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POST-HARVEST MANAGEMENT OF PERISHABLE PRODUCTS FROM FIELD TO TABLE USING SYSTEMS ENGINEERING APPROACH: A REVIEW

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ABSTRACT

Perishable food products are indispensable in maintaining good health. However, the rate of its loss/waste globally is quite alarming due to its effects of food shortage, economy instability and environmental threats due to the disposed waste. The scope of this study is to assess the level and effect of food loss/waste through literature reviews and to analyze how effective post-harvest management from planting to harvesting stages can help minimize food loss/waste in the global world. The system engineering approach, System Development Life Cycle (SDLC) was used to solve this problem. This approach explains the how the selection of a suitable farm site, planting/harvesting at the optimum time can contribute to reducing food loss/waste. The paper revealed that for good post-harvest management practice, there is a need to consider some key factors, which include selection of a suitable farm site (free of acidity), proper irrigation system, fertilization, harvesting at the right time and with the right tool, proper handling from field to the end users and across the supply chain, and the need for government intervention/support to provision of adequate, suitable storage facilities. The study confirms that public awareness of the implication of food loss/waste in the global world, intervention and proper monitoring/management of the perishable foods across the supply chain actors and support from the government towards the provision of accessible, affordable, and suitable processing and storage facilities will go a long way to curb food loss/waste, secure the growing population against hunger and our environment from environmental hazards.

Keywords: Post-harvest, High-Level System Diagram, System Development Life Cycle, Critical Concepts, Conceptual Models

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INTRODUCTION

Post-harvest management can be referred to as reducing food loss or waste across the entire supply chain (SC) (from the field till the product reaches the final consumer) without compromising food quality. Food loss occurs due to the quantitative (i.e., weight reduction) or qualitative (i.e., reduction in the nutritional composition) loss of food at different stages of the SC. On the other hand, food waste can be termed as food available for human consumption but not consumed, possibly due to physiological changes or other factors that make the food unacceptable. The physiological change may be due to physical or other factors that make the food unacceptable to the consumers. There is a need for the study and awareness of food physiology to have more insight into handling, processing, and storage techniques suitable for different food classes (Muhammed *et al.*, 2012). The physiological knowledge of food properties would give insight to scientist and engineers into the fundamental principles required that leads to the design of processing or storage equipment management (FAO, 2019; Asiru *et al.*, 2018). A good representation of food management and sustainability is given in Figure 1.

It should be noted that food waste goes beyond tossing leftovers in the trash. EPA (2018) reported that about 103 million tonnes (equivalent to 81.4 billion pounds) of food waste were estimated, equivalent to over 450,000 statutes of Liberties. The implication is that continuous practice of food waste could result in about 66 tons of food being wasted per second across the globe in the next ten years.

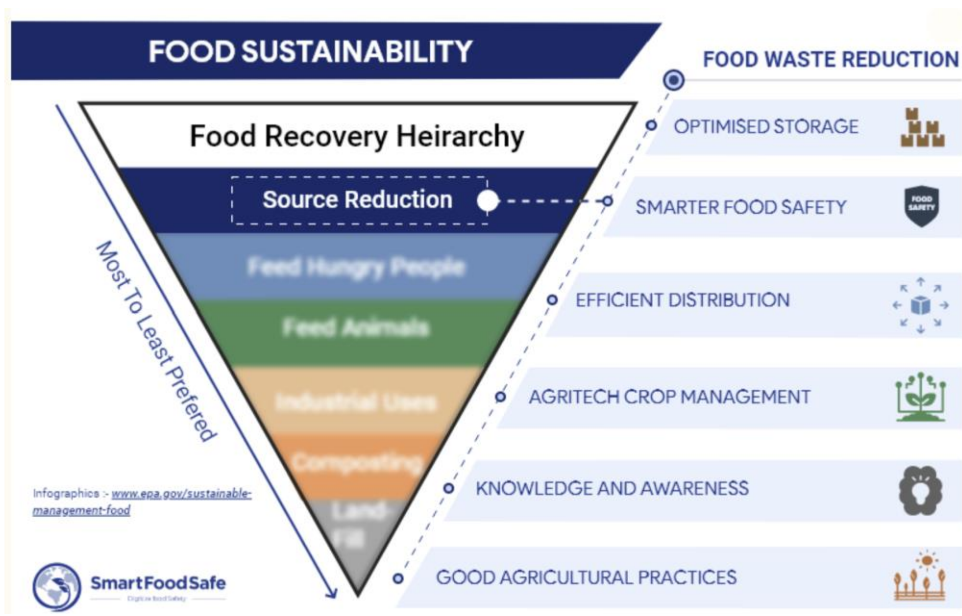

Figure 1: Food management and Sustainability Practice
Source: Anon (2023)

Post-harvest management is a global concern that needs urgent intervention. It is overwhelming that despite the money, time, and labor required to produce food from the initial planting stage till harvesting, up till today, about one-third of the food produced is still wasted. It has been analyzed that out of the total food production, about 45% of food loss has been traced back to occur at the entire supply chain, 18% of loss occurs at the processing stage, 14% of loss occurs from production before reaching the retail level and 40% at household level (Franscesco *et al.*, 2023; Subhamoy and David, 2022; NRDC, 2020; FAO, 2014). This constitutes about 1.3 billion metric tons of organic waste, eventually creating an unsuitable environment for the populace (Daniel *et al.*, 2023). It should be noted that three main factors influence post-harvest losses in perishable foods: physical (temperature, humidity among others), biological (pest infestation), and social factors (human behavior/attitude). All these factors, if well monitored, would help minimize post-harvest losses.

There is a need for quick and continuous intervention to address this issue of global food waste, which should be addressed from the initial stage of planting till the harvesting stage. These may entail choosing an excellent suitable site for planting, planting, and harvesting at the right time and with the right tools and adequate storage and processing facilities to store, preserve and process excess food for later use (Yebirzaf and Esubalew, 2021). All these require the joint intervention of the stakeholders, government, and consumers (Gokarn and Kuthambalayan, 2017). Here, the stakeholders, which involve farmers, make sure that the crop is planted at the right time, well monitored, and harvested at the right time and with proper tools; the producers/manufacturers and distributors of raw products make sure the products are well handled to avoid bruise or been stressed by the environmental factors of mainly, the temperature during across the supply chain. The role of the government here is to support the stakeholders by providing adequate, suitable, and affordable storage and processing facilities. All these strategies would help manage perishable produce while minimizing food loss/waste and enhancing food security. This role will help prevent the report of FAO (2023), which stated that up to about 230 Km^3 of water and 300 million barrels of oil may be required to produce the food wasted globally.

The impacts of food waste are enormous, part of which is its effect on the three core dimensions: sustainability, environmental livelihood, and financial stability (Flavio *et al.*, 2022; Carlotta *et al.*, 2018). However, Post-harvest management of agricultural products can help resolve various economic and social problems. Food availability to the populace will boost their wellness, and the rate of starvation will be highly reduced, especially in developing countries where over 50% of the population is malnourished. A meaningful reduction in post-harvest loss can help to boost food security globally. Also, promotes food safety by protecting food commodities from mold growth and contamination. This study aims to review some literature on food waste/loss and to proffer solutions using a systems engineering approach to enhance sound post-harvest management systems for food security.

Problem Definition of Post-harvest (P-H)Losses/wastes of Fruits and Vegetables

Farming activities is very tedious and time-consuming, and they require fund ranging from field purchase, fertilizer application, irrigation of farmland, harvesting, and transportation to the market, especially when it is on a large scale that contributes to the market economy. This means farmers are required to recover their costs and make a profit. P-H loss/waste needs to be tackled by monitoring activities from the growing stage of the crop from the field up to the harvesting stage. After that, the post-harvest management activities ensure that food quality is maintained while losses/wastes are drastically minimized. Unfortunately, the alarming rate of post-harvest losses in fruits and vegetables may be associated with any of the physical, biological, and social factors which are significant concerns, especially its impact on the nation’s economy and environmental effects.

High-Level System Diagram of P-H Management of Fruits and Vegetables

The diagram below explains the main factors affecting fruits and vegetables' post-harvest loss/waste. Figure 2 provides an overview of an entire system and identifies the main factors that would be developed at various interfaces.

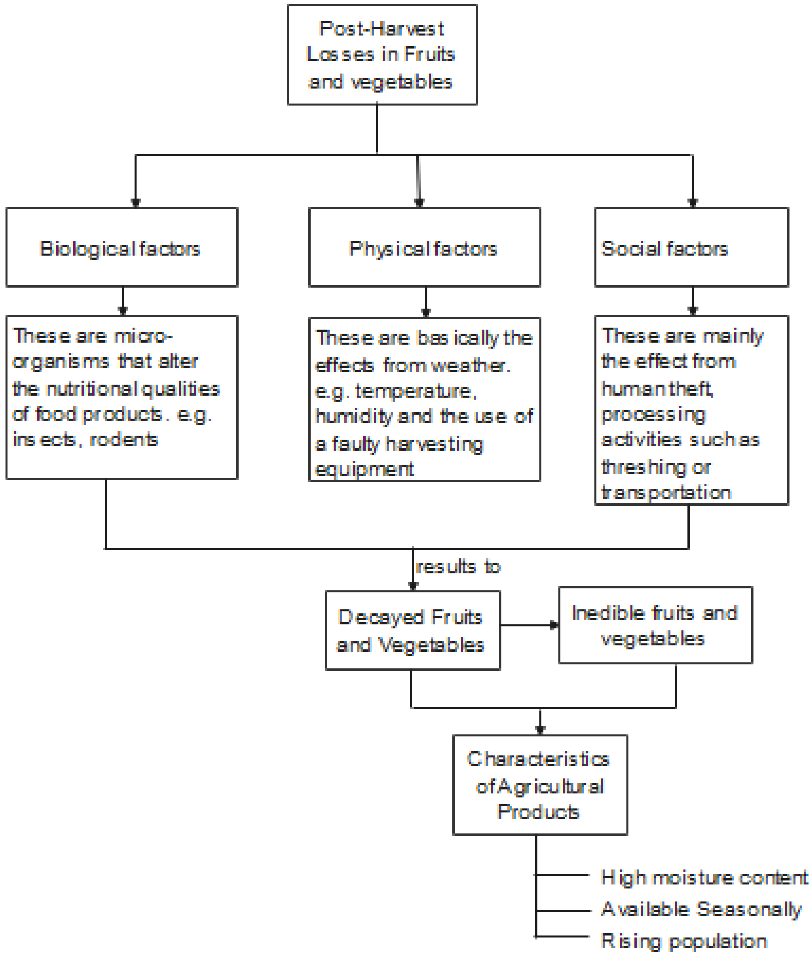

Figure 2: High-Level System Diagram
Source: Bello (2021).

System Development Life Cycle (SDLC)
The system engineering approach using System Development Life Cycle (SDLC) methodology was used in this study. It entails (as shown in Figure 3) the stages involved in solving the problem attached to post-harvest management. The SDLC methodology in a system engineering approach refers to a universal way of solving a problem because it moves through various stages from problem definition to high-level system diagram, problem description, conceptualization, the use case models (i.e., the use case scenarios and use case diagrams with actors), and the analysis diagrams (i.e., object-oriented, sequence, activity, and state) to proffer solutions to the problems. Figure 3 shows the System Development Life Cycle diagram. The critical concepts in the problem description are shown in Figure 4

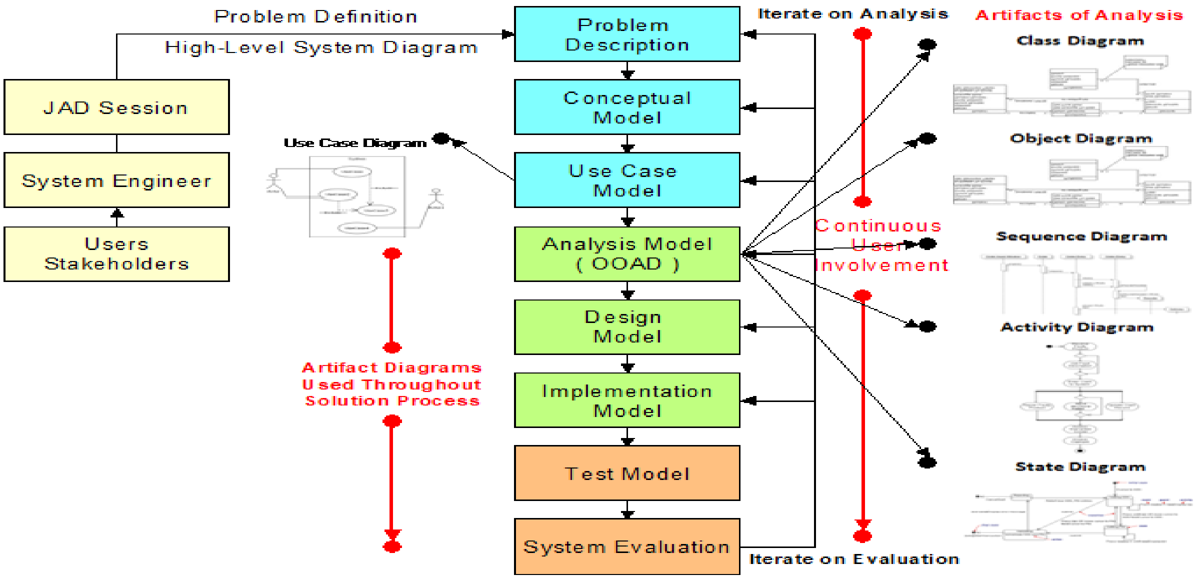

Figure 3: The System Development Life Cycle (SDLC) diagram
Source: LeeRoy (2021)

Problem Description of Post-harvest (P-H) Management of Fruits and Vegetables

Fruits and vegetables contain about 93% of water, hence, the main reason for rapid growth of fungal and bacteria diseases, which cause quick decay and make it inedible for consumption. There is a need to identify the exact problem that causes quick decay in order to use suitable approach to curb these losses.

Other primary factors leading to the problem are carelessness during harvesting (using faulty harvesting equipment), mishandling and transportation in which the product may sustain cut/bruise on its surface, thus, leading to its bacteria, fungi and mould attack. This later resulted in decayed/ inedible fruits and vegetables to the extent that the consumers rejected them. are shown in Plates 1a, b and c respectively.

(a) (b) (c)

Plate 1a: Fresh Fruits/Vegetables
Source: google.com/fruits/vegetables

Plates 1b and c: Inedible Fruits and Vegetables

Wine: Key concepts
Blue: Connecting verbs

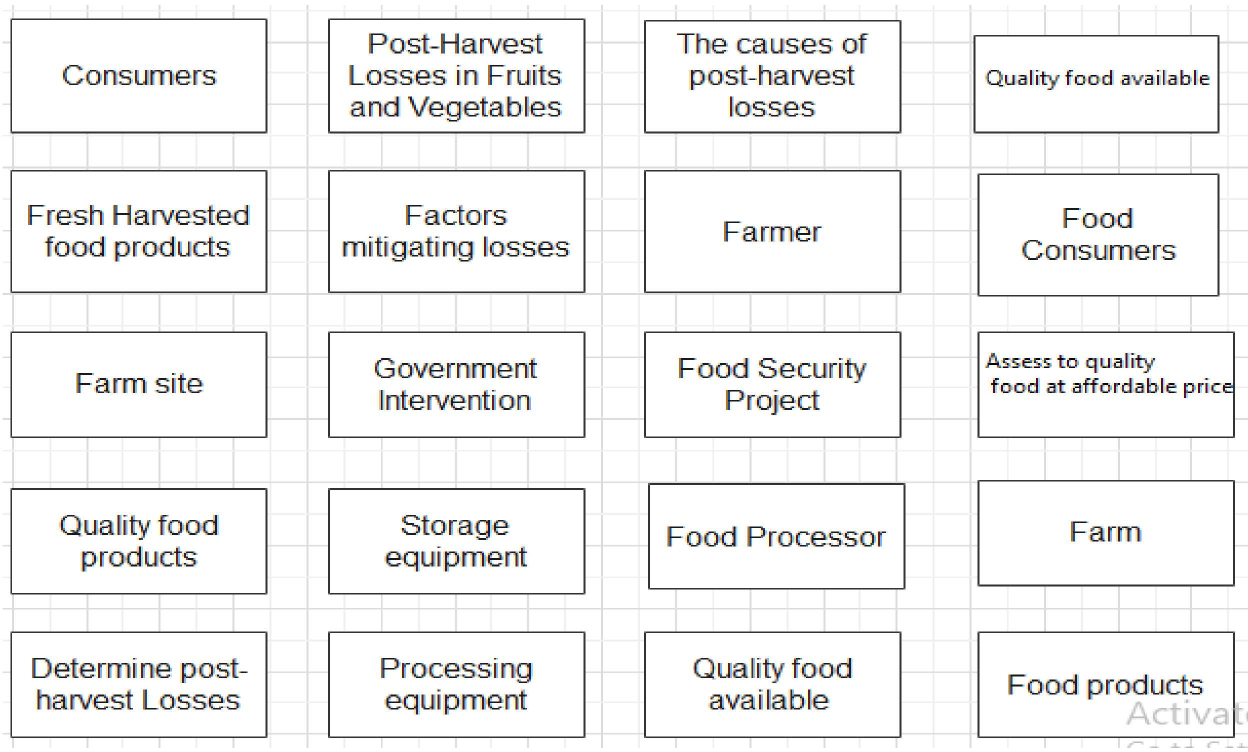

Figure 4: The Critical Concepts of P-H Management of Fruits and Vegetables
Source: Bello (2021)

Conceptual Model Post-harvest Management of Fruits and Vegetables

This can be termed as the representations of the concepts and relationships that exist between what contributed to Post-Harvest losses. The conceptual model gives the descriptive model of the system based on the interactions among the elements involved and the system's boundaries using various notations. Figure 5 shows the complete conceptual model of post-harvest management, which shows the element's interaction and the operations. The sub-systems of the concept model also follow in the subsequent Figures 5 to 11 he post-harvest loss contributors are shown in Figure 12. -In contrast, solutions to post-harvest losses involve using suitable equipment, proper handling and transportation facilities, and availability of processing and storage facilities, as shown in Figure 13.

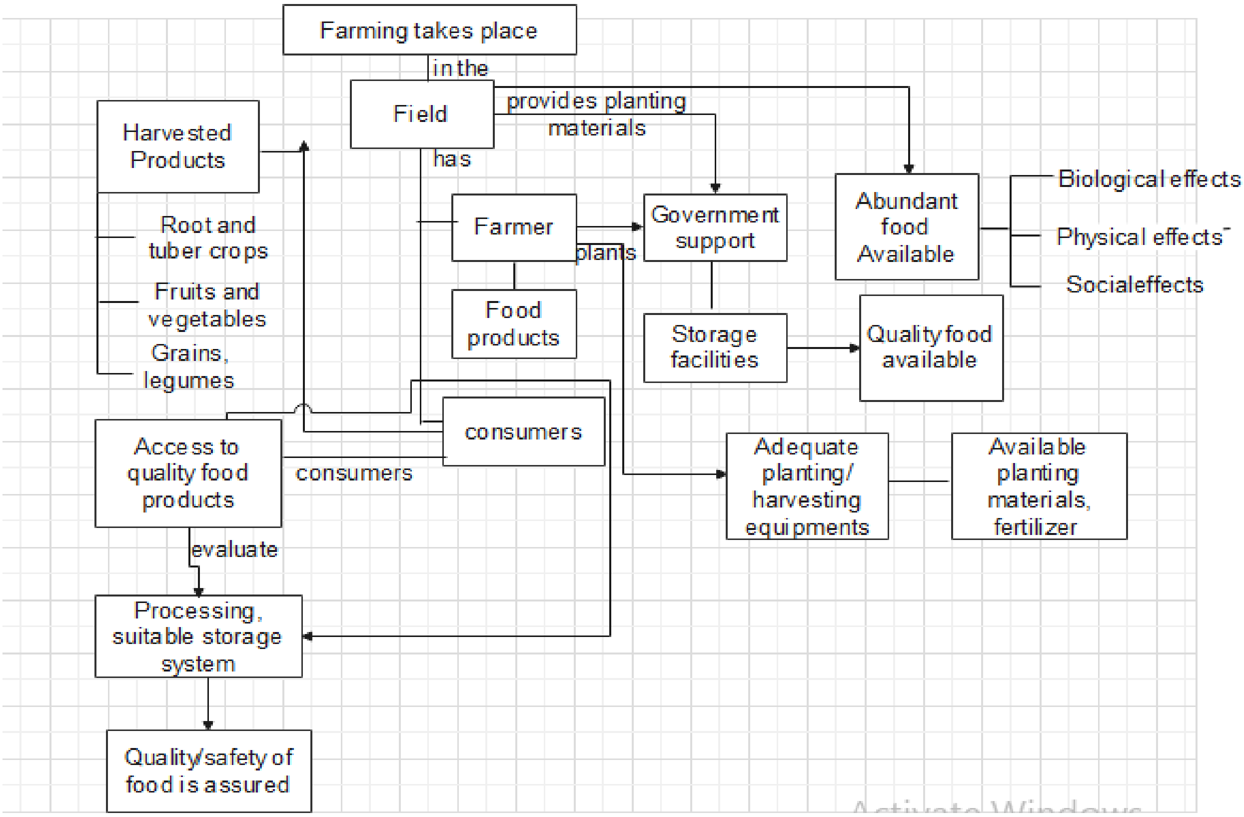

Figure 5 The Complete Conceptual Model of Post-Harvest Management
Source: Bello (2021)

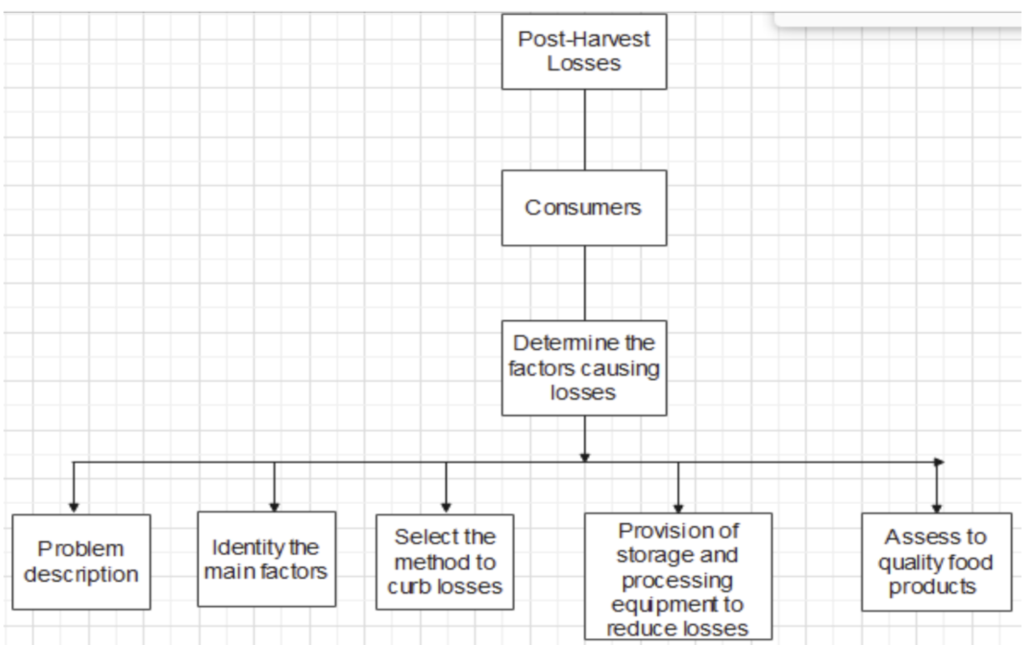

Figure 6: Subsystem Conceptual Model of Post-Harvest Management of Fruits and (Post-Harvest Management System)
Source: Bello (2021)

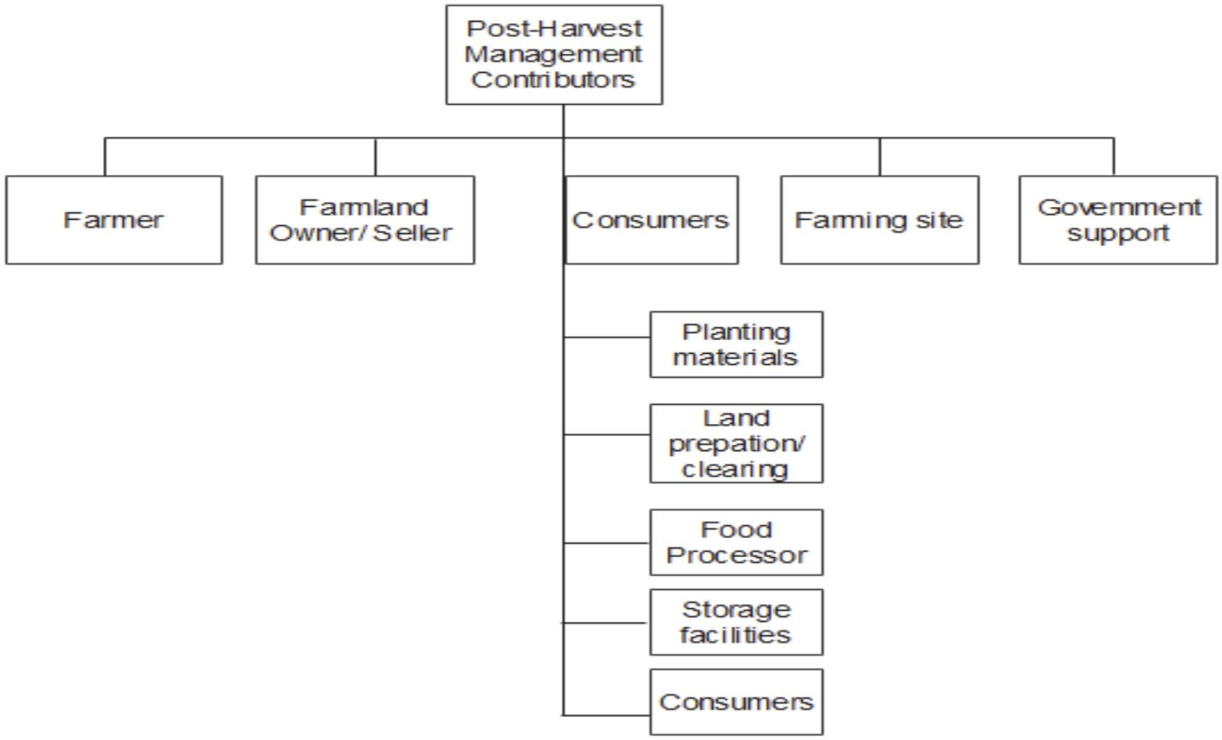

Figure 7: Post-Harvest Management Contributors
Source: Bello (2021)

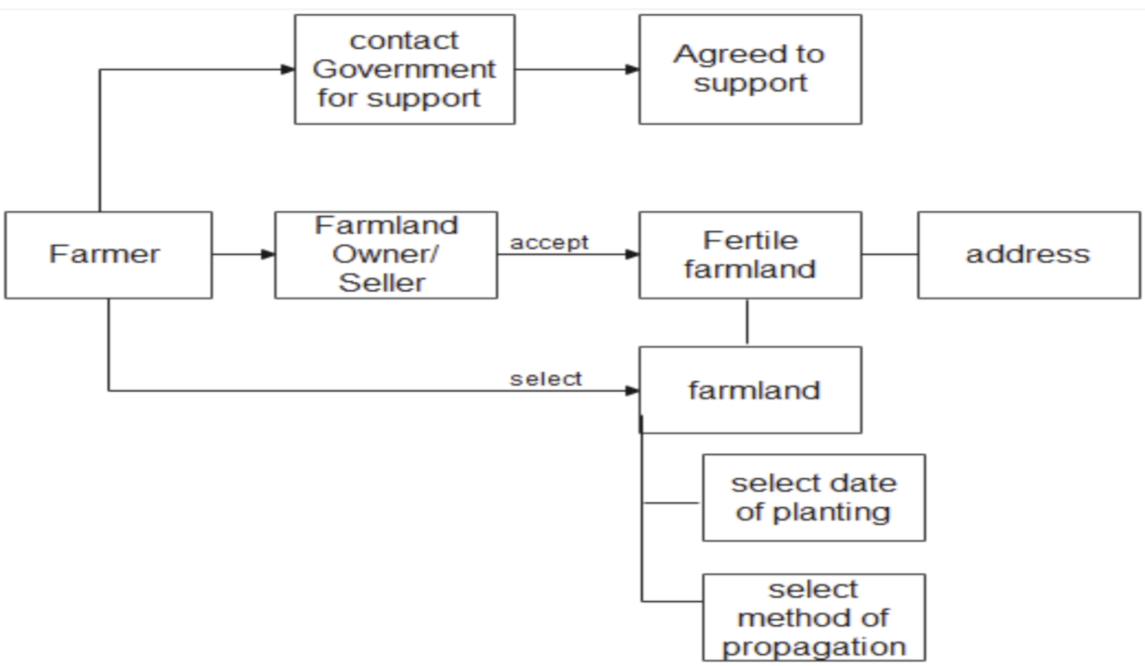

Figure 8: Selecting a Suitable Farm Location
Source: Bello (2021)

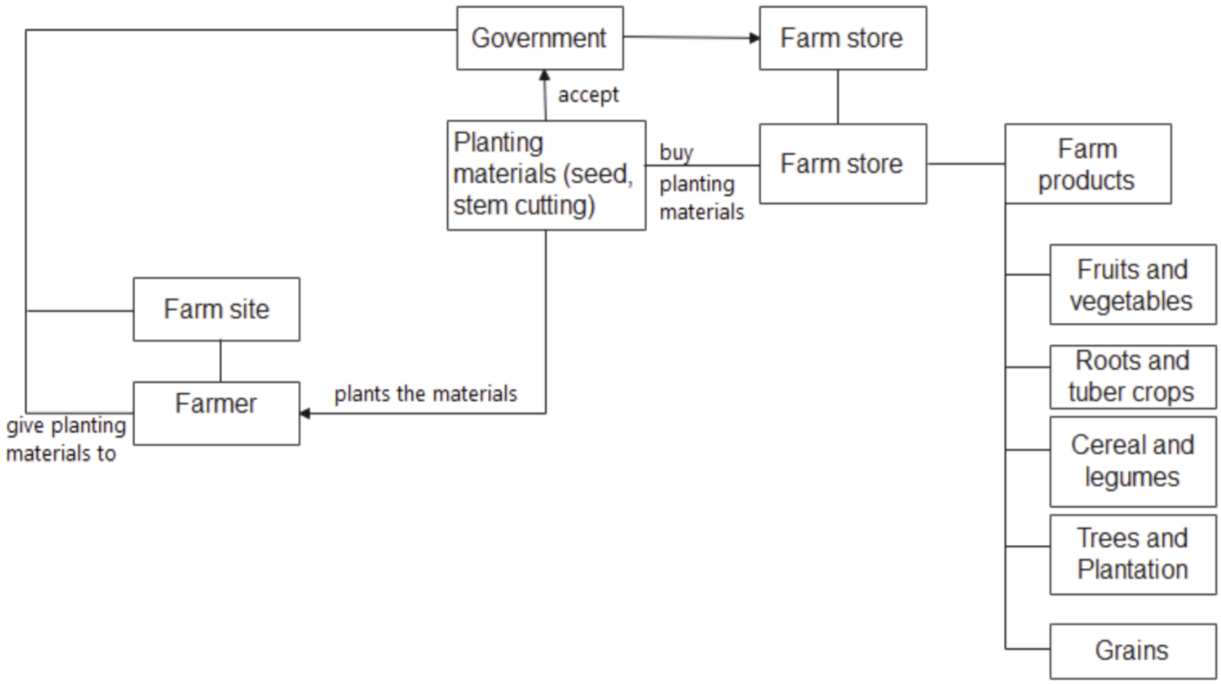

Figure 9: Buy Quality Planting materials and Carry out planting operation
Source: Bello (2021)

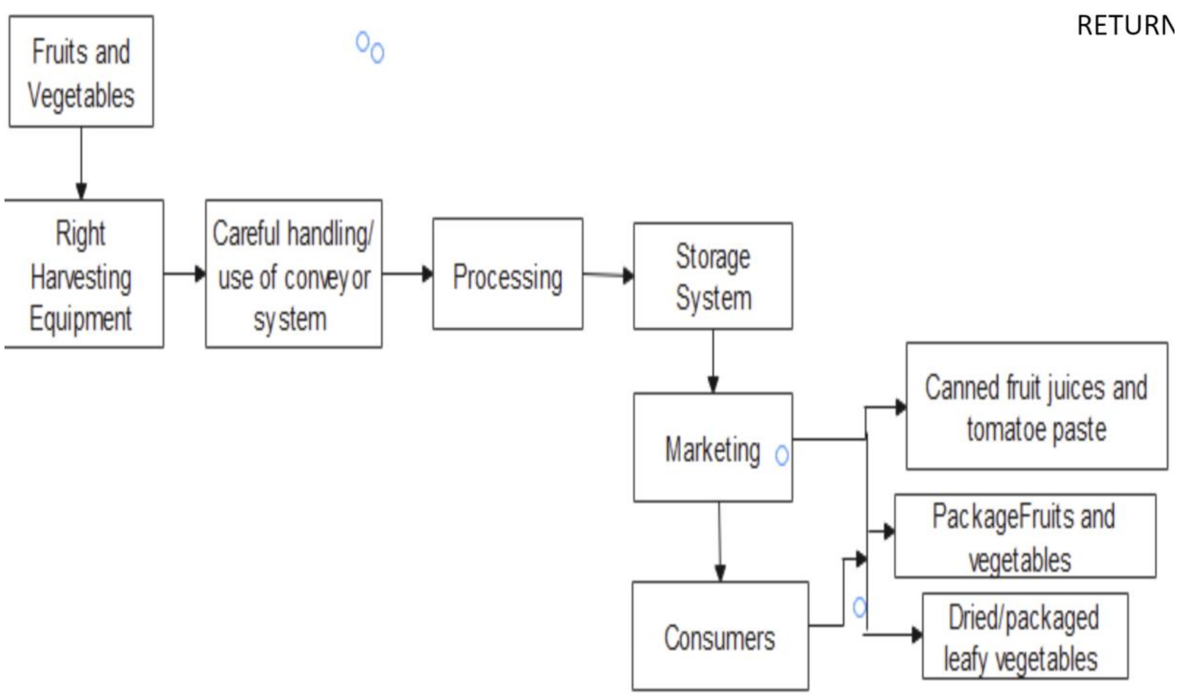

Figure 10: Harvesting and Processing to meet Consumers' needs
Source: Bello (2021)

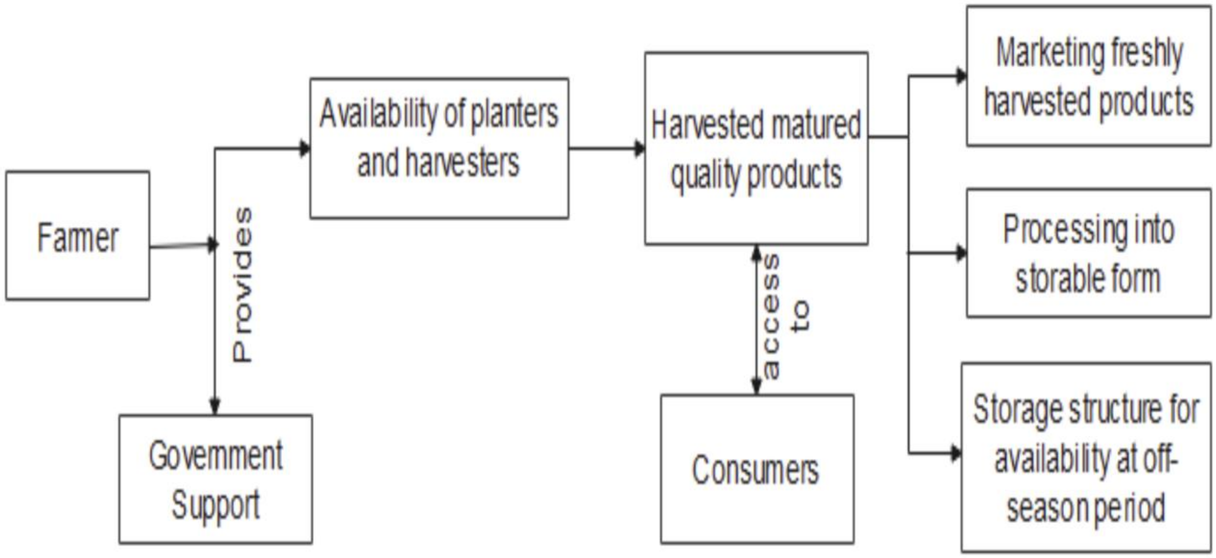

Figure 11: Quality Food at consumers' reach
Source: Bello (2021)

The contributors of the Post-Harvest management as shown in Figure 12 explains the actors involved at various stages. For instance, if the land is leased for farming activities, it should be for long-term usage so as not to disrupt operations on the farm and insecurity to the farmer. This means there should be an agreement between the farmer and the landowner that states some key factors, such as the parties involved, the property, the rental rate, and the lease length (NALC, 2023). This is because any disagreement between them could affect food production negatively, significantly, when the crops are not matured for harvest. The attitude of the Consumers towards food loss/waste in their respective households also impacts P-H management. If consumers are a wasteful type (i.e., if they stock more food than what they can consume within a specified period) would amount to overstaying the excess food, which later gets spoilt and hence a waste. On the other hand, consumers concerned about a greener environment will avoid excess food stock of what is not required in their household and only get what is needed to prevent food loss/waste. This could save about 40% of food loss/waste at the household level, as reported by Subhamoy and David (2022). Also, the fertility of the farmland and the clearing of the land by considering zero tillage practice tends to retain soil nutrients and contribute to the quality and safety of the crop that would be grown. In all, Government support for agricultural accessible, affordable agricultural supplies such as farmland, planting materials (such as seedlings), fertilizer, harvesting equipment, processing, and storage facilities are some of the properties that can contribute to P-H management.

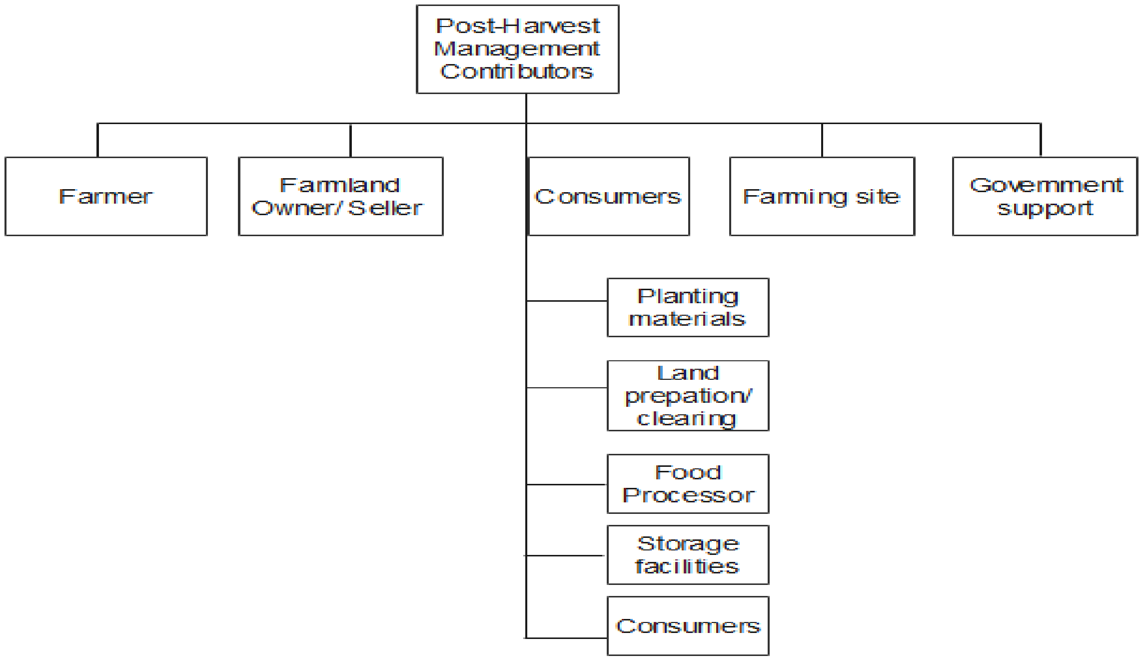

Figure 12: The Contributors of Post-Harvest Management
Source: Bello (2021)

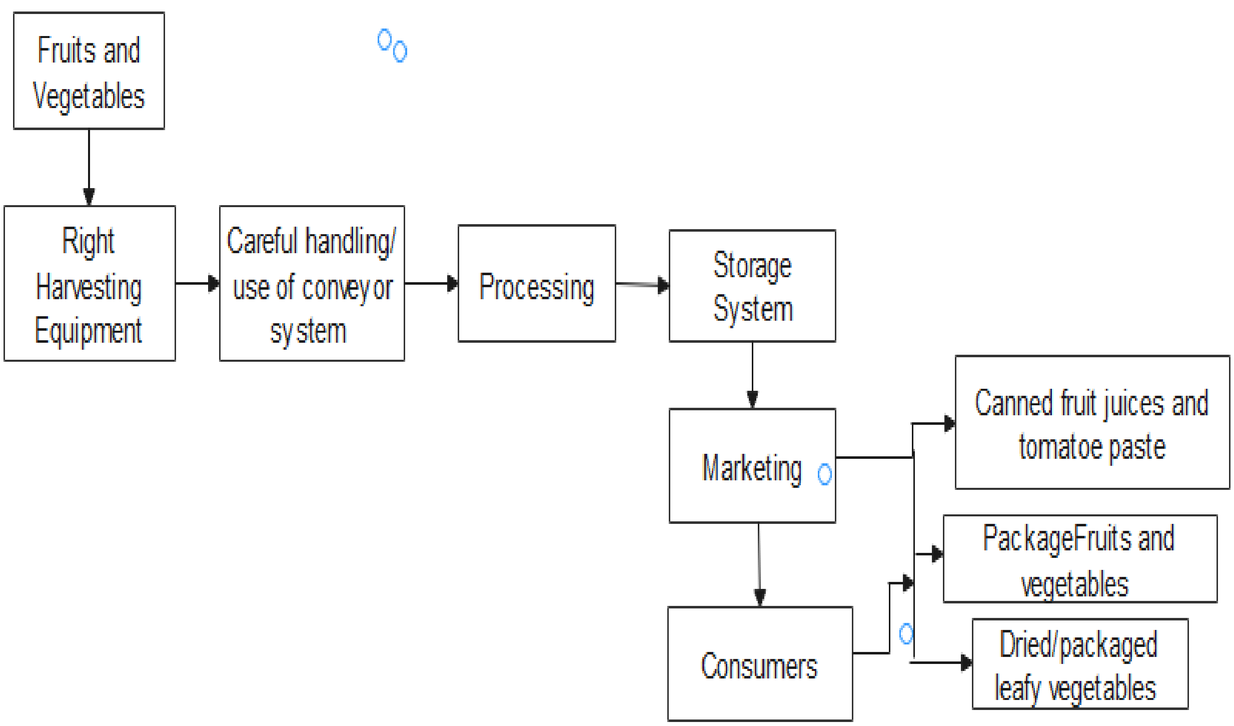

Figure 13: The Solution approach to Harvesting to prevent Post-Harvest Losses
Source: Bello (2021)

The Use Case Model

This is also known as the user requirements diagram. It consists of the use case diagram, the use case diagram with actors, and the use case scenarios. The model diagrams represent the beginning of the solutions to the research problem.

The Use Case Diagram

The Use case diagram allows the farmer, the government, and the consumers to identify the need for the post-harvest management system. It involves the actions, services, and functions the system needs to perform. The use case for this research is shown in Figure 14.

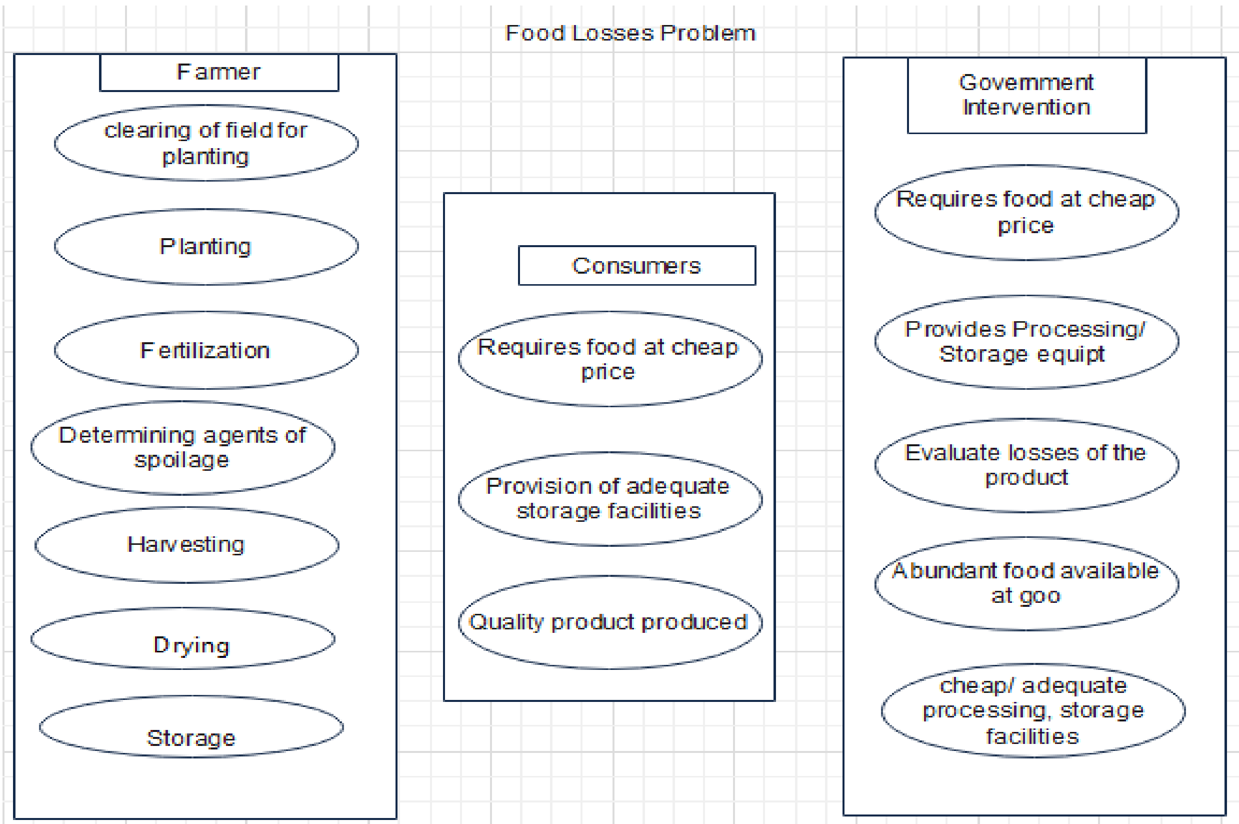

Figure 14: The use case Diagram for Post-Harvest Management
Source: Bello (2021)

The Use Case Diagram with Actors of P-H Management

This shows the activities required from the actors for a successful post-harvest system, starting from site selection to the harvesting stage, as shown in Figures 15 to 18. The actors here include the farmer, government, consumers, processing, marketers, distributors, and other stakeholders across the SC.

The Use Case Scenarios

The Use Case Scenario is referred to as a sequence of events that happen during a particular execution path within a use case of a system. The use cases for this research are explained using different scenarios, as shown in Figures 15-18, while the selected use cases with actors are given in the Use-case Scenarios in

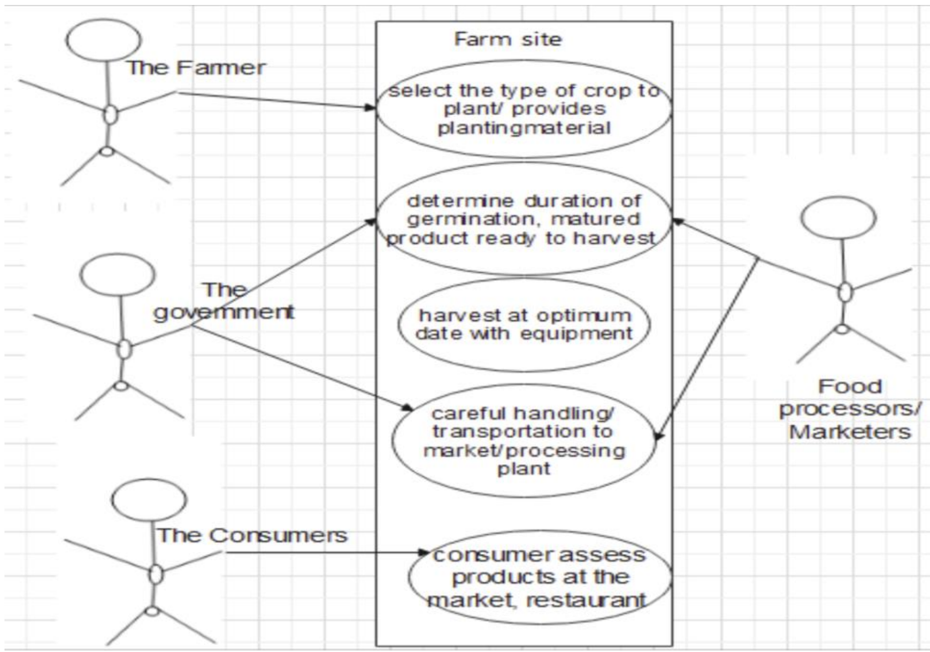

Figure 15: Selection of Farm
Source: Bello (2021)

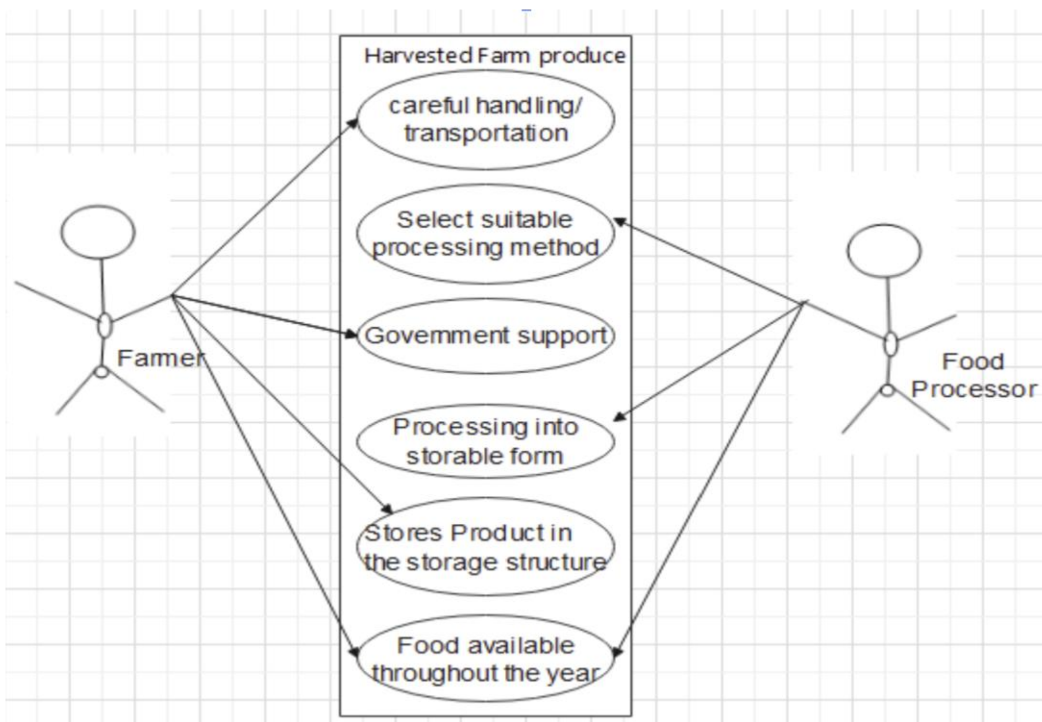

Figure 16: Harvested Farm Produce
Source: Bello (2021)

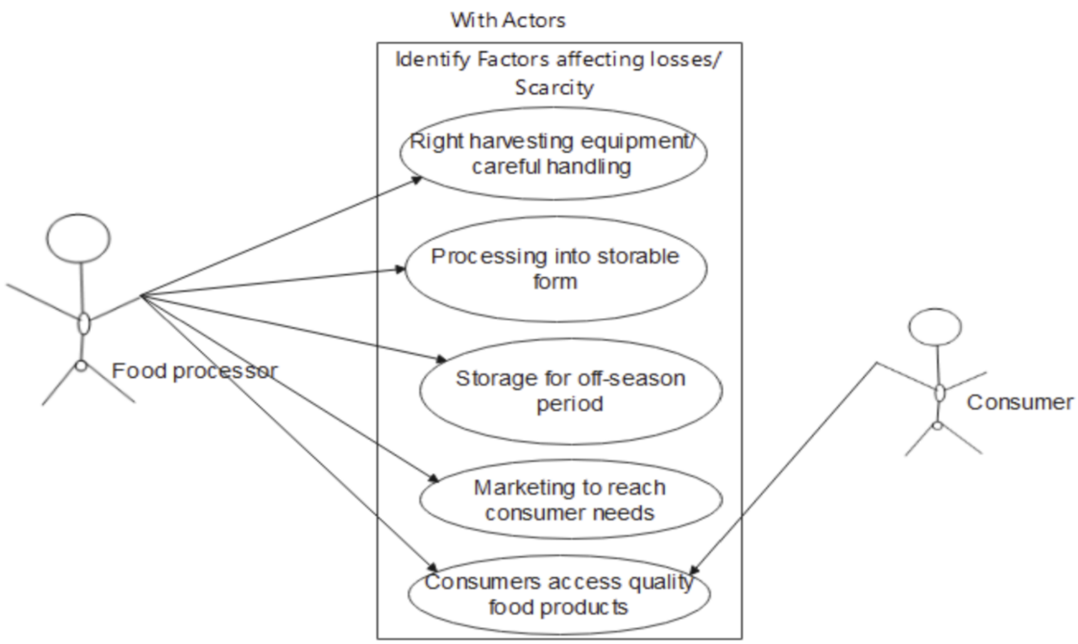

Figure 17: Factors Affecting P-H Losses
Source: Bello (2021)

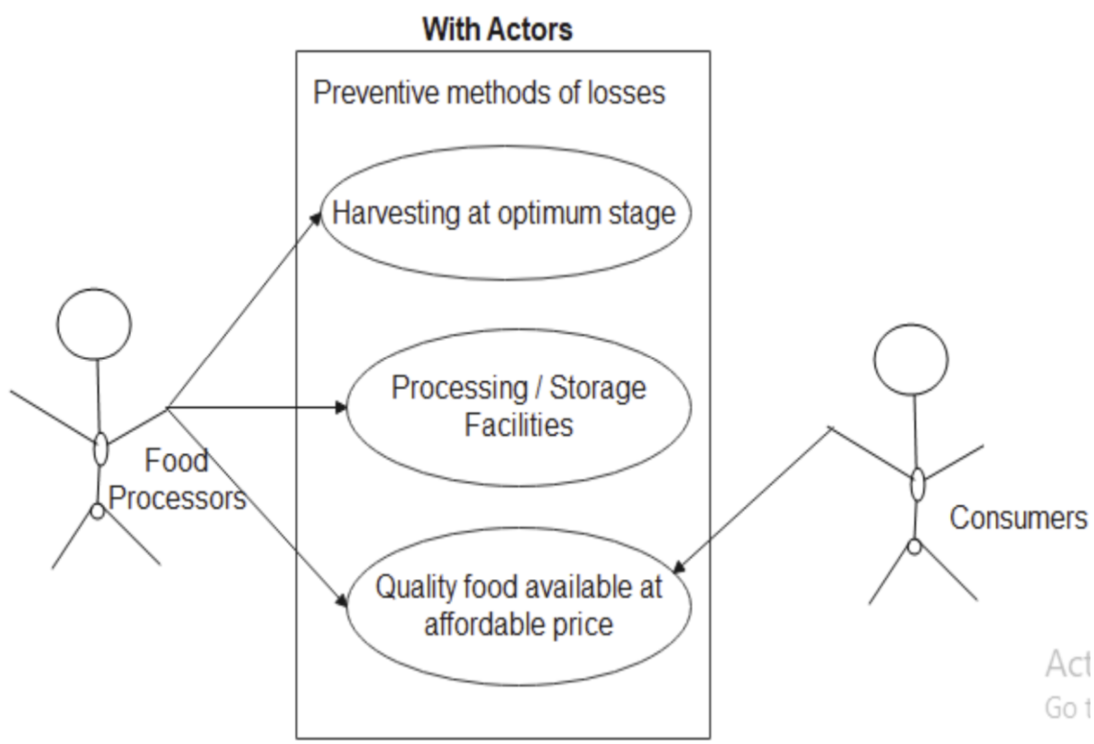

Figure 18: Preventive Methods of Post-Harvest Losses
Source: Bello (2021)

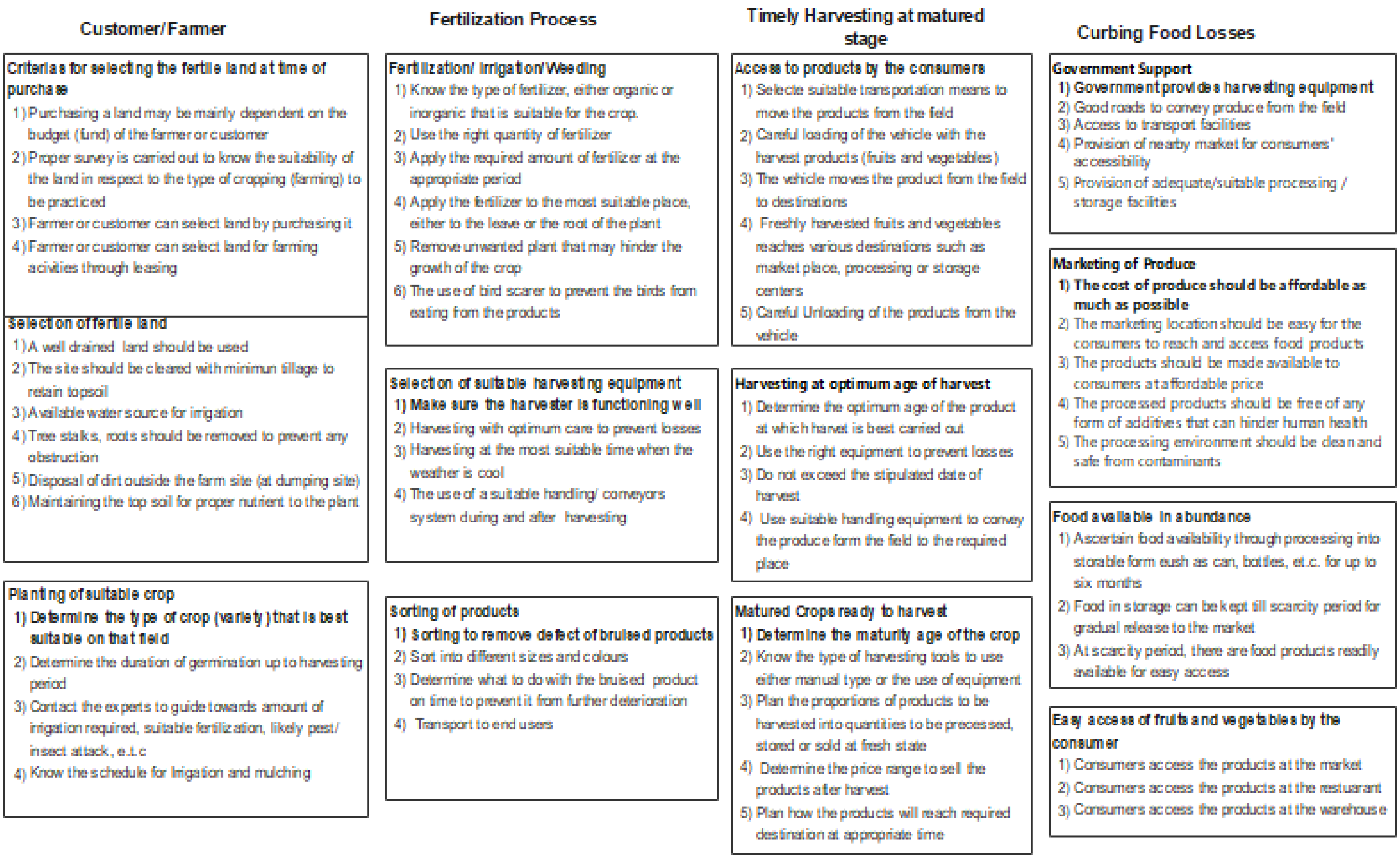

Figure 19: The use case Scenario for Post-Harvest Management System
Source: Bello (2021)

The Object-Oriented Model – The Solution to the Problems

The object-oriented method was used in Figures 20 to 25 to model the post-harvest management of food safety, which involves stages of activities required for crop growth, from selecting fertile land for planting to harvesting. The model shows that perishable products should be grown on fertile land before being harvested. Although object-oriented technology can address more complex problems, this model demonstrated the object-oriented approach that can be incorporated into farming activities to reduce food loss/waste. This approach considers some farm activities of food production. It defines the critical items in the problem (i.e., suitable farm site selection, irrigation, harvesting time and tools, etc.). To define the problem to be modeled, the farm activities are characterized by attributes (i.e., suitable farmland, date of planting, etc.), and the methods are used to define the operations (i.e., planting, irrigation, fertilization, Harvesting, Handling, etc.). Although a selection of suitable farm sites, attributes (such as planting activities and harvesting), and methods are critical to the modeling process, however, the relationships between the selection of suitable farm sites and harvesting at optimum time/tool are very critical to an excellent object-oriented model of post-harvest.

The Object-Oriented Model is the process of simplifying a problem through definition, analysis, and solution. Objects, attributes, methods, and the interactions between them characterize this.

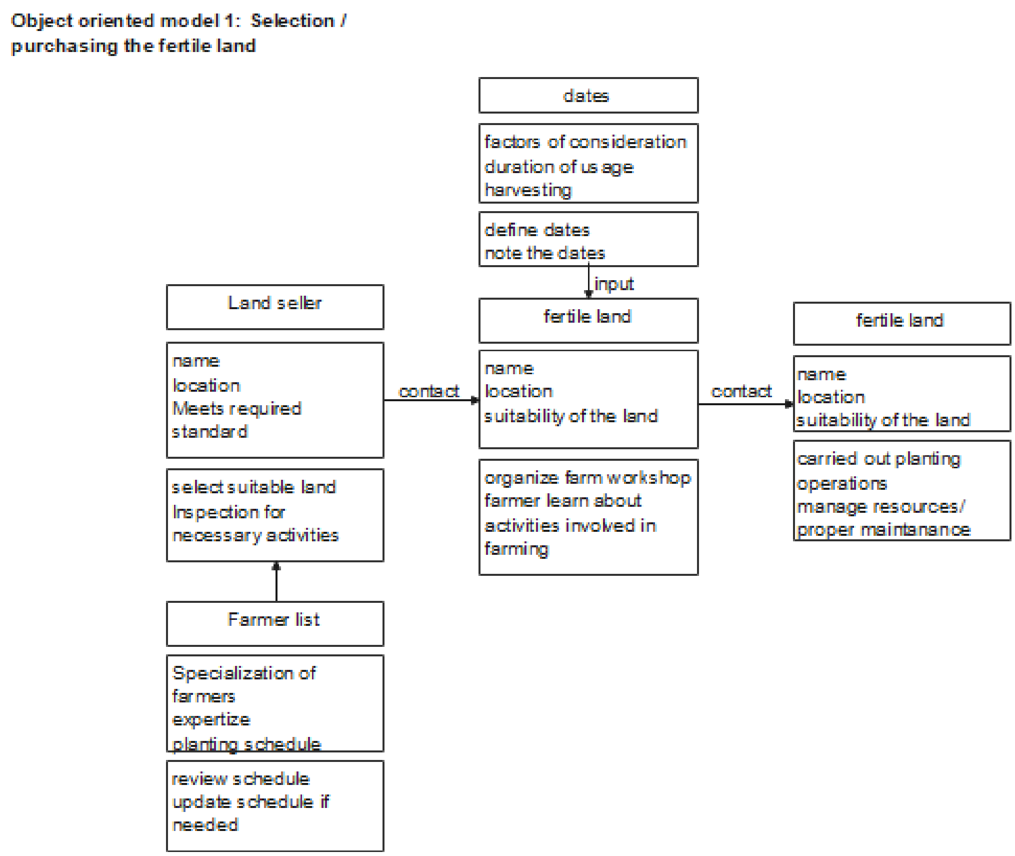

Figure 20: Object-oriented Model: Purchasing the fertile land
Source: Bello (2021)

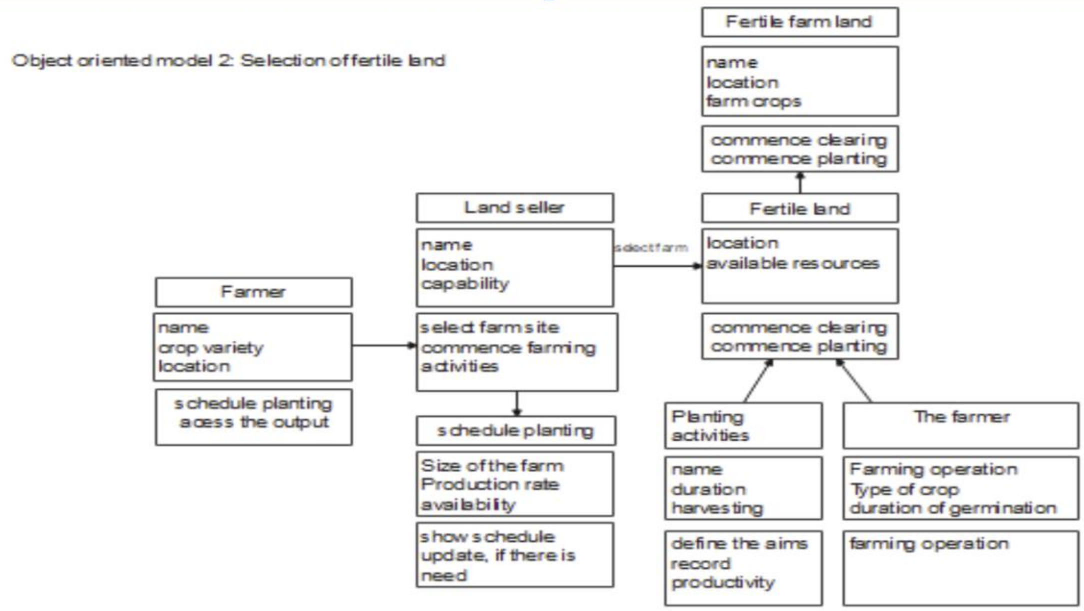

Figure 21: Object-oriented Model: Selection of fertile land
Source: Bello (2021)

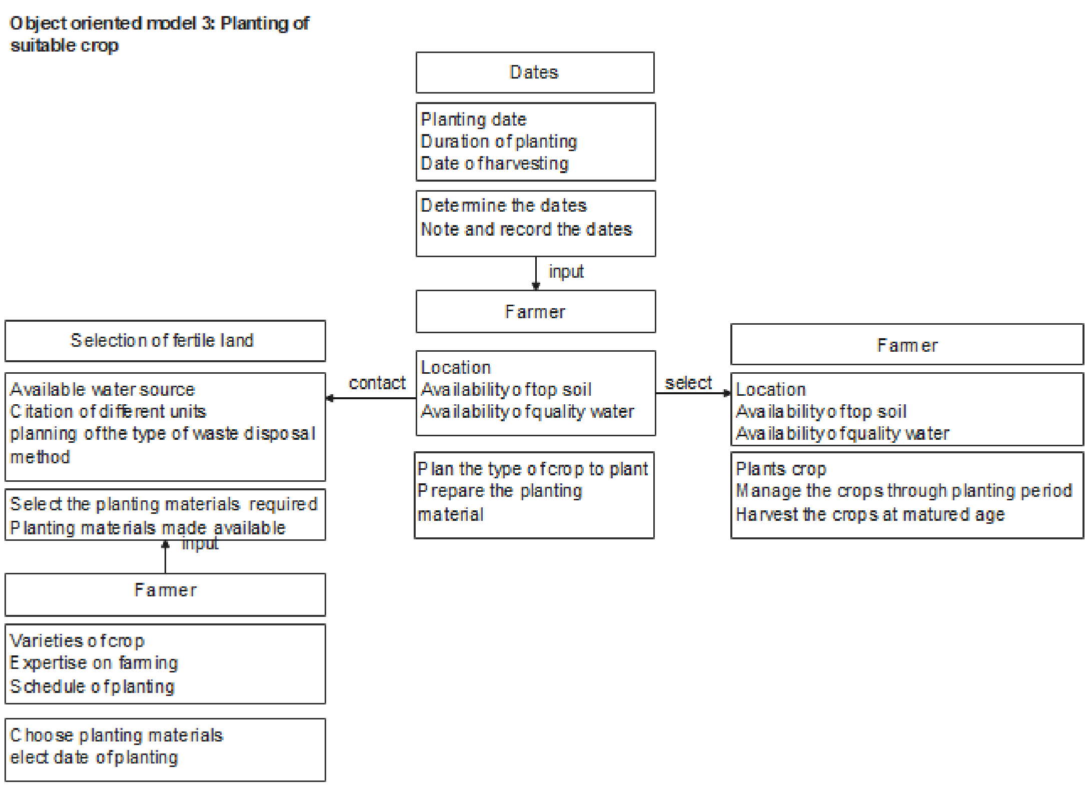

Figure 22: Object-oriented Model: Planting of suitable crop
Source: Bello (2021)

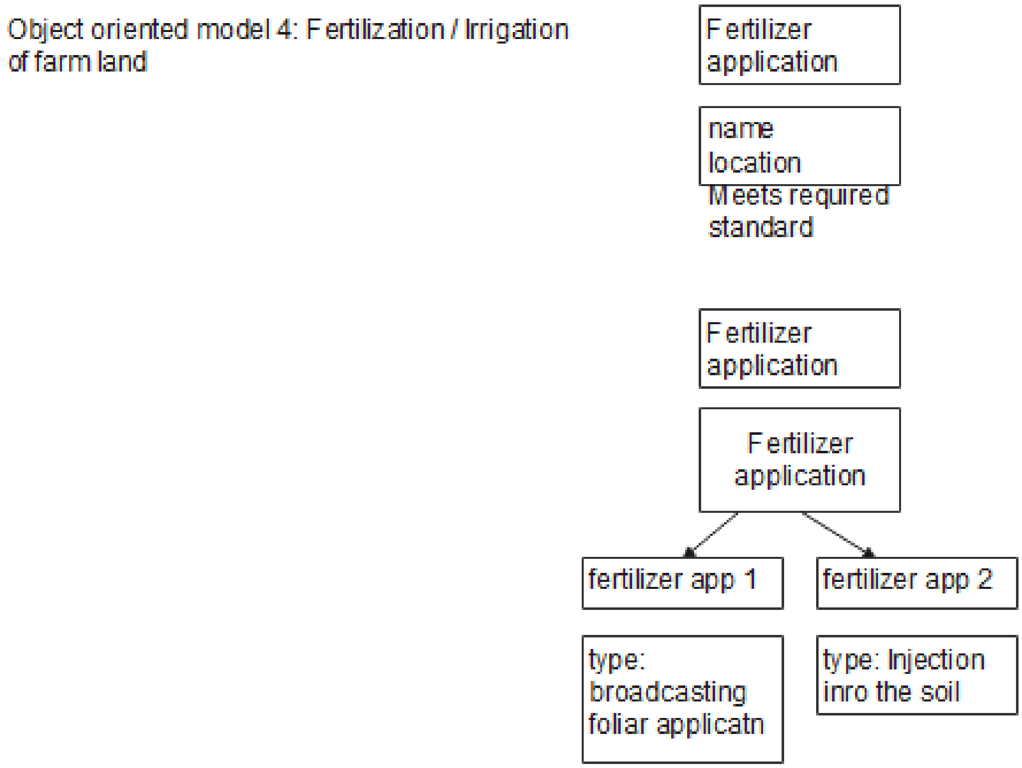

Figure 23: Object-oriented Model: Fertilization/Irrigation Process
Source: Bello (2021)

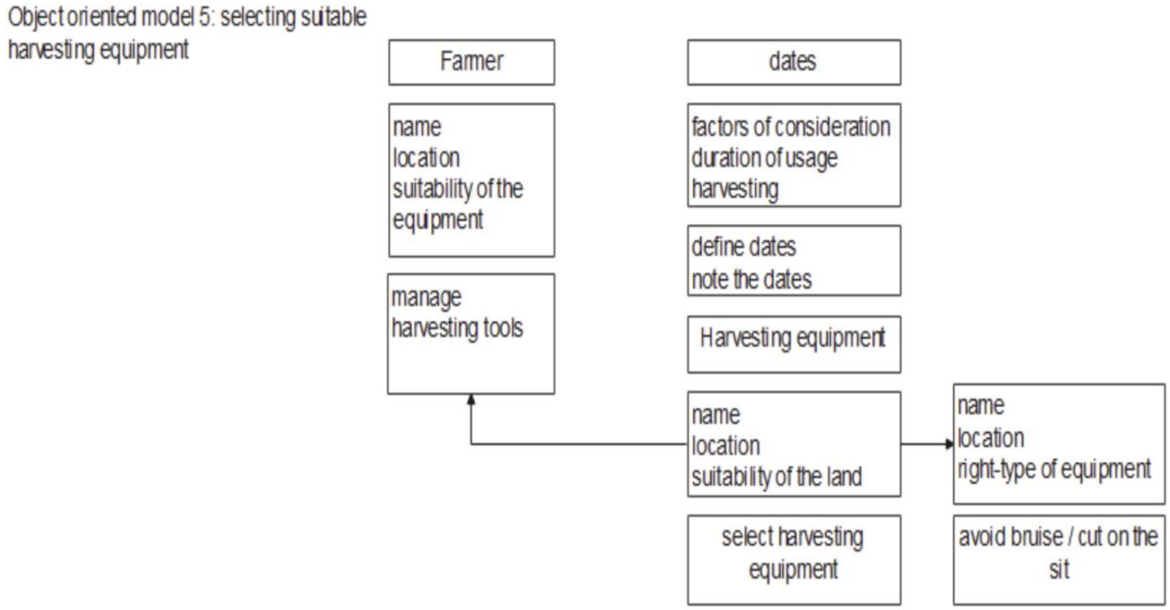

Figure 24: Object-oriented Model: Selection of suitable harvesting equipment
Source: Bello (2021)

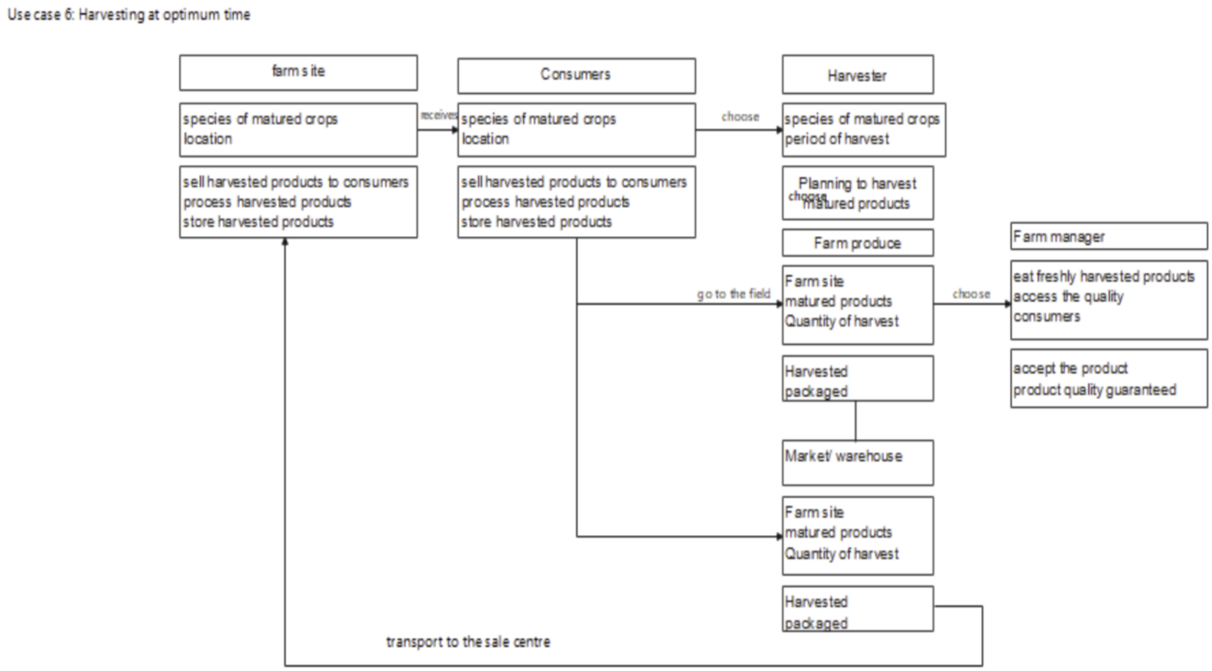

Figure 25: Object-oriented Model: Harvesting at the optimum time
Source: Bello (2021)

Sequence Diagram

The sequence diagram explains how activities are carried out to solve the issue of post-harvest loss and how its management can be enhanced. Figures 26 to 28 shows the process interactions arranged in time sequence used within Unified Modeling Language (UML). This allows visual representation of the interactions with the post-harvest management system.

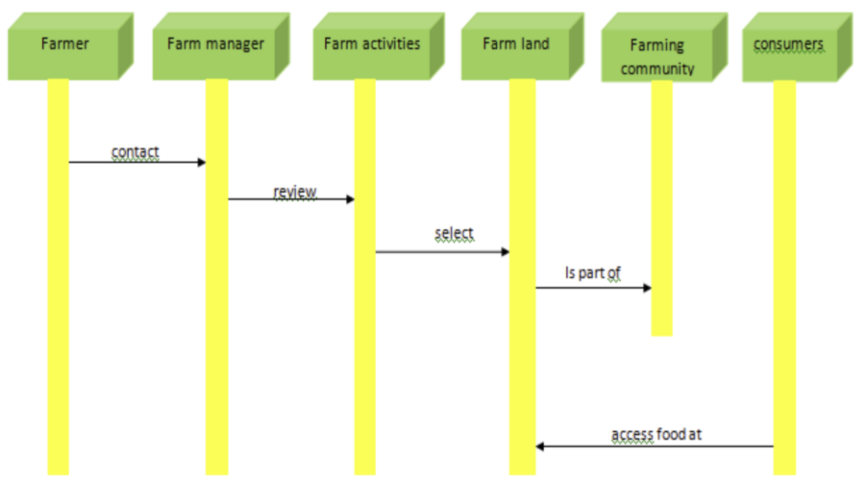

Figure 26: Sequence Diagram: Use-case 1- Selecting fertile land
Source: Bello (2021)

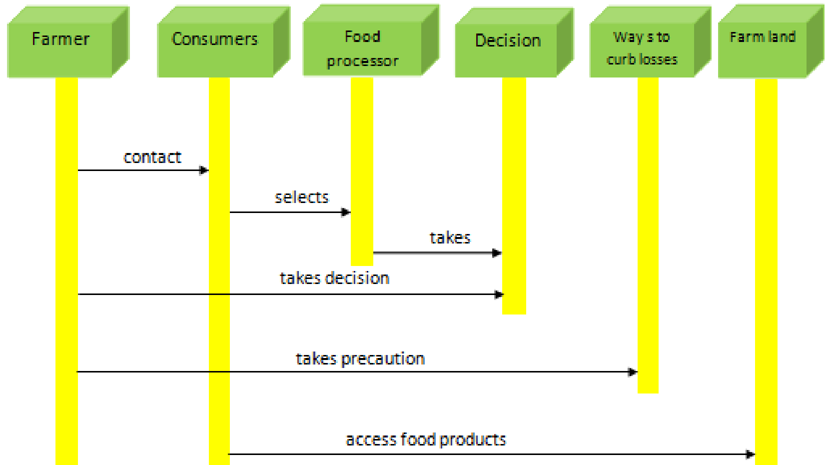

Figure 27: Sequence Diagram: Use-case 2- Planting of suitable crop
Source: Bello (2021)

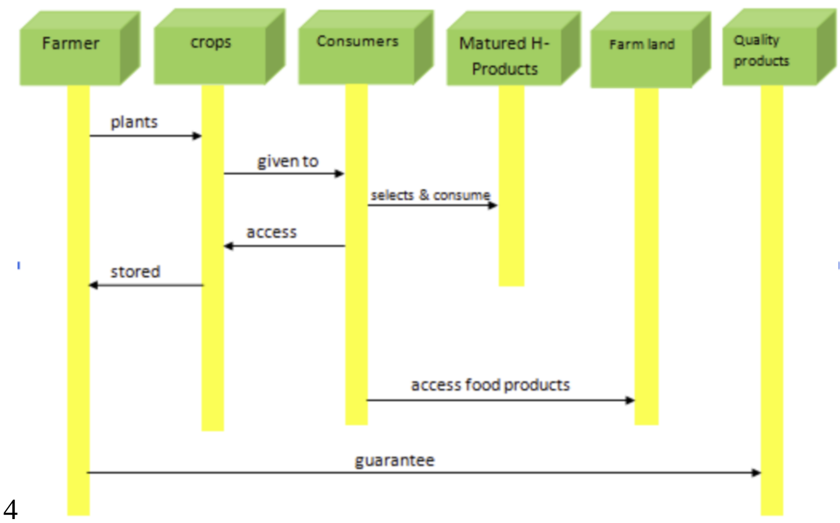

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Figure 28: Sequence Diagram: Use-case 3- Harvesting at an optimum stage
Source: Bello (2021)

Activity Diagram

This is a graphical representation of the stepwise flows of the activities involved in post-harvest management. Figure 29 shows the activities involved from the planting stage up to the harvest stage.

State Diagram

The state diagram describes the behavioral activities of the post-harvest management system. It gives a detailed explanation of a system.

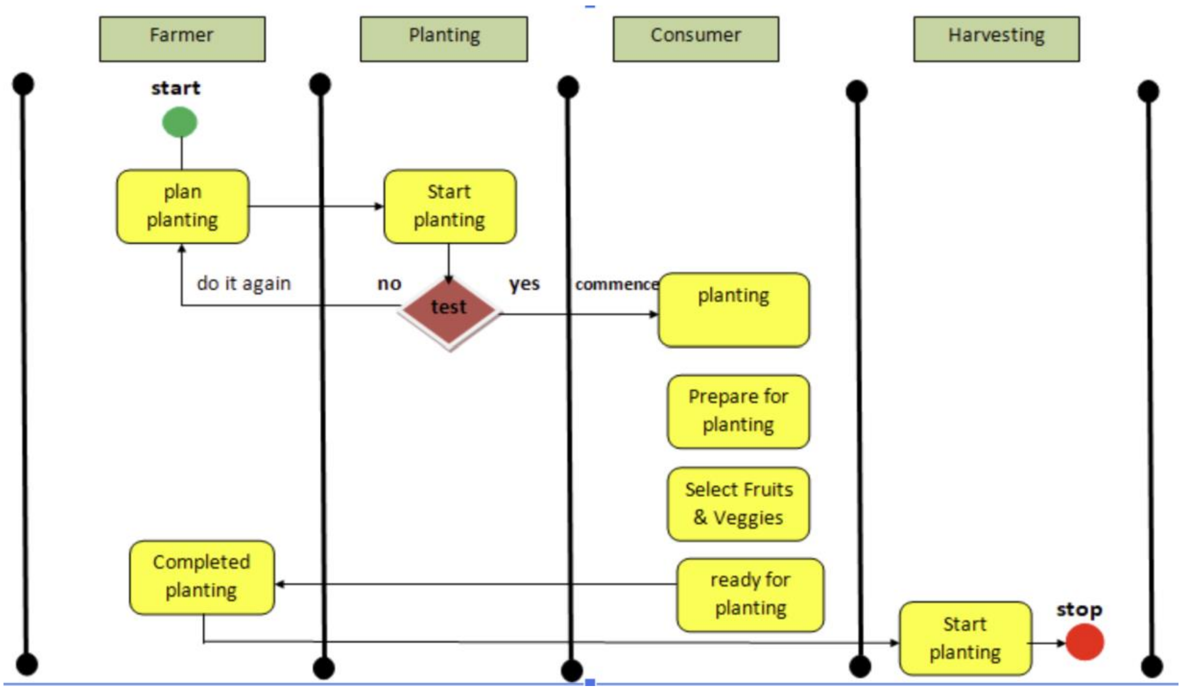

Figure 29: Activity Diagram: Farmer starts farming activities
Source: Bello (2021)

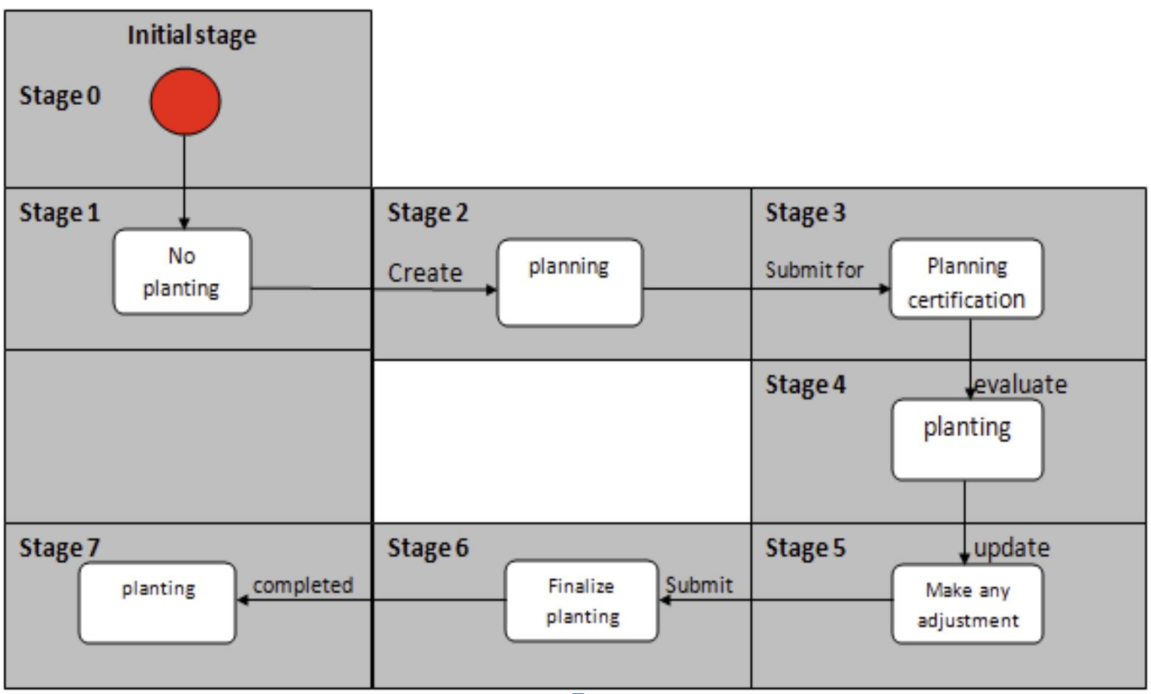

Figure 30: State Diagram: Farmer plans farming activities
Source: Bello (2021)

CONCLUSION

The following conclusions were made from the review:

- Land fertility/nature (for example, acidic soil) can alter the qualitative composition of perishable food products.
- Carelessness during harvesting, handling, transportation, threshing, etc., may increase the risk of post-harvest management.
- Physical, biological, and social factors mainly cause rapid deterioration in fruits and vegetables. Thus, the need for proper management to reduce food loss/waste.
- The perishable nature of fruits and vegetables requires harvesting at the right time and with suitable tools, careful/proper post-harvest handling, and immediate sale of harvested products to reduce environmental stress and guarantee quality.

Overall, awareness of the impacts of post-harvest loss/waste on the general public, intervention and proper management of all the supply chain actors (the stakeholders), and support from the government to the provision of accessible, affordable, and suitable processing and storage facilities will go a long way to curb food loss/waste, secure food against hunger and our environment from pollution.

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