CITY REGION FOOD SYSTEM TOOLKIT

Assessing and planning resilient and sustainable city region food systems

Example: Food Flow Mapping

Brief description	The following example has been adapted from the pilot experience on food flow mapping developed in Colombo
Expected outcome	Understanding the functioning of food flow networks of the selected commodities across the CRFS and analyzing efficiencies or inefficiencies related to impacts from (individual or multiple) hazards.
Expected output	Consequent identification and recommendation of efficient/viable food flow networks to tackle food supply challenges during climate and human health crises by improving urban and rural linkages to increase resilience
Scale of application	Rapid scan assessment
Expertise required	Research and analysis
Examples of application	Colombo, Sri Lanka
Year of development	2022
Author(s)	Carmen Zuleta Ferrari
Relevant CRFS Handbook modules; related tools, examples and activities	Rapid scan module

Full description and justification

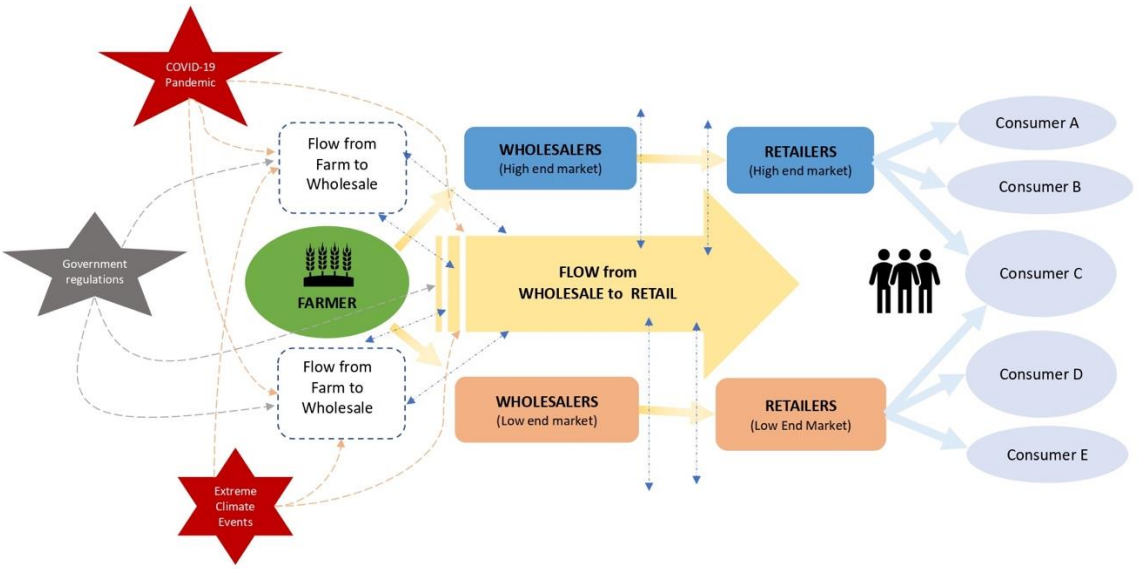
The following exercise was developed in Sri Lanka to identify weaknesses and strengths of the CRFS by understanding the functioning of food flows.

More specifically the study helped to:

1. Map the existing agrifood supply chains of the selected commodities
2. Record the climate-related & COVID-19 related risks, and inefficiencies prevailing at different nodes within each food supply chain / food flow network and interactions.
3. Determine, in the light of (1) and (2), the most efficient food distribution channels for the selected commodities, at a lower price with minimum losses.

The study used field based primary data collection to map distribution networks across the CRFS, identified the critical challenges along the supply chain nodes and proposed resolutions (logistics, storage, food safety, food miles, high prices, food loss/waste, food safety, markets, collection, distribution, etc.) - addressing vulnerable groups (e.g. urban poor/farmers with low margins).

Figure 1-Food flow mapping scheme, regulations, and hazards



Methodology for Food Flow Mapping in Colombo, Sri Lanka

(1) Selection of Commodities:

Food commodities were selected based on the prioritized items identified in the Risk and Vulnerability Assessment for Resilience Building in the Colombo City Region Food System (CRFS) (2021)[1], Overview of the Meat Industry in Sri Lanka - A Comprehensive Review (2016)[2], and Critical Analysis of the Status of Fruit Crops in Sri Lanka[3].

(2) Geographical Areas Covered:

The study covered all 9 Provinces and 25 administrative districts in Sri Lanka, to study the main inflows and outflows of the Colombo CRFS.

(3) Development of the Hypothetical Market Chain for the Selected Goods

A "Hypothetical Market Chain" was characterized including all possible players and their potential interrelationships for each commodity, based on the published information available and experiential learning of the researchers. The hypothetical market chain developed upgraded based on the consultations done at the provincial level meetings with the provincial government officers, Fact Finding Missions, Key Informant Surveys (KIS), and Focus Group Discussions (FGDs).

(4) Conceptual framework:

An economic model was developed to depict the behaviour of the value chain used in this study as the analytical framework is given below:

> Suppose that a food channel consists of three agents namely farmers, wholesaler and retailers who operate at the farm-gate, wholesale and retail markets. Farmers sell their produce to wholesalers at the farm-gate. Wholesalers purchase the produce at the farm-gate, add value and sell a value added product

[1] https://cgiar-my.sharepoint.com/:w:/g/personal/n_jayathilake_cgiar_org/EazbaZBTZblKhdbRyLhMdbgB07UzM6ASNhHebdmELjOdZQ?rtime=HDwMS7sT2Ug

[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4869538/#:~:text=In%20addition%2C%20chicken%20meat%20is,et%20al.%2C%202010).

[3] https://www.ishs.org/ishs-article/1278_37

to the retailer at the wholesale market. Retailers purchase the produce at the wholesale market, add value and sell a value added produce at the retailer market to the consumers who purchase the final product.

The objective of the farmers is to maximize profits.

$$Max\ \pi = TR - TC$$

Whereas, TR is Total Revenue and TC is Total Cost of production which is a function of quantity of production.

Suppose that the farmer produces two types of products using two different technologies and sell them in two different markets. The quality of the produce obtained from the two technologies is different. Denote Q_L as the low quality produce and Q_H as the high quality produce. Q_L is sold at FGP_L and Q_H is sold at FGP_H. The cost of productions of Q_L and Q_H are different and given by TC_L and TC_H.

The objective function of the farmer can be given by:

$$\pi = FGP_H Q_H + FGP_L Q_L - TC_H(Q_H) - TC_L(Q_H) - TC(Q_H + Q_L)$$

The supply of Q_H and Q_L can be obtained by differentiating the above equation by Q_H and Q_L, setting the first order conditions to zero and simultaneously solving the same.

$$Q_H = F\ (FGP_H, FGP_L, W_I, Z_H^F, Z_L^F\ )$$

$$Q_L = F\ (FGP_H, FGP_L, W_I, Z_H^F, Z_L^F\ )$$

Where W_M and Z are input prices the vector of exogenous variables.

The above functions indicate that supply level of each produce at the farm level is a function of farm-gate prices of the two products and input prices. The exogenous variables that determine supply levels may include available technologies to produce the two types of products and farmer characterstics.

The farmer sells the produce to the wholesaler. The objective of the wholesaler also is to maximize profits. The wholesaler purchases the produce from the farmer, adds value and sells to the retailer.

Consider that the wholesaler purchases Q_H from the farmer, produces V_H and sells it to the retailer at WSP_H. The objective function of the wholesaler is given by:

$$Max\ \pi = WSP_H.V_H(Q_H) - W_m.Q_H - FGP_H.Q_H$$

Where, W_m is the price of marketing functions. By differentiating the objective function by the respective quantity:

$$\frac{\partial \pi}{\partial Q_H} = WSP_H.\frac{\partial V_H}{\partial Q_H} - W_M - FGP_H = 0$$

Demand for the Q_H and supply of V_H can be obtained by solving the above function. They are given by:

$$Q_H^D = F\ (WSP_H, FGP_H, W_M\ , Z_H^W)$$

$$V_H^S = F\ (WSP_H, FGP_H, W_M\ , Z_H^W)$$

Similarly, demand and supply of the low quality produce can also be obtained.

$$Q_L^D = F\ (WSP_L, FGP_L, W_M\ , Z_L^W)$$

$$V_L^S = F\ (WSP_L, FGP_L, W_M\ , Z_L^W)$$

The above functions indicate that wholesale price, farm-gate price, prices of marketing services and exogenous factors (such as processing capacity and prices of packaging materials) affect the quantities demanded and supplied by the wholesalers.

The wholesaler sells the produce to the retailer at the wholesale market. The objective of the retailer also in to maximize profits. The retailer purchases the produce from the wholesaler, adds value and sells the final produce to the consumer.

Consider that the retailer purchases V_H from the wholesaler, produces C_H and sells it to the consumer at RP_H.

The objective function of the retailer is,

$$Max\ \pi = RP_H.C_H.(V_H) - W_S.V_H - WSP_H.V_H$$

Where W_S is price of storage.

$$\frac{\partial \pi}{\partial V_H} = RP_H.\frac{\partial C_H}{\partial V_H} - W_S - WSP_H = 0$$

Demand for the V_H and supply of C_H are given by

$$V_H^D = F\ (RP_H, WSP_H, W_S\ , Z_H^R)$$

$$C_H^S = F\ (RP_H, WSP_H, W_S\ , Z_H^R)$$

Similarly,

$$V_L^D = F\ (RP_L, WSP_L, W_S\ , Z_L^R)$$

$$C_L^S = F\ (RP_L, WSP_L, W_S\ , Z_L^R)$$

The above functions indicate that retail price, wholesale price, prices of storage services and exogenous factors (such as storage capacity and prices of storage services) affect the quantities demanded and supplied by the retailers.

In summary, the behavior of value chain actors are given by:

Two supply equations to show behavior of suppliers at the farm-level.

$$Q_H^S = F(FGP_H, FGP_L, W_I, Z_H^F, Z_L^F) \quad (1)$$

$$Q_L^S = F(FGP_H, FGP_L, W_I, Z_H^F, Z_L^F) \quad (2)$$

Two demand equations to show behavior of wholesalers at the farm-level.

$$Q_H^D = F(WSP_H, FGP_H, W_M, Z_H^W) \quad (3)$$

$$Q_L^D = F(WSP_L, FGP_L, W_M, Z_L^W) \quad (4)$$

Two supply equations to show behavior of wholesalers at the wholesale-level.

$$V_H^S = F(WSP_H, FGP_H, W_M, Z_H^W) \quad (5)$$

$$V_L^S = F(WSP_L, FGP_L, W_M, Z_L^W) \quad (6)$$

Two demand equations to show behavior of retailers at the wholesale-level.

$$V_H^D = F(RP_H, WSP_H, W_S, Z_H^R) \quad (7)$$

$$V_L^D = F(RP_L, WSP_L, W_S, Z_L^R) \quad (8)$$

Two supply equations to show behavior of retailers at the retail-level.

$$C_H^S = F(RP_H, WSP_H, W_S, Z_H^R) \quad (9)$$

$$C_L^S = F(RP_L, WSP_L, W_S, Z_L^R) \quad (10)$$

Once the proxies are selected to reflect different variables in the above functions, they can be econometrically estimated to ascertain the effects of variables included in the right hand side of the function on the supply of the products by the farmers and demand and supply by the wholesalers and retailers.

In particular, the variable Z, where superscripts show market level and subscripts show type of produce, can be used to accommodate various shocks to the system. For an example, the effects of COVID-19 shocks, climate shocks, and mitigation efforts of the government can be included where appropriate.

Further, when empirically estimated, a range of quality levels will have to be accounted rather than two types of products as denoted in the model as H and L. Accordingly, quality can be included as an exogenous variable of the model.

The exact measures to be computed and equations to be estimated can only be finalized upon computation of descriptive statistics of the data. A tentative list of proxies that can be used for the estimation are provided in Table 2 below.

(5) Development of indicators

Qualitative and quantitative measurement indicators were developed to determine the baseline to be used for determining inefficiencies in the food distribution channels.

Table 1 - The indicator framework used for the estimations

Variable	Notations	Proxies	Relevant equation
Supply at the farm level	Q_H^S, Q_L^S	Outflow of producers	1 and 2
Demand at the wholesale level	Q_H^D, Q_L^D	Inflow to wholesalers	3 and 4
Supply at the wholesale level	V_H^S, V_L^S	Outflow of wholesalers	5 and 6
Demand at the retail level	V_H^D, V_L^D	Inflow of retailers	7 and 8
Supply at the retail level	C_H^S, C_L^S	Outflow of retailers	9 and 10
Farm-gate price	FGP_H, FGP_L	Price of the outflow of farm producers	1, 2, 3, 4, 5 and 6
Wholesale price	WSP_H, WSP_L	Price of the inflow of wholesalers	3, 4, 5, 6, 7 and 8
Retail price	RP_H, RP_L	Price of the inflow of retailers	7, 8, 9 and 10
Prices of marketing services	W_M	Marketing costs	3, 4, 5, 6, 7 and 8
Prices of storage services	W_s	Storage costs	7, 8, 9 and 10
Z variables affecting farm-gate supply	Z_H^F, Z_L^F	Characteristics of farm producers	1 and 2
Z variables affecting wholesale demand	Z_H^W, Z_L^W	Characteristics of wholesalers	3 and 4

Z variables affecting wholesale supply	Z_H^W, Z_L^W	Characteristics of wholesalers	5 and 6
Z variables affecting retail demand	Z_H^R, Z_L^R	Characteristics of retailers	7 and 8
Z variables affecting retail supply	Z_H^R, Z_L^R	Characteristics of retailers	9 and 10

In addition, the performance of the food value chain can be presented using a number of indications in the measurements taken for the econometric estimation. The following identities can be used to construct indicators.

Marketing margins can be computed as follows.

1. Farm gate – Wholesale margins

$$MM_H^{FW} = WSP_H - FGP_H \quad (11)$$

$$MM_L^{FW} = WSP_L - FGP_L \quad (12)$$

2. Wholesale-retail margins

$$MM_H^{WR} = RP_H - WSP_H \quad (13)$$

$$MM_L^{WR} = RP_L - WSP_L \quad (14)$$

Where MM is the marketing margin. The first superscript shows the first market level and the second superscript shows the second market level. Food losses at different market levels can be computed as follows.

Farm-gate level:

$$Loss_H^{FW} = cf_H^{FW}.V_H^S - Q_H^D \quad (15)$$

$$Loss_L^{FW} = cf_L^{FW}.V_L^S - Q_L^D \quad (16)$$

Wholesale level:

$$Loss_H^{WR} = cf_H^{WR}.C_H^S - V_H^D \quad (17)$$

$$Loss_H^{WR} = cf_H^{WR}.C_L^S - V_L^D \quad (18)$$

Where, *cf* is conversion factor. The above model is graphically presented in the Figure 1 below.

(6) Food Flow Mapping

- The Food Flow Mapping exercise was based on an updated methodology adopted by FAO[4] in Kitwe, Zambia and in the Flood Flow Analysis completed by the "Practical Action" and "Janathakshan"[5] in Kesbawa, Sri Lanka.
- Food flow mapping incorporated a road network within each district and a province based on published information, and food that bypass public marketplaces and reaching warehouses, restaurants or consumers directly, as indicated by Karg et al[6].
- The Food Flow Mapping in Sri Lanka for the selected commodities were carried out using information collected through the Questionnaire Survey, Fact Finding Visits (FFVs), Key

[4] http://www.fao.org/in-action/food-for-cities-programme/toolkit/crfs-scan/characterisation-of-the-crfs/food-flow-mapping/en/
[5] https://ruaf.org/assets/2020/02/ReportofthefoodflowmappingKesbewaurbanarea.pdf
[6] Karg, H.; Drechsel, Pay; Akoto-Dans, E. K.; Glaser, R.; Nyarko, G.; Buerkert, A. 2016. Foodsheds and city region food systems in two West African cities. Sustainability, 8(12):1-32. doi: 10.3390/su8121175

Informant Surveys (KIS), and Focus Group Discussions (FGD) by engaging officials from the government, private sector agencies and farmers, and administering a pre-tested structured questionnaire-based survey. The different categories of stakeholders involved in the study will be as follows:

(a) State Agencies: District Director of Agriculture, Development Officers of the Department of Agrarian Development, Agricultural Instructor, Agriculture Research and Production Assistants.

(b) Private Sector Agencies: Management of the Dedicated / District Economic Centers, Logistic Service Providers, Whole sellers, Traders, Supermarkets.

(c) Community Groups: Farmer Organizations, Consumer groups.

- The FFVs, KIS and FGDs helped to upgrade the Hypothetical Market Chain/Food Flow, identifying the major issues related to the food flow within and outside the district, and details of the market places and food distribution channels.

- The data collection will be initiated from the key wholesale market places for the respective food commodities (e.g. Dedicated Economic Centers for fruits and vegetables, Peliyagoda Fish Market for marine fish, and other designated markets). Based on this Purposive Sampling strategy, Snowball Sampling Techniques will be applied thereafter to identify the remaining middle-stream towards the downstream and upstream.

- The food flow path mapping framework includes data collection (primary and secondary), mapping using GIS software, Spatial analysis, and evaluation as given below and in Figure 2.

(a) DATA collection

1. Through questionnaire survey
2. Supporting axillary spatial and non-spatial data
3. Data developed through GIS modeling

(b) GIS Mapping

1. Location point map
2. Attribute incorporation
3. Commodity wise mapping

(c) Spatial Analysis

1. Connectivity Development
2. Zone mapping
3. Inflow/ outflow assigning

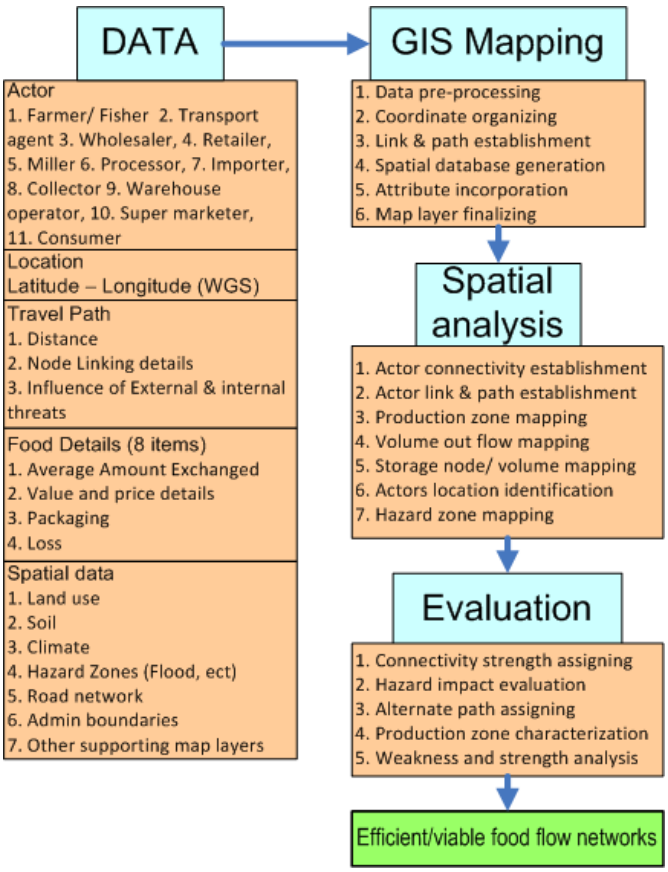
(d) Evaluation

1. Map interpretation & recommendation

- The production zones, especially for crops were identified using land use maps (efforts are being made to identify the productions zones for animal-based products using the national y available maps

- The high potential areas for each commodity were identified using the regional production statistics
- The market structures, including super markets of Sri Lanka was identified using secondary data, and the informal markets were identified using the survey questionnaire.
- The estimated commodity losses and changes in food flow paths based on climate change and human-health pandemic such as Covid-19 were also assessed and mapped using survey questionnaire, FGDs, etc.
- Food flow sketches were developed for each commodity within each district, based on the questionnaire survey and enumerators observations to support the food flow mapping exercise using the GIS software.
- The Mapping Tools depicted maps to elaborate the Subsystems of 'Political' (i.e. public policies, laws, rules and regulations etc.), 'Information & Services' (research, extension, finance, logistics etc.), 'Operational' (actors, institutions on production to consumer), and 'Natural Resources' (soil, water, biodiversity etc.) in particular.
- The placement of each player on the agri-food value/supply chain was done on a grid of relative 'Power' and 'Impact' as those would best explain the 'Current Situation Map' of those selected food commodities and facilitate the interpretations on the anticipated future structures systematically.

Figure 2 - Food Flow mapping Framework



(7) Survey Questionnaire – Primary Data Collection

- Primary data collection was commenced focusing on the large wholesale markets ("hubs") to help the researchers to move along the 'spokes' as directed by the respondents in the hub. The spokes were spread across the country to cover the 25 districts. Information collected through the questionnaire survey were in relation to the logistics, storage, food safety, food miles, food prices, food loss/waste, food safety, markets, collection, distribution, etc. for the estimation. The study sample included the vulnerable groups (e.g. urban poor and farmers with lower economic returns)
- The responses for the question guide used to gather data were analyzed to determine the characteristics of the respondents, the marketing functions they perform, constraints faced by them along the supply chain that hinder provision of a better service, potential interventions (both regulatory and facilitative policy, including investments and institutional set-up) that the government can work on to improve the situation.

Criteria adopted to establish the most prominent food flow paths

(1) The key player in the food flow pathways of seven commodities were identified based on the survey questionnaire administered in 25 districts across 9 provinces in Sri Lanka. Some players were categorized into one group as a single player performed many roles in majority of the occasions in some specific commodities.

   a. Paddy: Farmer, Collector/Transporter, Miller/Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer
   b. Maize: Farmer, Collector/Transporter, Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer
   c. Bean: Farmer, Farmer, Collector/Transporter, Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer
   d. Potato: Farmer, Collector/Transporter, Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer
   e. Banana: Farmer, Collector/Transporter, Wholesaler, Retailer (including supermarkets), and Consumer
   f. Chicken: Farmer, Collector/Transporter, Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer
   g. Marine Fish: Fisher, Collector/Transporter, Warehouse/Processor, Wholesaler, Retailer (including supermarkets), and Consumer

(2) The data were tabulated in MS Excel sheets at provincial level and considered for descriptive analysis. The data tabulated at the district level were considered for GIS mapping of the food flows. The GIS maps presented will identify the overall food miles, and changes in food prices of food losses across each segment of transactions from farmer to consumer.

(3) Based on the snowball sampling technique adopted for each commodity, starting from the main markets for each commodity in each district within a province, all possible combinations of transaction along the value chain that comprises of three players (two when the respondent was a farmer or when there were missing values) were considered for the descriptive analysis. Some examples for such transactions are given below:

Examples for the closest connectivity of transaction between two players:

Farmer to Transporter

Wholesaler to Retailer

Miller/Processor to Wholesaler

Examples for the closest connectivity of transaction among three players

Farmer to Miller/Processor to Retailer

Wholesaler to Retailer to Consumer

Transporter to Retailer to Consumer

(4) Consideration of such transactions can be used in developing the full chain of transactions at a scenario analysis in a given commodity across the country (note: The district, provincial and national level transactions were captured in the food flow mapping exercise)

(5) The missing links in the descriptive analysis were completed using the information gathered through focus group discussions with the key players in the food flow path of each commodity and enumerator observations.

(6) The study also analyzed the impact of Covid pandemic and climate change on selected components of the fold flow of the seven different commodities. In this exercise the transactions among three agents in the overall supply chain were considered based on the data available through the questionnaire survey, and the number of such combination was decided based on the commodity. The sub components in the food flow such as transport, storage, sorting, packaging, and labelling were considered to understand how such scenarios (pandemic and climate change) would have impacted such processes.

(7) Analysis of the resilience of different transactions to Climate Shocks and Pandemics such as Covid-19 was done by selecting the transactions that had most number of occurrence in food flow path of a given commodity. For easiness in explanation, the transaction among three actors having at least 5 observations based on the survey questionnaire and the food flow paths developed were selected and identified as the “Most Common Transaction Segments”. The number of most common transactions segments, thus, varied depending on the commodity studied.

(8) The final results of such analysis is provided for each crop for two scenarios captured from the survey questionnaire, (a) Pre-Covid and (b) During Covid (at the time when the survey questionnaire was administered)

(9) The descriptive analysis of the questionnaire survey is done based on the most common three-actor transactions. The three-actor transactions were considered most effective to describe the survey results due to the snowball sampling technique in the study, which always consider a nodal point with an actor forward (outflow) and behind (inflow) at a given time. Hence, such ;n; number of three-actor transactions resulted in from the survey for different crops were considered for the descriptive analysis.

(10) The quantitative analysis captured information from the questionnaire survey, focus group discussions, available secondary data, and expert consultation with the government and private sector organizations, and interviews with farmer organizations. The actors codes identified in the transactions are as follows

A Farmer

B Collector/Transporter

C Warehouse/Processor

D Wholesaler

E Retailer

F Consumer