Introduction

Food loss and waste (FLW) is a complex construct without a “comprehensive and globally applicable” [1] (p. 1) definition. Expressing its complexity clearly, concisely, and comprehensively in natural English (or another language) is a major challenge in defining the construct. The construct’s complexity arises from the scale, scope, and semantics of what it denotes. First, food in FLW denotes an array of plant- and animal-based products consumed as food, each with its subcategories. Second, loss and waste denote three sequential steps (consumption is implicit) by which the food is consumed and discharged. Third, food is used by an array of users. Fourth, food serves many purposes for the users. Fifth, and last, FLW is affected by the many stages of food production, storage, processing, and distribution. Thus, FLW is a combinatorial product of the many categories of food, multiple processing steps, different users, their different purposes, and sequential handling stages. There is a very large number of these combinations, each of which is a facet of the construct. Boiteau and Pingali [1] (p. 7) harmonize the definition as follows: “Food loss and waste is a reduction in the quantity or quality of the edible portion of food intended for human consumption when food is redirected to non-food uses or when there is a decrease in the nutritional value, food safety, or other quality aspect from the time food is ready for harvest or slaughter to consumption”. Their definition does not express the complexity comprehensively. An ontology using structured natural English (or another language) can express this complexity succinctly. Thus, building on the paper by Boiteau and Pingali [1], we present an ontological definition of food consumption, loss, and waste that addresses the challenge highlighted by the authors.
An ontology is an organization of the terminologies, taxonomies, and narratives of a problem that can be conceptualized as a scientific theory of the problem [2–6]. As a scientific theory, it can be used to describe, explain, predict, and control [7] FLW through feedback and learning [8,9] systemically as part of a broader ecosystem and systematically by exploring the innumerable pathways within it. The authors have used ontologies to study solid waste management [10], bio-medical waste management [11], air pollution management [12], and similar topics. In this study, we (a) present an ontology of food consumption, loss, and waste (the addition of consumption is necessary to make the construct logically complete, although we shall continue to use the common FLW acronym); (b) demonstrate how it encapsulates the present definitions of FLW; (c) discuss how it extends the present definitions to be “comprehensive and globally applicable” [1] (p. 1); and (d) delineate its implications for research on, policies for, and the practice of FLW.

2. Materials and Methods—Ontology of Food Consumption, Loss, and Waste

We approach the problem of unifying the definition of FLW top-down instead of bottom-up, as Boiteau and Pingali [1] have sought to do. We logically deconstruct FLW as

\[ FLW = \text{Stage of food chain} + \text{Food type} + \text{CLW (Consumption, Loss, Waste)} + \text{User of food} + \text{Objective of food}. \]

We take a systemic view of each subconstruct of FLW in the text equation. Thus, the proposed ontology of food consumption, loss, and waste (Figure 1) is an organization of 60 key words/phrases that define the FLW construct. These are terms selected based on field knowledge and research publications [13,14]. It is a word picture of FLW. The words/phrases are grouped into five columns—each represents a dimension of the problem. They are as follows: (a) Stage—the stages from production to utilization of food; (b) Food—the types of food; (c) CLW (consumption, loss, and waste)—the steps from consumption to waste of food by a user; (d) User—the primary users of food; and (e) Objective—the purpose of food consumption by the user. The words/phrases in each dimension constitute a taxonomy of the subconstruct denoted by that dimension. The elements in each taxonomy are reasonably mutually exclusive and sufficiently exhaustive. The dimensions are ordered left to right with adjacent words/phrases to connect them. Concatenating a word/phrase each from across the five dimensions with the adjacent connectors forms a natural English sentence, as illustrated by the three sentences below the ontology. Each sentence is semantically meaningful (although a little awkward grammatically), and the ontology can generate a very large number of them. The complete set of sentences so generated constitutes the definition of FLW.

Next, we explain the dimensions denoting each subconstruct in the following order: Objective, User, Food, CLW, and Stage. While this is not sequentially right to left, or left to right in the figure, it helps articulate the logic better. We conclude the section with a discussion of pathways to managing FLW that can be generated from the ontology.

2.1. Objective

Food is valued for the energy, the macro-nutrients, micro-nutrients, and for medication purposes [15–19]. It is also valued for the additives and excipients that contain, preserve, deliver, and enhance the first four values. Additives and excipients play an important role in the FLW ecosystem. Last, the residue from one user is valued for the value it may provide for another user (Figure 1—Objective).

FLW is predominantly focused on the first three (energy, macro-nutrition, and micro-nutrition) and residue; it is less focused on medication, and rarely on additives/excipients in as much as they affect the first three. The priority is contextual. In an energy-starved population, minimizing energy loss and waste will be important. In an energy-adequate population, optimizing macro- and micro-nutrition will be important. For all populations, especially those dependent on traditional and indigenous medicine, after assuring energy and nutritional adequacy, preserving the medicinal value will be important. The value of
additives/excipients may be based on explicit knowledge of their capacity to deliver the first four, or on tacit knowledge of historical, cultural, and local practices. The value of residue from a user will depend on the knowledge of its potential for use by another user.

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<tr>
<th>Stage</th>
<th>Food</th>
<th>CLW</th>
<th>User</th>
<th>Objective</th>
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<tbody>
<tr>
<td>Production</td>
<td>Plant-based</td>
<td>Consumption</td>
<td>People</td>
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<td>Crop farmer</td>
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<td>Use</td>
<td>Animals</td>
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<td>Livestock farmer</td>
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Illustrative pathways:
- Production (crop farmer) of plant-based (grains) for food consumption (use) by people for optimal energy value.
- Handling (logistics) of animal-based (fish/seafood) for food waste (active) by environment for optimal macro-nutrition value.
- Utilization (restaurant) of physical/chemical (preservatives) for food loss (repurposing) by plants for optimal micro-nutrition value.

Figure 1. Ontology of food consumption, loss, and waste.

The properties of food ingredients that determine the different types of value vary. Some properties are visible (for example, energy, sometimes synonymous with quantity), and many are invisible (for example, macro-nutrients, micro-nutrients, and medication). Some are based on formal, explicit knowledge; many are based on informal, tacit knowledge. Some can be measured easily; many cannot be measured easily. These properties determine the efficacy of feedback and learning to manage FLW.

2.2. User

Food is consumed in the traditional sense by people, animals, and plants [14,15,20–22] (Figure 1—User). While the dominant concern is on food intended for human consumption, the consumption by animals and plants must be considered as an integral part of the FLW ecosystem. Food that is not consumed by anyone reaches the environment, which absorbs it. Conceptualizing the environment as a user may be unusual but would help explicitly address the problems associated with environmental protection and sustainability. The four types of users constitute the ecosystem of FLW. Food that is lost or wasted by people may be consumed by animals and plants; food that is lost or wasted by animals may be consumed by plants; and food that is lost or wasted by all three is necessarily consumed by
the environment. Completing the cycle, what is consumed by the environment may affect the subsequent production of food, its quality and quantity, and thus FLW. The iterative cycle may continue thereby increasing or decreasing FLW.

Each user’s objectives are different in terms of consuming food and the consequent loss and waste. The objectives vary widely among and between users. The overall objective of managing FLW would be to optimize the value for all the users and their objectives.

2.3. Food

Food is broadly classified as plant-based and animal-based (Figure 1—Food) [23,24]. Plant-based food includes grains, vegetables, fruits, and the residue from the three. Animal-based food includes meat/poultry, fish/seafood, dairy, and the residue from them. Plant-based food may be fed to animals to produce animal-based food; animal-based food is unlikely to be fed to produce plant-based food. There is a third category of physical/chemical food substances that can significantly affect the consumption, loss, and waste of plant- and animal-based foods. These are additives, preservatives, nutraceuticals, etc. While their loss and waste are unlikely to be a major concern, they can have a significant effect on the loss and waste of plant- and animal-based foods. They can also have long-term effects on the subsequent links in the FLW chain.

The subcategories of the three types of food vary in their value to fulfill the objectives for the different users. Balancing them is central to optimizing the value and managing FLW. They are an integrated part of food production, storage, processing, and distribution cycle, but they are interdependent on each other. The composition of food consumed by the users varies based on their requirements, preferences, practices, and objectives. The composition of FLW varies correspondingly.

2.4. CLW (Consumption, Loss, and Waste)

CLW denotes the three—generally sequential—stages of the transformation of food to waste (Figure 1—CLW). Consumption denotes direct consumption, its reduction to other forms, and its reuse by/for the user [15,19,20,25–28]. Loss follows consumption and denotes processes of recovery and repurposing some of the value of food after consumption by/for the user [14,19,25,29,30]. Waste denotes what is left after consumption and loss—it may be active or inert. The CLW stages may be repeated with different users and objectives for the same food. For example, grains rejected by people may be consumed by animals.

The challenge of managing FLW is to optimize the value to the people, animal, and plant users and minimize the waste, both active and inert, reaching the environment. Realizing this may require multiple iterations with different types of food, users, and objectives.

2.5. Stage

Exogenous to the CLW of different types of food by the users for their value are many stages in handling food where too FLW can occur [31]. These stages are production, handling, storage, processing, distribution, marketing, and utilization (Figure 1—Stage). The stages and their subcategories are listed in the corresponding column of the ontology. How the food is handled at each stage can affect its consumption, loss, and waste. Further, since the stages are sequential, the effects of early stages on FLW can be amplified or attenuated in the subsequent stages through appropriate intervention.

The contribution of each stage to FLW will depend on the type of food, users, and the objectives of consumption. These stages may also be spatially and temporally remote from the ultimate user. Thus, loss and waste may occur without an opportunity for the food to be consumed.

2.6. Pathways

The 60 key words/phrases (excluding the column titles and connectors) in the ontology could be combined into \(\binom{60}{5} = 5,461,512\) (60!/(5!×55!)) 5-word/phrase unique combinations. From these combinations, the ontology encapsulates 19 × 11 × 7 × 4 × 6 = 35,112
combinations that denote the potential pathways to managing FLW in natural English. It is 0.64% of the total possible combinations. These pathways constitute the definition of FLW. The illustrative pathways generated from the ontology are (Figure 1—Illustrative pathways) as follows:

- Production (crop farmer) of plant-based (grains) substances for food consumption (use) by people for optimal energy value.
- Managing grains loss and waste at the stage of production of crops by farmers for optimizing the delivery of calorific value to people.
- Handling (logistics) of animal-based (fish/seafood) for food waste (active) by environment for optimal macro-nutrition value.
- Managing the logistics of environmental recycling of biologically active fish/seafood waste.
- Utilization (restaurant) of physical/chemical (preservatives) for food loss (repurposing) by plants for optimal micro-nutrition value.
- Managing the disposal of preservatives in food by restaurants as food to plants.

The large number of pathways encapsulated in the ontology as a small subset of the very large number of possible combinations of the 60 words/phrases demonstrate both the generative and selective power of the ontology. It is like a “Google Map” of the challenge of FLW. It can be used to navigate—with feedback and learning—solutions to the challenge, like with the ubiquitous digital map. It shows the large number of pathways, of which some may be known to be effective, some may be known to be ineffective, and many whose effectiveness is unknown. It is necessary to reinforce the effective pathways, redirect the ineffective ones, and research the unknown ones. In the next section, a comprehensive analysis of the current definitions of FLW is discussed through the lens of this framework.

3. Discussion—Correcting the Lacunae

The ontology defines FLW as a multi-dimensional, multi-step, iterative, dynamic process. Each column in the ontology is a dimension of the process. The steps may be within a dimension or may cut across many dimensions. Similarly, the iterations may be within and across dimensions. In other words, the pathways of FLW may crisscross the dimensions of the ontology and the elements within them. FLW is a process not a state. The present definitions fail to capture the dynamics of such an iteration and the associated complexity.

A major impediment to unifying the definition of FLW is the implicit gap in what the acronym denotes—food loss and waste. Loss and waste have a symbiotic relationship with consumption as they are deeply interconnected. As specified in the ontology, the focus should be on consumption, loss, and waste (CLW). Any definition that considers only loss and waste is necessarily incomplete. The ontology avoids this implicit bias.

Boiteau and Pingali [1], in their review, correctly point to the following lacunae in the definitions of FLW:

- “An abundance of terms with overlapping meanings” (p. 3).
- “Definitions driven by perspectives associated with FLW” (p. 5).
- “Timing and terminology” (p. 5) of measurement of FLW.
- Scope of food in FLW.
- Criterion for utilization of food—by who—to determine FLW.
- Criterion of edibility of food—by who—to determine FLW.
- Type—quantitative and qualitative—of FLW.

It is an excellent list. However, the harmonized definition the authors propose does not resolve the lacunae and help unify the definitions. In the following, we explain how our ontology can provide a unifying definition of FLW that addresses the above issues and is a “comprehensive and globally applicable” [1] (p. 1) definition.
3.1. Parsimonious Terminology

The 60 key words/phrases in the ontology, derived from the common body of knowledge on the subject, are adequate to define FLW. The columns represent distinct dimensions of FLW and are comprehensive. The taxonomies of the dimensions are reasonably mutually exclusive and sufficiently exhaustive. The organization of the ontology is such that (a) a dimension can be added to extend the scope of FLW; (b) each dimension’s taxonomy can be extended, if necessary, by adding elements; and (c) the elements of a dimension can be refined by adding sub-elements and coarsened by aggregating elements to change the granularity of the definition. The modularity of the ontology lends itself to such changes without the necessity of reworking the whole definition. Such additions and refinements may add only a few terms, but extend the scope (dimensions), scale (magnification), and size (number of pathways) in the ontology exponentially. The ontology, with parsimonious terminology, can capture the complexity of FLW clearly, concisely, and comprehensively.

Even if the terminology of the ontology is not identical to that in the definitions, one can establish equivalence through synonyms, hypernyms, and hyponyms. Keeping the ontology constant as the framework for integrating the definitions, in line with the top-down approach, would be easier than attempting to integrate and unifying them ground-up.

3.2. Stakeholder Perspectives

The present ontology includes the perspectives of the stakeholders in all the stages from production to utilization, steps from consumption to waste, and users from people to the environment. A stakeholder’s perspective can be denoted by a subset of the ontology. Multiple stakeholders’ perspectives can be integrated by mapping them onto the ontology. The modularity of the ontology makes such denotation and integration possible. Further, the ontology’s scale, scope, and size can be changed (as described earlier) to accommodate and fit any stakeholder’s perspective.

Last, the ontology can frame a stakeholder’s perspective in the unified context of the universal definition. Such a part–whole framing will highlight the systemic biases in a stakeholder’s perspective—what is emphasized, what is not emphasized, and what could be emphasized. Such an analysis will help define the intended consequences of the definition, its unintended consequences, and its potential innovative consequences.

3.3. Timing and Terminology

The timing and terminology issue is that of choosing the segment of the Stage dimension for the definition. Considering the cascading interdependence of the stages, it would be appropriate to include all of them. However, should one want to study Handling in greater depth and detail, the other stages can be hidden. Further, additional subcategories of handling can be added for greater detail, and sub-subcategories can be added for greater depth.

Continuing, the focus can be further narrowed to plant-based foods by hiding other types of foods, and to people’s CLW by hiding other users. Thus, the ontology (a) provides an integrated timing framework and (b) permits segmentation of the timing based on a stakeholder’s requirements.

3.4. Scope of Food

The denotation of food in the ontology is inclusive and exhaustive. In addition to the plant- and animal-based foods, it also includes physical/chemical ingredients in food. The last category, likely to be present in minute quantities compared to the bulk of what is considered food, can have an oversized influence on FLW and the value the food delivers. Food in the ontology also includes residue from plant- and animal-based foods that could likely be used by a different user in a subsequent iteration [32,33].
By refining the food categories, the ontology highlights the importance of considering the differences in their CLW. These subcategories fulfill different objectives and have different user profiles.

3.5. Utilization of Food

The food may be utilized by people, animals, plants, and the environment. It may be utilized in a household, restaurant, hotel, or an institution. There is an interdependence between the utilization by the four users that is a necessary part of the food ecosystem. Loss or waste for people may be a gain or choice for the animals and plants. Thus, the estimation of FLW utilization will depend upon the boundary chosen. It may include only people, people + animals, people + animals + plants, or people + animals + plants + environment. It is a problem of definition that will also likely affect the temporal boundaries for the determination of FLW. Focusing on a single type of user will have the shortest time horizon, adding more types will expand the time horizon. Thus, if one is focused only on the short-term FLW, one may focus on a single type of user; on the other hand, if the focus is on long-term FLW and ecological sustainability, one must focus on the full spectrum of users.

3.6. Edibility of Food

The edibility of food depends on its user. Food that is inedible to people may be edible to animals; food that is inedible to animals may be edible to plants; and food that is inedible to plants may be “edible” to the environment by default. The propagation along the edibility chain will depend upon the type of food and its subtype. Plant-based food may propagate better than animal-based foods. Ultimately, all waste must necessarily be “edible” to the environment, with potentially desirable and undesirable long-term consequences to the food cycle.

Further, physical/chemical ingredients in the food, both plant-based and animal-based, can affect its edibility to the users and consequently its FLW. These substances may be introduced at one or more of the stages from production to utilization, consumption-reuse, or loss-recovery and loss-repurposing. Thus, edibility may be transformed in significant ways for each type of food as it undergoes iterations among the stages, CLW steps, and the users.

3.7. Type of FLW

The ontology can describe all possible types of FLW qualitatively and exhaustively. It would be difficult to quantify all the qualitative descriptions due to difficulties of measurement, availability of data, quality of data, and similar factors. However, the challenge of quantification must not deter one from addressing a type of FLW.

Quantification can take place at many levels [14,34,35]. At the nominal level, one may simply measure the presence/absence of a type of FLW. At the ordinal level, one may rank order different types of FLW. At the interval level, one may assign subjective regular interval scale values (for example, using a Likert-like scale) to the FLWs with an arbitrary anchor. Last, at the ratio level, one may measure FLW on a scale with an absolute zero and objective, regular interval scale values. Nominal and ordinal level specification can be very relevant despite not appearing to be rigorous. Interval and ratio level specification can be rigorous but, due to challenges of measurement, quality of data, and related issues, may not be very relevant. The ontology specifies all possible types of FLW qualitatively; from them, one can choose the level of measurement suitable in a context.

3.8. Managing the Dynamics of FLW

FLW is a dynamic process and not a static state of a household, organization, locality, city, state, or country. Like on a “Google Map”, food traverses many pathways in the ontology in the process of being consumed, lost, and wasted within the boundaries of the entity. Many of these pathways have been discussed above. The pathways are iterative, cutting across many dimensions, and including many elements of a dimension. They are
complex, and navigating them through systematic feedback, learning, and redirection can optimize the value of objectives of user food consumption and manage the associated loss and waste. The ontology provides a framework for such feedback, learning, and redirection in research, policies, and practices.

Mapping the state-of-the-research on, -policies for, and -practice of FLW will highlight the gaps in each and the gaps in translation between the three. It will highlight the elements and themes that have been (a) frequently emphasized, (b) infrequently emphasized, and (c) never emphasized. From such a systematic analysis, one can draw conclusions about (a) pathways that have been effective and must be reinforced, (b) pathways that have been ineffective and must be redirected, and (c) pathways that have not been explored and must be researched.

3.9. Differentiation and Integration of FLW

Food CLW patterns can vary significantly by country, region, locality, geography, culture, and other parameters [24,36,37]. In medium- and high-income countries, food is significantly wasted at the consumption stage, whereas in low-income countries, food is lost mostly at the food loss stage [36]. These differences can be mapped within the framework and integrated within it. The patterns may also change over time due to a crisis like COVID-19 [38], type of use [39], the socioeconomic development of society [40,41], and other factors. These changes too can be integrated within the framework. Last, the patterns will be different based on the scale, scope, and size of the object of the study. Instead of one strategy being force-fit for all scales, scopes, and sizes, the framework permits the analysis of the differences and their integration into a coherent system.

To address the problem of FLW from any of the many above points of view, it is not necessary to consider the entire framework. One can define the boundary of a problem in a context by making the relevant elements endogenous and the others exogenous. Thus, to study the problem the point of view of utilizing stakeholders (household, restaurant, hotel, and institution), the earlier stages may be defined as being exogenous to the study. Similarly, for a micro-level study of vegetarian households, animal-based foods would be exogenous, although animals as users would be endogenous for plant-based food residue is often fed to animals.

By the same token, the framework can be used to integrate the research from different points of view, sizes, scopes, and scales. It is this ability that can be used to derive a “Google Map” to address the problem of FLW systemically and systematically.

3.10. Opportunities for Empirical Research

The ontology, as a theory of food consumption, loss, and waste, can be a systemic foundation for systematic empirical research on the subject. It can be used to synthesize the present empirical research on the subject and generate new research. It can be the foundation of descriptive, explanatory, predictive, and experimentally controlled research on the subject. Mapping the extant research, policies, and practices onto the ontology will highlight the bright, light, and blind/blank element/pathways in them. Harnessing the knowledge from the present research and promoting new research to fill the gaps would be the objectives of the empirical research. The following are some of the questions empirical research may address:

- Descriptive research of patterns of CLW by people in different parts of a country and different countries.
- Explanatory research of the flow of plant-based food cycles among the people, animals, plants, and the environment.
- Predictive research of the change in content of free meals for school children on the objectives.
- Experimentally controlled research on the effect of processing of additives and preservatives in food consumed by people on the residue.
• Quantitative measurement and monitoring of CLW in an institution to predict future FLW.
• Field experiments to find ways to reduce food loss and food waste while increasing nutrient food consumption.

3.11. Value Added by the Ontology

We conclude our discussion by highlighting the value added by the ontology to advancing the research, policies, and practices for the management of FLW. It is true that the terms and concepts of the ontology are familiar to experts in the field, and that they have been explored and applied globally by international organizations such as the United Nations, Food and Agriculture Organization, and the European Community. While the institutions’ frameworks clearly highlight many of the key issues in managing food loss and waste, they also have very significant biases and blind spots that can affect the strategies for and outcomes of managing FLW. The ontology corrects these shortcomings. We discuss how the ontology can enhance the present body of knowledge and practice of FLW.

It has become a cliché to state that a whole system is greater than the sum of its parts. The ontology encapsulates this principle. It makes the whole visible—like the wise man [sic] does in the parable of the blind men and the elephant—and changes the perspective, making it more than the sum of the familiar elements. By organizing the familiar elements systematically and extending them logically, it provides a systemic perspective that illuminates and enhances the traditional perspectives. It formulates the problem more inclusively. Thus, it highlights and corrects the biases and blind spots of the extant frameworks. Instead of re-emphasizing more of the same traditional avenues, it incorporates and extends them to develop novel ones. We shall highlight a few.

The ontology extends the focus from FLW to food consumption, loss, and waste (CLW). The implicit bias in excluding consumption significantly affects the management of loss and waste. Yet, the exclusion persists. If an element is not part of the problem formulation, it will not be part of its solution; consumption must be part of the problem and the solution. CLW by the four types of users (people, animals, plants, and the environment) in the ontology is a zero-sum game for sustainability and must be managed systemically. The simple extension of focus may appear minor, but it can have a dramatic impact on the outcomes. It introduces the pathways of changing loss and waste by changing consumption patterns of use, reduction, and reuse by the different users.

The ontology highlights the necessity of considering all the four types of users for a sustainable ecosystem. People’s CLW has been the dominant concern in the scientific literature, policies, and practice. This skews the perspective, for the CLW of animals and plants too are integral to how the CLW chain affects the environment and is affected by it. Further, by denoting the environment as a user, the ontology makes it endogenous to the challenge of managing food CLW and not exogenous to it. The environment is considered a part of the problem and not just of the solutions for sustainability.

The ontology includes both plant-based and animal-based foods and sidesteps the either/or debate about their inclusion/exclusion in some of the frameworks. Systemically, both, with their physical/chemical components, must be managed. The ontology rises above the either/or debate and provides an inclusive perspective and eliminates potential blind spots.

The ontology includes all stages of the supply chain for all types of food for all users. Managing the sequential dependence in the chain is critical to the effective management of food CLW for sustainability. The feedback loops between the stages, from subsequent stages to the prior ones, and the feedforward loops from the prior to the subsequent stages are not explicates in the ontology but can be visualized systematically using it. They play an important role in maintaining the continuity of pathways that are effective, changing the ones that are not effective, and discovering ones that have been unexplored. Instead of studying the food supply chain as a silo, the ontology helps visualize the chain as integral to the system of managing food CLW.
The ontology presents an integrated perspective on the value of food—energy, macro-nutrition, micro-nutrition, medication, additive/excipient, and residue. The value requirements vary by the user, and the value delivered vary by the type of food. Further, the pattern of consumption, loss, and waste of food by the users for obtaining these values vary widely. The ontology provides a framework to manage the pathways to deliver these values optimally.

Thus, the ontology can be used like a “Google Map” to navigate the pathways to optimize the value of food CLW. While many pathways may be familiar, many are not. Feedback and learning using the ontology can aid continuity, change, and discontinuity in the optimal management of CLW. It can help lessen “more of the same” solutions and increase “many of the different” solutions, as illustrated above.

3.12. Research Limitations

The ontology is a structured natural English framework. Its validity is partly determined by the semantics of the words, phrases, and pathways in it and derived from it. Consequently, it is subject to variations based on the syntax and semantics of the language, the users, and the context. The simplicity of the framework allows it to be easily transferred to other contexts, translated into other languages, and applied using the local vernacular; however, care must be exercised to accommodate the differences in the grammar and semantics of the languages and dialects.

A second limitation of the ontology is the granularity of its representation—it matches the granularity of the present discourse on the subject. Yet, to address FLW effectively, one may need to address it at a finer level (for example, different types of grains) or at a coarser level (for example, loss in the aggregate, without considering recovery and repurposing). Changing the granularity will affect the number of pathways combinatorially, and hence the complexity of the challenge. It may become necessary to focus only on a segment of the ontology, and not the whole, at a different level of granularity. For example, one may focus the research only on the utilization stage and not include the other stages.

A third limitation of the ontology is the boundary it defines. The denotations of the dimensions and the elements define the inclusion/exclusion of parameters that affect FLW. For example, the context (country, culture, geography, socioeconomic structure), the scope (block, city, district, state, country, region), and timeframe (short-term, medium-term, long-term) are exogenous to the present ontology. By choice, the ontology focuses tightly on the core logic of FLW. The other dimensions can be added to change the scope, if necessary, with the concomitant increase in complexity and the number of pathways. The scope could also be decreased by eliminating a present dimension (for example, the Objective), but that would diminish the logical validity of the ontology.

These limitations can be overcome easily because of the modularity of the ontology. A dimension can be added or deleted without prejudice to the others, taxonomies can be refined and coarsened, and they can also be extended with new elements and contracted by eliminating redundant ones. Such changes will change the size (the number of dimensions and elements), scope (the type of dimensions and elements), and scale (the granularity of dimensions and elements) of the problem definition and the associated complexity.

4. Conclusions

The paper presents a unified definition of food consumption, loss, and waste as an ontology. The construct’s combinatorial complexity cannot be clearly, concisely, and comprehensively expressed in a traditional linear narrative. It requires an ontology. The paper relates the ontology to the other extant definitions of the construct and assesses them systematically to integrate the definition of FLW and address their lacunae. With the increasing demand of sustainable practices for food consumption and reducing the food loss and food waste in the system, it becomes important to understand the system. The framework helps to define the construct to include all three—food consumption, food loss, and food waste. It can help understand the dynamics of the full spectrum of stages, their
impact on consumption, loss, and waste, and the complete knowledge cycle associated with it.

The paper addresses a pressing need of the domain and presents a framework that is integrative and innovative, consonant with the need for solutions with similar characteristics. The novel systemic framework can guide the development of roadmaps for systematic research, policies, and practices to address the challenge. It can help to identify and to rectify the biases and blind spots in the current approaches and to institute a system of feedback and learning to guide the future trajectory of the domain.

The contribution of the ontology of food consumption, loss, and waste is analogous to that of the “wise man” [sic] in the parable of the blind men and the elephant. By making the whole visible, it can help integrate the many fragmented, often conflicting, and complementary definitions. It can help advance the agenda for research, policies, and practices on the subject through collaboration and cooperation. It can help formalize knowledge in the three domains, transfer knowledge between the subdomains, and translate knowledge between them to achieve the Sustainable Development Goal target 12.3 [1], food security [42], and nutrition security [43].

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