Improving Sustainability of Orange Supply Chain: A System Dynamics Model to Eliminating Pre-Harvesting Loss, Increase Workers, to Improve Farmer's Profit

Emad Alzubi and Bernd Noche
Transportsysteme und -logistik, Fakultätsingenieurswissenschaften
Universität Duisburg – Essen
Keetmanstr. 3-9, 47058 Duisburg, Germany
emad.alzubi@stud.uni-due.de; bernd.noche@uni-due.de

Abstract

The agricultural supply chain plays an important role in the increasing food loss and waste (FLW) due to different causes. However, this can be seen in citrus products like orange as this fruit is subject to different and critical conditions of FLW especially at the farm where workers are a key factor. This paper contributes by proposing solutions to decrease orange loss before and during harvesting. Consequently, this would lead to boosting food security levels. A system dynamics model was built to simulate and compare the results to the current situation. In addition, the case farm was selected for the purpose of the data collection from Jordan. The proposed model enhanced sustainability performance in general since the number of workers required to cultivate the mature orange has been increased to 13 instead of 10 in the current scenario. Furthermore, farmers' profit improved by 19.5% in comparison to the current scenario because the sold orange has been increased and consequently this impacted the amount of orange loss pre-cultivation and reduced to be 9.5 tons rather than 26.09 tons in the current scenario. Nevertheless, implementing the proposed model can lead to maximizing social and economic performance while maintaining the environmental impacts at a low level as the orange loss decreased significantly. Further research can be done in the direction of applying circular economy and reverse logistics into the orange supply chain to integrate orange by-products and waste into an innovative logistics network to reduce the consumption of limited natural resources.

Keywords
Agricultural supply chain, orange, System dynamics, farmer's profit, and sustainable performance.

1. Introduction
The importance of the food sector worldwide starts from the fact that it touches the daily life of humans and animals. However, the food supply chain (FSC) consists of different stages; these are the farm, processors, distribution, retailers, and consumers. Each echelon in FSC contributes in different portions to the FLW, and therefore, there is a strong need to analyze each stage alone. For perishable products, such as fruits and vegetables in general; lead time, temperature, humidity, and other weather conditions are important drivers for FLW. The Food and Agricultural Organization (FAO) estimated the FLW through the supply chain stages around 33% of the total food produced in 2011 (FAO 2011).

The impacts associated with this huge amount of FLW affects the three dimensions of sustainable development. It has environmental impacts due to the greenhouse gas (GHG) emissions, and land depletion due to the landfill and the agricultural practices related. Contributions to the economic dimension are summarized in the costs related and consequently the net profit of the associated stakeholders. In addition, the impacts to the social dimension could be condensed in the economic welfare of the stakeholders, workers' reimbursement, expanding the gap in food supply and demand (food security level), and increasing poverty and hunger rates. And therefore, analyzing the loss that occurs at the farm and shortening the lead time would lead to improving the overall sustainability performance.
In Jordan, the food sector contributed with JOD 4.11 billion which is about 6.3% of the gross domestic product (GDP) in 2016 (GIZ 2019). Nevertheless, agriculture alone contributed 5.6% to the GDP in 2019. In addition, the number of

workers in agriculture reached 91,000 in 2019 (MoA 2021). On the other hand, farmers in Jordan looking for ways to improve their profit especially with the high agricultural input costs.

Orange is an important fruit for everyone. In the post-harvesting stage; Orange loss and waste (OLW) generated through its supply chain (SC) in Jordan have been estimated at around 16% by the department of statistics in Jordan (DoS 2021). Figure 1 illustrates produced orange, imported orange, exported orange, consumed orange, and the wasted quantities of orange from 2002 – to 2019. However, the amount of wasted orange was considered for all stages in the SC after the farm gate, but the farm was not considered. This paper aims to give information about the orange loss at the farm stage and propose a solution to trying to eliminate the lost orange there. The proposed solution will be modeled and simulated using the system dynamics techniques and the results obtained will be compared with the current state of the farm selected for the case study analysis.

2. Literature Review

Food loss and waste (FLW) is getting increasing importance for many reasons in the literature. Researchers such as Göbel et al. (2015) stated that FLW has a great impact on the hunger rate since it leads to increasing the food cost and increasing the gap between food supply and demand. Similarly, Pingali et al. (2017) shared the same in conclusion, especially in developing countries. Other researchers such as Eriksson et al. (2014) clarified that FLW can affect competitiveness directly due to the limited natural resources, which in the end affect the economic performance. From another point of view, FLW is considered by other researchers like Brancoli et al. (2020) because of the associated environmental impacts. In addition, Ali et al. (2021) revealed that FLW can affect sustainability performance since it reduces the natural resources associated to satisfy the demand of future generations.

Agricultural products are very sensitive to different conditions which makes managing ASC more complex. A recently published study by Lu et al. (2022) claimed that the loss in fruits and vegetables in China is estimated to be 27.7% and 13.2% in post-harvesting. However, the loss in agricultural products still can have value as an input material for other industries, animal feeds, or used for biogas production (Garcia-Garcia et al. 2019). In the pre-harvesting stage of fruits, AlHiary (2012) addressed the probable causes that might increase the loss in Jordan, and they reported that un-trained workers are a major factor. Nevertheless, literature mainly concentrates on analyzing and reducing FLW in the post-harvesting stages.

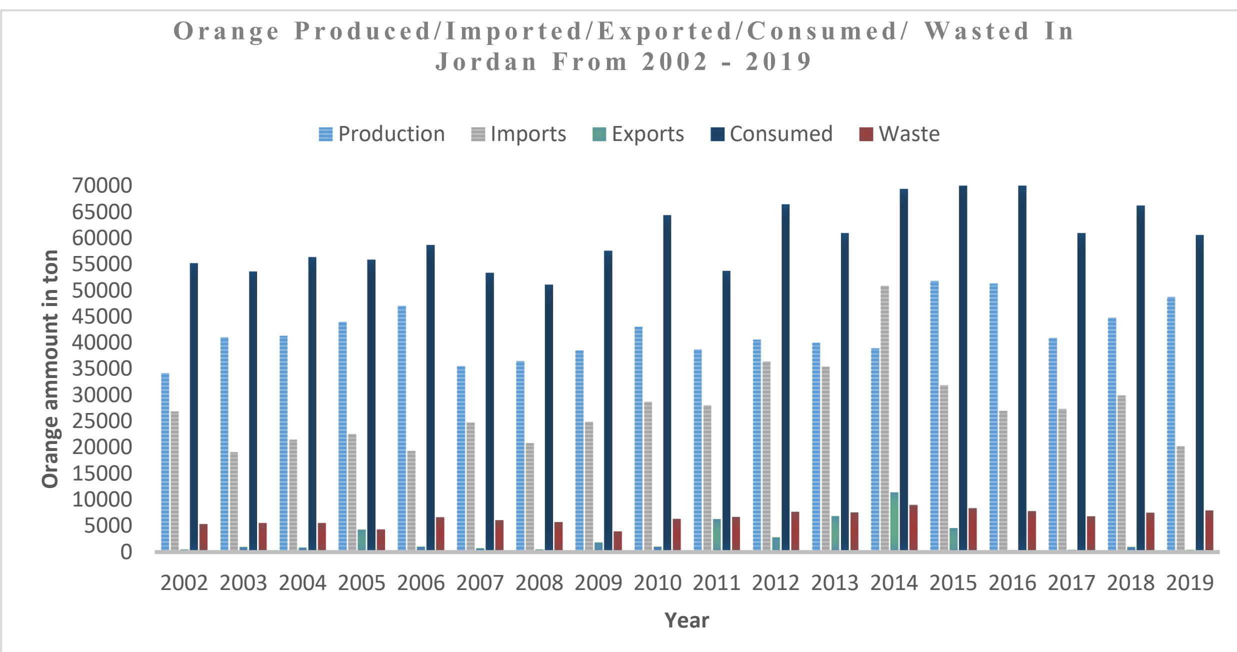

Figure 1. Produced, imported, exported, consumed, and wasted orange in Jordan in 2002 - 2009

Citrus fruits e.g., orange is very sensitive, and their deterioration is faster than other agricultural products. in farms, hiring an insufficient number of workers during cultivation is one of the main causes to increase the loss (Dusch et al. 2018). Citrus canker is another cause for orange loss in farms, which was reported by Ferreira et al. (2016). In addition, Ceratitis capitata is an insect that might increase orange loss, especially in the Mediterranean region (Lo Verde et al. 2011).

In this paper, we analyzed orange loss in farms at pre and during harvesting and proposed a solution, which was simulated by using system dynamics (SD). In literature, SD is mainly used to simulate complex systems to understand their behavior. For instance, SD was used to predict and propose an effective management model for food waste by Lee et al. (2019). Nevertheless, SD has been also used for different purposes in orange SC, and other citrus products, for example, Mufidah et al. (2019) implemented SD to compare different scenarios of mandarin industry in Indonesia, while Ferreira et al. (2016) used SD to evaluate the behavior of competitiveness when implementing different planning polices in citrus agribusiness in Brazil. This paper, and in addition to the above mentioned, contributes to filling the gap in research, by implementing the SD approach to simulate the proposed solution which aims to improve sustainability performance in a rural area which is Jordan Valley, which at the end contributes to integrating sustainability into industrial engineering.

3. Methods
It is obvious when building a simulation model to follow several steps which are problem communication, identifying the affecting parameters, model development, model validation, and verification, suggesting improvements, and finally extracting the results (Sterman, 1989).

3.1 Problem definition
Jordan is a developing country that lacks natural resources, the FLW in 2021 is about 935,000 tons. This would lead to the depletion of the available resources there. In addition, the lack of water resources in Jordan is another important reason to rethink about this amount of FLW. FAO (2003) ranked Jordan in second place in terms of poorness of water per capita. Nevertheless, data from DoS about orange in Jordan presented in Figure 1, shows that 16% of orange lost in the post-harvesting stages through the SC. However, the farmer of the case study reported that in addition to that, the loss in farm prior harvesting varied between 20 – 30% of the total orange produced.

The area of the case study farm is 3 ha, which contains about 900 orange trees. In addition, 10% of the land is used for service roads. The loss is 20 – 30 % of the total production. Moreover, this high percentage of orange loss is due to different reasons. One of these is workers' availability. Mainly workers are escaping from working at farms due to long working hours, low wages, seasonality, and unstable working conditions. workers in the farm case study are working 10 – 12 hours/ day and 6 days per week. Their income is based on the orange crates they can collect at the end of the day (JOD 15 for every 50 crates), crates capacity is 5 kg. In addition, they might be fired at the end of the season as they are not needed anymore. Another reason is the Ceratitis capitata. Although the farmer is performing all practices scheduled for pesticides, he suffers from some of the neighboring farmers since they do not do these practices to save their costs. This leads to an increase in the associated costs as the farmer case study is practicing extra pesticides to avoid this issue. However, it was reported by him that all these costs (labor costs, pesticides costs, fertilizers, energy costs, and water costs) are summarized under operational cost per orange crate which is JOD 0.5 / crate. Other expenses are the cost of packaging crate is JOD 0.17, transportation cost per crate to the central market in Amman is JOD 0.3, tax per crate and middlemen commission in the central market is JOD 0.15. All these lead to lower net profit which in the end affects the farmer's sustainable performance.

3.2 Assumptions
Other input parameters used in the model are:
- Simulation period is one year in which 52 weeks, the orange season starts in the second week of September.
- Average orange yield per tree is 90 kg.
- Worker performance is 60 kg/day. Identified in the model 360 kg/week
- Practices pesticide according to plan 4 times per year.
- Cultivated oranges are not stored on the farm, daily transportation to the central market.
- Number of workers available is varied between 4 – 10.
- 10% of the cultivated orange is sold directly to consumers before transportation. 10% are sold to a local supermarket, and 80% are transported and sold in the central market.

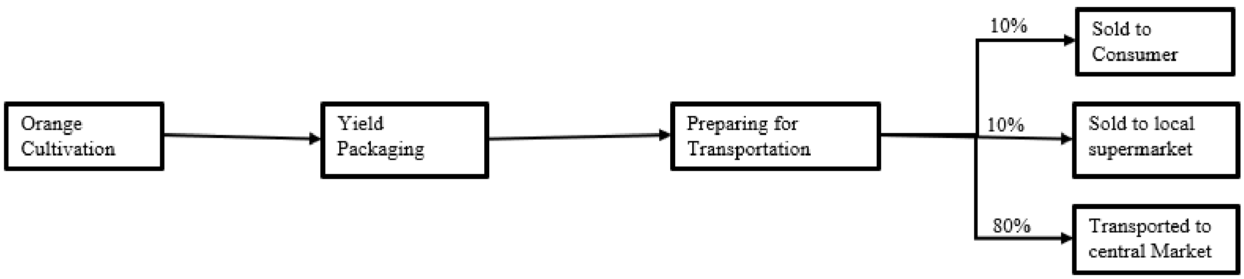

Figure 3. Orange cultivation process in farm

3.3 Model development

According to the aforementioned information, a summary flow chart was developed is illustrated in Figure 2. Workers start collecting the mature oranges in a box with a capacity of 15 kg, then they move it to a place near to the service road where it will be packaged in smaller crates with a capacity of 5 kg. then the crates will be collected in the vehicle, counted, and prepared to be transported. 10% of the crates are sold directly to consumers, 10% sold to a supermarket near to the farm, and the rest will be transported to the central market.

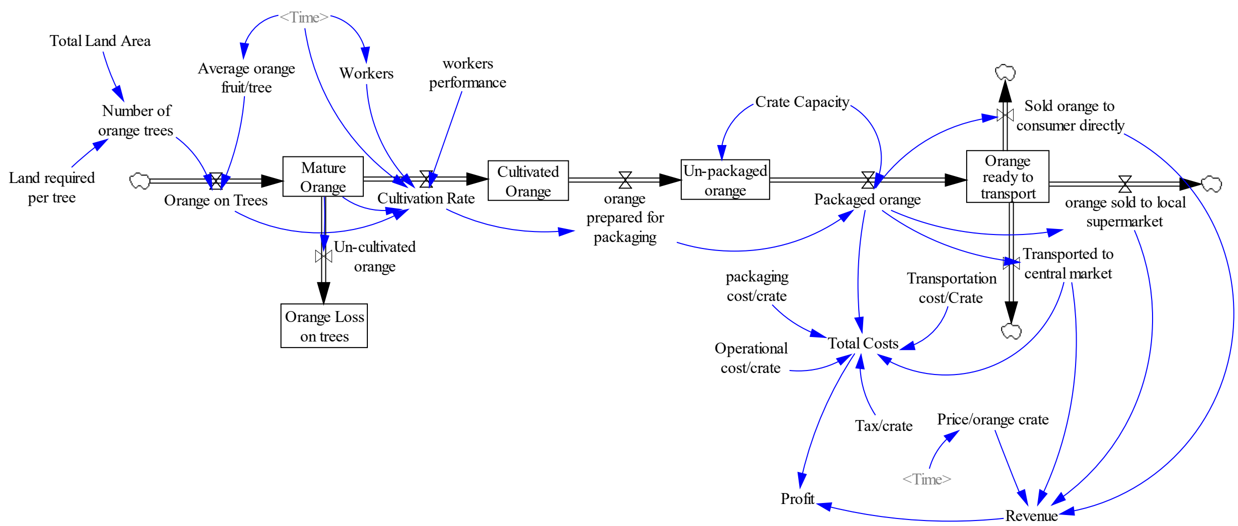

Figure 2. Stock and flow diagram of the case study farm

Accordingly, an SD model was built using Vensim® PLE software (Figure 3). The model can calculate orange production, farmer revenue, costs, profit, and orange loss in pre-and during harvesting. In order to be able to calculate the revenue, the selling price per orange crate (5 kg) is retrieved from the data published by the Ministry of Agriculture (MoA) in Jordan (Table 1). In Addition, the mathematical equations used in the model are summarized in Table 2 according to the variable's types. In the model, it is assumed that the cultivated orange is transported on the same day to the central market in Amman to shorten the lead time and to keep the quality at a high level, what makes it easier to be applied is that the fact the farmer owns the truck used to transport the yield. The revenue will be used to calculate farmers' profits. Farmer indicated that his yearly average profit is around JOD 30,000 at the end of the season.

3.4 Model validation

For model validation, we followed different approaches verified in the literature. The first of which depends on the concept of causal-loop diagram, and testing the model under extreme conditions (Das and Dutta, 2013). Setting specific input parameters to the value of 0 must give some specific output a value of 0 too. For example, when setting the value of workers' performance to 0 there must be no cultivation and consequently, no revenue will be generated. On the other hand, comparing the results from the model to the actual situation as Alzubi et al. (2019) did. Table 3 compares the results from the SD model to the actual. The actual data compared to the results are orange loss, and profit generated. However, the percentage difference shows that the loss from the model is within the range of the data obtained from the case study farm and the difference in profit between the model and actual data is 8.8%.

Table 1. Average orange selling price per crate in the central market in 2019 (JOD)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Price	2.16	2.33	2.33	-	-	-	-	-	3.77	3.46	3.26	2.67

Table 2. variables, and mathematical equations used in the SD model

Variable	Type	Equation
Average orange fruit/tree	Aux	STEP (IF THEN ELSE (Time<=26, RANDOM UNIFORM (3.5, 5, 0), 0), 1)
Number of orange trees	Aux	Total Land Area/Land required per tree
Price/orange crate	Aux	IF THEN ELSE (Time<=20, IF THEN ELSE (Time<=16, IF THEN ELSE (Time<=12, IF THEN ELSE (Time<=8, IF THEN ELSE (Time<=4, 3.77, 3.46), 3.26), 2.67), 2.16), 2.33)
Revenue	Aux	"Price/orange crate"*(orange sold to local supermarket + Sold orange to consumer directly +Transported to central market)
Total Costs	Aux	("Operational cost/crate" + "packaging cost/crate") *Packaged orange + "Transportation cost/Crate" *Transported to central market + "Tax/crate"*Transported to central market
Profit	Aux	Revenue-Total Costs
Workers	Aux	IF THEN ELSE (Time<=26, RANDOM (4, 10,1), 1)
Orange on Trees	Flow	"Average orange fruit/tree"*Number of orange trees
Cultivation Rate	Flow	IF THEN ELSE (Time<=26, IF THEN ELSE (Time<=20, IF THEN ELSE (Orange on Trees <=workers performance*Workers, Orange on Trees, workers performance*Workers), IF THEN ELSE (Mature orange<= workers performance*Workers, Mature Orange, workers performance*Workers)), 0)
Orange prepared for packaging	Flow	Cultivation Rate
Un-cultivated orange		STEP (Mature Orange, 1.5)
Packaged orange	Flow	Orange prepared for packaging/Crate Capacity
Orange ready to transport	Flow	INTEG (Packaged orange - orange sold to local supermarket-Sold orange to consumer directly - Transported to central market, 0)
Orange sold to local supermarket	Flow	INTEGER (0.1*Packaged orange)
Sold orange to consumer directly	Flow	INTEGER (0.1*Packaged orange)
Transported to central market	Flow	INTEGER (0.8*Packaged orange)
Mature Orange	Stock	(Orange on Trees-Cultivation Rate-"Un-cultivated orange", 0)
Cultivated Orange	Stock	(Cultivation Rate-orange prepared for packaging, 0)

Table 3. Comparing results from SD model the data obtained from the case study farm

Comparison	**Results from SD model**	**Data from farmer**	**% Difference**
% Not cultivated orange (Loss)	26.77%	20 – 30%	Within the range
Profit	JOD 27,349.41	JOD 30,000	8.8%

4. Results and Discussion

4.1 Numerical Results

The results obtained from the model give a good indication in terms of the difference to the actual data from the farm as illustrated in Table 3. At the end of the orange season (week 26) the total revenue generated, total expenses, and the net profit that the farmer received are 42,052.44, 14,703.03, and 27,349.41 respectively. This was generated from total selling 71,380 kg of orange cultivated during the season. The amount of loss due to hiring not enough workers (maximum 10 workers) and diseases is 26,090 kg.

5.2 Proposed Improvements

In the proposed improvement we connected the amount of mature orange to the hiring rate so that we hired a sufficient number of workers to cultivate 90% of the orange on trees as illustrated in Figure 4. The rest are considered as losses due to the diseases that might occur during the season. However, to motivate workers to work on the orange farm we suggested to labor income by JOD 0.1 per orange crate paying them JOD 20 for every 50 orange boxes instead of JOD 15. Although there is an increase in costs due to the increase in the operational costs (JOD 0.6 instead of 0.5 per crate), the results from the improvement mode show that there is a significant enhancement in revenue and profit as can be seen in Figure 5. The average number of workers needed to cultivate the orange has been increased from 10 to 13. Values of revenue, costs, and profit from the improvement model in JOD are 50,733.65, 18,066.23, and 32,667,43 respectively with an increase of almost 19.5% to the profit. In addition, in the improved scenario, the loss was dropped by 62.6%. However, a comparison between current the scenario and the improved scenario of the weekly results to the revenue, costs, profit, and orange loss can be depicted in Figure 5.

From a sustainability point of view, the results above are showing improvement in the overall sustainability performance. For instance, improving farmer economic performance can enhance both environmental as well as social performance. The environmental dimension has been improved by decreasing orange loss at a farm when improving the social dimension and hiring 3 more workers who increased orange yield. Also, motivating workers by increasing their income can lead at the end to maximizing social benefits and help in reducing the gap to their needs.

5.3 Contribution of the results

The results can quantify the orange loss and waste through the SC stages at 26%. However, when adding the orange waste (16%) reported by DoS (2021), the total orange loss and waste can be considered at 42% which complies with the results from the developing countries studied by Lipinski et al. (2013). Reducing this amount along SC requires understanding the drivers and causes at each echelon in the SC. On the farm level, the number of workers plays a vital role in cultivating the mature yield before it reaches the excess maturity level, and therefore, workers' compensation strategy is a key solution to motivate workers to come and work on farms. Nevertheless, this goes in line with the results reported by AlHiary (2012) in the study performed on some types of fruits in Jordan. A similar discussion has

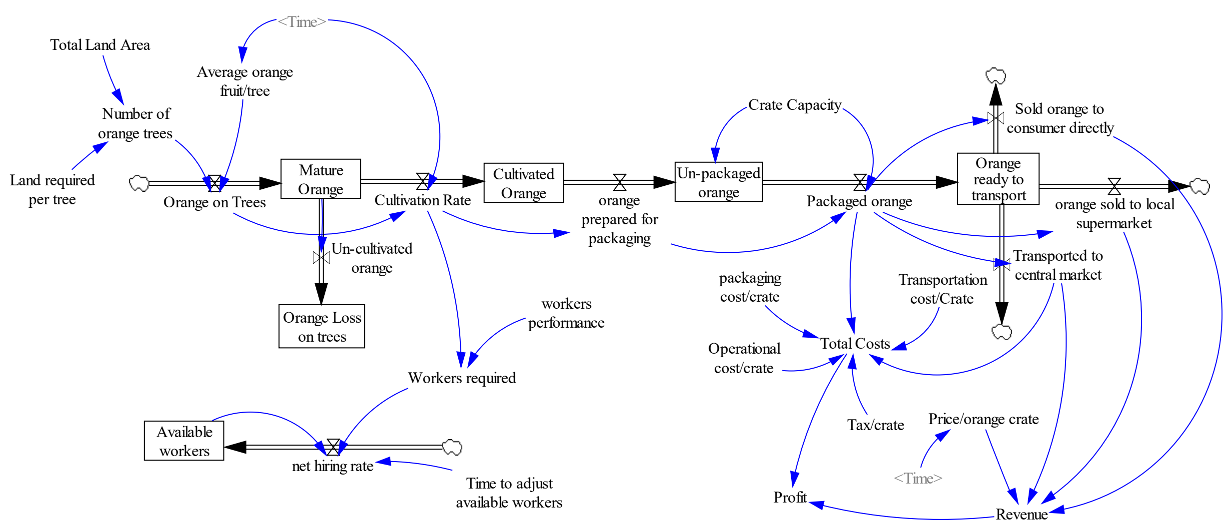

Figure 4. Stock and flow diagram showing the improvement scenario

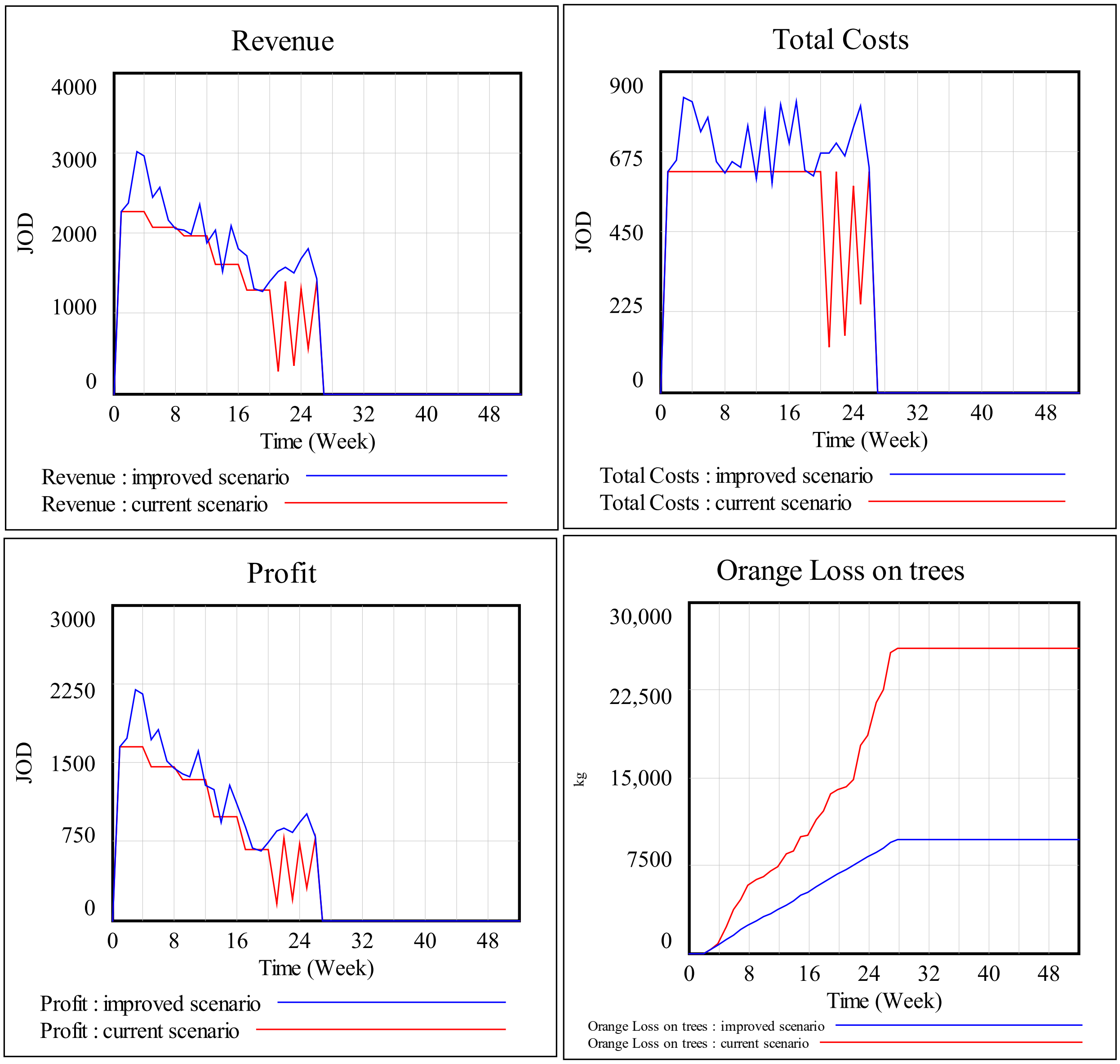

Figure 5. A comparison between current and improve scenarios in terms of revenue, costs, profit, and orange loss

been found in the study by Dusch et al. (2018) in citrus farms in Brazil. Results also address the relationship between FLW and shortage of workers available on the farm level, which has been also addressed by Baker et al. (2019). Hiring more workers, and increasing the labor compensation lead to an increase the total costs as discussed by Zahniser et al. (2018) but this will lead to an increase the total yield which might lead to an increase the income and will result in enhancing the net profit, decrease the loss and waste which improves the food security level.

5. Conclusion

The paper presents a case study of an orange farm in Jordan to improve orange farmers' sustainability performance as mentioned previously. The simulation model was built using the SD approach to measure the improvement. It was found that increasing the number of workers can lead to a significant improvement in the farmer's profit and a reduction of orange loss. For instance, 3 more workers helped in increasing the profit by 19.5% and a reduction in the orange loss by 62.6%. however, reducing the orange loss by this percentage can contribute to reducing the gap between orange supply to the domestic market the demand which influences the food security level. In addition, hiring 3 more workers on the farm would lead to a decrease in the unemployment rate which reached 24.7% by the end of 2021 (DoS, 2021).

This paper contributes to the literature by integrating sustainability and agriculture to industrial engineering, which has several implications for stakeholders. On one hand, it adds the body of knowledge information about food loss at farms which is still under-explored in the literature. On the other hand, it can be used as a reference for practitioners who would like to apply the concept simulated in Figure 5. A limitation that must be addressed in this research, is that the case study farm is fully occupied with orange trees, there is no other citrus tree. Future research might be to extend the application of the proposed simulation model and implement it to other citrus products, and other farms in Jordan Valley since the farm is located there and farms there are divided into agricultural units with areas varied between 3 – 4 ha.

References

Alhiary, M., Estimation of post-harvest losses of some fruit crops in Jordan, *Journal of King Saud University,* vol. 24, no. 2, pp. 151 – 162, 2012.

Ali A., Xia, C., Ouattara, N., Mahmood, I., Faisal, M., Economic and environmental consequences' of postharvest loss across food supply Chain in the developing countries, *Journal of cleaner production,* vol. 323, pp. 129-146, 2021.

Alzubi, E., Atieh, A.M., Abu Shgair, K., Damiani, J., Sunna, S., Madi, A., Hybrid integrations of value stream mapping, theory of constraints and simulation: Application to wooden furniture industry, *Processes,* vol. 7, no. 11:816, 2019.

Baker, G., Calvin, L., Gillman, A., Kitinoja, L., Osland, T., Pearson, P., Prezkop, L., Roe, B. E., Spang, E., Tooley, J.B., Tomato tales; Comparing loss-reduction drivers and opportunities across U.S. fresh tomato supply chains, in: *The Economics of Food Loss in the Produce Industry*. p. 20, 2019.

Brancoli, P., Bolton, K., Eriksson, M., Environmental impacts of waste management and valorisation pathways for surplus bread in Sweden. *Waste Management,* vol. 117, pp. 136–145, 2020.

Das, D., Dutta, P., A system dynamics framework for integrated reverse supply chain with three way recovery and product exchange policy, *Computer in Industrial Engineering,* vol. 66, pp. 720–733, 2013.

DoS., *Deprtment of Statistics in Jordan*. Available: http://dosweb.dos.gov.jo/product-category/jordan-in-figures , Accessed on November 01.2021

Dusch, S.S., Ribeiro, D., Knobloch, P., Behind the Scenes of the Juice Industry, Available: https://reporterbrasil.org.br/wp-content/uploads/2018/12/squeezed-behind-the-scenes-of-the-juice-industry-.pdf, Accessed on January 12, 2022.

Eriksson, M., Strid, I., Hansson, P.A., Waste of organic and conventional meat and dairy products - A case study from Swedish retail, *Resour. Conserv. Recycl*. vol. 83, 44–52, 2014

FAO, Global Food Losses and Food Waste – Extent, Causes and Prevention. Düsseldorf, Germany, Available: http://www.fao.org/3/mb060e/mb060e.pdf, Accessed on November 01, 2021.

FAO. Review of World Water Resources by Country, Available: https://www.fao.org/3/Y4473E/y4473e00.htm#Contents , Accessed on November 01, 2021.

Ferreira, J.O., Batalha, M.O., Domingos, J.C., Integrated planning model for citrus agribusiness system using systems dynamics. *Comput. Electron. Agric*. vol. 126, pp. 1–11, 2016.

Garcia-Garcia, G., Stone, J., Rahimifard, S., Opportunities for waste valorisation in the food industry – A case study with four UK food manufacturers. *Journal of Cleaner Production*. vol. 211, pp. 1339–1356, 2019.

GIZ, Jordan ' S Food Processing Sector Analysis and Strategy for Sectoral Improvement, Available: https://www.giz.de/en/downloads/Jordan%20Food%20Processing%20Sector%20Analysis%20and%20Strategy%20for%20Sectoral%20Improvement.pdf, Accessed on January 12, 2022.

Göbel, C., Langen, N., Blumenthal, A., Teitscheid, P., Ritter, G., Cutting Food Waste through Cooperation along the Food Supply Chain. *Sustainability,* vol. 7, pp. 1429–1445, 2015.

Lee, C.K.M., Ng, K.K.H., Kwong, C.K., Tay, S.T., A system dynamics model for evaluating food waste management in Hong Kong, China. *Journal of Material Cycles Waste Management*., vol. 21, pp. 433–456, 2019.

Lipinski, B., Hanson, C., Lomax, J., Kitinoja, L., Waite, R., Searchinger, T., Reducing Food Loss and Waste, 1–40, Available: https://www.wri.org/research/reducing-food-loss-and-waste , Accessed on January 21,2022

Lo Verde, G., Caleca, V., Lo Verde, V., The use of kaolin to control Ceratitis capitata in organic citrus groves. *Bull. Insectology*, vol. 64, pp. 127–134, 2011.

Lu, S., Cheng, G., Li, T., Xue, L., Liu, X., Huang, J., Liu, G., Quantifying supply chain food loss in China with primary data: A large-scale, field-survey based analysis for staple food, vegetables, and fruits. *Resour. Conserv. Recycl.* vol 177, no106006, 2022.

MoA, National Strategic Report (2021 – 2030), *Jordanian Minist. Agric*, Available: https://doi.org/http://www.moa.gov.jo/Default/Ar, Accessed on November 28, 2021.

Mufidah, L., Arshad, F.M., Sidique, S., Sugiyatno, A., Ibragimov, A., The Evaluation of Several Alternative Policies' Impact on The Mandarin (Citrus Reticulata) Industry in Indonesia: A System Dynamics Analysis. *Agro Ekon*. vol. 30, pp. 28–40, 2019.

Pingali, P., Mittra, B., Rahman, A., The bumpy road from food to nutrition security – Slow evolution of India's food policy. *Glob. Food Sec*. 15, 77–84, 2017.

Sterman, J.D., Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment. *Manage. Sci*. vol. 35, pp. 321–339, 1989.

Zahniser, S., Taylor, J.E., Hertz, T., Charlton, D., Farm Labor Markets in the United States and Mexico Pose Challenges for U. S. Agriculture. USDA Econ. Res. Serv. 1–40, 2018.

Biographies

Emad Alzubi received his BSc in industrial engineering and management from the German – Jordanian University (GJU), Amman in 2010; an M.Sc. in Sustainable resources management from the Technical University of Munich (TUM), Munich in 2014. Since October 2020, he is a Ph.D. student at the department of Transport Systems and Logistics at the University of Duisburg – Essen. He served in the Department of Industrial Engineering, GJU in Amman as a faculty member and as Engineering Workshops manager (2016-2020) and as a project engineer. He also served as a project engineer at BMW through the company Loesch und Partner GmbH (2014-2016), Munich. In 2011, he worked as a research and teaching assistant in the industrial engineering Department in GJU.

Prof. Dr.-Ing. Bernd Noche is member of the institute for Product Engineering for advanced research in product life cycles and responsible for Logistics Engineering and the design of modern Supply Chains. He studied Cybernetics Engineering at the University of Stuttgart and worked several years in the Fraunhofer Society as a research engineer in the field of computer assisted logistic systems where Computational Methods had to be developed for the emerging field of logistics. In 1986 he became CEO of an IT based consulting company, focusing on the application of simulation-based techniques in industry, trade, and services. With his dissertation about the design of a decision-oriented simulation environment he was entitled to use the doctor's degree. In the year 2000 he responded a call for a software-oriented professorship in logistics at the Gerhard-Mercator University of Duisburg. Besides his research activities he is working as an evaluator and consultant for several international companies and governmental institutions.