9. Modeling

9.1 Overview of the Method

Models are used to infer the amount of FLW by calculation. A model is a simplified version of the real world; it uses mathematical terminology and a mathematical approach to estimate FLW based on the interaction of multiple factors that influence the generation of FLW. These factors may be causal and directly affect the amount of FLW generated (e.g., grain storage practices), or may be contextual in that they are more indirect (e.g., weather conditions) and may amplify the effect of the causal factors. Using a model is one of three methods described in this standard that are based on "inference by calculation." The others are undertaking a mass balance and using proxy data (see Chapters 8 and 10 of this document).

There are a number of ways in which models can be used to estimate FLW. A wide range of modeling approaches may be used, drawing from various disciplines including statistics, economics, and operational research.

Models for FLW may use factors such as climatic, agricultural, or other data from which a scientific analysis has demonstrated that FLW values can be calculated. One example is the African Postharvest Losses Information System (APHLIS),[18] which uses a well-documented algorithm to express postharvest losses of grains in Africa, based on scientific literature; local data; and local factors such as rains at harvest time, agricultural practices, or storage and marketing practices (see Box 9.1).

Models that rely on previously established relationships between measurable factors (e.g., weather conditions) require two kinds of information:

- **Information about the factors that can affect the level of FLW** (e.g., timing of rain and timing of crop harvests). This information may be available from existing datasets, if they are sufficiently reliable, or it may need to be quantified.
- **Information about the nature of the relationship between these factors and FLW.** The relationships between measurable factors and FLW are described by mathematical functions (e.g., formulas) within the model. These relationships may already have been established (e.g., reported in literature) or may need to be determined through a new study. This involves understanding, for example, how harvesting a crop that is wet from recent rain may influence the likelihood of damage that results in FLW. Another example is the relationship between temperature during storage and insect damage. Higher temperatures result in faster life cycles among insects, which results in higher levels of damage by insects.

Another approach to modeling uses information on the relationship between the amounts of FLW generated and economic factors (e.g., output of a sector) to estimate levels of FLW within an economy.[19] Box 9.2 provides an example of this type of economic modeling.

Other modeling approaches simulate the system that generates FLW. For example, an estimate of FLW can be obtained by tracking food as it is bought, stored, and consumed. An example of this simulation approach is the Milk Model developed by WRAP,[20] which is described in Box 9.3.

ADVANTAGES AND DISADVANTAGES

The principal advantage of using models is their relatively low cost, especially compared with measurement- and approximation-based methods. They are especially valuable in agricultural contexts due to the need to measure or approximate FLW in different seasons and locations, and by crop type, soil type, and agricultural system. Models can be used to generate provisional data that can be improved later with measurements or approximation. This is useful when a quick estimate is required.

The main disadvantage of modeling is the risk that the resulting estimates of FLW will be inaccurate. Inaccuracies can result from the following:

- Unfounded assumptions may be included in the model. This tends to happen where there is a lack of reliable data on the factors included or where the relationships between the factors and FLW are inadequately understood or cannot be reliably quantified. This can result in a model structure that does not adequately reflect the real world.
- Data may be drawn from contexts, locations, or environments that are too dissimilar from those where the FLW arises.
- Mathematical relationships among model elements may be inappropriately applied.

LEVEL OF EXPERTISE REQUIRED

An in-depth knowledge and understanding of the information used within the model is required. This includes knowledge about the data on which the model is based and the relationships between different factors and FLW.

Some mathematical and statistical knowledge is required to understand how the model operates, which factors are included in and excluded from the model, and how to estimate uncertainty.

Simple models can be built in standard spreadsheet packages, but more complex models may require more specialized types of software, which can require training, expertise, and experience to operate.

COSTS

The cost of modeling is a function of the human resources required to develop, populate, and use the model. There may also be costs associated with purchasing datasets. Using a model to infer the amount of FLW typically costs less than undertaking a measurement or approximation of FLW.

9.2 Guidance on Implementing the Method

The type of model an entity uses will differ depending on the scope of the model and the nature of the data included within it. This section provides guidance for an entity using an existing model. It does not provide guidance on creating a new model. An entity seeking to develop a new model should consult with professionals skilled in the design of models because the process requires specialized expertise.

1. UNDERSTAND SCOPE OF THE MODEL

As Chapter 6 of the *FLW Standard* explains, a well-defined scope, aligned with the five accounting principles and an entity's goals, is important for ensuring that an FLW inventory meets an entity's needs. In using a model, an entity should confirm that the scope of the model aligns with the scope of an entity's inventory, defined by the timeframe, material type, destination, and boundary. Chapter 6 also describes how the scope chosen by an entity for its FLW inventory should be aligned with its underlying goals for addressing FLW.

2. REVIEW CHARACTERISTICS OF THE MODEL AND USE IF SUITABLE

An entity should search relevant literature and contact experts to determine whether there is an existing model that suits its purposes. This is important because it will usually be cheaper and quicker to use a model that already exists than to create a new one.

In selecting a model, an entity should understand why the model was developed, and how it has been used previously. In addition, an entity should understand how the model works—its structure and the factors included within it. If a model seems to be potentially usable, steps should be undertaken to verify and validate the model outputs for the situation the entity wishes to model.

(These considerations are also useful for an entity working with an experienced professional to develop a new model.)

Review of factors and relationships incorporated in the model

An entity should have a good understanding of the structure of any model it decides to use. This includes understanding the factors and relationships incorporated, because the accuracy of a model is critically dependent on the inclusion of all important factors affecting FLW. For instance, in agricultural settings, this requires knowledge of the crop being grown and the range of factors that could affect FLW during and after harvesting.

The owner of the model may have used several techniques for identifying the appropriate factors to include. These include literature reviews as well as workshops in which experts are consulted. These techniques typically provide a list of measurable factors that directly or indirectly influence FLW. Alternatively, an approach such as systems thinking may have been adopted to produce a qualitative diagram that reflects the understanding of how FLW is produced.

All models are simplifications of the real world. A good model is complex enough to robustly explain the generation of FLW (so that it is fit for its purpose), but no more complex than that (because the effort involved to develop the model quickly increases with complexity).

Some simplification will also be dictated by whether data are available or relationships between factors are known. Data may be sparse on the factors that influence FLW, and consideration should be given to whether there is adequate understanding of the relationship between the factors that influence FLW and its generation, including whether that relationship can be quantified. An entity should be clear on whether important factors have been excluded (e.g., because there are insufficient data to include them) and the impacts of their exclusion on the results.

Validation and verification of model

Validation and verification are important steps of model development; they define whether a model can appropriately be used under conditions specific to the entity. They may also lead to substantial improvements to the model.

An entity using a model should undertake some validation of the existing model to check that it accurately calculates the level of FLW given certain values for the factors (i.e., inputs to the model). This can be achieved by comparing the levels of FLW predicted by the model against measurements of FLW from the real world in situations where the factors (inputs) are known. Validation is difficult in situations where there are few real-world measurements, or where all the real-world measurements have been used to determine the relationships in the model (i.e., there is no new data against which to validate the model).

If possible, an entity should verify whether the model accurately represents the intended relationships between the factors and FLW. Its ability to do so will depend on the transparency of the existing model and its complexity. Verification can be achieved by checking results from the model against results that have been independently calculated in an alternative way (e.g., by hand), which might detect whether any of the relationships are described incorrectly within the model. Validation and verification are simplified when the model is clearly documented.

Using existing model

If a suitable model is identified, discussions should be initiated with the owner of the model to ensure that it will satisfy requirements (e.g., align with the scope of the FLW that the entity is quantifying) and that it can be applied to the inventory's specific case. It will also be necessary to arrange access. In some cases, intellectual property rights may preclude models being used by others although it is always worth exploring ways in which these issues could be overcome.

It is good practice for an entity to document clearly how it used a model, including values for factors used for each "run" of the model and any options or choices required.

Examples of models used to quantify FLW

Boxes 9.1–9.3 provide a series of examples of models that have been used to generate estimates of FLW.

Box 9.1 | Modeling Postharvest Losses for Cereal Grains in Africa

The African Postharvest Losses Information System (APHLIS) provides estimates of weight losses from the postharvest chain for the most important cereals grown in Sub-Saharan Africa.

To make loss estimates, APHLIS uses a model and relies on two distinct sources of data:

- **Postharvest loss (PHL) profiles** quantify the expected losses at each link in the postharvest chain. These data are derived from the scientific literature.
- **Seasonal data** quantify losses that occur on a seasonal or annual basis (e.g., because of weather-related factors). These data are submitted by African specialists in the APHLIS network.

PHL PROFILES

One problem of seeking to provide PHL profiles is that PHL data have been collected in only a few parts of Sub-Saharan Africa. It is therefore inevitable that, in the creation of the PHL profiles, many different provinces will have to share the same data. This sharing was achieved by clustering the data from provinces of various countries that are basically similar with respect to climate. The climates of Sub-Saharan Africa have been classified according to the Köppen system[a] and, for the purposes of APHLIS, are of three types: tropical savanna, arid/desert, and warm temperate.

There is a PHL profile for each crop in each climate. Thus with seven crops (maize, sorghum, millet, wheat, barley, rice, and teff) there are a total of 21 (3 x 7) profiles. Except for maize, the profiles are specific to the technologies associated with smallholder farming. For maize, there are profiles for both smallholder and large-scale farming.

In the creation of PHL profiles, it is necessary to create a generalized loss figure for each step in the postharvest chain. The basic data on which these are based came from the scientific literature and the PHL Network. These data were refined by:

- removing outliers;
- avoiding the use of information from questionnaires and "guesstimates" where there is information from a more robust (measurement) approach; and
- averaging the remaining data.

SEASONAL DATA

Several "seasonal" factors can have a substantial bearing on the actual estimate of FLW. Data on these seasonal factors include the impact of:

- damp weather during any of the harvests, which would make drying difficult;
- the proportion of grain that is marketed within the first three months, thus will not enter farm storage for any significant time;
- the length of the farm storage period; and
- in the case of maize, whether the larger grain borer *(Prostephanus truncatus)* is expected to be a significant pest.

APHLIS is entirely documented and the underlying data and sources are all available online. It also offers a downloadable calculator that uses the same underlying model and into which specific, local data can be input.

[a] APHLIS. "Understanding APHLIS." May 2014. Accessible online at http://www.aphlis.net/downloads/Understanding%20APHLIS%20ver%20%202.2%20May%2014.pdf.

Box 9.2 | Using National Economic and Trade Data to Estimate FLW

One type of model makes use of information found in national accounts of economic activity and national trade data. This information is then combined with data on waste and loss from which FLW can be calculated by applying appropriate factors and assumptions. This means that total waste generation—rather than FLW—is the starting point for this type of modeling.

This approach may require assumptions to generate an estimate (e.g., it may be assumed that the amount of FLW is related to the gross output of a sector). Examples of the approach include:

- Delahaye et al. (2011) introduced a method using national accounts tables which quantified the underlying driving forces of changes in total waste and landfilled waste.
- Reynolds et al. (2014) proposed a method using national accounts tables to estimate the types and quantities of waste generated in both industry and households, which has been applied to Australia.

Sources: Delahaye, R., R. Hoekstra, and L. Nootenboom. 2011. "Analysing the Production and Treatment of Solid Waste using a National Accounting Framework." *Waste Management & Research* 29(7); Reynolds, C., A. Geschke, J. Piantadosi, and J. Boland. 2015. "Estimating Industrial Solid Waste and Municipal Solid Waste Data at High Resolution using Economic Accounts: An Input–Output Approach with Australian Case Study." *Journal of Material Cycles and Waste Management* 3.

Box 9.3 | Using Discrete Event Simulation for Milk FLW

A "Milk Model" was developed by WRAP (The Waste Resources and Action Programme) to explore the factors that affect FLW of milk in households in the United Kingdom. The model allows activities relating to purchasing, storage, and consumption of milk to be simulated and provides an estimate of milk FLW for the modeled household. It also allows the impact of attributes of the milk (e.g., its shelf life) to be explored. The system created in the model includes many of the features that are important to household FLW. However, by modeling only one product—milk—rather than all food and drink, it allows many insights to be uncovered that are frequently obscured by the complexity involved in studying total household FLW. Many of the findings for milk, however, are relevant to other fresh food products purchased and consumed at a similar frequency (e.g., sliced bread).

The modeling technique used was discrete event simulation, which is a well-established method, but one that had not been applied previously to FLW in the home. It allows data and insights from a large range of sources to be used together within a single framework to understand the system in question. This work suggests that system-based approaches to considering FLW prevention in the home can increase understanding of the issues and estimate the approximate impact of potential changes.

Source: WRAP (The Waste Resources & Action Programme). 2013. *The Milk Model: Simulating Food Waste in the Home.* Banbury, UK: WRAP.

Endnotes

18. APHLIS is accessible at www.aphlis.net. For more on APHLIS, see Hodges et al. (2014).

19. One of the hurdles presented by economic-based models is the conversion of financial data to physical quantities. When undertaken incorrectly, this can lead to some unanticipated results (see Joosten et al. (1999)). Furthermore, the relationship between FLW generated and economic factors can lead to uncertainty of results in some cases (Andersen et al. 2007; Östblom et al. 2010; Andersen and Larsen 2012).

20. WRAP (2013b).