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DYNAMICS OF FOOD LOSS AND WASTE CAUSES ALONG THE AGRIFOOD CHAIN IN ROMANIA

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Abstract

The investigation of the causes and consequences of food loss and waste has been extensively explored in the literature, given its significant impact on both the local community and the national economy. This paper suggests various comprehensive approaches concerning food loss and waste (FLW) in Romania, considering the broader European context of the FLW phenomenon based on a bibliographic study, a statistical approach of the causes dynamics analysis and a system-based approach leading to an integrated view of the phenomenon. In order to accomplish this purpose, we have used statistical material originated from national and European statistical institutions and we have processed it using direct observation and interpolation. Our objective was to identify various factors contributing to food loss and waste throughout the agrifood chain and analyse their impact on the FLW phenomenon. The findings revealed that the primary factors contributing to food waste are associated with economic aspects. This study serves as a foundational step for subsequent research endeavours.

Key words**:** *food waste, food loss,system, agrifood chain, Romania*

INTRODUCTION

Food waste in Romania is a complex problem [3], influenced by several factors and which leads to widespread effects [14]. The main causes include excessive food production, supply chain issues [5], consumer behavior [2], expiration date and food labeling, restaurants and the food industry, poverty and inequitable food distribution, awareness and education [9] and government policies [19]. The actions [1] made to prevent and combat food loss and food waste [4] have been made extensively worldwide and in Romania [17], related to the agrifood chain and also on an individual basis generation of food waste [8]. In the same time, a series of alternative measures [10] are thought related to food loss and waste (FLW) at a national and global scale [15] using several methods such as reusage [16], game theory [11] or technology-based approaches.

This paper shows a summary related to the food waste causes and their dynamics in Romania, comprising a short bibliographical study and a statistical analysis regarding the food waste phenomenon in order to determine the amount of influence of several factors on the food waste amount and their potential harmful impact [13] on agrifood chain processes [18]. In this context, a variety of materials and methods, including direct observations, correlation analyses, and statistical procedures, were employed to derive significant findings pertaining to the evolution of food waste in Romania.

MATERIALS AND METHODS

In order to determine the aspects that influence the food waste in Romania, we have

followed several results from previous research papers and determined the dynamics of the food loss and waste causes in Romania. In this regard, the process of this assessment involves several steps:

(a) The identification of the key factors contributing to food loss and waste through a thorough analysis of existing literature and an in-depth review of relevant bibliographic sources.

(b) The conduct of statistical observations and the run of a comprehensive overview of the principal statistical indicators associated with these identified factors.

(c) The assessment of the impact of these statistical indicators (treated as independent variables) on the statistical indicators for food waste (regarded as dependent variables) is conducted through a statistical correlation analysis.

(d) The evaluation of the significance and the exploration of the statistical, economic, and social implications of the established relationships.

The bibliographic study will use a research database (Dimensions.ai) and a term mapping software (VOS Viewer), which will process the database search results. The statistical analysis was made using the data extraction and interpolation from the existent datasets (e.g., Tempo online data base of the National Institute of Statistics and Eurostat). The assessment of how these indicators affect the quantity of food waste will be accomplished by calculating the Pearson correlation coefficient for each indicator, treating them as independent variables, and the food waste indicator as the dependent variable. A multiple correlation was not made between the multitude of statistical indicators and food waste quantity due to small amounts of data within the series. The examination of these influences and their statistical, economic, and societal implications will be conducted through the interpretation of statistical parameters derived from the obtained correlations. This interpretation will primarily rely on the utilization of t-tests applied to these correlations and the outcomes they yield. Finally, the modelling part of the research will determine the dynamics of the FLW causes based on a causal loop diagram and a primary stock-and-flow diagram for the FLW phenomenon modelled via System Dynamic (SD) method.

RESULTS AND DISCUSSIONS

The bibliographic study

Agriculture and the food industry can produce large quantities of food and managing it can be difficult, leading to waste. Issues within the supply chain, spanning from storage to distribution, can contribute significantly to food waste. Additionally, consumer behavior, such as over-purchasing and discarding uneaten food, represents another significant contributing factor.

Table 1. The list of the terms resulted from the bibliographic study for “food waste” sorted by the number of occurrences

No.	Term	Number of occurrences	Relevance score
1.	study	1,093	0.4741
2.	waste	946	0.4326
3.	production	614	0.4521
4.	product	578	0.5925
5.	food	554	0.4836
6.	impact	542	0.3088
7.	country	525	0.5371
8.	process	483	0.4367
9.	use	464	0.3945
10.	review	440	0.3892

Source: own data processed from Dimensions.ai datasets

The bibliographic study exploring food loss and waste in Romania focused on key phrases including "food waste" as the first term and "food loss and waste" as the second term, combined with specific regional terms like "Romania." The outcomes of this search underscored that the predominant research in this domain is centered around economic-based topics. The data processing stage of the search results considered two primary indicators provided by the VOS Viewer software, i.e., the number of occurrences of the term in the search results and the relevance score, which delimited the most used terms that were more specific to the

search term and not used in common subjects. According to the software documentation, this score is used to exclude generic terms and to increase specificity of the mapping process. The lower threshold for the term "food waste" was set to 100 number of occurrences and to 50 for the term "food loss and waste", due to a low number of results for the same threshold as the first term. Table 1 presents a list of the terms that were found based on the number of occurrences of the term in the search results for the threshold of 100 occurrences. The prevalent terms in research concerning food loss and waste in Romania are predominantly associated with systems and production systems. Specifically, these terms are interconnected with the agrifood chain, encompassing aspects such as "production", "product", "food", "process" and "waste". This pattern underscores that the primary focus of the research is directed towards understanding the economic causes and impact of food loss and waste. The most relevant terms used for the first key phrase were related to economic stages of the agrifood chain also (food industry, consumer, circular economy) and also to biological events (pandemic, covid). Table 2 presents the results for the same term filtered by the relevance score.

Table 2. The list of the terms resulted from the bibliographic study for "food waste" sorted by the relevance score

No.	Term	Number of occurrences	Relevance score
1.	pandemic	137	9.3120
2.	covid	168	8.1642
3.	food industry	111	2.1019
4.	sample	178	2.0567
5.	day	132	1.8778
6.	consumer	282	1.6373
7.	author	111	1.3108
8.	person	171	1.2806
9.	circular economy	226	1.2309
10.	chapter	152	1.0199

Source: own data processed from Dimensions.ai datasets

Table 3 presents a list of the terms that were found based on the number of occurrences of the second term in the search results for the threshold of 50. Table 3 presents the results for the same term filtered by the relevance score. The results from the second terms shows little difference from the first term results, with a slight tendency towards sustainability and management in case of frequency of terms and more geographical (regional and global) approaches in case of relevance (FAO, India, China, European Union, region, group), leading to a primary conclusion that the research is also made based on comparisons with several key stakeholders related to the FLW phenomenon, as well as the concern related to agriculture terms (agriculture organization, volume, field).

Table 3. The list of the terms resulted from the bibliographic study for "food loss and waste" sorted by the number of occurrences

No.	Term	Number of occurrences	Relevance score
1.	food	310	0.2047
2.	country	205	0.4064
3.	approach	187	0.3209
4.	book	180	0.5208
5.	research	177	0.2918
6.	management	160	0.3149
7.	issue	159	0.2661
8.	sustainability	141	0.2712
9.	economy	129	0.8917
10.	industry	126	0.3397

Source: own data processed from Dimensions.ai datasets

Table 4. The list of the terms resulted from the bibliographic study for "food loss and waste" sorted by the relevance scores

No.	Term	Number of occurrences	Relevance score
1.	FAO	51	5.4594
2.	agriculture organization	50	5.4172
3.	India	54	4.2763
4.	China	59	4.0284
5.	European Union	68	3.2397
6.	group	78	2.9435
7.	region	95	1.8386
8.	economy	129	0.8917
9.	volume	59	0.6297
10.	field	80	0.5395

Source: own data processed from Dimensions.ai datasets

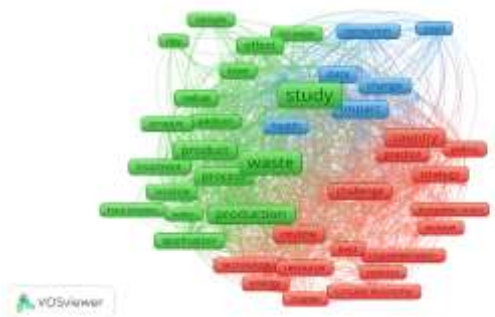
The determination of the terms mapping was made based on the two values for the occurrence threshold (50 and 100). For each value, a map was generated based on the number of the occurrences. The obtained maps are shown in Fig. 1.

The both maps (a) and (b) from Figure 1 show three main clusters related to FLW phenomenon:

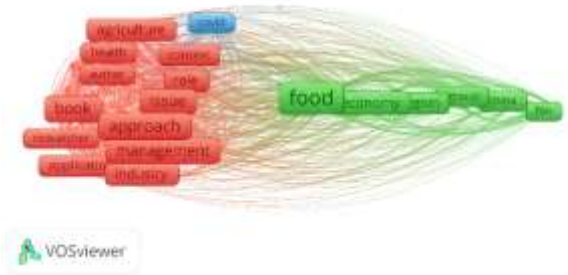
-economic cluster, shown in green, comprised of terms such as "study", "effect", "time", "value", "production", "source", "food", "economy", "region" for both search terms;

-systems and agrifood chain cluster, shown in red, comprised of terms such as "country", "industry", "practice", "policy", "strategy", "circular economy", "industry", "management", "approach" for both search terms;

-public health cluster, shown in blue, comprised of terms such as "health", "consumer", "impact", "covid" for both search terms.



(a)



(b)

Fig. 1. The search term maps obtained for (a) 100 occurrences for "food waste"; (b) 50 occurrences for "food loss and waste"

Source: own data processed from Dimensions.ai datasets

This configuration leads to the conclusion that the research of the food loss and waste phenomenon in Romania is mainly related to aspects referring to agrifood chain and its situation within the economy systems with mentions to health issues generated by recent events (COVID-19 pandemic).

The statistical analysis

According to the previous step, the main factors have been into consideration:

-*economic factors*: GDP per capita, inflation rate (IR), crop production;

-*social factors*: students enrolled in education, students enrolled in tertiary education, consumption expenditure per household, poverty threshold;

-*environmental factors*: land use, plastic packaging waste per capita.

The presentation of the factors is shown in the next part of the paper.

Fig. 2 presents the evolution of GDP per capita in the period 1995-2022.

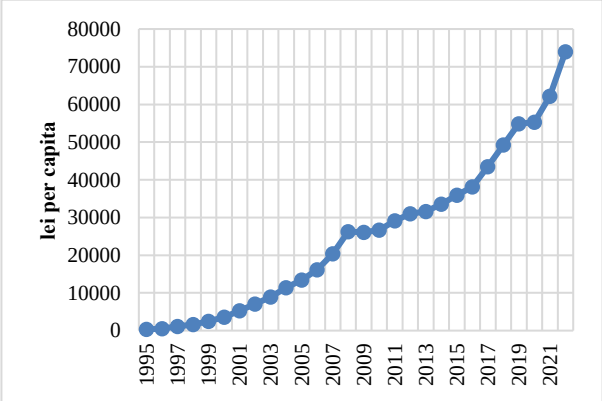


Fig. 2. GDP per capita evolution in Romania between 1995 and 2022

Source: TEMPO database, National Institute of Statistics Romania [12].

The main indication of the GDP evolution shows that a steep increase is stated between 1995 and 2022, at an average value of Lei 35,000 per capita.

Fig. 3 presents the evolution of the inflation rate (IR) in Romania in the period 1991-2022, which reflects a major decrease between 1991 and 2000 and a stabilization between 2000 and 2022.

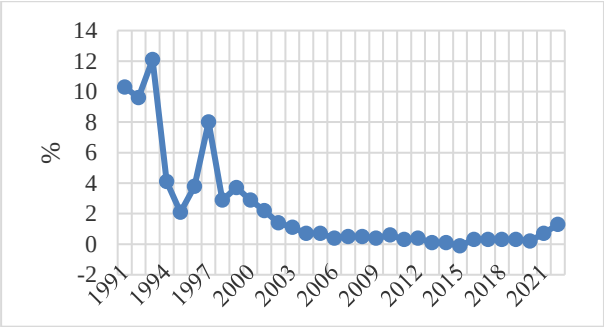


Fig. 3. The inflation rate (IR) evolution during 1991-2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

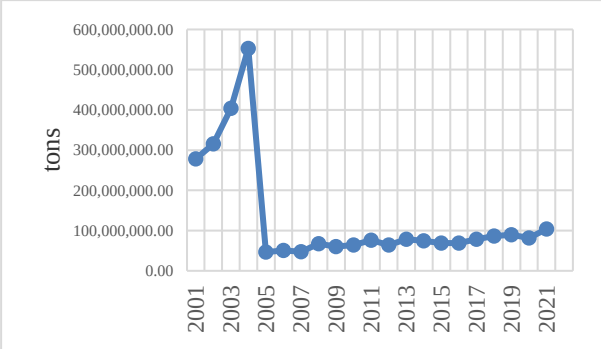


Fig. 4. Crop production between 2001 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 4 presents the evolution of crop production (measured in tons) in the period 2001-2022 in Romania.
The graphic shows a major and abrupt decrease in 2005, followed by an slight increasing trend.

Fig. 5 presents the evolution of the number of students enrolled in all levels of education (primary, secondary, tertiary) in the period 1990-2022 in Romania. The graphic based on the statistical data reflects that student enrollment registered a trend with minor fluctuations.
Figure 6 illustrates the trend in the enrollment of students at the tertiary level of education in Romania from 1990 to 2022. The graphic emphasizes that the proportion of students enrolled in tertiary education comprises nearly 15% of the total student enrollment. Furthermore, it indicates that after reaching a peak in 2005, the number of tertiary-level students has experienced a significant decline.

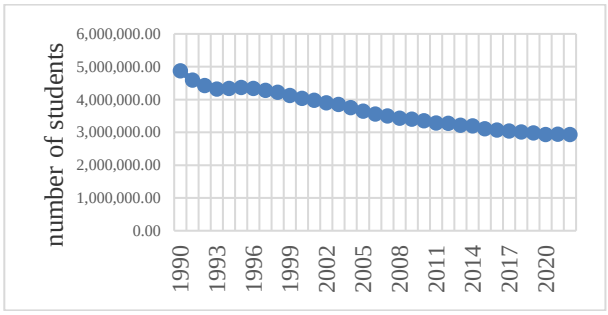


Fig. 5. Students enrolled in all levels of education between 1990 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

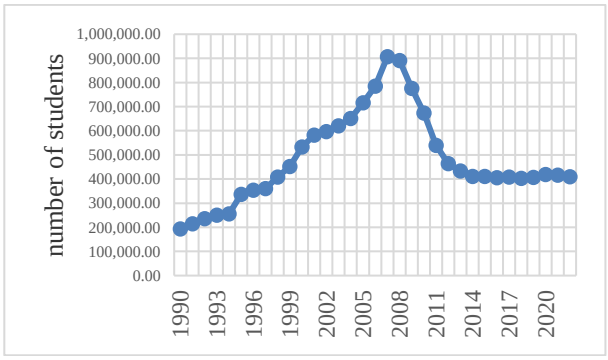


Fig. 6. Students enrolled in tertiary education between 1990 and 2021 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 7 presents the evolution of household consumption between 1995 and 2022 in Romania. The value of the annual average consumption level is situated in 2022 at above Lei 50,000 per household and the general tendency in the studied period was an ascending one.

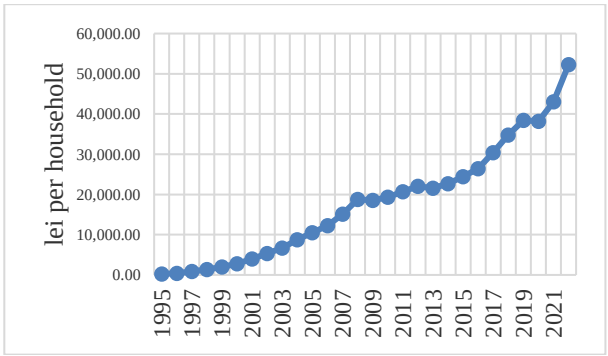


Fig. 7. Household consumption between 1995 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

Fig. 8 presents the evolution of the surface of land used for agriculture which between 1990 and 2022 recorded a slight decrease in Romania.

Fig. 9 shows an increasing trend in the evolution of quantity of plastic waste sourcing from packaging per capita in the period 2008-2019 in Romania.

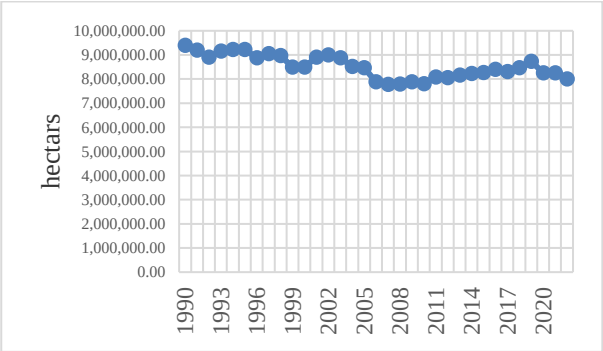


Fig. 8. Land use for agriculture between 1990 and 2022 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

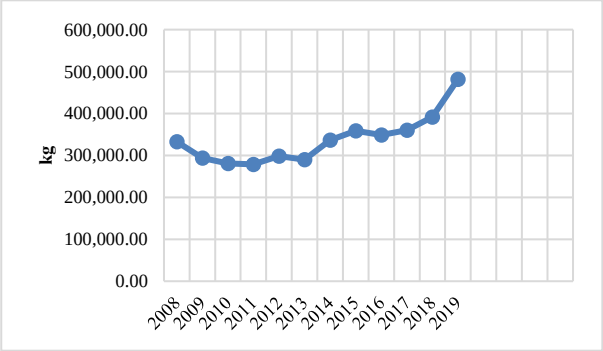


Fig. 9. Plastic packaging waste between 2008 and 2019 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

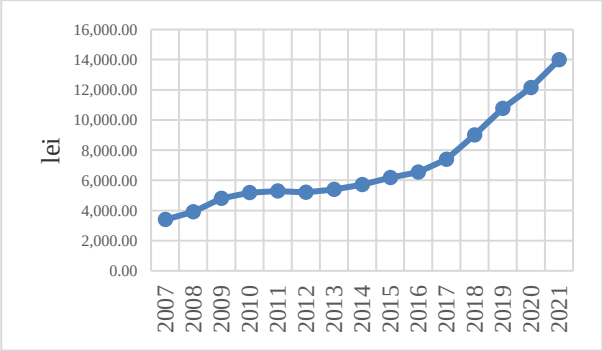


Fig. 10. Poverty threshold between 2007 and 2021 in Romania
Source: TEMPO database, National Institute of Statistics Romania [12].

In the interval 2007-2021, the poverty threshold registered an increasing trend, showing that the population has difficulties related to poverty (Figure 10).

Fig. 11 presents the evolution of the total quantity of the food waste in three main areas (households, food manufacturing and agriculture) in the period 2004-2020 in Romania.

The data for total food waste was aggregated as the sum of the quantities of FLW categories based on the source. We can observe that after 2008, the quantity of food waste generated from the agricultural processes has deeply decreased, after 2010 the main food waste generator being the household components.

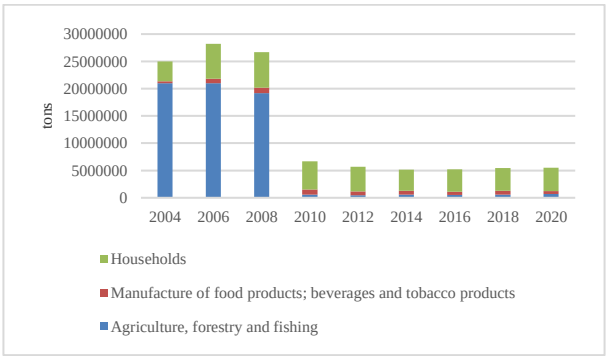


Fig. 11. Total food waste between 2004-2020 in Romania
Source: Eurostat [6].

Correlations between variables

Each indicator was established as an independent variable in the determination of a correlation between two variables.

For each indicator, the dependent variable was established to be the total amount of food waste, shown in

Fig. 11, with missing values from 1990 to 2004 and odd years between 2004 and 2020 being determined using the interpolation method. Then, a determination of a Pearson correlation coefficient (PCC) was made between each pair of the independent variables and the dependent one and the statistical significance was verified using a t-Test (two-sample assuming equal variances). The number of observation (Obs.) for each pair of variables was established as the

number of common years presented in the statistical series of data.

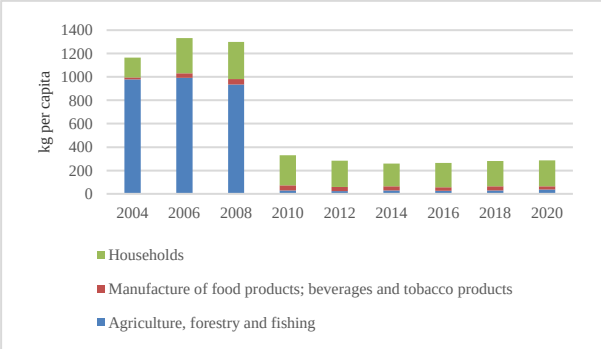


Fig. 12. Food waste per capita between 2004 and 2020 in Romania
Source: Eurostat [6].

Fig. 12 presents the evolution of the quantity of the food waste per capita in the period 2004-2020 in Romania. These values remain at an average level of 200 kg per capita after 2010, with the same situation repeating from the total quantity context.

Table 5. The correlation coefficients (PCC) between the independent variable considered each studied indicator and the dependent variable considered "total amount for food waste" in Europe

No.	Indicator	PCC	p-value	Obs.
1.	GDP	-0.36	0.00000000000000000001	11
2.	HICP	-0.51	0.00005330940000000000	11
3.	Crop production	-0.48	0.00000000000000000593	11
4.	Students enrolled	0.36	0.00000000000000000006	6
5.	Students enrolled tertiary	-0.29	0.00000000000000326481	8
6.	Household consumption	-0.57	0.00000000000000001194	11
7.	Land use	0.54	0.00000000000000022399	9
8.	Plastic waste	-0.53	0.00000000000000000003	11

Source: own determination

Table 6. The correlation coefficients (PCC) between the independent variable considered each studied indicator and the dependent variable considered "total amount for food waste" in Romania

No.	Indicator	PCC	p-value	Obs.
1	GDP	-0.88	0.0000000003740	26
2	IR	0.51	0.0000000000006	30
3	Crop production	0.56	0.0002930000000	20
4	Students enrolled	0.83	0.0000000001030	31
5	Students enrolled tertiary	0.01	0.0000000000003	31
6	Household consumption	-0.88	0.0000000003710	26
7	Land use	0.57	0.0000006160000	31
8	Poverty threshold	-0.05	0.0003530000000	12
9	Plastic packaging waste	-0.48	0.0001550000000	14

Source: own determination.

For the discrete variables (i.e., the ones which presented values for several years), the approximation of a continuity throughout the years was made using an interpolation method. The values for the explained methodology are presented in Table 5 for Europe (from a previous research) and in Table 6 for Romania.

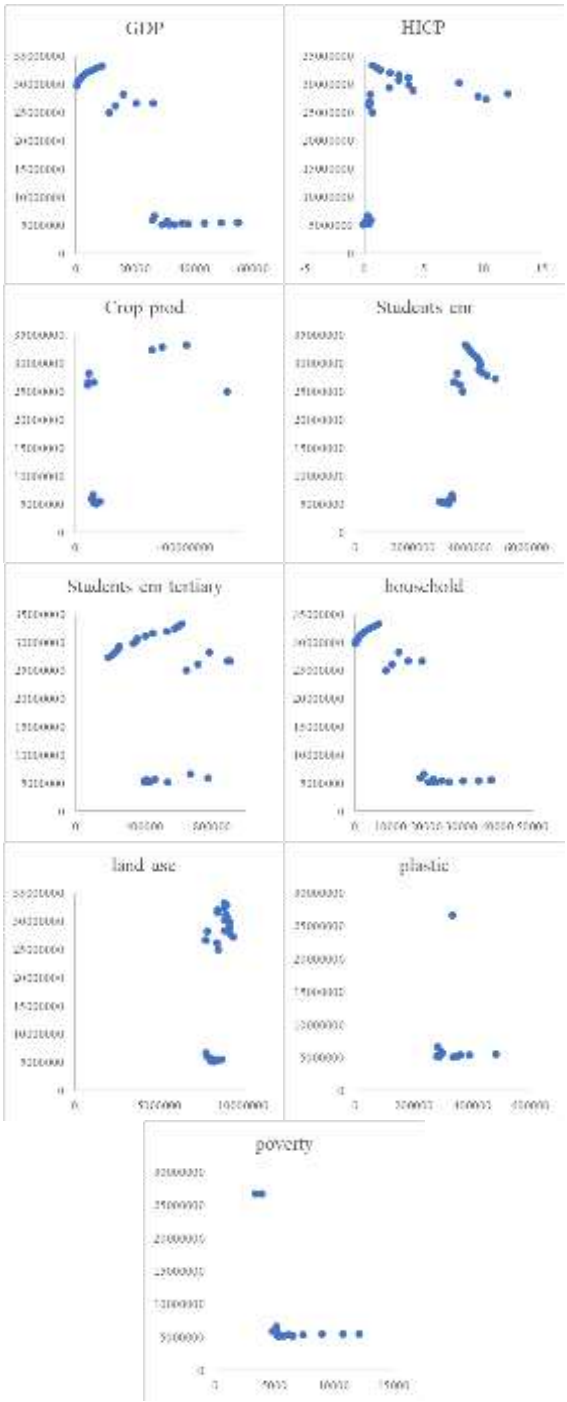


Fig. 13. The graphical representation of the correlation determinations
Source: own determination.

As we can observe, all the correlation determinations were statistically significant (p-value being lower than 0.05), with inverse correlation determined for GDP, household consumption, poverty threshold and plastic packaging waste and direct correlation for the IR, crop production, the total number of enrolled students and the number of enrolled students in the tertiary level and the land use for agriculture. The graphical representation of all the correlation determinations is shown in Fig. 13. The values of the PCC (Pearson Correlation Coefficient) show a medium or low intensity of correlation between the independent variables and the dependent one, as the cloud shape of the data points emphasize in the graphical representation of the correlation determinations. From the independent variables, the ones with the most influence found on food waste are the GDP per capita (inverse), IR (direct), crop production (direct), students enrolled (direct), household consumption (inverse), land use (direct) and plastic packaging waste (inverse).

Factors determination

Related to the previous research, several categories of factors have been determined, as follows:

(a)*behavioural factors*, related to human individual behavioural patterns and reactions;

(b)*demographic factors*, related to societal behavioural patterns and trends;

(c)*biological factors*, related to the food composition and natural processes;

(d)*policy-based factors*, related to rules and regulations, as well as campaigns related to food behaviour;

(e)*economic factors*, related to agrifood chain, from food production to food consumption.

Related to the placement of factors within the agrifood chain, classified in the latter category, we can define the next checkpoints: food production, processing, packaging, logistics, distribution and consuming.

The model will be presented based on the linear structure of these checkpoints, taking into consideration the categories of factors and their major influence on the food loss and waste phenomenon.

A list of the factors taken into consideration for the model structure and taxonomically classified is presented in Table 7.

For the mentioned parameters In Table 7, there were also added several variables that complete the model and connect several parameters and which will be presented in the next subsection.

Model design and structure

The present model is created based on the parameters presented in Table 7. One of the results is the obtaining of a causal loop diagram, shown in Figure 14, where the parameters were connected in order to establish a causal influence related to food waste. To further detail the model, a stock-and-flow diagram will be projected, in order to determine the quantitative aspects of the food waste phenomenon, based on the agrifood chain phases.

Table 7. The list of factors taken into consideration for the model structure

No.	Category	Factor	
1	Behavioural	Buying patterns	
		Habits	
		Attitudes	
		Subject norms	
		Educational background	
2	Demographic	Age	
		Number of members in household	
		Region	
3	Biological	Food perishability	
		External biological agents (e.g., COVID-19 pandemic, food toxins, bacteria, viruses)	
4	Policy	Social policies related to food waste	
		Economic policies related to income	
5	Economic	Producer	Productivity
			Management type
		Processing	Number of processing phases
			Quality standards
		Packaging	Package parameters
		Logistics	Logistic parameters
			Storage
		Distribution	Promotions
			Sales volume
			Low prices
		Consuming	GDP per capita
			Income

Source: own determination.

A primary form of this diagram is shown in Fig. 15, taking into consideration only the main quantities of lost and wasted food and their flow within the system. The causal loop diagram presented Fig. 14 was created using the Vensim (causal loop) and AnyLogic

(stock and flow) software and presents the most important parameters delimited in Table 7. The list of factors taken into consideration for the model structure in respect to the agrifood chain phases.

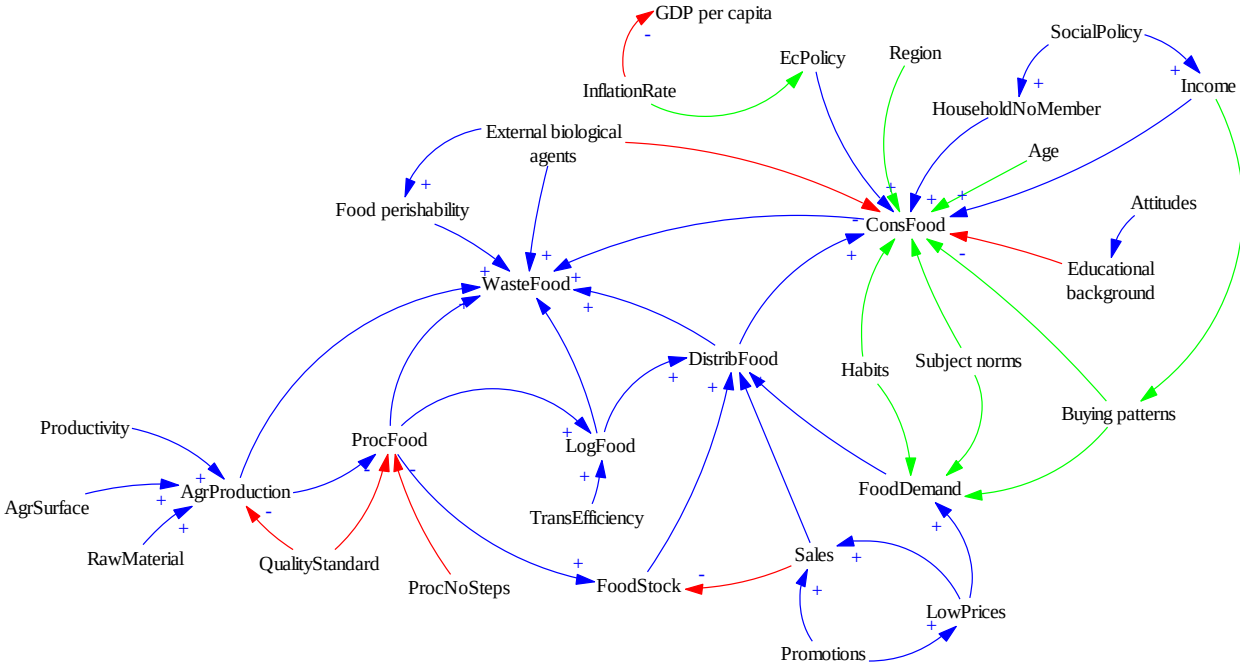


Fig. 14. The causal loop diagram for the considered food waste model
Source: Own determination.

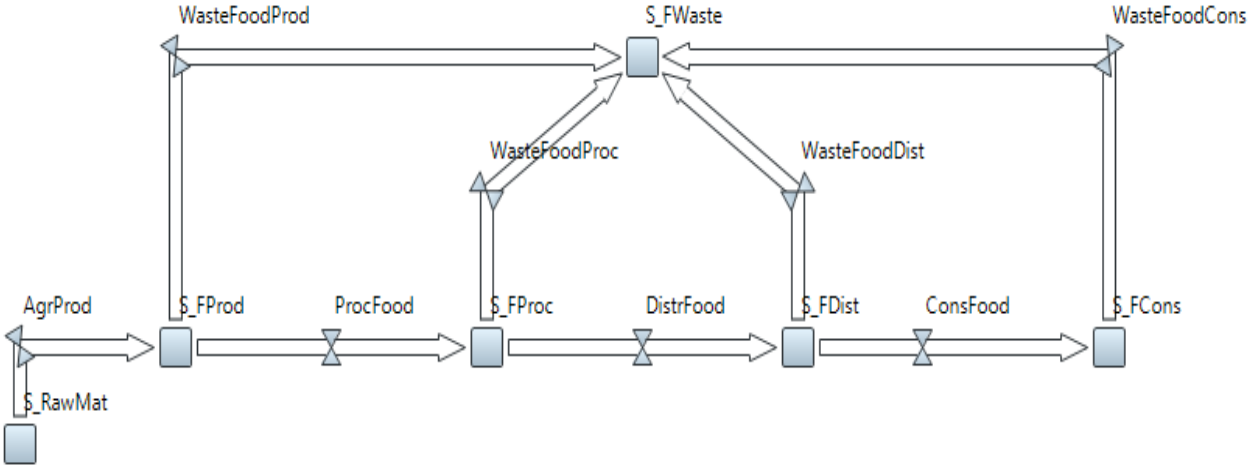


Fig. 15. Primary structure of the stock and flow diagram for the considered food waste model
Source: own determination

The blue arrows indicate a positive influence, the red ones a negative influence and the green ones indicate a mixed influence, based on the context of the model. In future researches, the green arrows will be detailed and transformed in either positive or negative dependencies.

This model illustrates the complex agri-food chain and its interactions related to food waste. The chain starts with agricultural production (AgrProduction) and raw materials and goes through food processing (ProcFood), distribution (LogFood) and retail sales (DistribFood) to consumers (ConsFood). Food waste (WasteFood) is influenced by many factors, including processing and distribution efficiency, food stocks, food demand and consumer behavior. In turn, food waste affects inventory, costs and waste awareness. Farmers, as producers of raw materials, have a

significant impact on the entire agri-food chain.

By analyzing feedbacks and interactions, this model highlights the need for effective resource management, consumer education and collaboration between all levels of the agri-food chain to reduce food waste and bring social, economic and ecological benefits.

CONCLUSIONS

Food waste in Romania has complex origins and involves multiple aspects, including consumer behavior, business practices, supply chain management and quality standards. Expiration dates and incorrect food labeling can cause people to throw away food that could have been safe to eat. In the food industry and restaurants, large portions and irregular menus can lead to waste. Inequality in food distribution and the level of awareness and education may also play a role.

Changes in food waste dynamics can be influenced by socioeconomic developments, education and awareness, and government policies.

Addressing food waste requires efforts at government, industry and individual levels [7] to promote more efficient management of food resources and reduce waste.

Future work will be established for the refinement of the data using more specific datasets and the usage of the results in further analysis of the effects, impacts and solutions for the food waste phenomenon.

ACKNOWLEDGEMENTS

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