loss figures for the desired level, such as the regionally or nationally.

As a general observation, during harvesting, in-field drying, stacking, transport, threshing, drying and cleaning, losses caused by biological agents should be adjusted to a dry-weight basis. Other losses are usually expressed in terms of weight of material at 14-percent moisture content (Boxall 1986). Boxall (1986) found that it was more convenient to work on the basis of the dry weight of grain, which could then be simply calculated from the formula:

\[
\text{Dry wt. of grain} = \text{wt. of grain} \times \frac{(100 - \text{m.c. of grain})}{100}
\]

m.c. is moisture content

To do comparisons with other loss assessment figures, losses should be expressed as percentages (rather than adjusted weights) with a clear statement of the basis of the presentation (the denominator of the percentage). Losses that occur during harvesting, in-field drying and stacking operations are expressed as a percentage of yield, which is defined as obtained yield (maximum quantity of clean grain less the losses being assessed). For threshing and cleaning, the losses are expressed as a percentage of the grain input to the operation. It should also be noted that farmers' practices during harvesting (and rainfall), duration of in-field drying, and stacking, have a marked effect on the level of losses.

3.4. DATA COLLECTION AND MEASUREMENT IN LOSS ASSESSMENT STUDIES

Building a suitable sampling frame is normally the first stage when planning a main loss assessment survey. First and ultimate sampling units vary depending on the level/stage of the post-harvest during which losses are being measured.
Lists of those units should be prepared to allow proper selection of sampling units.

At the harvesting level of the chain, villages (or their groupings) are commonly the primary sampling units, holders are the secondary sampling units, and fields the ultimate (tertiary) sampling units.

The primary sampling units may be clustered prior to sampling. Simple or stratified random sampling may be used to select the holders; for each chosen holder, a simple random sample of subplots within fields can then be selected.

For threshing, cleaning, drying, transportation, and processing, villages are primary sampling units and holders serve as the secondary sampling units.

For these levels, additional sampling stages are necessary; for instance selecting a random sample of produce, such as maize and cobs, to be threshed and observed for lost or damaged grain.

For storage, villages are the primary sampling units, holders are the secondary sampling units and the storage units (if there are more than one) within the holding are the ultimate sampling units.

The villages (the primary sampling units) may be selected through simple random sampling or stratified random sampling or may be sampled with probability proportional to size. FAO has produced a number of useful guidelines and manuals on these procedures.

3.4.1. GRAIN LOSSES AT THE FARM LEVEL
A. Losses during harvesting

Strictly speaking, losses during harvesting are post-production rather than post-harvest losses. In fact, they were not considered by Harris and Lindblad (1978).

Ideally, this stage of the value chain should benefit from a linkage with an annual production survey that contains a crop-cutting component. The crop-cutting plot is selected at random within the field before harvesting by the holder. The crop inside a crop-cutting plot (usually 10 meters x 5 meters or 5 meters x 5 meters, depending on the type of crop) is harvested according to the usual farmer practices and the yield is weighted and recorded. After the harvested produce is removed from the plot, all grains shed or missed are then carefully picked up for estimating harvest loss.

If a stratified two-stage random sampling design has been used with the village serving as the primary sampling unit and holder as secondary sampling unit,
estimates of production and loss per hectare can be produced as follows (FAO 1980):

$p_{ij}$ is production per hectare for holder $j$ in village $i$

$a_{ij}$ is the area under the crop for holder $j$ in village $i$

$A_i$ is the area under the crop for village $i$

$l_{ij}$ is loss per hectare for holder $j$ in village $i$

$m$ is the number of sampled holders

$n$ is the number of sampled villages for the given stratum

\[ P_i = \frac{\sum_{j=1}^{m} a_{ij} p_{ij}}{\sum_{j=1}^{m} a_{ij}} \] is the estimate of production for village $i$

\[ P = \frac{\sum_{i=1}^{n} A_i p_i}{\sum_{i=1}^{n} A_i} \] is the estimate of production per hectare for the given stratum

\[ L_i = \frac{\sum_{j=1}^{m} a_{ij} l_{ij}}{\sum_{j=1}^{m} a_{ij}} \] is the estimate of loss for village $i$

\[ L = \frac{\sum_{i=1}^{n} A_i l_i}{\sum_{i=1}^{n} A_i} \] is the estimate of loss per hectare for the given stratum

Hence, the percentage loss in this harvesting stage is given by

\[ PCL = \frac{L}{P} \]

Estimates of variances for $P$ and $L$ can easily be derived as well as for their ratio $PCL$. 
Using crop-cutting techniques to assess yields in the normal annual agriculture production surveys conducted in developing countries is extremely difficult. Therefore, the application of these techniques for loss assessment should be carefully evaluated for the situation at hand. In fact, there is still no best single ideal method for crop-cutting

**B. Losses during stacking/stooking**

In the literature, it has been suggested that losses associated with stacking and stoking be measured when the operation is being carried out normally by ensuring that the stacks or stooks are built on a plastic sheet or tarpaulin to collect all scattered grains when the bundles are later removed. This approach may be problematic if the labourers perceive the situation as not being “normal and hence try to handle the bundles (carefully or roughly) differently from the usual situation.

Loss of quality may occur for newly harvested grain stacked for threshing during a wet season as it may become moldy or discolored when exposed to humidity for relatively long period. In cases in which there is severe deterioration of grain leading to rejection of the crop as being unfit for human consumption, reduction of quality may be expressed on a quantitative basis. In cases in which the grain is not rejected, some sort of estimate of the reduction in quality can be provided by contrasting the condition of a carefully processed sample of grain from a stack/stook at threshing time with that of a sample drawn at the time of stacking/stooking.

If grain remains stacked or stooked for many months, the process can be regarded as a means of storage during which losses to rodents, birds, insects and micro-organisms may occur. Hence, the standard techniques for estimating losses due to insects during storage can still be applied, though it might be difficult to estimate losses due to birds and rodents. Using the standard technique, grain samples are collected at stacking time and before threshing; they are then carefully threshed and analyzed for insect loss. There was no substantial account in the literature of such technique being used.

**C. Losses during threshing/shelling**

Data on grain loss during threshing and shelling should be collected from a sample of produce from the sampled holders.

Losses during threshing may occur following: (i) incomplete threshing (grain remains on the straw); (ii) damage through the grain; or (iii) spillage and scattering during the process.
In cases of incomplete threshing, random samples of bundles of harvested crops are threshed by farmers' methods, and the grain obtained is weighed and recorded. After that, the remaining straw is carefully examined for grain that has escaped the threshing process. Hand-winnowing is done next to bring the two samples to the same quality level. Moisture content measurement is conducted for both samples and their weights are converted to standard moisture content.

Assessing grain damage during threshing is similar to other processing stages. Basically, all processing steps leading to the final products are standardized; the grains are threshed by the farmers’ methods and by an optimal method, which provides the optimal yield of the undamaged grain.

There is little guidance in the literature on ways to assess these losses that occur as the result of scattering and spillage. Some researchers have suggested that the losses can be assessed by spreading a large sheet on the threshing floor to capture the scattered grains. This, however, may be difficult to achieve in practice, especially if the area to be covered is expansive (grains can be scattered several meters from the point of threshing).

In the case of maize shelling, losses may be due to grains remaining on the cob or damage caused to the grain by the shelling method applied. The technique for assessing the loss of maize on the cob is similar to assessing threshing losses as shown above. Usually the loss is expressed as a percentage of the total weight of the grain; some researchers however, have elected to express it as a percentage of the weight of shelled grain.

It could be useful to examine grain damage caused by the shelling process, possibly to provide an indication of the efficiency of the shelling instead of an estimate of food loss. In that case, shelled grain is grouped as a representative sample of a minimum of 200 grains and examined for damage in order to express the number of damaged grains as a percentage. Then a second sample of cobs is hand-striped and a sample of 200 grains observed as previously to constitute a check of shelling damage.

Estimates of average losses for the given stratum can be computed as follows (assessment and collection of data on post-harvest food-grain losses (FAO 1980):

\[ P_i \] is the estimated grain production for village \( i \)

\[ p_{ij} \] is grain production for holder \( j \) in village \( i \)
\(\chi_{ij}\) is the percentage loss of any kind for holder \(j\) in village \(i\)

\(m\) is the number of sampled holders

\(n\) is the number of sampled villages for the given stratum?

\[
X_i = \frac{\sum_{j=1}^{m} p_{ij} \chi_{ij}}{\sum_{j=1}^{m} p_{ij}} \quad \text{is the estimate of percentage loss of grain for village } i
\]

\[
X = \frac{\sum_{i=1}^{n} p_i X_i}{\sum_{i=1}^{n} p_i} \quad \text{is the estimate of percentage loss of grain for the given stratum}
\]

Variances and hence standard errors can also be worked for \(X\).

**D. Losses during cleaning/winning**

Losses during cleaning/winning occur as the result of edible grain passing into the chaff. To estimate the losses, a sample of grain in a single batch is taken and the quantity of chaff and grain obtained in the operation are recorded.

Lost grain isolated from a sample of chaff has to be grossed up to obtain the total quantity. The percentage is calculated on the basis of grain obtained by normal cleaning. In cases in which two or more samples are taken, the results are averaged to get the percentage loss in the winnowing process. Stratum and regional levels of percentages are then computed from the holder percentage level using the same technique as applied in the threshing/shelling stage.

**E. Losses during drying**

To estimate losses during the drying stage, the following data are required: the quantity of grain initially spread out for drying; the moisture content (reduction in weight resulting from loss of moisture is not counted as loss) of the grain; and the quantity of dried grain collected (with its moisture content) by the farmer after drying. There are many methods for determining moisture content. Therefore, special care must be taken to ensure that the methods applied are uniform in any given region.

To estimate losses at this stage, a stratified two-stage random sampling design is assumed. The difference between the initial quantity of grain spread out for drying and the quantity of grain collected after drying is divided by the initial quantity of grain spread out to obtain the percentage loss. To get the obtained percentage at the stratum and regional levels, the formulae used for the threshing/shelling stage apply.
F. Losses during storage

Storage losses are investigated at the farmer, trader, and government distribution agency levels. Hence, the losses must be estimated differently. As discussed earlier, in countries where crop-cutting surveys are being conducted annually, a sample of farmers can easily be obtained from the annual production survey; otherwise, a multistage stratified sampling of farmers can be used, as already described. Loss data may be collected at different frequent intervals, depending on the prevailing period and mode of storage. Loss in weight during storage caused by insects and molds, rodents and birds at the farm and village levels, must always be related to the quantity in store at the time of the assessment. Many methods have been devised for assessing losses during storage; the most original methods are found in the manual of methods compiled Harris and Lindblad (1978); these methods were then reviewed by Boxall et al (1981) and by Compton A. J. et al. (1995 and 1998), in the 1990’s to make them more “rapid” (hence also less reliable); for the purpose of illustration, the original methods (compiled by Harris and Lindblad (1978)) are quickly reviewed here. The reference section of this report contains the essentials of the other methods; in addition, new methods are also being devised by researchers in other countries around the world.

As reported in by Harris and Lindblad (1978) and Adams and Schulten, suggested three methods to determine losses in grains due to insects and microorganisms.

Losses due to insects

**Determination of the weight of a measured volume of grain** is carried out by using the **standard Volume/Weight method (SVM)**, also known as **volumetric/bulk density**. Under this method, the dry weight of a standard volume of grain is measured by a standard method at the beginning of the storage period and is compared with the dry weight of the same volume of grain after a certain storage period (depending on farmers practices in the study region — six to nine months — in some African countries). The dry weight of a standard volume of grain depends on the moisture content and the grain variety. This is probably the most reliable method of loss determination. A variation of the technique can be used s when baseline samples cannot be obtained (Boxall 1986). The modified standard volume/weight method uses an artificial baseline prepared by selecting undamaged samples from the grain present in the store at the time of loss determination. The loss is then the difference in weight (expressed as a percentage) between the undamaged and the damaged sample.
With the moisture content being approximately the same, there is no need for conversion for moisture.

**The count and weight or gravimetric method:** The count and weight method provides an estimate of losses in cases in which a baseline cannot be determined at the beginning of the storage period and requires only minimal equipment. The method, which is applied to a single sample, requires the computation of (a) the proportion by weight of grains damaged by insects and (b) the percentage of damaged grains. Damaged and undamaged grains in a sample of 100-1000 grains are counted and weighted. The weight of the sample is compared with the weight it would have registered in the absence of damage. The base equation of FAO (1985) reads as follows:

\[
\% \text{ weight loss} = \frac{[UaN - (U + D)]}{UaN} \times 100
\]

With \( U \) = weight of undamaged fraction in sample

\( N \) = total number of grains in sample

\( Ua \) = average weight of one undamaged kernel

\( D \) = weight of damaged fraction in sample

When using this formula, the percentage weight loss has to be adjusted to 14-percent mcwb, or moisture content should be stated. Percentage weight loss can also be computed using a formula that does not require the value of the mean weight of undamaged grain. This method has some sources of error, which may give negative weight-loss figures at low infestation levels. Other variations of the formula have been reported as follows: (Harris and Lindblad 1978)

\[
\% \text{ weight loss} = \frac{(UNd) - (DNu)}{U(Nd + Nu)} \times 100
\]

Where \( U \) = weight of undamaged grain,

\( Nu \) = number of undamaged grains,
D = weight of damaged grains,  
Nd = number of damaged grains.

This formula does not require knowing the value of the mean weight of undamaged grain.

There is a variation of the traditional count and weigh method in cases in which maize grain kernels are destroyed or lost, as opposed to being damaged by pests. In those cases, the losses are grossly underestimated when using the traditional count and weigh method. A modified count and weigh method was proposed by J.A.F. Compton (Compton, Floyd, Ofosu and Agbo 1998) for assessing losses due to insect pests in stored maize cobs. In essence, the method is applied by counting the destroyed grains in each cob and applying an adjusted calculation through an eight-step process. After performing the eight steps, the formula as given by Compton is as follows:

$$\text{Percentage weight loss} = 100 \times \frac{TND(W_d + W_u)W_u + FW(N_dW_u - N_uW_d)}{TND(W_d + W_u)W_u + FW(N_d + N_u)W_u}$$

Where TND = total number of destroyed and missing grains,
FW = the final weight after the eight-step process,
Nd = number damaged grains in subsample,
Nu = number undamaged grains in subsample,
Wd = weight damaged grains in subsample,
Wu = weight undamaged grains in subsample.

This method is an improvement on the traditional one when maize grain kernels are destroyed or lost during storage.

**The Converted Percentage Damage Method** is based on the percentage of insect-damaged grain in a sample and its conversion to a weight loss using a predetermined factor. This method, which is only suitable for insect damage, provides a useful estimate for a quick appraisal of losses. Although the method is liable to the same sources of error as the modified standard volume/weight method and the count and weighs method, it has apparently given good results
in practice. Hence, it is recommended to use this method instead of guessing when these two earlier mentioned methods cannot be used.

Boxall (1986) suggests that once the relationship between percentage damage has been established through a laboratory experiment, a conversion factor can be calculated and subsequently used to determine the weight losses in other samples of the same type of grain. Adams and Schulten (1978) recommended that the percentage damage/weight loss relationship be established from the count and weight method. This obviously, is the reason why this method is subject to the same sources of errors as the count and weight method. The conversion factor is calculated from the formula by using the figures from the count and weigh technique:

Most of these techniques that were compiled by Harris & Lindblad (1978) involved collecting grain samples from the farmers and sending them to distant laboratories for further analysis and returning them afterwards; this back and forth movement of grain samples created of lot of delays for getting the results of the surveys. Hence, the attempt of J.A.F. Compton and other researchers (Compton et al 1992, Compton and Sherington 1998) to devise rapid and improved methods and avoid sending sampling grains to the lab. Instead, they devised visual scales (maize cobs) and standard charts (maize grains) to be used directly in the field during enumeration. By using visual impression, the enumerator is able to match the farmers’ sample cobs with various classes of infested cob portrayed in the pictures handed over to them. The percentage weight loss assigned to the picture with the corresponding appearance can later be entered as the weight loss for the cob. The enumerator can then sum up the number of cobs assigned to each class; the percentage weight loss for the maize stored in cob form is determined by using the following formula (Compton and Sherington 1998):

\[
Vissloss = \frac{aN_1 + bN_2 + cN_3 + \ldots + nN_i}{N_T}
\]

Where

\(Vissloss\) = weight loss estimated using the visual scale

\(a\) to \(n\) = damage coefficients for each class

\(N_1\) to \(N_i\) = Number of cobs in each class

\(N_T\) = Total number of cobs in the sample
To estimate the weight loss for maize stored in grain form, the enumerator uses a standard chart. The enumerator randomly selects separate samples of perhaps 100 grains each from the farmers’ maize. It then places the grains in a liter plate to physically count the damaged grain. The process is repeated for the samples and an average number of damaged grains per 100 grains is established. The number of damaged grains is read off against a predetermined regression chart to find the percentage weight loss.

As a result of these new technologies, the techniques have become faster and less cumbersome; in addition, they clearly demonstrate, once again that the sampling statistician (who might not know about biological laboratory calibration of experiments), has to work very closely with the biometrician and other food loss specialists to ensure that these techniques are beneficial.

The thousand grain mass method (TGM) is another method (Boxall 1986) that was advocated for determining insect losses while helping to overcome the problems encountered with both the volumetric and the count and weigh method. This technique has been modified from a standard procedure of determining the weight of one thousand grains and thus is known as the thousand grain mass method (TGM). The multiple TGM technique, a variation of TGM has also been proposed to take into account the variations in grain size and the difficulties in obtaining representative samples when using the traditional TGM.

TGM is the mean grain weight multiplied by 1000, corrected to a dry weight. It is calculated by counting and weighing the number of grains in a sample. To avoid possible sources of error and bias, the sample is not adjusted to a specific weight or number of grains; a reference TGM is determined from a sample of grain collected at the beginning of the storage season and compared with subsequent measurement throughout the season. The weight loss in a sample of grains is given by the formula (Boxall 1986):

\[
\frac{\text{Initial TGM} - \text{Sample TGM}}{\text{Initial TGM}} \times 100
\]

Dry weight TGM can be derived from the following formula:
Where $M_D = \frac{10m(100 - H)}{N}$

$m$ = mass (weight) of grains in the sample

$N$ = number of grains in sample

$H$ = moisture content in sample

However, there was no account in the literature of a practical application of these TGM techniques in loss assessment studies.

**Losses due to micro-organisms (molds)**

Grains infected by micro-organisms lose weight at a rate which varies according to the grain moisture content, temperature and the amount of physical damage to the grain. There appears to be minimal research on the quantification of losses stemming from molds at the farm level. The methods used to assess weight losses caused by insects can be used for assessing losses caused by micro-organisms. The loss in weight caused by micro-organisms in a sample of grain can be calculated by comparing the damaged (infected) sample with a baseline (undamaged) sample. As in the case of insect losses assessments, the baseline sample should ideally be collected at the time the grain is stored.

**Losses due to vertebrate pests (rodents and birds)**

Data and appropriate studies and techniques to assess losses caused by rodents and birds in the literature are lacking. There have been proposals that in order to measure loss of grain cobs or heads caused by rodents, an estimate of the percentage of grain removed needs to be calculated first; second, undamaged cobs or heads of the same size as the damaged ones should be shelled or threshed and the grain weighed; last, the loss is calculated by multiplying the weight by the percentage of grain removed. It is not clear however, how this method should be used.

In the literature, it has been proposed that losses of threshed grain to rodents can be estimated by comparing the weight of grain stored with the weight of grain removed, provided that allowance is made for other losses, for example, losses caused by insects. This can be really challenging within farm-level studies because of the difficulty of monitoring grain movements in and out of
farm storage (unless the study is conducted in an experimental way under more controlled conditions).

There is no generally accepted methodology for assessing bird losses after harvest, though losses before harvest are known to be extensive. The little guidance that exists revolves around estimating losses in the field. At some other stages of the post-harvest system, a comparison of weights of grain entering and leaving the stage (correcting by moisture content) can be made in order to estimate losses caused by birds. However, estimating such losses during storage still remains a difficult task.

Calculating total storage losses

To conduct assessments of total storage losses at the farm level, the losses calculated from samples should be related to the quantity of grains originally stored and to the pattern of grain consumption.

When grain is being removed at regular intervals during the storage season, total loss caused by insects can be gauged by calculating the loss in each quantity of grain removed by comparing samples of grain that has been removed with a sample of grain collected at the beginning of the season. Boxall (1986) gives the example as illustrated in the following table.

<table>
<thead>
<tr>
<th>Months during which grain is removed</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity (volume) of grain removed (%)</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Weight loss in sample (%)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Weight loss (as percentage of total stored)</td>
<td>0.1</td>
<td>0.2</td>
<td>0.45</td>
<td>0.75</td>
<td>1.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Cumulative weight loss (as percentage of total stored)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.75</td>
<td>1.5</td>
<td>2.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Ideally, quantities of grain stored put into and removed from storage should be weighed, however, in practice, this may be extremely difficult to do. Hence, some sort of estimation of grain quantities has to be made.

In some studies, volume occupied by the produce in storage was measured and transformed into a standard weight using a predetermined factor and quantities of grain removed calculated by reference to standard baskets. Grain removed was first placed in the basket; with prior knowledge of the dimensions of the basket used, the volume and weight of grain removed could be calculated. In
other studies researchers had to rely on the use of traditional/local volume measures to obtain estimates of quantities of grain stored and removed.

After accurate figures of average quantity of grain stored is obtained, the aggregate loss of grain during the storage period and its breakdown by causes of loss, such as insects and molds, are obtained for the holding, stratum and regional levels. Estimates of the same indicators can be obtained using the estimation formulae similar to those derived at the threshing/shelling stage.

G. Losses during transport

Losses in transport at the farm level may occur in (a) transport from field to the threshing floor, (b) from threshing floor to the storage and (c) from storage to the market, with different modes of transport being used at different stages. Losses are normally estimated as difference in weights between the quantity loaded and the quantity unloaded. When transport operations may take days, samples will be taken at the loading stage and at the unloading stage, and then examined for change in moisture content and qualitative damage during transit.

Based on the percentages obtained, percentage losses for any given stratum/region can be derived using the procedure described in the threshing/shelling stage.

Estimating percentage losses at the stratum/regional levels (based on percentages obtained at holding level follows the same procedure as indicated in the threshing/shelling stage.

H. Losses during processing

Traditional hand processing or mechanical processing is used to process grain through dehusking, milling and grinding of grains. At this stage, grain loss is normally expressed as a reduction in the quality of the finished product, although there may be some physical loss of grain through spillage. At large-scale, commercial mills, grain is usually processed in a continuous operation; grain can also be processed in small batches, such by hand pounding, using querns or village custom mills. Loss assessment studies at the farm level are mostly concerned with the latter mode of processing. In that case, it should be possible to weigh the grain before processing, and after to obtain a measure of physical loss. In addition, a comparison between the products of the process with that of a sample of grain carefully processed in a laboratory provides an indication of the loss of quality.
Estimating percentage losses at the stratum/regional levels (based on the percentages obtained at holding level follows the same procedure as indicated in the threshing/shelling stage.

I. Losses during packaging

Losses occurring due to defects in the methods of packaging and handling of grains can also be estimated. Data on different types of packaging could be collected for a selected sample of farmers to study the efficiency of alternative methods of packaging. However, within the context of the post-harvest value chain, the losses at this stage do not seem important.

Estimating percentage losses at the stratum/regional levels is based on percentages obtained at the holding level following the same procedure as indicated in the threshing/shelling stage.

3.4.2. GRAIN LOSSES AT THE INTERMEDIARY LEVEL

In this category, reference is made to government distribution agencies, mills, marketing cooperatives, wholesale and retail traders. Losses at the intermediary level are to be estimated at the stage of transport, storage, processing, packing and distribution. For transport, storage and handling by market handlers, a sample of such handlers is to be selected and the required information collected. In the same way, a random sample of mills/processing factories, may be chosen and the data collected.

The design used for this stage calls for a two-stage stratified random sampling with the market of some sort as the primary sampling unit, and the intermediary as the secondary sampling unit. For each sampled intermediary, different kinds of percentage losses are computed and then grossed-up to stratum/regional levels using the same techniques as in the threshing/shelling stage.

In the case of mills and similar units, a single stage sampling design can be used and the estimation formulae will get even simpler.

3.4.3. GRAIN LOSSES AT GOVERNMENT WAREHOUSES

Government agencies and other public distribution agencies should maintain detailed administrative records of grains received and dispatched. Food technology specialists working in these agencies are expected to collect samples of grains periodically and record pertinent information, such as moisture content, insect and pest infestation and other causes of damage. Hence, these agencies should, therefore, have readily available comprehensive data on the levels of losses and their causes.
A number of these types of surveys have been conducted in various countries around the world, mostly in India for food grains, such as maize, rice, sorghum and wheat). APHLIS has been very active in Southern and Eastern Africa regions concentrating on the maize crop.

The selection of warehouses may be done through a single stage random sampling if many are available or all of them can be selected if there are only a few of them. Estimates of average and percentage loss can be worked out as in the case of mills.
Key issues with post – harvest loss assessment studies

4.1. KEY ISSUE 1
No uniform concepts, definitions and measurement techniques have been used in different studies. For instance, many studies have not mentioned the causes of losses or the techniques used by the farming households to mitigate losses, and the stages/levels of the value chain vary among the studies.

4.2. KEY ISSUE 2
Boxall (1986) stated: "There has been a somewhat piecemeal approach to post-harvest loss assessment. Studies of discrete parts of the post-harvest system have been undertaken, but rarely have losses at the different stages been considered in relation to each other..."

In addition to this state of affairs, most studies have also been one-off, and in complete isolation with each other and with the other surveys of any country's national statistical system. For example, annual agricultural production surveys with crop-cutting components, farm management surveys, food consumption and nutrition surveys, income and expenditure surveys, could possibly collect valuable and useful information for food loss assessments through piggybacking on the specific modules.

4.3. KEY ISSUE 3
There were number of gaps in terms of, for example, crop/food items coverage, agroclimatic locations and, stages of the value chain.
There were number of gaps in terms of, for example, crop/food items coverage, agroclimatic locations and, stages of the value chain.

It appeared clearly that:

1. The documents were all about assessment of post-harvest losses;
2. These assessments were mainly for maize, tomato, food grain, wheat, rice, soybean, bean, vegetables and fruits;
3. The main stages of the food loss value chain under scrutiny were storage, harvesting, and milling;
4. The main countries/locations involved were Ethiopia, Malawi, India, Nigeria, Tanzania, Ghana and Sub-Saharan Africa;
5. The main actor in most studies was the farmer;

It can, therefore, be concluded that there were a number of gaps concerning the coverage of the loss assessment studies in terms of crops (commodities), countries and stages of the food loss value chain, based on the titles of the documents.

The body of content of the documents confirmed the trend observed from the titles of the documents and brings about more detailed information. Some notable observations were the following:

1. Maize remained the most studied crop, followed by wheat, then rice and soybean;
2. The most investigated stage of the food loss chain was storage, followed by harvesting, then transport/transportation, handling, drying, threshing and winnowing;
3. Factors causing losses were pests, insects and, rodents;
4. Sampling methods and their corresponding units of observation (farmers, households, farms, and respondents) were mostly used during the assessments;
5. The measure/indicator mostly investigated was weight loss.

### 4.4. KEY ISSUE 4

**Standard errors** (used in general in surveys to give an idea of the validity of the estimates of key variables/indicators) were not always reported; **non-sampling errors** are more difficult to estimate and are rarely provided. The sampling errors that were reported tended to be quite high; that meant low quality estimates. To rectify this, it is necessary to increase the sample sizes, which would increase the cost time devoted to the entire operation, and also boost the non-sampling errors.
4.5. KEY ISSUE 5

Most loss figure estimates were provided at a **high level of disaggregation**. For instance, “maize storage losses, were estimated at 5% ... ”, without specifying the actors on the food chain that make use of storage or the storage techniques used by each actor. This type of statement does not provide the necessary actionability required by food decision-makers concerned with practical issues of food loss prevention and reduction programmes.

4.6. KEY ISSUE 6

**Accessibility** of the results of the completed studies was rarely discussed and did not appear to be a major concern for most researchers. In fact, many of these studies were not immediately published after the field work; when they were published, they appeared in scientific journals and other types of academic papers. Decision makers around the world are finding it very difficult to get the data/information they need to take action; hence, systems must be put in place to allow rapid access to the results of food loss studies.

4.7. KEY ISSUE 7

The outcomes of surveys and loss assessments exercises are only valid for the conditions under which they were undertaken. **Seasonal effects** have had and will always have an impact on the level of losses. This impact can only be determined if the results of these studies are available for a number of years.
Implications of the key issues

The following observations made by Boxall (1986) are still very relevant today:

“The methodologies developed for farm-level studies cannot be applied to commercial systems. Although loss may be attributable directly to physical, chemical, or biological factor, the root cause may be shortcomings of management and an approach which takes account of such factors is required”.

He then concludes by adding: “By application of a systems approach, it will be possible to determine the resources required for the attainment of acceptable, minimum levels of loss for any archetypal agricultural system.”

It is interesting to observe that Boxall is not talking about improving individual methods, such as SVM, (these can always be improved through, for example, better use of modern technologies, but instead he is referring to a new approach/strategy, a systems approach that looks at the big picture.

That is quite similar to one of the ideas behind this review exercise, as y mentioned in the introduction. In addition, this information system approach can provide a positive answer to the research question as stated again below.

“Given the research work that has been done and the corresponding practical implementations, is it possible to craft a standard methodology for collecting data and estimating post-harvest losses taking into account the context of developing countries?”

APHLIS is also an information system approach, a framework for post-harvest loss assessment that has been in existence for a number of years and can therefore provide lessons learned to this present activity.
As defined by Irny and Rose (2005):

“Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

A methodology does not set out to provide solutions — it is, therefore, not the same thing as a method. Instead, it offers the theoretical underpinning for understanding which method, set of methods or so called “best practices” can be applied to specific case, for example, to calculate a specific result.”

Methodology is mentioned as being applied to a field of study. The first order of business then is to clarify this field of study and learn more about it. This field of study in essence is a system that encompasses a lot of information, entities, and processes related to food loss and waste. As food losses is a very wide and complex domain, the focus of this work under the Global Strategy is on statistical methods for estimating post-harvest losses, which is just one aspect of a much broader issue. In the present report, the system is be referred to as the Food Loss and Waste Information System (FLAWIS) or FLIS if only a system for food loss is being built. By thinking in terms of systems, as recommended by Boxall (1986), and solving problems at the more general level, problems at the specific level may be solved in a rapid, more optimal, efficient way. Instead of grappling with a number of one-off loss assessment studies that do not share consistent methodologies, a solid framework to collect, process, analyse, and disseminate food losses and waste using a common methodology can be progressively built and improved upon.

While this framework is important, all aspects cannot be addressed in this activity. Also, other initiatives such as the Global Initiative on Food Loss and Waste are dealing with other aspects; hence, this activity will ensure that the statistical methods for estimating post-harvest losses are aligned with the standards developed by those initiatives.

In general, an information system can be defined at a high level as comprising of the following main elements:

1. **Actors/users** of different kind and nature that make decisions and undertake various activities within the system.
2. **Data and information** flowing through the system that is used for decision-making and carrying out activities.
3. **Rules/procedures**, which determine the interactions between users and
data/information.

4. **Information technology tools** designed for collecting, analysing, storing and disseminating data.

The information system is completely defined if the following questions are answered for each of the main elements:

1. **Actors/users** Who will use what information, to make what decisions? Who will provide that information?
2. **Data and information** What are the information needs, and what data should be collected? How should the data collection activities be organized in order to avoid duplication and inconsistencies?
3. **Rules/procedures** Who does what and when, so that information is inputted into the system, processed and communicated at the right place, in the right format and at the right time?
4. **Information technology tools** What tools (hardware and software) are necessary to implement the rules and procedures?

What then are the specific features of an information system for collecting, measuring, estimating and reporting food loss and waste information?

The concept of a generic food loss and waste information system can be illustrated as below:
An information system for managing food loss and waste has additional characteristics as listed below:

- The stated goal of preventing/reducing food loss and waste.
- The stated objectives of quantifying commodity loss levels, identifying factors contributing to food loss and waste and identifying best practices, among others.

This emphasizes the modular nature of the whole system. Hence, countries do not need to develop everything at once; instead they can elect to gradually start building the modules that they need the most first and then concentrate on the additional ones, as resources become available. As a lot of information and resources already exist, the food grain component would be a natural target for the initial design and implementation for many developing countries. Developed countries would directly start designing and implementing the food waste compartment.

In order to properly answer these questions, one must objectively and positively explore the fundamental aspects of a typical FLAWIS:

1. Basic implementation principles.
2. Main components and phases.
3. Planning and physical execution guidelines for assessment studies.
4. Performance monitoring and evaluation.
6

Basic implementation principles

6.1. BASIC IMPLEMENTATION PRINCIPLES

The FLAWIS shall be fully owned and managed by the country, shall focus on country needs, and through consensus-building, shall be developed gradually and incrementally; loss assessment activities within the system should be undertaken within the country's framework of surveys.

Since 1985, FAO and other United Nations organizations have been promoting the development of long-term programmes for the development of agricultural statistics in developing nations. A document entitled “Food and agricultural statistics in the context of a national information system” (Greig and Reeves 1985), was published. Countries were encouraged to bring statisticians, economists, rural development experts and other social scientists who deal with information for policymaking in food and agriculture together to develop a model of the food and agriculture domain. Primary and secondary data sources would then provide the data pool needed for a national information system on food and agriculture. Primary data sources comprised of the agriculture census, population census, industrial census and sample surveys on, for example, the annual agricultural production, livestock, farm management, post-harvest losses, food nutrition and consumption, household income/expenditure, and the labour force. Secondary data sources include administrative records, local community records, technological research and international statistical publications.

More recent FAO publications, such as The World Programme for Census of Agriculture 2010, which contains developments on integrated systems, the global strategy to improve agricultural and rural statistics and the guidelines on sectoral plans for agricultural and rural statistics, focus on an integrated agricultural and rural statistics system, including an integrated survey
framework and medium-long term well-articulated and user driven survey plans.

By emphasizing the linkages between these data sources, countries would:

1. Achieve conceptual and classification uniformity;
2. Optimize the use of scarce available statistical resources;
3. Prevent overloading any statistical operation/survey/inquiry with too many items;
4. Prevent publishing conflicting statistics;
5. Provide all data needed for total analysis;
6. Ensure full processing, analysis and user availability of collected data.

In other words, countries are encouraged to prepare long-term integrated statistical programmes as part of their national information system for decision-making in food, agriculture and rural development.

Hence, national loss assessment/measurement exercises should also be designed and implemented within frameworks that factor in the developing countries context and the experiences of FAO in that regard.

The majority of the loss assessment systems that were investigated did not make an explicit and clear-cut reference to an integration and/or linkage with other statistical operations/studies/surveys within the national information system of any given country; the only exception was the FAO manual cited above. The manual says: “To economize the collection of data on food-grain losses, it will be desirable to link such surveys with some other agricultural surveys such as crop-cutting surveys for the estimation of total food production, food consumption surveys, etc... The estimation of post-harvest losses will involve a multidisciplinary approach and therefore in planning such inquiry, specialists, such as statisticians, plant pathologists, entomologists, agricultural engineers and other technologists, should be associated.”

In general, collection of data on food-grain losses has been carried out in an ad-hoc manner, in isolation with each other and with other statistical operations.

**Concepts, definitions, classifications, in loss assessment activities should be harmonized with those in other data sources within the national system.**

This has at least two implications: (a) terminologies, concepts and definitions specific to loss assessment surveys should be uniform within a region or country; and (b) loss assessment surveys making use of concepts like
household, holding, holder, should ensure that they conform to the standard definitions of those concepts.

It was observed that even between loss assessment surveys, no uniform concepts, definitions, and classifications have been systematically used.

The guidelines on classification being finalized by FAO-ESS under the Global Strategy will be used to improve on the present situation.

6.2. MAIN COMPONENTS AND PHASES

A loss assessment system should include a mission statement, a vision statement, sound goals/objectives, data sources, core numeric items/indicators with clearly stated levels of disaggregation, resources (legal, human, infrastructure and finance), data management processes (collection, processing and storage), reporting and dissemination processes.

The aim of most loss assessment studies/systems is overwhelmingly to help prevent food losses, and/or achieve food loss reduction. When goals or objectives are clearly specified, the method, scope and coverage of the survey can be deduced easily. Additionally, this will enable the setting of priorities for loss reduction efforts.

6.2.1. DATA SOURCES

The data collection system of FLAWIS should feature a three-pronged strategy that gets data from primary sources, administrative records and technological research information data sources. Primary sources data is to be obtained through a proper survey, which uses sampling techniques. Administrative records are secondary data from government and other institutions. The data covers, for example, rainfall, temperature and humidity information. These are data on factor variables that affect loss variables. By technological research data, it is meant the data generated by the conduct of agronomic trials or experimental designs, as usually carried out by agronomists in government-managed research stations or agricultural colleges.

6.2.2. CORE INDICATORS

For FLAWIS, a minimum list of indicators (survey items) needs to be identified for monitoring and evaluation of loss prevention and reduction programmes encompassing all relevant categories of the system (inputs, processes, outputs and outcomes, impacts) at national, agro-ecological, regional and subregional levels, as well as at other relevant dimensions, such as the stages of the value chain, actors and loss causing factors. Also, the indicators must be selected
based on a rigorous criteria of usefulness, reliability, quality, feasibility and accessibility.

6.2.3. RESOURCES

For FLAWIS to succeed, the country must be committed by ensuring the necessary policy, legislative, regulatory, financial and managerial environment. Infrastructure in its various forms is also required for a fully operating system. The managerial environment should clearly specify the institution(s) responsible for steering, coordinating and guiding the data collection, analysis and dissemination processes that are carried out within the food loss and waste information system. For instance, suggested institutions the central statistics agency or the ministry of agriculture, or a food-loss reduction programme committee within the country?

6.2.4. DATA MANAGEMENT

These processes enable collection through direct/indirect measurement, processing, storage, and querying of data within the system. The estimation/analysis processes should provide estimates of loss figures cross tabulated by the relevant dimensions/categories. Extrapolation from the samples to population estimates should be available. In addition, the system should also make possible the fitting of different kinds of models to perform predictive analytics using modern machine learning techniques. In this way, losses at various stages of the value chain could be predicted in advance and inform the decision-making process.

6.2.5. REPORTING & DISSEMINATION

The reporting/dissemination system should make it possible to quickly provide the results of the surveys. It should also leverage the possibilities offered by the Internet, such as cloud, web access, map display with Google Earth, Google Fusion Tables and Google Maps.

6.2.6. PHASES

Loss assessment studies within FLAWIS should typically be comprised of at least two phases: (a) the baseline or pilot survey phase followed by (b) the final survey phase.
6.3. PLANNING AND EXECUTION AND EXECUTION GUIDELINES FOR ASSESSMENT SYSTEMS

Preliminary system design and implementation should consist of the following steps:

1. Set up a government coordinating body with participation of relevant stakeholders, data users and producers, for overseeing the design and implementation of FLAWIS.

2. Assemble the material available on food loss, make a diagnostic/assessment of the current state of the existing food system, and distribute the material to the participants.

3. Organize a workshop or series of workshops at the national level to review the material with the aim of identifying all core variables/indicators along with their dimensions, that are relevant to the country’s food loss system and the major policy concerns.

4. Identify the data sources, statistical data management, and analytical activities, needed to produce the indicators listed previously.

5. Develop a five-year plan that will produce the identified statistical and analytical activities, and ensure that the plan is approved by the national coordinating body. Ideally, this plan will include the necessary human, material and financial resources – staff and training requirements, office space, vehicles, computers and accessories, computer services, survey equipment, such as moisture meters, the Global Positioning System, tablets and cell phones, and annual operating expenses.

6. Implement the plan, and regularly monitor and evaluate its performance.

6.4. PERFORMANCE MONITORING AND EVALUATION

FLAWIS should be monitored closely and evaluated in order to gauge its performance, and inform upcoming plans to improve the country's food loss information system over time. Evaluating the system and planning improvements should involve all major stakeholders (producers, users and financiers of at various levels of food loss information and related statistics) within the country. Relevant stakeholders, for instance, may be the ministry of agriculture, the bureau of statistics, the national monitoring and evaluation office, the prime minister's office, senior agronomists, statisticians, donors and international organizations involved in the food sector, such as FAO.
The national coordinating body that has been instrumental in the design and development of the food loss information system should also coordinate the evaluation process and be responsible for mobilizing and coordinating stakeholders in the process.

The heart of this system is the way it obtains data from three different sources (area-wide field surveys, administrative records and trials/experimental designs) and combines them to calculate/estimate losses at selected levels of the food loss chain for different actors. Hence, this is not a modeling exercise. The process involves simple statistical estimation techniques using regression methods that may provide reasonable standard errors at least cost. Moreover, the SVM and the visual loss procedures for measuring storage losses caused by insects are based on regression techniques. In the SVM method, for instance, the standard baseline curve for dry weight of a fixed volume of grain has the following relationship with percent moisture content:

\[ Y = a + bX \]

where dry weight is denoted as \( Y \) and percent moisture content is denoted as \( X \).

The laboratory biometrician is tasked with estimating the coefficients \( a \) and \( b \) using data based on the samples received from the field.

So, once data has been collected and measurements made available, estimates from the various samples have to be extrapolated to whatever level deemed necessary. In fact, the methods outlined here are an application of statistical estimation techniques known as “ratio estimation” or more generally “regression estimation” as described by sampling statistician L. Kish (Kish, 1995).

As already pointed out, using the loss assessment techniques on a large-scale sample surveys is prohibitively expensive when measuring dependent variables, such as weight loss, on a large sample, especially at the harvesting stage during which crop cutting takes place. However, they are more manageable when measuring independent variables, such as technology and those related to the environment, that do not require any measurement; moreover, some of these independent variables can be made available from within administrative databases. Trial/experimental designs can produce precise results at a small scale and are not prohibitively expensive. The contemplated strategy is then to judiciously combine them to take advantage of both. Trials and experimental designs are suited to analytical models on a relatively small sample in which the values of the dependent variables, such as weight loss, are collected together.
with the values of the most relevant independent variables, such as technology and those related to the environment, and the most significant parameters derived. The same independent variables are to be collected during an area-wide sample survey on a reasonably large sample. In a third step, the values of the independent variables from the area-wide sample survey are combined with the parameters derived from the trials/experimental designs to provide the needed estimates.

These processes can now be easily carried out with the available processors and data science software. In addition, the data are also most probably already available in developing countries for initial testing and calibration. The more detailed workings of these techniques will be made available in future design reports.
Appendix

A quick way to locate the gaps under study was to apply natural language processing (NLP) techniques to investigate at rapid pace and better synthesize the content of the 56 documents under review. This entailed a two-step process that involved (a) processing the titles of the documents to find out what they were about and (b) processing the content of the documents. There are many ways to present the results from a NLP treatment of a group of documents (called “corpus” in technical parlance). For this study, the results are shown through (a) the ubiquitous histogram and (b) a word cloud. The histogram shows the frequency distribution of the words that represent the main entities being studied within each document; the word cloud provides the same information but in another form. Frequent entities are drawn bigger and bolder compared to less frequent ones.

The word cloud showing the many entities/concepts referenced in the titles of the 56 documents under study is presented as follows:
The histogram showing the many entities referenced in the titles of the documents under study presented below confirms the information shown in the word cloud. In addition, it allows direct reading of the entity names on the word axis.

Below it the word cloud for a review of the entities/concepts covered within the contents of the documents under review.
The histogram corresponding to the word cloud is as follows:
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