International Workshop on Food Loss and Waste
Prevention targeting Mediterranean countries

Socio-Economic and Environmental Impacts Assessment of Food Losses across Horticultural Supply Chain in Egypt

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Contents

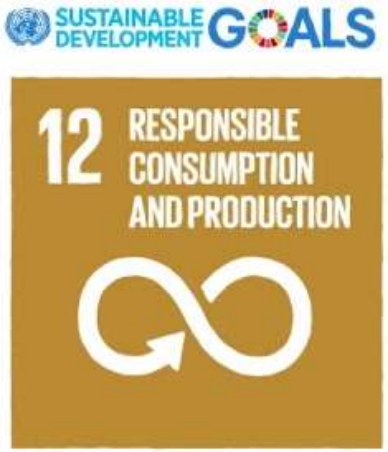
1 Introduction

Food losses and waste is global issue especially the developing countries.

1. **One-third (1.3 billion ton) of the world's food is losing annually.**
2. **Costs the global economy $940 billion**
3. **Emits 8% of planet-warming greenhouse gases (GHG)**
4. **Consumes a 25% of all agriculture water each year.**

1 Introduction

SDG Target 12.3, "By 2030, halve per capita global food waste at the retail and consumer levels and **reduce food losses along production and supply chains, including post-harvest losses**".



SDG Indicator
12.3.1

Measuring
FOOD LOSS

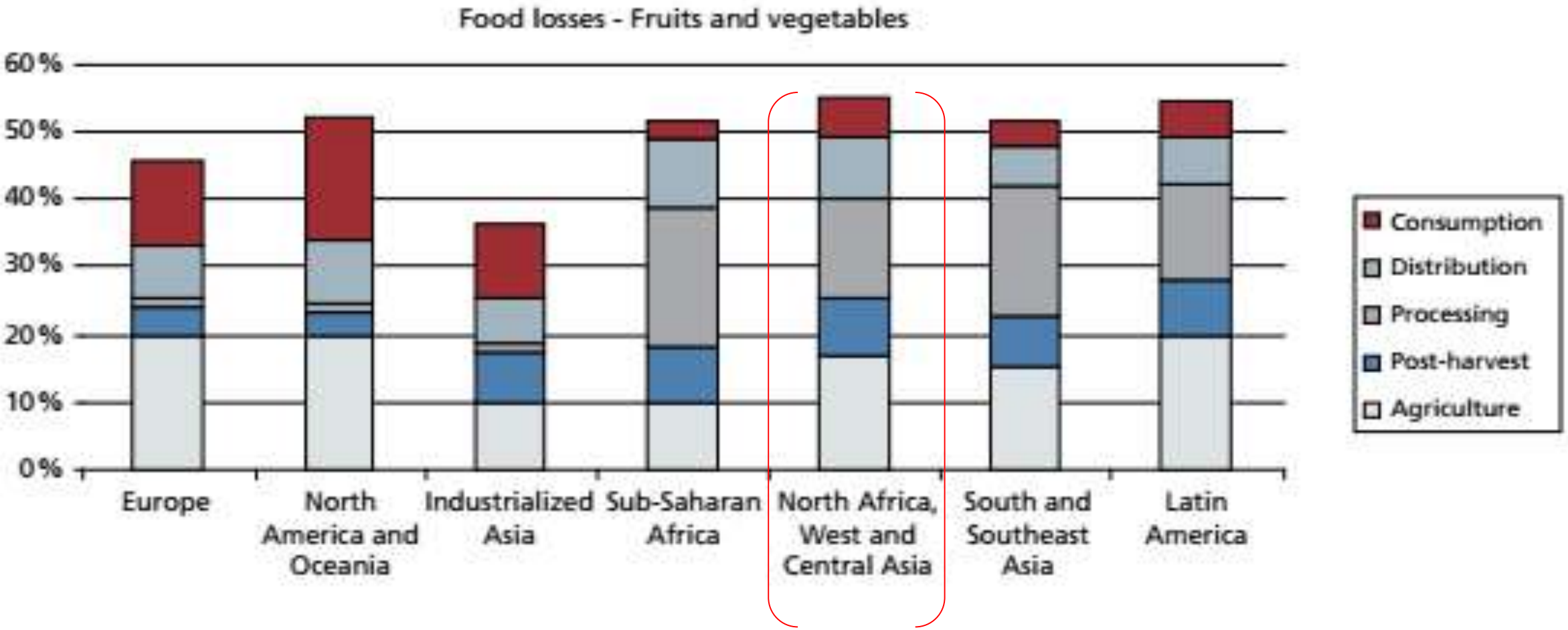
Reducing food losses by 50% during different FSC stages in developing countries could decrease the number of undernourished populations by 63 million, decrease the harvested area sequentially water utilization and greenhouse gas emissions associated with food production (Munesue et al., 2015).

Losses and waste in the NENA region by commodity

Grains	Fish	Meat	Dairy	Fruit and Vegetables
				
14-19 %	26 %	13 %	26 %	45 %

Source: (FAO, 2011)

Part of the initial production lost or wasted at different stages of the FSC for fruits and vegetables in different regions



Source: (FAO, 2011)

2 Research Questions

1. **What are the main influencing factors on PHL across horticultural supply chains?**
2. **Where is the hot-spot of PHL across stages of horticultural supply chains?**
3. **How much economic and environmental addition could be achieved for individual supply chain actors and national economy through reducing PHL for study crops?**

2 Aim of Study

This study aims to assess and analyze socio-economic and environmental impacts of post-harvest losses for the major horticultural crops in Egypt at the different stages of the food supply chain (postharvest handling, processing, and intermediates), identify and analyze the causes for losses.

3 Methodology and Sampling Strategy

❖ Data Collection and Sampling strategy

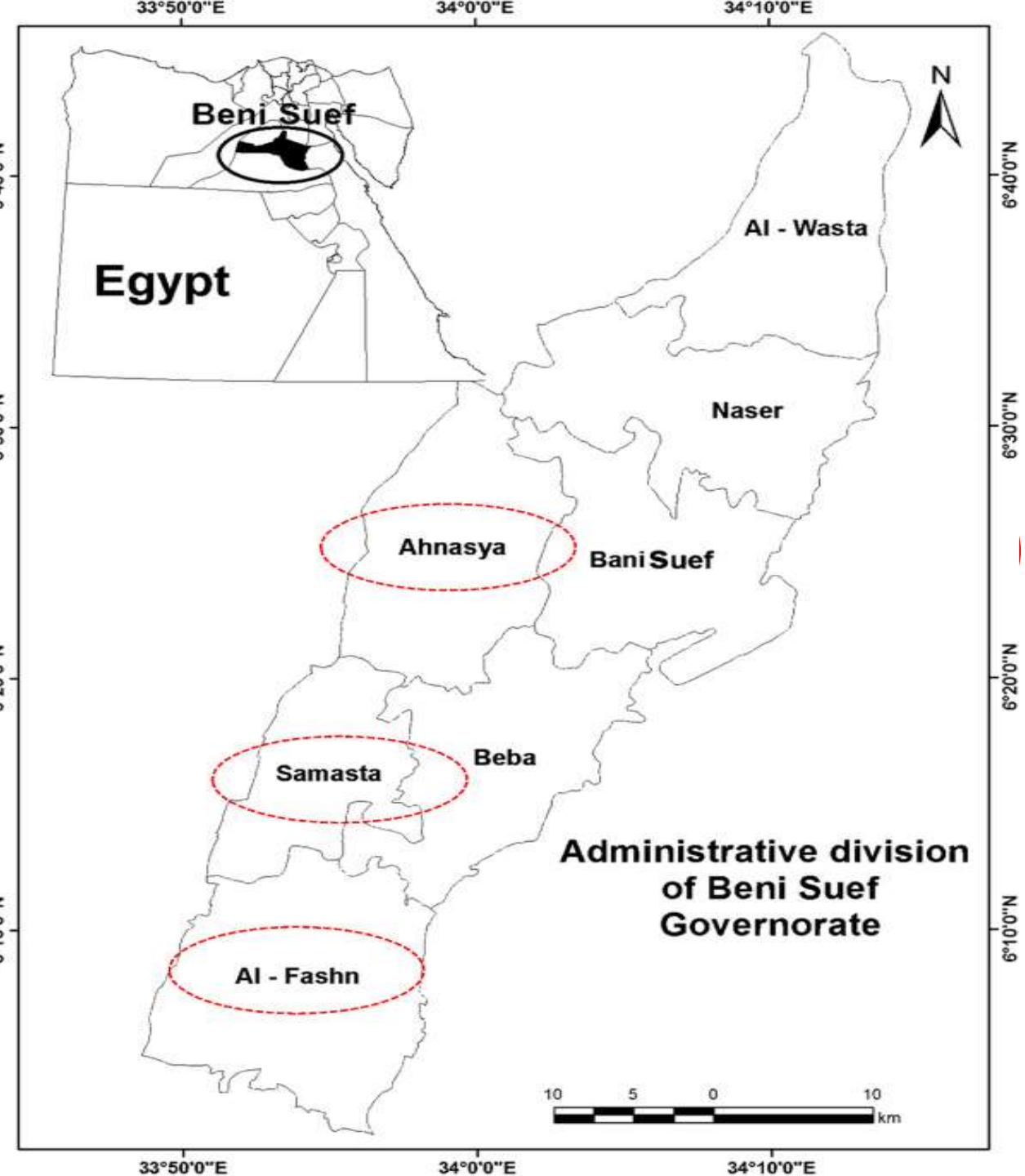
1. Study Area

2. Study Population and Sampling

A multi-stage sampling strategy adopted for the ultimate selection of vegetable stakeholders.

Randomly 218 tomato farmers were selected from the villages.

120 intermediates selected randomly including (25 wholesaler, 30 local traders', 30 vegetable groceries, 10 supermarkets, and 25 hawkers). Five tomato processors have been investigated from the factories in the industries zones, Egypt.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34°0'0"E
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6°40'0"N
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Beni Suef
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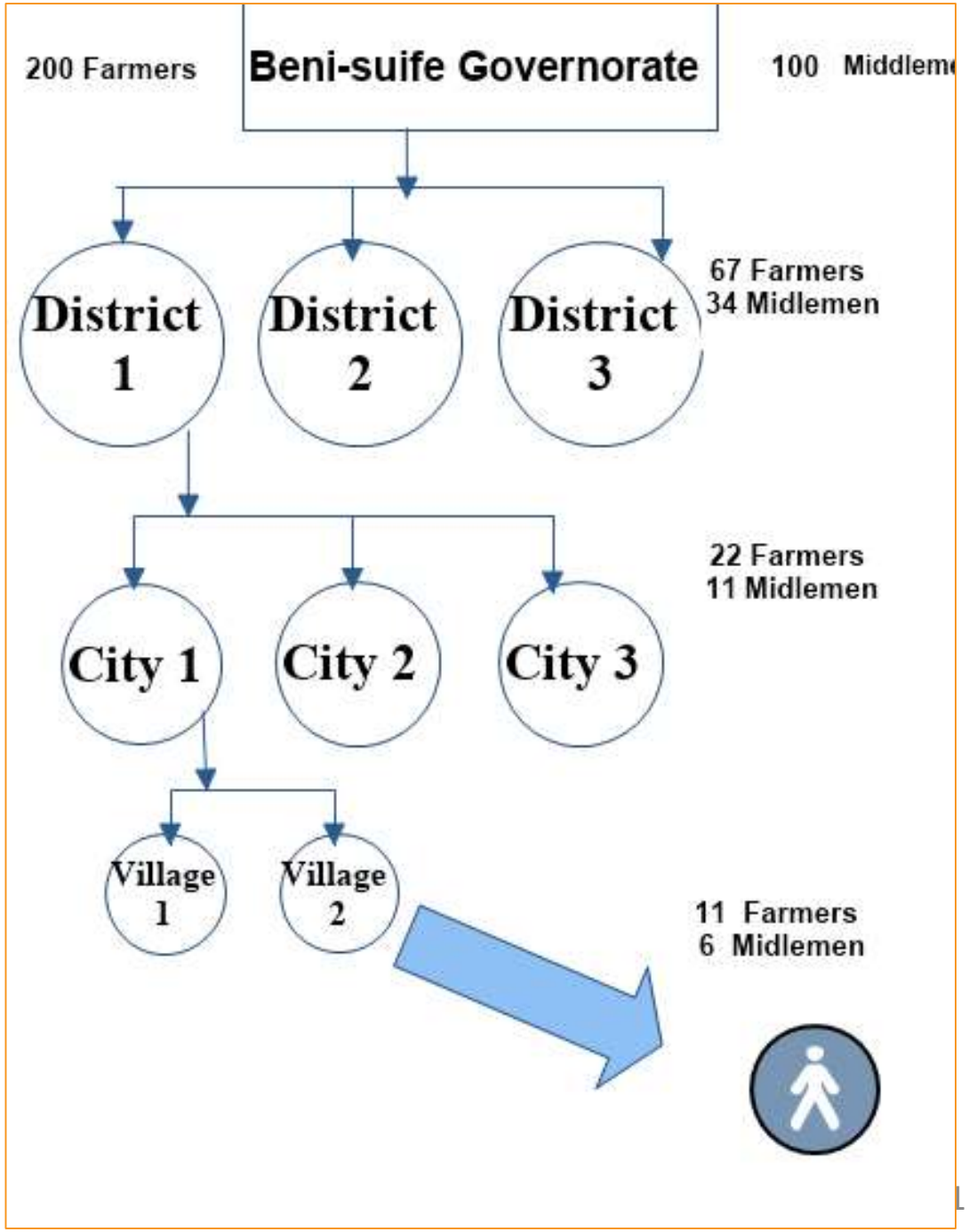
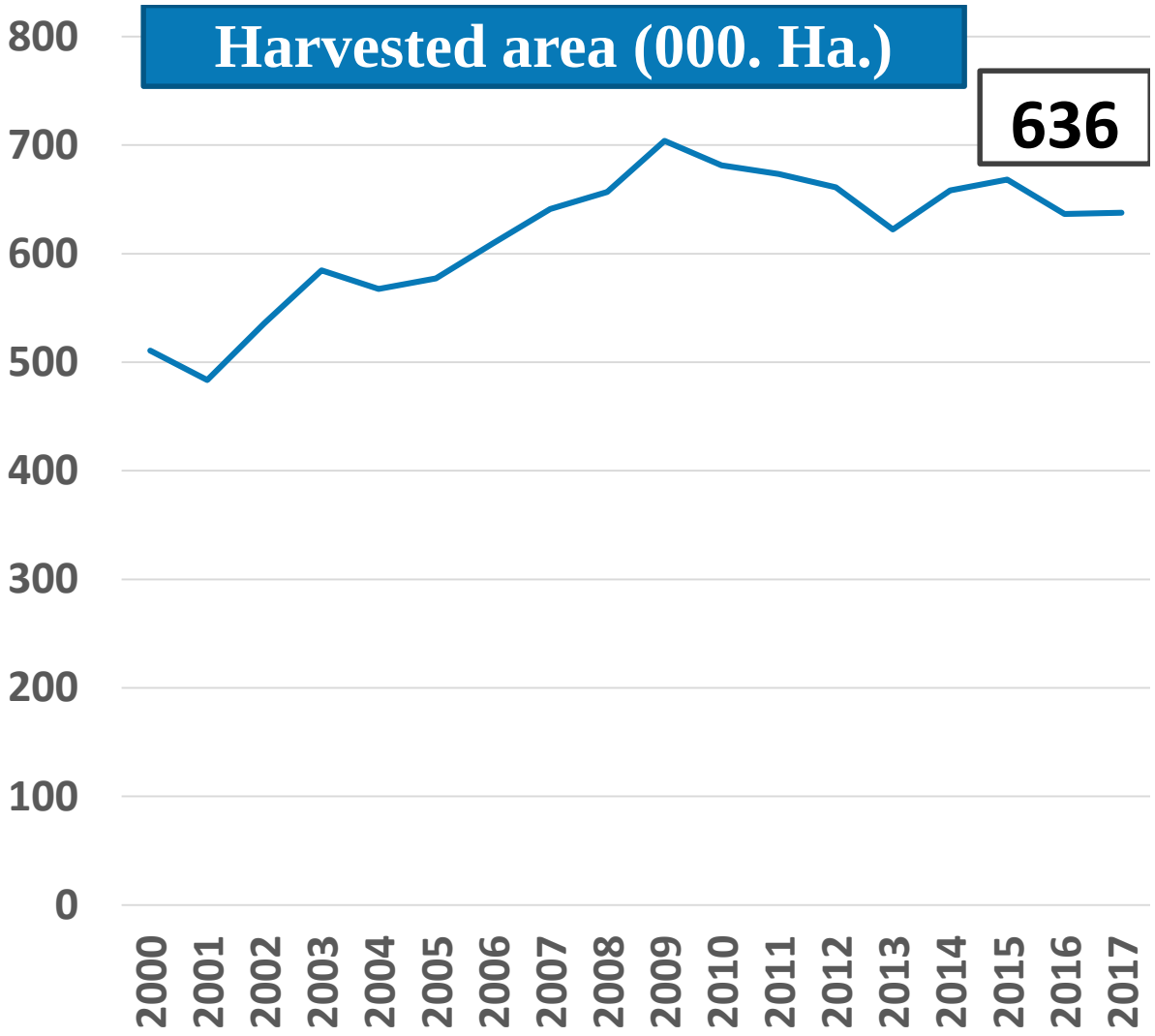
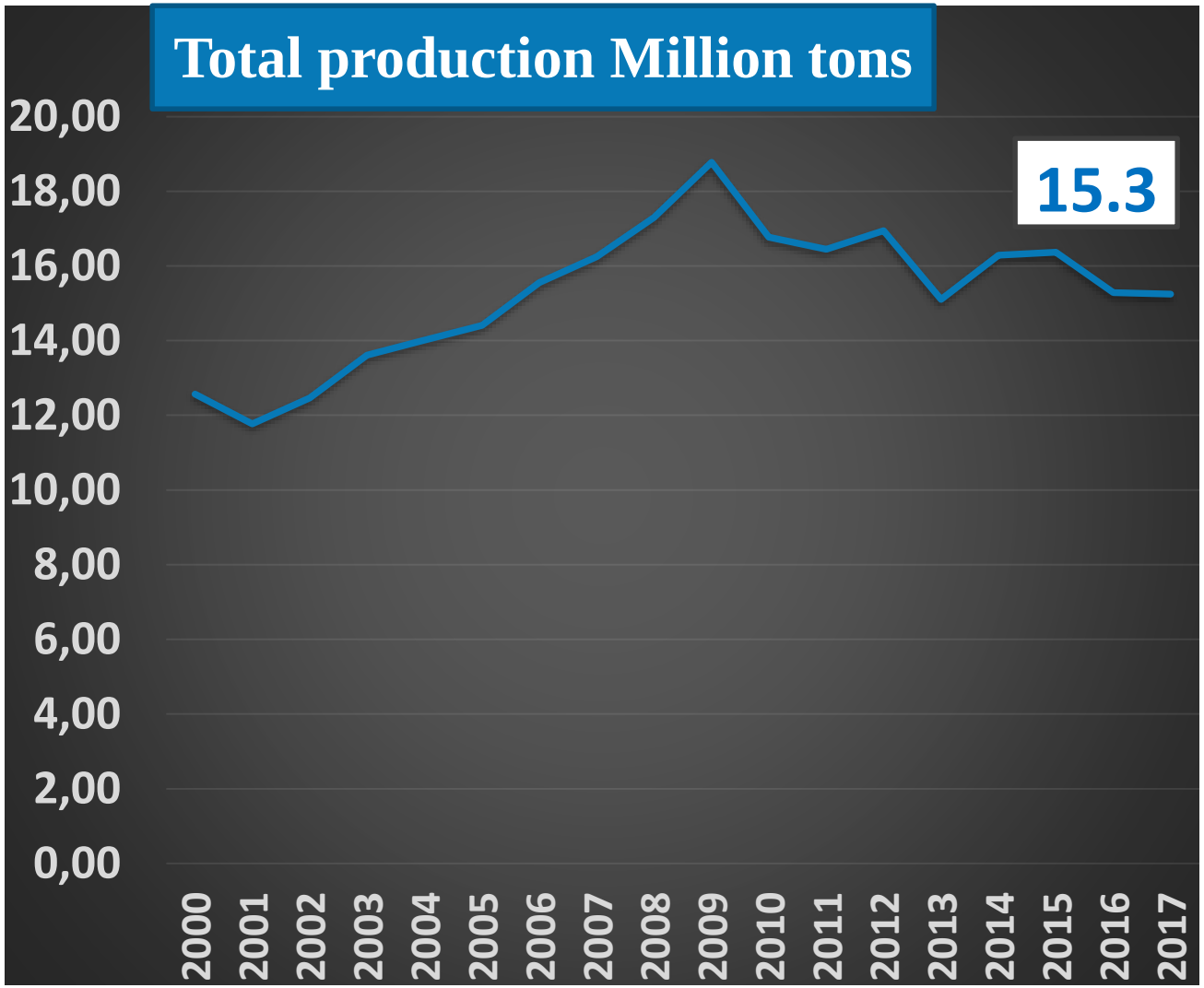
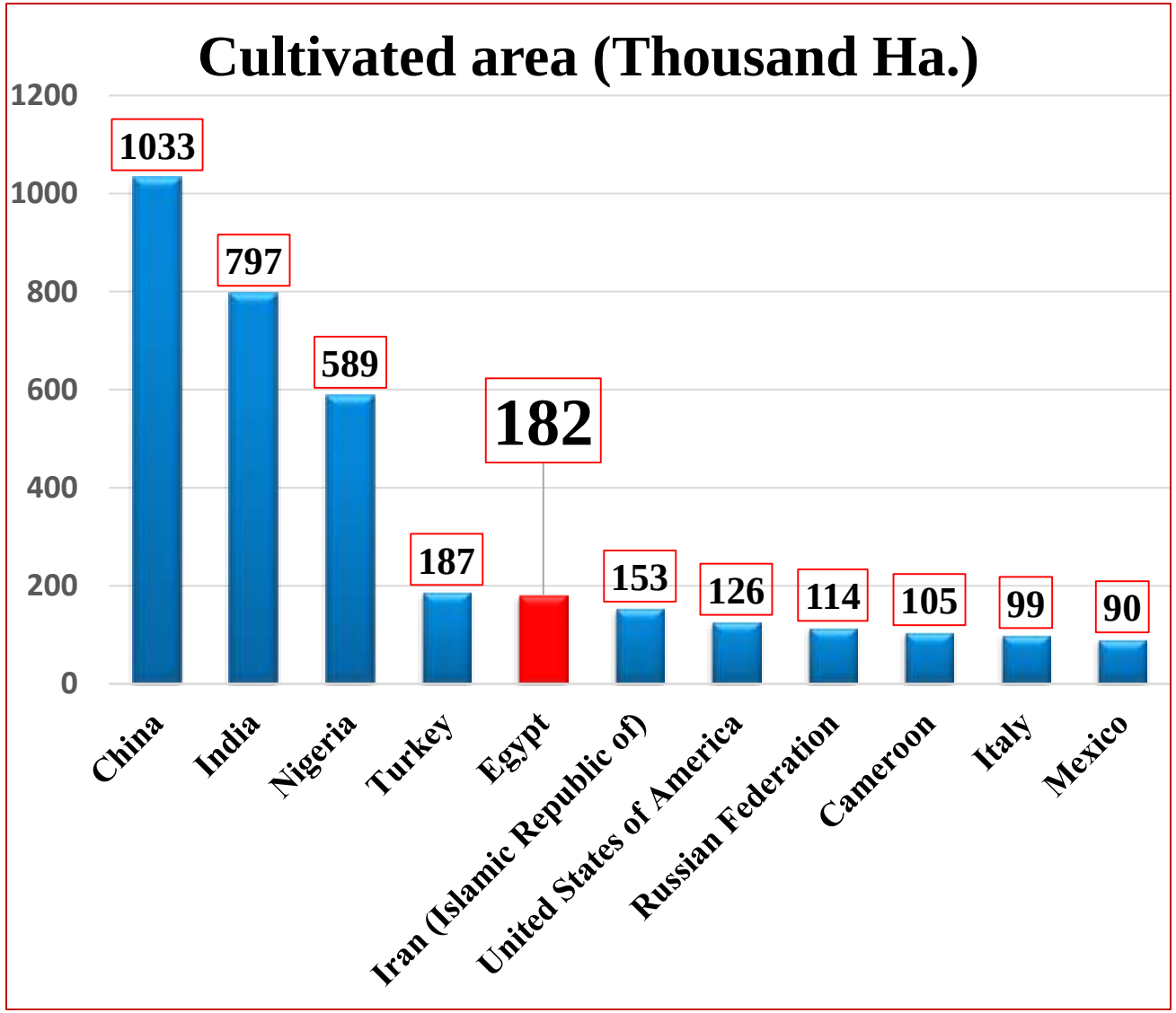

200 Farmers
Beni-suife Governorate
100 Middleme
District 1
District 2
District 3
67 Farmers
34 Midlemen
City 1
City 2
City 3
22 Farmers
11 Midlemen
Village 1
Village 2
11 Farmers
6 Midlemen

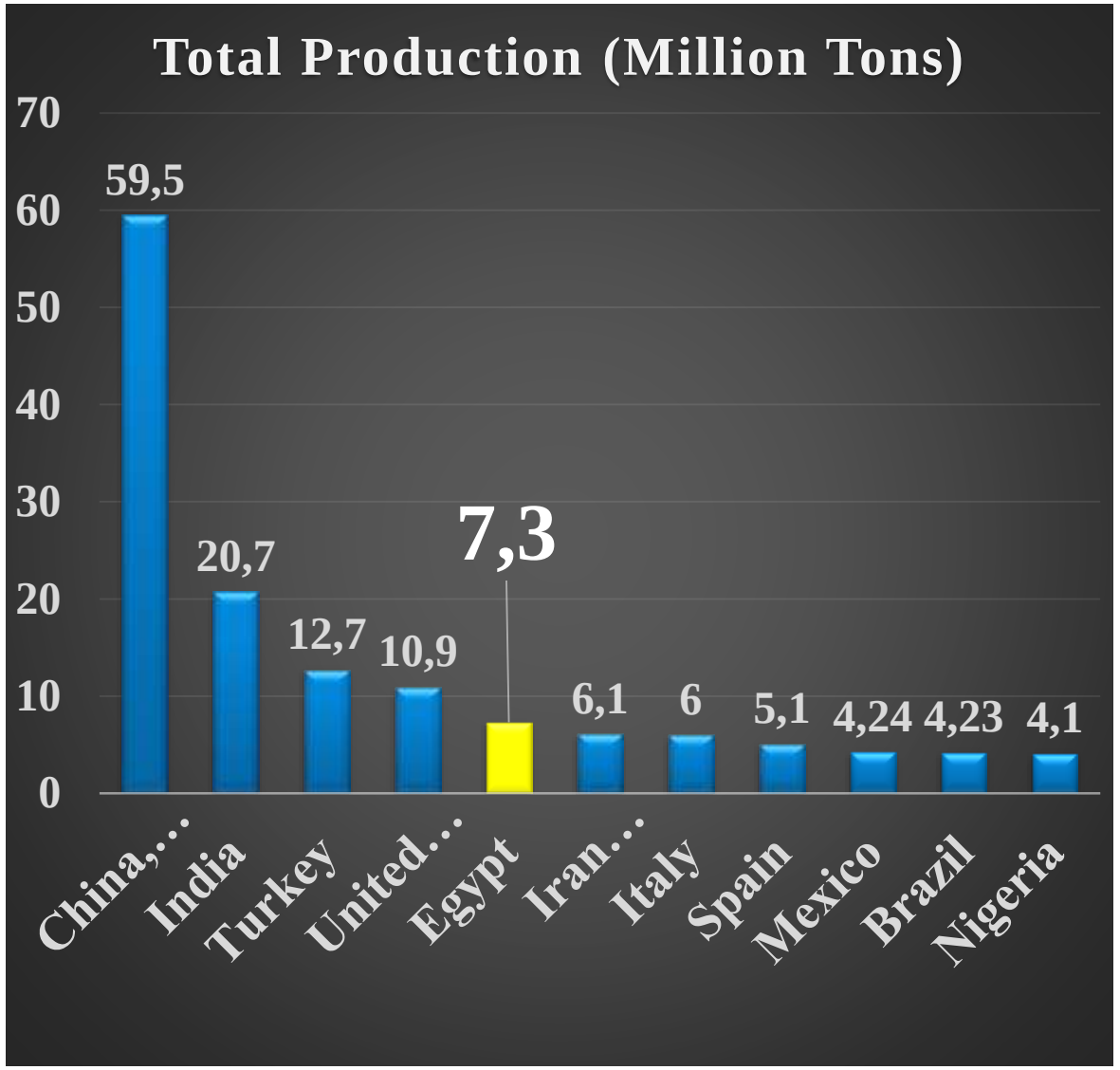
Vegetables Area Harvested and total production in Egypt (2000- 2017)





Tomato cultivated area and total production in Egypt 2017



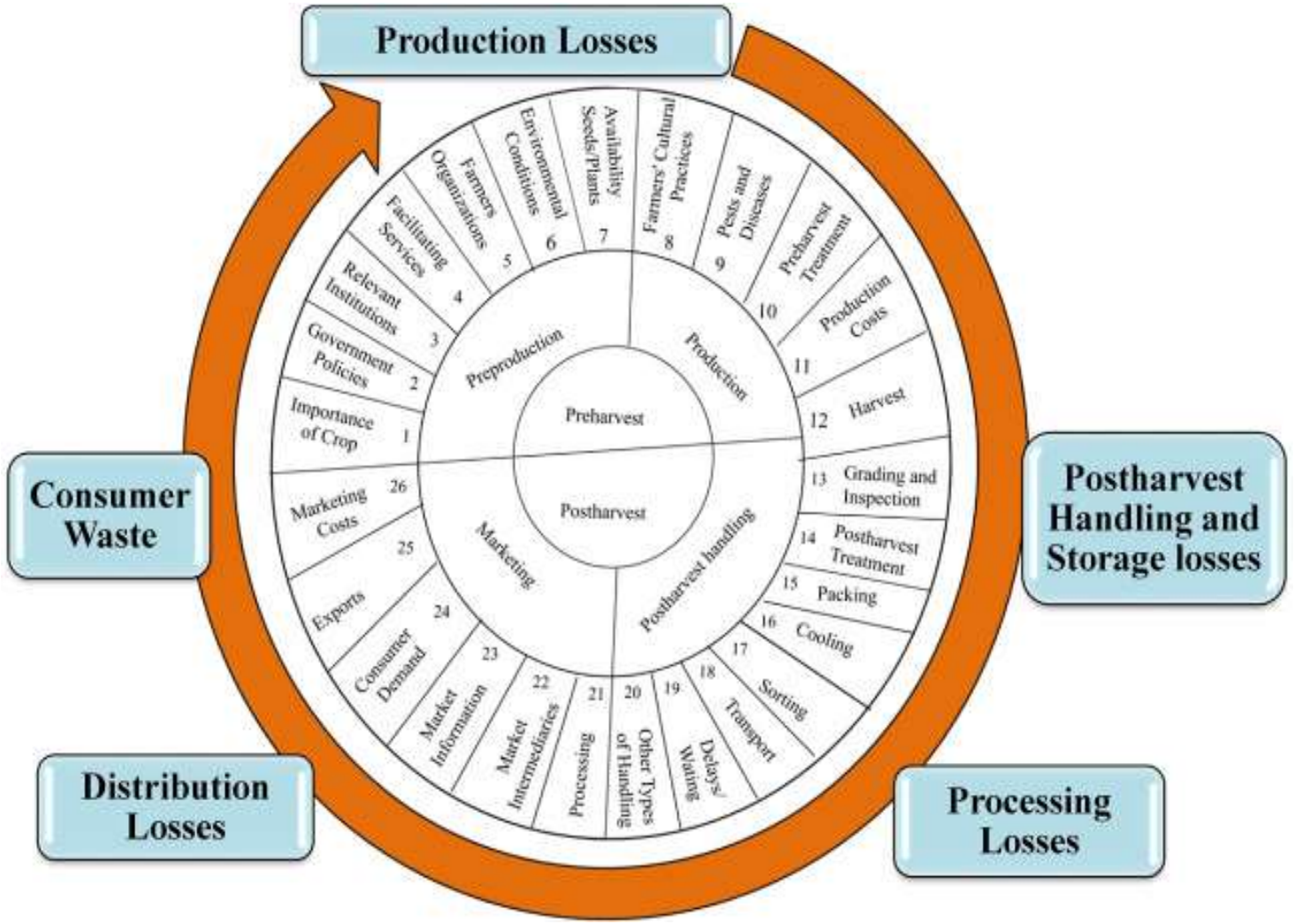


3 Methodology and analytical approach

1. **Life Cycle Assessment (LCA)**
2. **PHL estimating methodology (category method)**
3. **Estimation of the lost resources used to produce the PHL and its' environmental impacts** (Water, Energy, Land and Co2 Footprint indexes)
4. **Analysis of Variance (ANOVA)**

Life Cycle Assessment (LCA)

Five stages of food losses across the food supply chain according to the (LCA) Merged with the main components of **agricultural value chain** from the food losses perspective, modified from **(LaGra et al., 2016).** This highlights the importance of interaction between agricultural practices and operations (pre and post-harvest) as a mean for reducing food losses and waste along food supply chain.



1- Category method to estimate PHL

This approach has been used for the first time by (Compton and Sherington, 1999) and recently by (Delgado et al., 2017). The losses in each category have been estimated as separate ones because of the difference in the **unit price** (LE/Kg) in each category. This is recommended by the recent study (Bellemare et al., 2017).

Table A.2
Description of visual scale categories and uses of each category of tomatoes in Egypt

Class	Damage level	Description and uses	Grade	C*">*
1	Undamaged	For export, fresh consumption and processing respectively.	Grade	0.05
2	Slight damage	A few infested fruits (3–4%). Always acceptable for food and usually mixed with Class 1. Sells at top price.	A	
3	Slight–moderate damage	Less than 5% of the fruits infested or injured. Acceptable to farmers and traders for mixing with Class 1 and 2, if in small proportion. Otherwise may be occasionally mixed with Class 4.		
4	Moderate damage	About 5–10% of the fruits infested or injured, but still with acceptable appearance for some consumers. Acceptable for human food by poorer groups and in lean seasons. Rarely mixed with good fruits and only for immediate consumption. May be mixed with Class 5.	Grade B	0.10
5	Severe damage	Over about 50% of the fruits injured or damaged. Normally animal feed; used for human food only in time of scarcity, when it is mixed with higher grades. Still saleable in certain conditions, at low price.	Grade C	0.5
6	Very severe damage	Fruit thrown away by farmer and unsaleable. Mostly the farmers are left this fruit in the field during the primary sorting in the farm-gate or unharvested it from the beginning. For the intermediaries and processors, they are selling it as an animal feed or landfill (garbage).		

*Damage coefficient in each category.
Source: Modified from (Compton and Sherington, 1999).

For the farmers the following formula has been used

$$WeightLoss_P = (Q_{Prod.p} - Q_{PH.p}) + \sum_{i=1}^{I} (C_i * QC_{iPH.p}) \quad (1)$$

$$ValueLoss_P = (V_{Prod.p} - V_{PH.p}) + \sum_{i=1}^{I} (Price_{ideal.p} - Price_{Ci.P}) * QC_{iPH.p} \quad (2)$$

Where $ValueLoss_P$ represents the value of the quantity that lost between harvest and postharvest (mass degradation) plus a price punishment by category (quality degradation), And Q_P, Q_{PHL} are the quantity of total yield after harvesting and after post-harvest respectively, C_i is the damage coefficient for category i (where the total number of categories are I), as showed in Table A2 QC_{iPH} is the quantity in each category after post-harvest. V_P, V_{PHL} are respectively the value of all production after production and after post-harvest. $Pice_{ideal}$, $Price_{Ci.P}$ are the average sale price for an ideal product and sale price for a product in category *i*. The first term in both equations represent the total value or quantity losses, the second term refers to the quality degradation.

PHL for intermediaries estimated as a following;

$$WightLoss_m = WightTotalLoss_m + \sum^{I} C_i * \left(QC_{iPurchase,m} - QC_{isale,m}\right) \qquad (3)$$

$$ValueLoss_m = ValueTotalLoss_m + \sum^{I} \left(P_{ideal,m} - P_{Ci,m}\right) * \left(QC_{iPurchase,m} - QC_{isale,m}\right) \qquad (4)$$

$WightLoss_m$ and $ValueLoss_m$ represent the full quantity and quality degradation that completely disappeared from the value chain. $WightTotalLoss_m$ and $ValueTotalLoss_m$ refer to the weight (or value) of the mass that was totally lost at the middlemen level. C_i is the same damage coefficient as showed in Table A2 $P_{ideal,m}$ and $P_{Ci,m}$ are the average sale price for an ideal product and sale price for a product in category i at the middlemen level. $QC_{iPurchase,m}$ and $QC_{isale,m}$ are the quantities in each category at purchase and at the sale, which obtained from the difference between the total purchase and total sales within a given period. For the processors, they reported the losses in the quantity in addition to the inappropriate tomato-fruit for processing (e.g. green tomato).

2- Estimation the lost resources used to produce the PHL

$$Lost\ resouces_{qi} = \beta_i * PHL_{national} \quad (5)$$

where $Lost\ resouce_{qi}$ is the quantity of input i used to produce the lost food, $PHL_{national}$ is the aggregate quantity of food losses at the national level. β_i represent per ton requirements from the i input, we used the FAO estimates in our calculations (FAO, 2020). We used the estimated quantity of water ($m.^3\ kg^{-1}$) for tomato in Egypt calculated by El-Marsafawy et al., to estimate the total lost water quantity across the tomato supply chain (El-Marsafawy et al., 2018).

3- Estimation the Environmental impacts of PHL including grey water and greenhouse gas emissions (GHG)

Water footprint coefficient of production was used to estimate wasted water produced by the lost food (Mekonnen and Hoekstra, 2011).

$$Water_{grey} = WF_{grey} * PHL_{national} \quad (6)$$

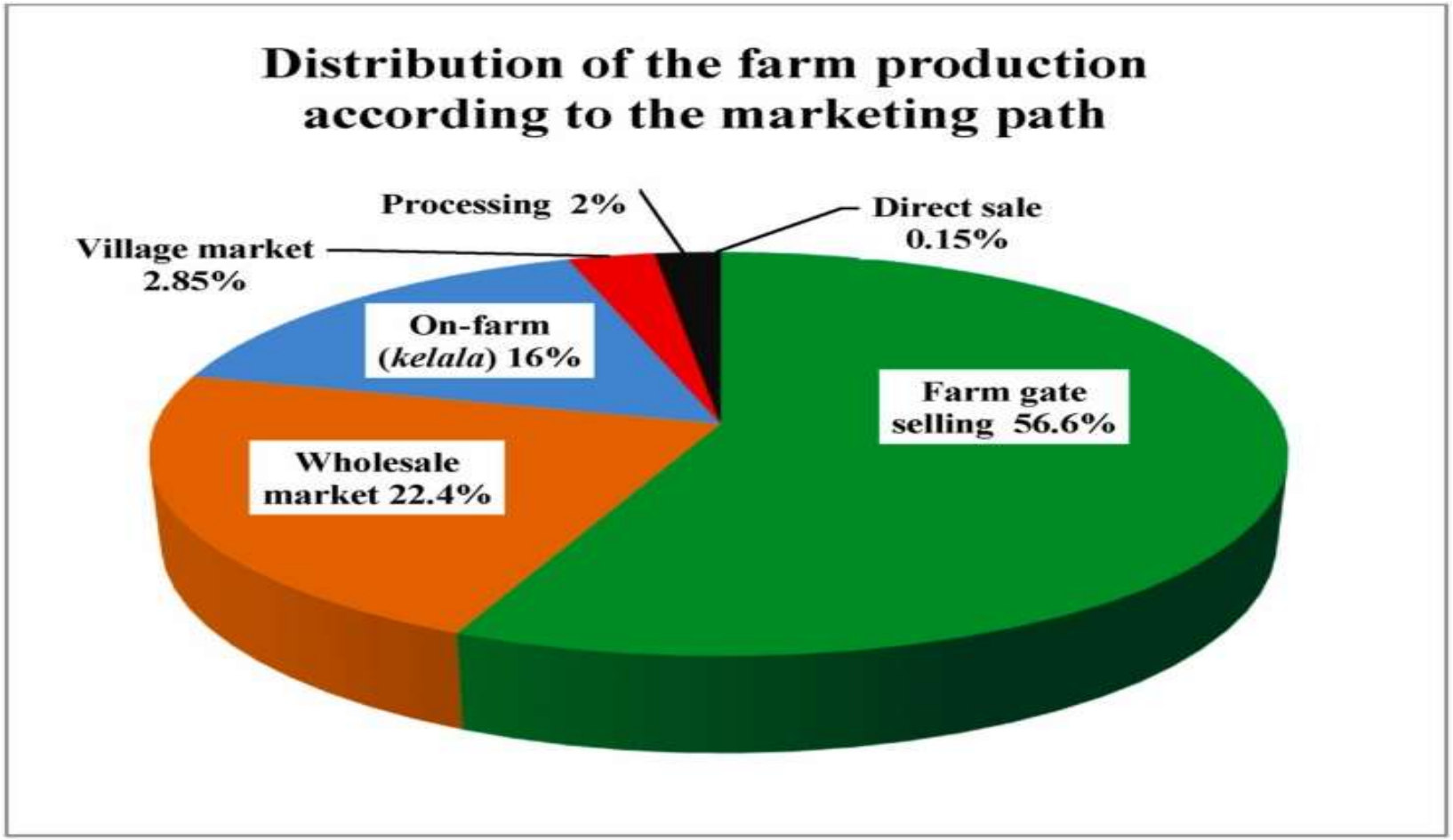
where $Water_{grey}$ represent the lost water in each category (m^3), WF_{grey} represent water footprint ($m.^3$ ton^{-1}) for tomato derived from (Mekonnen and Hoekstra, 2011), and $PHL_{national}$ calculated at the national level.

GHG is caused by the use of chemical fertilizer and energy consumption during food production, which calculated as follows: (Page et al., 2012)

$$CF_{PHL} = CEF * PHL_{national} \quad (7)$$

where CF_{PHL} represents carbon emission associated with PHL in kg, CEF is the carbon emission factor (carbon emission per weight unit of food in ton CO2eq/Kg). We used the estimated GHG coefficient for tomato calculated by (Poore and Nemecek, 2018).

4 Results



Distribution the farm production according to the marketing path; more than farm production is sold on the farm gate by the small growers. The remaining quantity is divided between wholesalers and village traders, which should consider for designing effective interventions.

1- Distribution the sold production according to the grade of quality in the different nods across tomato supply chain in Egypt.

	Grade of the production	% Grade A	Average Price LE*/Kg	% Grade B*	Average Price LE/Kg	% Grade C	Average Price LE/Kg
	Farmers	80	1.45	20	0.70	–	–
	Local trader	75	2	25	1.3	–	–
	Wholesaler	73.2	2.62	26.8	1.76	–	–
Retailers	Vegetable groceries	54.15	3.88	39.15	2.66	6.7	1.19
	Hawker	44.2	3.15	49.4	2.25	6.4	1.05
	Supermarket	70	5.17	30	4.5	–	–

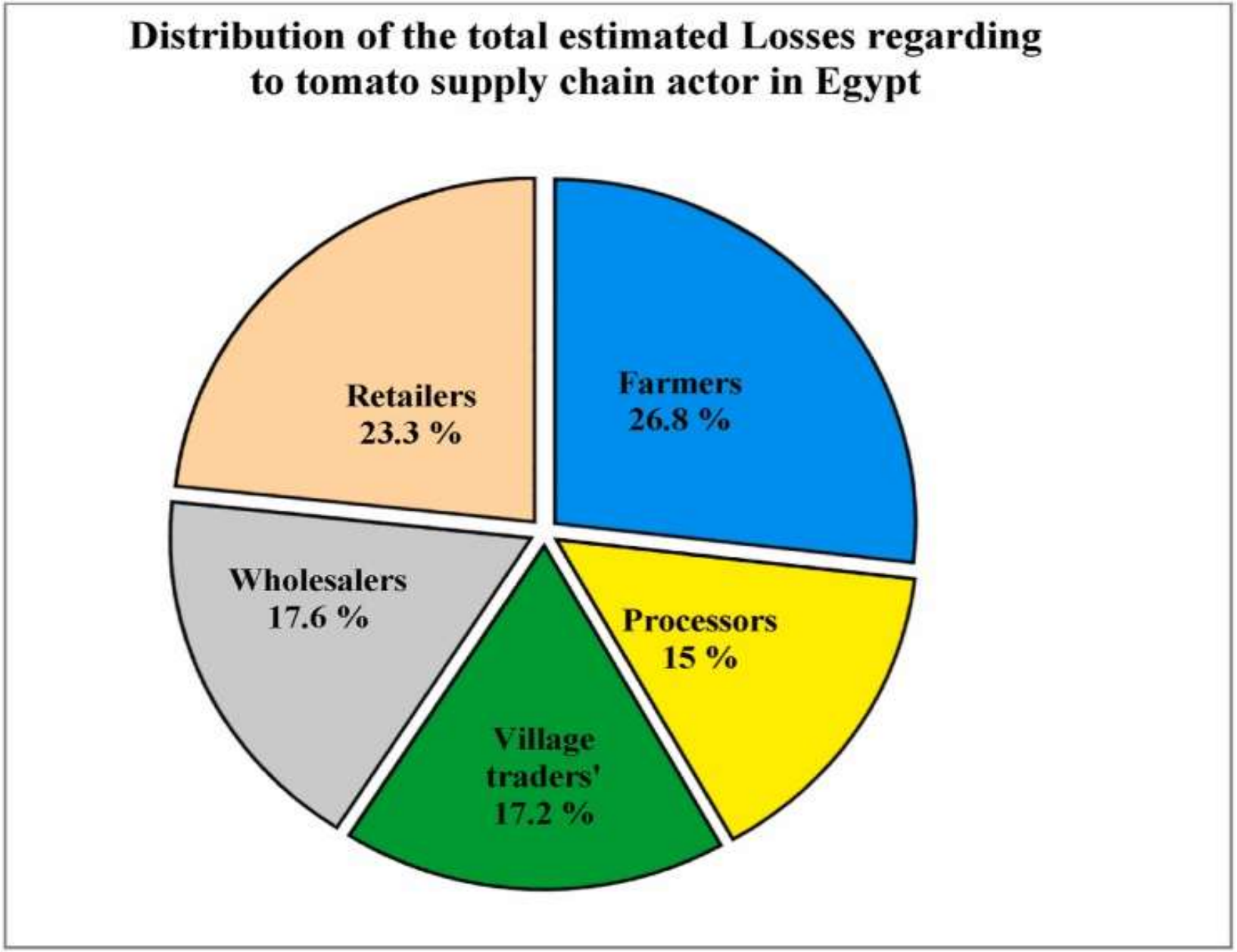
* Average of annual exchange rate 2020. 1$ = 15.7562 Egyptian pound.

2- Estimated quantity, quality and its' economic value of the PHL for the different actors across tomato supply chain in the national level in Egypt.

Actors	% Average quantity Losses (1)	% Average quality Losses (2)	% Average whole Losses (1 + 2)	SD	Total PHL* MT	PHL Value (Million LE)	Value (Million $)
Farmers	7.95	5.52	13.36	2.37	1.04	1511	95.9
Processors	7.5	–	7.5	0.56	0.51	608	38.6
Local trader	2.5	6.1	8.6	4.35	0.54	1076	68.3
Wholesalers	2.6	6.2	8.8	3.12	0.55	1434	91
Retailers	1.74	9.89	11.63	–	0.60	2442 *	155
Total			49.89		3.24	7072	448.8

*Average of the total tomato production in Egypt is 7.8 Million tons (2000–2019).

Note: We estimated the losses in each stage by using the remainder (total quantity –PHL quantity in the previous stage).


Distribution of the total estimated Losses regarding to tomato supply chain actor in Egypt
Retailers 23.3 %
Farmers 26.8 %
Wholesalers 17.6 %
Processors 15 %
Village traders' 17.2 %

3- Lost resources which used to produce the PHL across tomato supply chain in the national level in Egypt.

Inputs	Resource Requirements	Unit per tone	Total lost resources at national level (Million)	Reference
Land	32.51 ton/hectare	**0.03**	**0.08316**	FAO state estimations
Water	10.58 Kg. m^{-3}	**94.52**	**306.24**	El-Marsafawy et al. (2018)
GHG Emissions	1.4 Kg co_2eq/Kg	**1400**	**4536**	Poore and Nemecek (2018)
Fertilizers; Nitrogen (N), Phosphorus (P) and Potassium (K)	342.26 N unit/hectare	**8.78**	**28.46**	FAO state estimations
	68.9 P unit/hectare	**1.77**	**5.73**	FAO state estimations
	20.72 K unit/hectare	**0.53**	**1.72**	FAO state estimations
Pesticides	5.5 litter/hectare	**0.14**	**0.46**	FAO state estimations
Human Laborer	100 laborer day/hectare	**2.57**	**8.32**	Calculated from the collected data
Machine labor	90 h/hectare	**2.31**	**7.48**	Calculated from the collected data

These estimations based on the total estimated PHL (3.24 million tons), from harvesting till the product reaching to the final consumer.

Food losses across tomtoes supply chain in Egypt

Inputs

Land | Water | Energy | Laborer | Pesticides | Fertilezers

Production to consumption

Production → Harvested → 13.36 ± 2.37

Production → Uharvested

Harvested → Demostic Market

Demostic Market → 80% of production → Grade 1

Demostic Market → 20% → Grade 2

Harvested → Preparing for exporting → Packing and prepration Stations

Packing and prepration Stations → High quality → Export

Packing and prepration Stations → Grade 2

Grade 1 → Local trader 8.6 ± 4.35

Grade 1 → Wholesealer 8.8 ± 3.12

Grade 2 → Processing 7.5 ± 0.56

Processing → Export

Local trader → Hawker 11.5 ± 0.52

Wholesealer → Vegetable grocery 11.5 ± 0.77

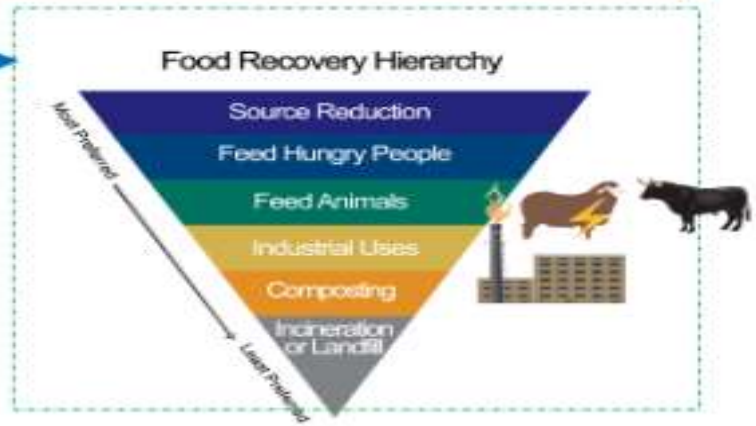
Processing → Supermarket 8.6± 2.13

Hawker → Consumed

Vegetable grocery → Consumer

Supermarket → Consumer

Consumer → Unconsumed



Wasted Resorces

- Land; 80 Thousand hectares
- Freshwater; 306 Million m^3
- Fertilizers; 28 N, 5.73 P 1.72 K (Million unit)
- Pesticides; 460 Thousand litters
- Human Laborer; 8.32 Million laborer day
- Machine labor; 7.48 Million hours

- GHG; 4.5 Million tonnes co_2eq
- Grey Water; 139 Million m^3

Causes of post-harvest losses across tomato supply chain as the respondents reported

(1) **Neglect postharvest operations** (e.g. sorting, packing, grading); at the farm, which leads to increasing the percentage of PHL along the following downstream stages of FSC.

(2) **Using inappropriate packing boxes**; most of the farmers are using the palm crates which lead to increase the percentage of injured fruits during handling and transporting tomato (Anriquez et al., 2021).

(3) **Late harvesting;** farmers might late harvesting because of the price fluctuation or/and seasonal production and surplus issues, which lead to over-maturity and increase the destroyed fruits particularly for the perishable products like tomato (Arah et al., 2016).

(4) **Insufficient skills; improper handling** of the products at the farm and marketplace (e.g. over-packing for the crates, and leaving tomato exposed to the sun after harvesting without shed during post-harvesting, marketing and transporting).,Additionally insufficiency of proper storage facilities.

(5) **Pests, bacteria and funguses infestation**; which increase the percentage of the injured fruits consequently the ratio of PHL at different stages.

(6) **Lack of infrastructure and logistics;** insufficient infrastructure and shortage of government legalizations are the main reason for increasing the FLW, followed by inadequate marketing systems and technological and environmental causes (Ali et al., 2021). And

(7) **lack of linkage between the farmers and processing units**; through contract farming, this issue could be tackled, which could decrease the risk for the farmers due to the price stability and for the processors, they will secure a good and sustainable source for raw materials (Wang et al., 2014).

Significant differences from one-way ANOVA have ben used to comparing the different group means. PHL percentage between the farmers in the different districts, middleman level particularly investigated distributors (retailers).

Table A.4
ANOVA test results to compare the difference of average PHL percent between the farmers in the selected three districts.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.004	2	.002	2.540	.081
Within Groups	.164	197	.001		
Total	.168	199			

Table A.5
ANOVA test results to compare the difference of average PHL percent between the intermediaries (local traders', wholesalers, retailers) in the investigated area.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	216.893	4	54.223	23.982	.000
Within Groups	260.019	115	2.261		
Total	476.912	119			

Table A.6
ANOVA test results to compare the difference of average PHL percent between the interviewed retailers (vegetable grocery, hawker and super-market) in the investigated area.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	130.366	2	65.183	67.486	.000
Within Groups	59.884	62	.966		
Total	190.250	64			

6 Conclusion

- In low-income countries, quantity PHL occurs mainly upstream FSC during the harvest and postharvest operations, while the quality increase downstream FSC because the lack of cold-chain transportation and storage infrastructure.

- Most of the tomatoes growers in Egypt are small farmers, low educational and income levels, which should consider for designing an intervention that aims to reduce PHL and achieve sustainable resource management.

- The total PHL is varying between the **different marketing paths** and the short supply chain could contribute to minimizing the PHL ratio. That highlight the diverse of FSC could reduce PHL.

- Reducing the PHL play a curial role in minimizing the natural resource consumption along with the FSC, this **represents an economic** and **environmental opportunity for enhancing the income** of individuals and accelerate the national and global economy to be more sustainable.

- Adopting a **short supply chain** might be the appropriate solution to **maximize the producer profit and minimize the losses at various stages of FSC**. Interventions could include; collective marketing, supported technologies, **access to microcredit and better** transportation & storage infrastructure, which requires **intensive public-private investments**.
- **Handling practices** like harvesting, precooling, cleaning and disinfecting, sorting and grading, packaging, storing, and transportation are playing an important role in maintaining quality and extending shelf-life.

- This highlight the role of **agricultural education** to disseminate the **best agricultural practices** including the postharvest operations for perishable products. That could raise their **knowledge**, improve their **skills and practices**, and change their attitudes to be more sustainable producers and users for the limited resources.
- Tomato **processing** could participate in reducing the percentage of PHL but it requires adopting an **incentive strategy** to support farmers getting the **varieties that satisfy processing requirements** and provide a fair price for tomato producers.

- Designing more efficient and appropriate intervention strategies aim reducing PHL in developing countries should taking into concern **cost-effectiveness**, simplicity of generalizing, and competency of generating increased profits for small stakeholders, to achieve sustainable FSC and improvement of the welfare of society.
- PHL has multidimensional downstream and upstream **environmental impacts**, which requires being analyzed with an **integrative approach and prevention efforts may have greater environmental benefits than recovery.**

- Regarding the environmental impacts, some farmers spray chemicals and **fungicides on the plants to sustain the freshness**, color and solidity of tomato fruits after harvest and maintain their shelf-life. That could lead to **food safety problems**, additional negative environmental impacts, and increasing production cost, which requires more research to evaluate the social, economic and environmental impacts of the various alternative interventions for reducing the PHL.

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Inputs

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Preparing for exporting

Packing and prepration Stations → High quality → Export

Packing and prepration Stations → Grade 2

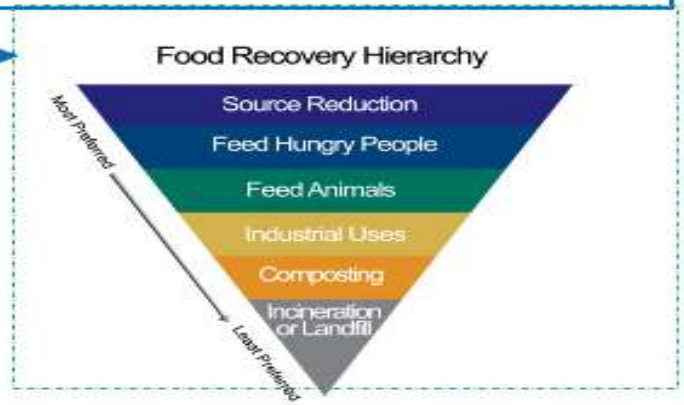
Demostic Market: 80% | 20% of production

Grade 1 | Grade 2

Local trader 8.6 ± 4.35 → Wholesealer 8.8 ± 3.12 → Processing 7.5 ± 0.56

Hawker 11.5 ± 0.52 | Vegetable grocery 11.5 ± 0.77 | Supermarket 8.6± 2.13

Consumed ← Consumer → Unconsumed



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