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RESEARCH STUDY

GREENING VALUE CHAINS: UNDERSTANDING THE FOOD SAFETY CHALLENGES & SUSTAINABLY REDUCING FOOD LOSS & WASTE

Greening Value Chains: Understanding the Food Safety Challenges & Sustainably Reducing Food Loss and Waste

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Disclaimer

The information, data, methods and results presented in this study are prepared and interpreted by the authors of this study. The data represent both primary and secondary data which were collected by the Integrated Dairy Research Network team (www.idrn-dairy.org)

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Abbreviation

SL No	Abbreviation	Full Name
1	BAU	Bangladesh Agricultural University
2	BSTI	Bangladesh Standard and Testing Institute
3	BVC	Beef Value Chain
4	BVC	Beef Value Chain
5	CF	Carbon Footprint
6	CMP	Cost of Milk production
7	COMPO	Cost of milk production only
8	CP	Consumer Price
9	CSA	Climate-Smart Approach
10	DVC	Dairy Value Chain
11	DVC	Dairy Value Chain
12	FAO	Food and Agricultural Organizations
13	FP	Feed Price
14	GBVC	Green Beef Value Chain
15	GDVC	Green Dairy Value Chain
16	GHVC	Green Horticulture Value Chain
17	HVC	Horticulture Value Chain
18	HVC	Horticultural Value Chain
19	IBRN	Integrated Beef Research Network
20	IDRN	Integrated Dairy Research Network
21	IFCN	International Farm Comparison Network
22	MP	Milk Price
23	WF	Water Footprint

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Executive summary

Background

The Covid-19 pandemic globally reinvented the opportunity and potential of Agriculture to be the most resilient and important sector within the food sector. Amidst this, the sector faces challenges in safety, quality and wastage during production, processing, transportation, marketing, and consumption. The increasing concern on food safety, quality and reduction of greenhouse gas emissions are the key drivers for transforming the existing production to the new system of production, which entails the introduction of Greening Value Chains. The introduction of Green to the entire value chain perspective is therefore a key area for sustainable development. Among the agricultural commodity, dairy, beef and horticulture (fruits and vegetables) are predominant for nutrition, economics, health and environment.

Green Food Value Chain (GFVC)

The value chain is linked with increasing productivity and sustainability due to the fact that increasing domestic food production (milk, beef and horticulture) is associated with three key pillars: 1) Better functioning of the value chain; (including now, turning towards Green Value Chains); 2) Competitive environment among the farmers and processors; and 3) Congenial policy decisions. However, maintaining the food value chain is a complex task considering the ever changing consumption patterns and increasing concern for food quality and safety and environmental pollution problems. To take the food sector forward while focusing on the safety, quality and reduction of food loss, the introduction and execution of the Green Value Chain concept is highly impactful for sustainable and climate solutions for future production to consumption approach. Keeping this purview, this study aims to contribute towards mapping the green existing and proposed green value chain with a view to reduce food wastage, provide a framework for safety as well as quality assurances within the value chain. This study further, identifies the challenges, and proposes recommendations to overcome those challenges and develop a catalogue for greening the food value chain.

Methodology

The methodology applied in this study is holistic in nature and combines data, methods, models, expert opinion (modified Delphi Technique), stakeholders' perception (Focus group discussion). The data has been compiled from the Integrated Dairy Research Network's (IDRN) dairy sector database and a number of sources are from secondary data. The concept of network which includes the transect survey, are conducted per month as a regular activity of the network, was also applied. The model that was applied for the dairy (+ partly for beef) is the Technology Impact Policy Impact Calculations (TIPICAL) Model; for the beef sector, the newly on-going database under the Department of Animal Nutrition was utilized. In regards to horticulture, secondary data was mostly used.

Value chain and food production system

Critical synthesis of the various studies on dairy/beef/ horticulture value chains reflected that each of the study focused on specific interests and in some cases multi-level and stakeholder value chains were depicted. The major knowledge gap was that none of the value chain study in Bangladesh focused on the Green Concept and this is quite logical, as the concept of green

is new and innovative to the food system. In case of the dairy value chain, the farmers are marketed by both formal and informal marketing chain. In the formal sector, the milk delivered to the processors is only 2.4% in Bangladesh against the global level delivery level of 68% to the formal processors.

The existing traditional marketing channel of beef cattle majorly consists of beef farmers or fatteners, traders or middlemen or both and consumers. However, direct selling of beef cattle from farmers to consumers hardly occur. Additionally, import from neighboring countries (India, Nepal and Myanmar) in regards to beef cattle especially during Eid-ul-Adha is another minor component of the traditional beef marketing channel. In case of the horticulture value chain, several categories of traders known as middlemen are involved in the value chains of horticultural products (fruits and vegetables) in Bangladesh. In most cases, the marketing involves local traders (foria), commission agents/large traders (aratdar), wholesalers, and retailers. Finally, the results obtained from the study focused on value chains are well accepted and provide multi-dimensions to take actions points for further development.

Challenges on food quality, safety, wastage and greening the value chain

The food sector is under challenges as the safety, quality and the greening concept is currently not well addressed within the production system and upward linkages (processing, distribution, marketing, as well as consumption). For dairy, the concept of green was evaluated using the Farm Simulation Model Approach but was done only for dairy (as the data is not available for the other two sectors: beef and horticulture); it was found that improvement in the management (including feeds and feeding system improvement, fertilizer changes, feed composition/ration) was the key driver for reducing the greenhouse gas emissions and thus towards increasing the green element in the dairy farms. However, this was associated with increasing costs of milk production to maintain a green dairy farm. At the same time, farm resilience has increased as the operating profit margin has increased. Unlike dairy, beef farming, which is transforming from beef fattening to beef farming is also a growing sector. The demand for beef cattle has two to three seasonal picks (Eid-ul Azha, fasting days followed by Eid-ul Fitre and festivals during winter). The beef supply is highly volatile. The beef value chain is still in the traditional phase where the traders and middlemen dominate the beef cattle value chain. The import of beef cattle is still taking place but the process of import is not well recognized.

Green/Climate friendly solutions

The concept of green in this sector is relatively unutilized and not yet fully explored. There are some clear findings that show that markets cannot do it alone when it comes to greening the food value chains. There is a need for not only green demand and raised awareness among consumers but also long-term perspectives and investment is required from other market players such as manufacturers, middlemen, processors, the government, etc. Furthermore, evaluation of various interventions strategies (*such as input use for sustainable production, management practices, distribution system, consumer's perception/ awareness and economics of the value chain*) for optimizing the greening value chain, food security, food safety and food wastage for dairy, beef and horticultural products are required. In relation to the food safety, quality and food loss, it is revealed that farmers are mostly the starting point to take initiatives for ensuring the quality and reduce loss. The loss is substantially higher in fruits and vegetables in comparison with beef and dairy. The implication of this study's results are significant in a sense that the results can be integrated with the future change in the farming practices (keeping

options for the processing, distribution, marketing and consumption) towards achieving a green farming system, thus establishing green value chains in Bangladesh.

Way forward and policy implications

The results from this study revealed that transitioning from the existing value chain to a greener value chain would require making changes in the entire value chain. The food safety, quality and food loss in dairy, beef and horticulture were also revealed, based on the available information; for quantification of the actual loss in the various segments of the value chain, there is a need to further expedite. The transition from traditional to green value chains for producing safe and quality products for the consumers is to be ensured following the concept of the Rio Marker. The implication of this study can also be aligned to the strategic goal of the Danish Government who eventually would like to fully green Denmark and secondly, would also like to extend the cooperation on an international scale.

Keywords: Value chain, dairy, beef, horticulture, green, Bangladesh. Food safety, quality and food loss

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1. Context, background and problem statement

1.1 Context and background

As an agro-based country, a series of food value chain systems are operated daily in Bangladesh. Feeding more than 160 million mouths is solely dependent on those daily ongoing national and international food value chain systems. However, maintaining the food value chain is a complex task considering the ever changing consumption patterns and increasing concern for food quality and safety (Delloite, 2016) and environmental pollution problems (Hilmi, 2020).

Moreover, several factors make the systems even more challenging to be climate-friendly, such as extensive use of pesticides or antibiotics during the production stage of food products, improper post-harvest raw materials processing, and missing value addition, due to lack of proper knowledge of processing etc. Those aforementioned problems lead to a major problem namely food wastage, even before the products reach the consumer. According to the United Nations (UN), around 14% of food produced is lost between harvest and retail. In comparison, an estimated 17% of total global food production is wasted afterwards (11% in households, 5% in the food service and 2% in retail). The per capita food wastage at the global level is 74 kg/year. In Bangladesh, food wastage recorded is 65 kg/year per capita.

It is alarming that 8-10% of global emissions are associated with unused or wasted food, which affects our environment. Therefore, we need a smart system development to solve food security and safety issues and acknowledge environmental pollution.

Green food value chain (GFVC) is a well-developed perspective that allows initiation that can be taken on the major food value chain system activities with a systematic and holistic climate-smart focus on the environmental perspective (Hilmi, 2020). The base of the GFVC concept mainly focuses on two essential subjects 1) sustainable development with follow-up topics like the green economy, green growth and the cyclic or circular economy as it is implemented to the agricultural and other food section and 2) development approach in the existing food value chain (Loconto et al., 2014).

1.2 Problem statement

The food sector has been facing multiple problems due to various factors and multi-section actions. The transition of the food sector towards safety and quality, as with the increasing concern of the consumer’s preference and increasing economic growth, has created the opportunity for enhancing the growth of the sector. To make the food sector, safe and quality full, along with decreasing the loss of the food towards achieving the green food sector, the sector has been facing a number of problems which are of high interest for the researchers. It is imperative to tackle those problems and make the sector greener. In a nutshell, the sector is facing the following problems:

1.2.1 Food wastage

A significant amount of foods are produced but not consumed by humans, which negatively impacts the global environment and economic and social loss (UNEP, 2021). Food waste has become the major contributing factor to the world's three biggest problems: climate change, nature and biodiversity loss and environmental pollution due to creating difficulties in waste

management, aggravating food insecurity. According to UNEP (2021), if the total food wastage and loss are considered as a country, that would be the highest greenhouse gas producing country in the world. Therefore, UN sustainable development goal 12.3 intends to achieve food waste and food loss and lower to it at least half of the current amount by 2030.

1.2.2 Inefficient food value chain

Despite all the aspects like producing, harvesting and process and manufacturing other products, it is necessary to maintain the efficiency of the different food value chains to achieve global food security (Horton et al., 2019). Inefficiency in the food value chain leads to food loss and food waste in every component of the food value chain (e.g. producer, processor, distributor and consumer). Therefore, identifying the causes of inefficiencies and rectifying them is required for the smooth and sustainable maintenance of the food supply chain from field to fork.

1.2.3 Lack of value addition

One effective way to increase profit and reduce food loss and food waste is value addition. However, value addition needs to be done only with consideration of consumer health. Overusing different preservatives, growth promoters, antibiotics etc., might increase production and profit; however, the consumer faces a dangerous threat of deteriorating their health from present to the upcoming future. Therefore, efficient and consumer-friendly value addition needs to be considered.

1.2.4 Food safety and quality

The food safety issue is one of the biggest challenges in any step of the food value chain process, as it is subjected to various challenges (CDC, 2020), such as

- Transformation of food production, processing and supply. In addition, importing of food from outside countries
- Environment deterioration consequentially leads to more chance of food contamination
- The different outbreaks of contamination and diseases
- Resistance to new and evolving bacteria and toxic substances
- Transformation of consumer perception and preferences
- Changes in the tests that detect foodborne diseases

1.2.5 Lack of Greening concept

The concept of greening in the food sector is new and innovative to the case of Bangladesh's food sector although safe production, antibiotic free and organic production are in the agenda for food production. The greening concept implies that production to consumption is taking place while caring for the environment and safety and quality issues are also ensured.

1.3 Justification of this study

With the increasing demand for food for the overgrowing population, it is necessary to maintain an efficient food value chain with a significant focus to reduce food loss and food waste, to save the environment for the present and future generations. Further value needs to be added to the produced food to fulfil the satisfaction of consumers with minimum impact on the environment.

Global food systems, which are influenced by the growing human population and climate change phenomenon, have a substantial impact on it. The situation is worsened in the developing countries like Bangladesh compared to the developed countries. Food systems are integral to human health as well as sustainability of the planet (Fanzo et al. 2021). Increasing food demand often involves destruction or overexploitation of non-renewable resources such as land and water (Marc and Yoshihide, 2019). Extra burden on these resources results into environmental degradation. In such an alarming situation, green production strategies/ activities along the value chain can play a pivotal role to meet the global food demand without compromising environmental integrity and human health (Kaswan et al. 2019).

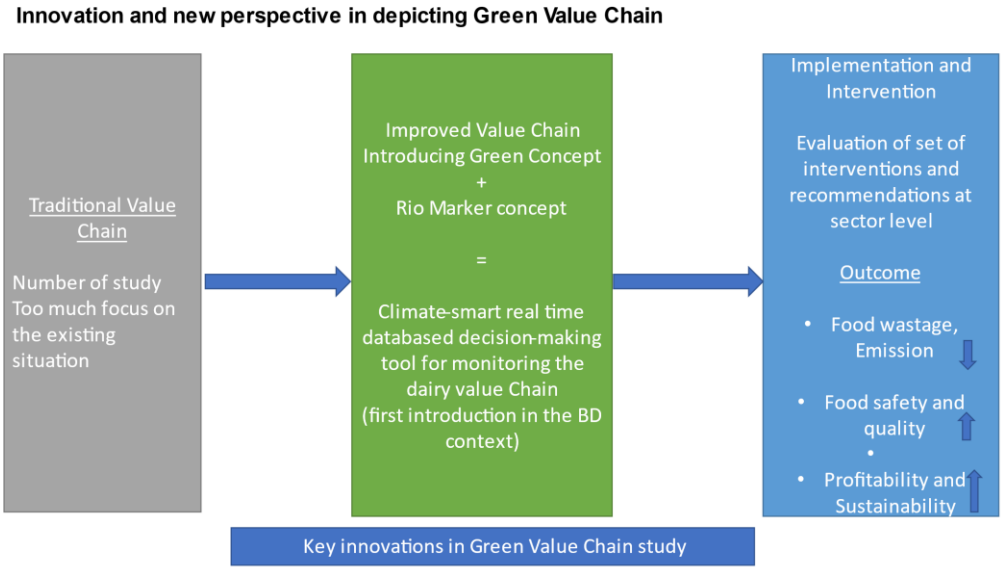


Figure 1. Innovation of the Component of the Green food value chain and its possible impact to the food sector

Traditional value chain analysis focused largely on in-house operations, large number of middle men involvement and overlooked the environment and health issues of human beings. These considerations remain critical, but today's climate change dynamic demands a more holistic view (considering environment and health) of the entire agri-food value chain. Improved food value chain should consider the environmental component for sustainable food value chains and how this can contribute to the reduction of the environmental footprint as a result of food chain processes, operations and transactions. Such strategies relate to carbon and water footprints, for example, as well as food waste and loss prevention, soil, ecosystem services and biodiversity conservation (Hilmi, 2020).

The key motivation for this study is focusing on greening the food sector as an ultimate goal and lies on the fact that changes in the production system and transition from the traditional food value chain toward the green value chain, is expected to have a positive impact on the food safety, quality and food loss which is depicted in Figure 1.

Typically, the food value chain approach is linear in nature, the process of adding value from farm to fork, and with the new focus and integration of greening food value chains, provide for a more holistic and circular view of how in reality food value chains operate in the context of

the natural, social and economic environments (Hilmi, 2020). The concept of circularity within food value chains finds its foundations in the subject matter area of the circular economy. The circular economy look at flows that regenerate and provide new business models, these new business models creating value in new ways (Ellen MacArthur foundation, 2013) considering the food wastage, emission, food safety and quality, and profitability and sustainability.

1.4 Scope and objective of this study

1.4.1 Scope of this study

This study demonstrates to answer the two important research questions:

- Can the concept of green be incorporated into the existing food value chain to reduce food loss and increasing food safety and quality in Bangladesh?
- Based on the Rio-marker and green concept, is it possible to combine the food safety challenges to maintain efficient value-added food value chain systems in Bangladesh?

However, considering the time frame, covid-19 travel restrictions and resources available in one hand and on the other hand, addressing the most relevant food sector that are driving the nutrition security in Bangladesh, this study is restricted to three sectors: Dairy, Beef and Horticulture (Fruits and Vegetables). This has enabled the authors to dive into three sectors in order to develop the catalogue for defining and implementation of the green concept in those three sectors in Bangladesh. However, considering the link with international collaboration, this study includes the Rio-markets concept of the OECD with specific interest of the Danish agri-food sector which has targeted to reduce greenhouse gas emissions by 70% in 2030. This study also emphasized on the food safety, food quality and food loss within the value chain in Dairy, Beef and Horticulture.

1.4.2 Objective of this study

The study aims to contribute towards the reduction in food wastage, provide safety/quality assurances in the value chain, identify gaps and improve the processes in the value chain. This will be to ensure a safe and traceable value chain with less wastage, resulting in healthy and more quality products to consumers. Considering the food systems approach, this study has focused on two important sectors, Agriculture and Livestock. Within livestock, the dairy and beef value chain and within agriculture, the horticultural value chain was selected. This will be to ensure a safe and traceable value chain with less wastage, resulting in healthy and more quality milk, beef and fruits and vegetables products movement from producers to the consumers. The specific objectives are:

- Mapping and identification needs to be initiated to highlight the overview of the food production and challenges in Bangladesh
- Identify a list of the most relevant value chains in Bangladesh with specific focus on dairy, beef and horticulture
- To address safety and quality issues and recommendations to tackle the challenges embedded within the dairy, beef and horticulture value chain
- To propose a catalogue of green and climate friendly solutions in dairy, beef and horticulture based on the identification of the challenges

The study is a step wise approach that is undertaken in phases where the first phase is identification and mapping with an overview into produce / production issues, safety/quality challenges and recommendations for implementation of climate friendly / green best practices and solutions which are expected to be implemented in the second phase (application interventions at the field).

Thus, this study is equally to be benefitted by Bangladesh and Denmark. Bangladesh would find the existing status of dairy, beef and horticulture sector in respect to the green concept while Denmark would be able to define the next strategy by the Government of Denmark for Denmark and Bangladesh.

1.5 Report structure

This report consists of 4 sections, where section 1 is introductory describing the background and the context of the existing food systems, value chains, food wastage and food loss to set the scene for justifying this study. The scope and objectives and possible implication of this study are also explained in this section. Section 2 provides detailed methods, models and data generation and networking approach that were applied to fulfil the objectives of this study. This methodology was described in a more detailed manner so that possible replication or extrapolation is possible for other researchers. Section 3 is depicted in the key findings with four sub sections, each section reflecting one specific objective. Sub-section 1 provides the production systems and its related activities on food sector, while subsection 2 and 3 provides the mapping of the existing value chains along with the challenges each of the value chain is facing and some proposed recommendations for overcoming those challenges. Subsection 4 provides proposal on a catalogue for climate-smart solutions for greening the dairy, beef and horticulture space. This report ends with section 4 which provides the interpretative summary, conclusions and recommendations that are applicable for both Bangladesh and Denmark.

2. Methods and Approach

2.1 Understanding the TOR and agreement and making alignment with Rio Markers

The first inception meeting was held with Mr. Ali Mushtaq Butt (Commercial Counsellor, Head of Trade Mission and DANIDA Business) and his team member Mr. Sakib Muhammed Islam Chowdhury and we agreed on the proposed Terms of Reference (ToR) for execution of this study. As per the ToR, the key highlight of this study, is to identify how and to what extent the concept of Green might be improved through changing the farming practices and how does the changed farming practices increase the safety, quality and climate resilient food production in Bangladesh. The probable execution strategy of this study and resources are allocated to conduct this study. The study justification, scope of this study and objectives were set according to the TOR. However, the ToR was addressed in this study as much as possible except the case where some of the activities were affected by Covid-19 travel restrictions.

2.2 Team formation

In order to execute the study and bring the expected output, this study has brought four additional team members (Table 1) who are relevant to this study and has substantially contributed to increase the quality of the work.

Table 1: Key competence of the team member

SN	Team Members	Position	Specialties
1	Dr. Mst. Nadira Sultana PhD and Post doc in Germany on LCA based water and carbon footprint	Team Members	Climate and environmental aspect (water and carbon footprint)
2	Mr. Shafiqur Rahaman Shishir PhD Student, the University of Melbourne, Australia	Team Members	Feeds and feed processing and nutrition
3	Prof. Dr. Md. Harun Ar Rashid MSc in Sustainable Agriculture (Denmark) PhD in Plant & Environmental Sciences (UK) Postdoc in Horticulture (USA)	Team Members	Sustainability in Agriculture & Horticulture
4	Prof. Dr. Md. Salauddin Palash PhD in Agribusiness and Market chain (Germany)	Team Members	Business and market chain development in Livestock and Fisheries
5	Dr. Mohammad Mohi Uddin PhD and Post doc in Germany Associate Professor and Team Leader of the IDRN research group, BAU	Team Leader	Networking (Dairy, Beef)

2.3 Desk study

This study made a deep dive into the existing literature review to identify the knowledge base that has been made so far on the value chain study and the relevant study for dairy, beef and horticultural sector development. The emphasis was given for visualizing the gap between the

existing study and future needs while it also evaluated the Rio-marker concept to bring a holistic view on the concept of Green into the value chain for producing safe and quality products for the consumers.

2.4 Field study

For addressing the green value chain actors and strategies, a field survey to the Rangpur District was decided where the transect survey, focus group discussion (FGD) and stakeholders' perception were expected to be used as key tool. However, due to Covid-19 travel restrictions, alternative options were explored where the Networking Approach was applied in relation to the dairy value chain; this in turn provided the access to the required database that were used in this study. The Integrated Dairy Research Network (IDRN) database was used which was maintained for a four-year (48 months) horizon (January 2018 till December 2021) both at farm and sector level from >25 districts. In addition, the International Farm Comparison Network (IFCN) was also applied which allowed us the backward data since 1996 and also Technology Impact Policy Impact calculations (TIPICAL) Model.

For the Beef Value Chain, the field survey was done within the goal of the development of Integrated Beef Research Network (IBRN) under the Department of Animal Nutrition, Bangladesh Agricultural University. In both cases, the field survey data refers to December 2021. For Horticulture, it was mostly secondary data. Upon relaxation of covid-19 travel restrictions, a field study is envisioned and if so, then it is expected to incorporate the field survey data as well.

2.5 Data generation and validation: Application of the concept of Networking

This study applies the concept of the Integrated Dairy Research Network (IDRN) for team formation, data pooling, data validation and model selection. As this study comprises of three sectors, a multi-team approach along with multi-stakeholders' participation was ensured for getting the right result for execution of this study. Within this network approach, the data were collected using i) Transect survey, ii) Panel Help Survey and iii) Focus group discussion. Data was collected through an established and well-trained skilled database team who provides the data on a monthly basis. Furthermore, we designed a special questionnaire for collecting the data pertinent to this study. The data collected was validated with panel of experts. The stakeholder's analysis was applied for getting cross sector perception and future directions within the value chain. The stakeholder analysis was done in the district of Rangpur.

2.6 Modelling typical dairy farms for greening value chain

Utilizing the network concept, two typical farms were selected for simulation of the interventions and their impact on the typical farm in order to make a solution-oriented value chain catalogue for dairy (the most) and in a limited manner to beef. The application of the Farm Simulation Model was very helpful for identifying the interventions that would bring the various scenarios and their impact on specific indicators. The study done by Uddin et al., (2020) using the Farm Simulation Approach for estimating the impact of Covid-19 was highly relevant in this study. This study applies the methods developed by International Farm Comparison Network (IFCN) methodology which is calibrated to address the local dairy system by using the Integrated Dairy Research Network (IDRN) network approach.

The IFCN method consists of Typical Farm Approach and the Technological Impact Policy Impact Calculations (TIPICAL) Model (Uddin et a., 2010, Hagemann et al., 2011) Hemme et al., 2014, Sultana et al., 2015). The Farm Simulation Approach applied in the study done by Uddin et al., 2012 and Ndambi et al., 2009 and Uddin et al., 2020, was also applied in this study.

The selected two typical farms were BD-2 (Bangladesh 2 cow dairy farms) which represented the household farm (HH) and BD-14 (Bangladesh 14 cow dairy farms which represents family farms (FF) in Bangladesh. The HH and FF represents 82% of the total dairy farms in Bangladesh (Uddin et al., 2020).

The two typical farms were modelled as the "BD-2 Baseline HH" and "BD-14 Baseline FF" which were simulated for Interventions as "Feeding and Management Improvement" and considered as a way for greening the value chain (particularly from production side). The milk production is a highly important activity of the dairy value chain as 80% of the total costs incurred in production, 80% of the greenhouse gas emission is linked with milk production at farm level and 80% of the political decision is linked with milk production (IFCN, 2021). Therefore, this study has been following simulations which were modelled for understanding what might be taken as action points for making the dairy green. The description of the Baseline farms and Simulated Farms (IMS = Improved Management System) are depicted in Table 2

Table 2. Description of the typical farms used for modelling for green dairy farms (as a way for greening value chain)

Farm description	**Unit**	**BD-2-Baseline**	**BD-14-Baseline**	**BD-2-IMS**	**BD-14-IMS**
Country	txt	Bangladesh	Bangladesh	Bangladesh	Bangladesh
Region	txt	Central, north and northwest	Central, north and northwest	Central, north and northwest	Central, north and northwest
Data Period	month/year	January - December 2021	January - December 2021	January - December 2021	January - December 2021
Cows - Number	no.	2	14	2	14
Milk yield	kg ECM/year	927	1,262	996	1,303
Returns from dairy enterprise on total farm returns	%	62%	76%	66%	80%
Land base of the farm	ha	0.4	2.3	0.4	2.3
% grassland	%	13%	15%	25%	22%
% land rented	%	0%	0%	0%	0%
Labour input - total	1 LU=2100 h	0.8	2.5	0.9	2.3
Family labour input	1 LU=2100 h	0.4	0.5	0.4	0.5
Share of family labour on total labour	%	46%	19%	41%	20%

Farm description	Unit	BD-2-Baseline	BD-14-Baseline	BD-2-IMS	BD-14-IMS
Liabilities of the farm	1000 USD/year	0.1	0.4	0.1	0.6
% Liabilities of farm assets	%	0.7%	0.6%	0.8%	0.9%

BD-2 Baseline: Bangladesh 2 cow Baseline Household Farms, **BD-14 Baseline**: Bangladesh 14 cow Baseline Family Farms. **BD-2 IMS**: Bangladesh 2 cows simulated HH for improved Management system, **BD-14 IMS**: Bangladesh 14 cows simulated FF for Improved Management Systems

Improved Management systems includes Changes in the Feed ration to reduce both rice straw and green grass, increasing the quality of the ration (increasing Crude Protein and Metabolizable Energy), Increasing the feed price, increasing milk yield and milk price

ECM = Energy Corrected Milk (standardized to 4% fat and 3.3% Protein)

Using the data and model results as described in the table xx, the greenhouse gas emission (CO2 equivalent kg/kg Milk SCM) by applying partial Life Cycle Analysis (LCA) model of the IFCN (Hagemann et al., 2011) and water footprint estimation (H2O liter/kg Milk SCM) by applying the Global Water Footprint Model, developed by Sultana et al., 2015. The water footprint model was also based on the LCA.

As an indicator of green, the simulation model was applied to demonstrate as a case study for proposing a catalogue for climate friendly solutions for dairy. The total emission of greenhouse gas emission (kg CO_2 equivalent/100 kg ECM) and water footprint that were modelled using the IFCN carbon and water footprint model (developed by Hagemann et al., 2011 and Sultana et al., 2015) were estimated as baseline case and was then simulated at farm level by applying the improvement management practices, in order to estimate the potential decrease in the greenhouse gas emissions and also the water footprint, as a way to green the dairy sector.

Furthermore, the typical dairy farm is also modelled to estimate the costs required for reduction of greenhouse gas emissions and water footprint in order to define the sustainability of the greening concept to the case of Bangladesh. The higher costs of milk production are not likely to be sustainable, as the higher cost of milk production decreases its competitive position locally and globally and also decreases the cash flow for paying the cash costs for operating the dairy farm.

At the same pace, data is also limited for the Beef and Horticultural sector, which could be taken as next steps for a detailed field study to generate the pertaining data for analysis. The same approach can also be applied for the upstream of the value chain to see how greening could be possible (Processors, distributing and marketing) but this can be done once the required field survey is possible (particularly the stakeholder analysis), once Covid-19 restrictions are relaxed and travel becomes safe.

2.7 Data analysis

Data was analyzed using the Microsoft 365 Excel Family (Licensed version) and Technology Impact Policy Impact Calculations (TIPICAL) model version 5.6 software developed by International Farm Comparison Network (IFCN).

3. Key findings

3.1 Overview of the food production and challenges in Bangladesh

Bangladesh is marking 50 years since the glorious liberation in 1971 and has made graduate increment in economic growth, health, and food and nutrition security. Bangladesh has already attained lower middle-income country status in 2015 and planned to graduate to an upper middle-income country by 2031 and successively, become a prosperous high-income country by 2041 (GED, 2020). The government of Bangladesh has initiated the National Food and Nutrition Security Policy (NFNSP) (2020) and Plan of Action (2021-2030), recognizing the need for transformation of food systems (GoB, 2020). Food systems encompass all people, institutions and processes by which agricultural products are produced, processed and brought to consumers. Since Bangladesh's population is projected to reach 230-250 million by 2050, ta sustainable food production and distribution approach is necessary to over the challenges of food safety, quality and losses.

3.1.1 Production agriculture

Agriculture is a major driver of economic growth, contributing to 13.35% of GDP in 2019-20 and engaging 40.6% of the labour force (BER, 2020). Bangladesh is rich in crop, livestock and fisheries diversity. Improved and stress tolerant crop varieties, livestock strain and fish species have been developed by a dynamic agriculture research system. No success story is out of demerits. Therefore, in production agriculture, there are some issues that need to be addressed such as, excessive fertiliser and chemical use in food production, antibiotic and growth hormone use in livestock production, and food waste and loss due to inadequate management, transportation and mechanization process. Sustainable intensification, diversification, emissions reduction, and increasing resilience of production will be prioritized, in line with targets under SDGs 6, 13 and 15 (clean water and sanitation, climate action, life below water and life on land).

A large number of environmental impacts and product quality issues are linked to production agriculture and the consequences are associated with different sub sectors of agriculture such as crops, livestock and fisheries and way of production practices. For example, the measurement of environmental and quality/safety standards of crops varies from those associates with the production process of livestock. However, despite the intensity or the type of effects associated with a product, the design of its production is one of the most important stages of its life cycle (Achillas et al. 2019). As a consequence, the design of the production process directly affects its overall environmental and quality/safety footprint of the produce.

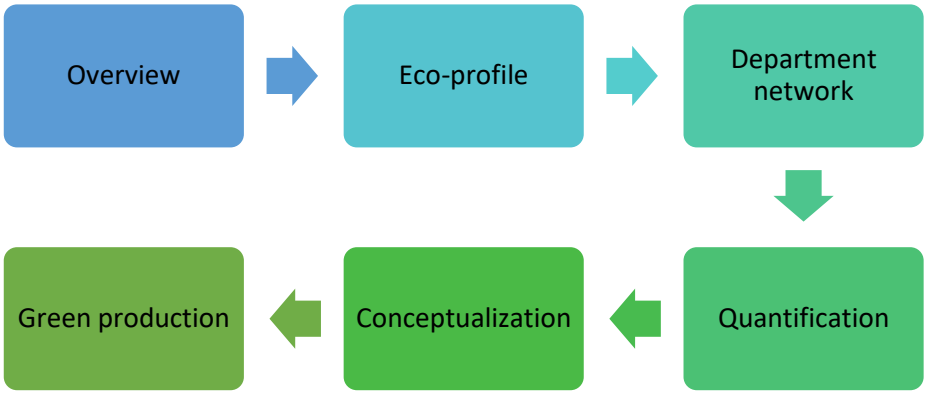


Figure 2. Stages of green production (Adapted from Achillas et al. 2019)

Figure 2 shows the stages of production (though Achillas et al. 2019 developed this model for manufacturing sector, but it is also applicable to production agriculture). The overview stage is probably the most important stage of the entire process. At this stage, an analysis of the production process and identification of all the individual stages is made. The following stage deals with data organization and categorization in order to create the ecological profile of the enterprises/certain products. In the production process, several departmental activities are inclined. In order to deal with the abuses, the individual departments of the production process must be identified, recorded and defined by the standard of procedures (Brugha & Zsuzsa, 2000). To engage in a green production procedure, a quantified life cycle assessment and environmental conceptualization of the product is necessary. Successful completion of the previous stages leads to the last stage of green production process.

Over the year, the supplies and variety of dairy, livestock and poultry products have increased. The relative abundance of poultry meat and eggs is undeniable. According to the Department of Livestock Services (DLS), egg, milk and meat production is 15.5 billion 9.4 MMT, and 7.26 MMT, respectively (GoB, 2019). Egg production covered an estimated 98.8% of domestic demand, while milk production covered only 66% of estimated domestic demand (GoB, 2019). On the other hand, in case of horticultural crops, the share to agricultural GDP, has increased over the period. It is claimed that horticulture sector generates more than half of the value addition in agriculture (FPMU, 2020).

3.1.2 Food production challenges

Production agriculture/ food production system is facing many problems. More commonly, rain fed farming system usages lower level of inputs than irrigated areas and it might be more efficient if integrated farming can be practiced. The agriculture sector of the country will have to face a lot of challenges in the near future. The most significant of those challenges are noted below:

- **Loss of arable land:** Gradual decrease of agricultural land is one of the major problems of agricultural sector of Bangladesh. Bangladesh has lost about 0.39% land per annum, and it rises to 0.72% when considering loss of prime crop land only (Quasem, 2011).

- **Sustainable use of resources and Sustainability:** There is no free lunch on earth, this statement is especially true for production agriculture. Growing more food to feed the growing population creates more pressure on natural resources, which affects the whole food systems severely including safety aspects of human life as the availability of agricultural land, water and overall climatic endowments are decreasing. For example, organic matter content of soils is much below the critical level of 1.5% (Karim, 1997); 25-30% of irrigation water is used by crops and the rest is lost due to faulty flood irrigation system (Karim, 1997; Mondal, 2005); 4-14% of rice yield in Bangladesh is lost every year by different insects/pests (Mondal, 2010). The strategy should be to increase production by making lesser use of critical inputs like land and water, and greater use of technologies. The sustainability of the food sector is key indicator for continuation of the growth of the food sector, in particular, dairy, beef and horticulture, which is the fundamental source for nutrition security. The social, economic, environmental and institutional -four different dimensions are leading to the sustainability parameter, which makes the value actors in a complex situation balance among those four indicators.
- **Farm mechanization:** In Bangladesh, though agriculture sector still consumes more than half of the labour force, it still faces a shortage of agricultural labour at peak seasons which sometimes creates a problem in the sector. Expansion of mechanization is needed to compensate the shortage of power, farm labour and the declining interest of young people to stay in agriculture.
- **Commercialization and diversification of Agriculture.** Agriculture is moving from a subsistence level farming to commercial level. In the wave of globalization, small holders need to be enabled to integrate in the markets to effectively contribute to the production of high value crops such as milk, meat, fish, vegetables and fruits (Rahman, 2017).
- **Technology dissemination.** Attaining research level yield and output in the field level of any new/improved agricultural technologies is difficult because of not following/accepting the recommended management practices. Therefore, it has remained an issue of concern for many years. Farmer's acceptance of a technology does not depend on the attributes of a technology, but on many socioeconomic factors associated with adoption of a technology (Rahman, 2017).
- **Inefficient marketing system.** Long/multi-layer marketing system forces unfair prices of agricultural commodities by the producer in one hand and at the same time, the consumer pays more without creating any extra marginal utility. Certain characteristics of agriculture such as perishability, seasonality, etc. require especial attention to make the system efficient.
- **Challenge of climate change impacts.** Agriculture in Bangladesh is still highly dependent on nature; and due to harsh behaviour of natural crops, these are sometimes damaged or they do not grow according to expectations. The country is the victim of climate change impacts such as sea level rise, low/high rainfall, unexpected temperature variation, change in seasonal humidity variation, etc. Atmospheric CO_2, CH_4, SO_2, N_2O, etc. are mainly responsible for temperature increase resulting in the rise of sea level. Temperature rises by 1.0^0C would inundate 18% area of Bangladesh as indicated by different studies (IPCC, 2007). Adverse climate effect significantly on food and fibre production, safety/quality and supply of the raw produce.

- **Adulterated/ tainted with toxic chemical.** Rampant use of chemicals, insecticides/ pesticides, antibiotic, growth hormone, additives/ preservatives, etc. adulterate the agri-food value chain which has a direct effect on human-life and indirect effects on environment.
- **Enhance agricultural research and development.** To increase agricultural productivity and production, research and development plays a crucial role in any sub-sector of agriculture. It is evident that the agriculture of Bangladesh has been suffering from low productivity, which shrinks the supply of the market and destabilises the market prices.

3.1.3 Government initiatives/ policies around production agriculture and food system

Bangladesh agriculture has moved from low productive agriculture to a food self-sufficient economy through the adoption of modern/diversified revolution technologies. At the same time, the food system is also transforming rapidly. The GOB is implementing different development projects/programs and developing different policies to keep the pace with the agricultural revolution. Some important activities are:

- Development of stress (flood, drought, salinity and high temperature) tolerant crop varieties.
- Introduction of crop zoning technology.
- Enhancement of extension activities to promote modern cultivation method/ disseminate new technologies at farmer level.
- Mechanization of agricultural activities such as sowing, planting, weeding, harvesting, thrashing, etc.
- Establishment of Agriculture Information and Communication Centre (AICC) at union level (low administrative level).
- Promotion of agriculture and agriculture-based services through mobile operators.
- Promotion of organic pest control method and organic agriculture activities.

Policies around food system:

- Perspective Plan of Bangladesh (2021-2041)
- Delta Plan for 100 Years (2030, 2041 & 2100) (water management)
- Voluntary review of SDGs by different ministries, being led by GED, Planning commission
- National Food Policy (2006)
- National Food Policy Plan of Action – NFP PoA (2008-2015)
- Country Investment Plan II (2021)
- National Social Security Strategy (NSSS) of Bangladesh (2015)
- Bangladesh Climate Change Strategy and Action Plan (2009)

3.2 Description of most relevant Value Chain within the food production system in Bangladesh

Within the Agricultural Food Production Systems, three value chains were listed using value chain mapping which are relevant and mostly contributing to nutrition security, where food safety and loss are highly important. The value chains are:

i) Dairy Value Chain
ii) Beef Value Chain
iii) Horticulture Value Chain

3.2.1 Dairy value chain

The dairy value chain in Bangladesh is widely discussed and addressed in various studies (Rahman et al., 2013; Oman et al., 2019; Quisumbing et al., 2013; Jabbar, 2010; World Vision, 2018; Islam, 2017; Oman et al., 2019; Heifer International, 2013; Kabir et al., 2018; Muzareba and Khondkar, 2021) which reveals that the results obtained from the study focused on value chains are well accepted and provide the multi-dimensions to take actions points for further Development. The review of the Dairy Value Chain Study in Bangladesh that were done so far done depicted in the Table 3 in order to provide their focus and identification of the knowledge gap within the DVC.

Table 3. Dairy Value Chain Study so far done in Bangladesh along with their focus

SL No.	Context of the Value Chain	Key focus	Authors	Year
1	Dairy Value Chain Development in Bangladesh with a Focus on the Northwest Region	Productivity, prodigality, policy	Jabbar	2010
2	Can Dairy Value-Chain Projects Change Gender Norms in Rural Bangladesh?	Gender improvement	Quisumbing et al.	2013
3	Dairy Value Chain in Bangladesh	Dairy value chain and supply chain + different models	Heifer International	2013
4	Analysis of dairy value chain and mapping of potential Solar Chiller Sites in North and South regions of Bangladesh	Solar energy driven Chiller Function	Islam	2017
5	Value Chain Assessment at National Level	Dairy Development	World Vision	2018
6	A study on Milk Value Chains for Poor People in Bangladesh	Dairy product quality	Kabir et al.	2018
7	The dairy and beef value chain in Bangladesh: Diagnostics, investment models and action plan for development and innovation	Dairy: milk production, processing and marketing	FAO-UNIDO	2019
8	Insights on Production End of the Dairy Value Chain in Bangladesh	Dairy Value chain actors and benefit	Muzareba and Khondkar	2021

Considering the milk production, processing, marketing system, and consumption and the concept of green dairy value chain (as new and innovative to the Bangladesh food sector), the value chain mapping is depicted in Figure 3.

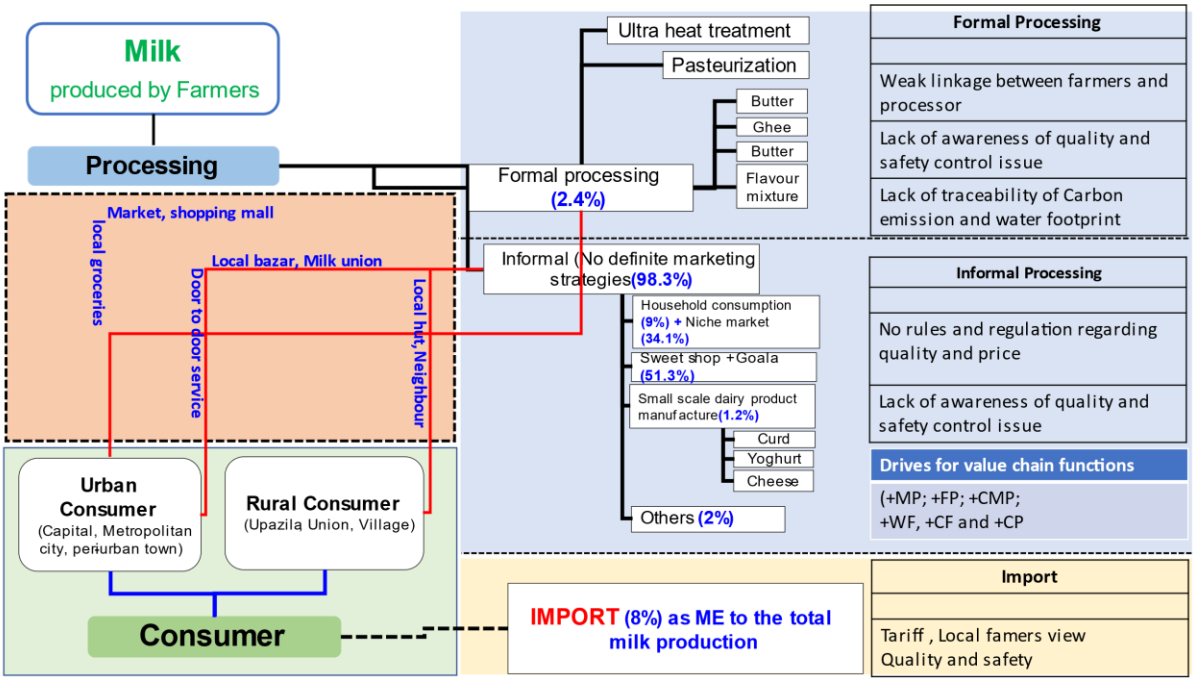


Figure 3: Mapping Dairy Value Chain in Bangladesh

Note: MP = Farmgate Milk Price; FP = Feed Price; CMP = Cost of milk production; CP = Consumer milk price (+ = high, - low compared with global price)

Critical synthesis of the various studies on the Dairy Value Chain reflected that each of the study focused on the specific interest and in some cases, multi-level and stakeholders value chains were depicted. The major knowledge gap was that none of the value chain study in Bangladesh focused on the Green Concept and this is quite logical, as this green concept is new and innovative to the food system. To combine both the green concept and to also make a comprehensive value chain covering the total actors and activities, this study provides a single value chain entailing multiple activities and actors which are depicted in Figure 3. This will further illustrate for the introduction of Green to the Dairy Value Chain.

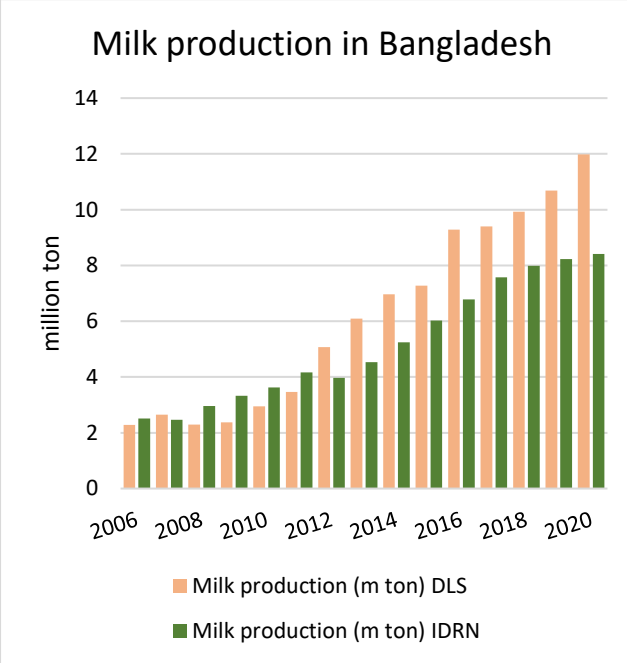
3.2.1.1 Dairy Farms, milk production and its development

The total dairy farms in Bangladesh stands at 1.52 million which are classified as household (small), family farm (medium) and business farm. This is based on two categories: on the total livestock unit/farm and total dairy cows (Lactating and Dry cow). According to IFCN, the dairy farms are classified globally into three categories: Household Farms (HH), Family Farms (FF) and Business Farms (BF) which are also adopted to Bangladesh (Uddin et al., 2020). The total household, family and business farms in Bangladesh, based on dairy unit, the share of the household (HH), family (FF) and business (BF) represents 74.7%, 23% and 2.3%, of the total farms in Bangladesh which corresponds to 1.14 million (11.4 lac), 0.35 million (3.5 lac) and 0.03 million (34960). The average milk yield is 6.05 kg/farm/day for household, for family farm, it is 10.59 kg/farm/day and for business farm it is 114 kg/farm/day

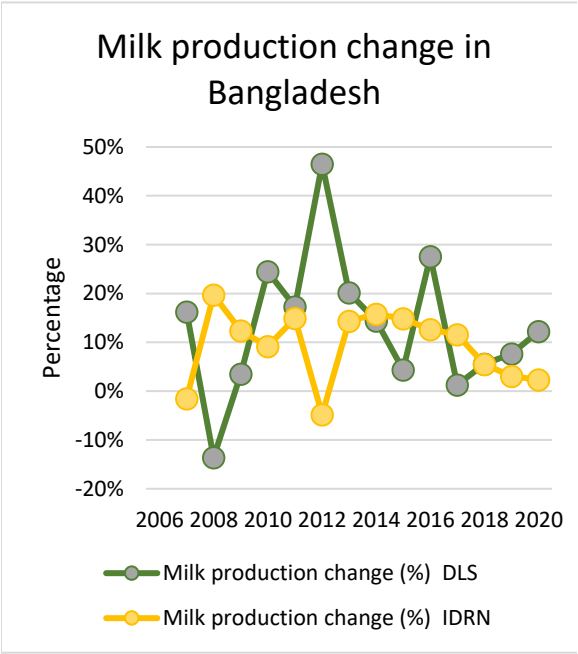
Bangladesh produces 11.98 million tons of milk while according to IDRN, the total milk production is 8.41 million ton in 2021 (DLS, 2021 and IDRN, 2021) and is ranked as 23rd in world milk production among 121 countries in 2021 which was on 25th in 2019 (IFCN, 2021). The milk production and its growth changes are depicted in Figure 4. The dairy sector has been

growing with an average growth of milk production of 14.4% per year from 2006 to 2020 (as per the DLS data) while the IDRN data reveals average growth for the same time 9.3%.

This indicates a strong progress of the dairy sector in Bangladesh mainly driven by the government initiatives on the implementation of the Livestock and Dairy Development Project (LDDP) with the financial support from World Bank (2019 - 2023). The number of dairy farms is estimated at 1.52 million. The milk price is +44% higher than the global milk price while the feed price was also very high (+41% higher than the world feed price) in January 2022 (IDRN, 2022)



Milk production over the year in Bangladesh (DLS vs IDRN)



Growth change in milk production in Bangladesh (DLS vs IDRN)

Figure 4: Milk production and growth change over the year in Bangladesh (DLS vs IDRN)

Considering the recent development (2015 - 2020), the milk production increased by 6,3% while the dairy farm number increased by 1.3%. Milk yield per cow increased by 5.5%. The average farm size increased from 2.7 cows/farm to 3.2 cows/farm. The top herd size class growth (21-25 cows/farm) during this time according to Cumulative Annual Growth Rate (CAGR) was 13%, which signifies the growth of local milk production. On the other hand, the regional share of the milk production growth from 2015 to 2020 was found in Rajshahi division as the highest (9.3%) and lowest in Mymensingh (0.9%). Bangladesh is still deficient in milk production and has not reached self-sufficiency. Considering the deterministic approach of demand (250 g milk per day per person) over the next 10 years, Bangladesh can reach self-sufficiency by 2030 (according to DLS data) but can reach 79% (according to IDRN data), if the demand become stochastic. Both DLS data and IDRN data showed that Bangladesh cannot self-sufficiency within 2030 (Uddin et al., 2020). This implies to evaluate the dairy value chain and its challenges to boost the milk production in Bangladesh.

3.2.1.2 Milk processing, distribution and marketing and consumption within Dairy Value Chain in Bangladesh

Formal Sector

The formal dairy sector comprises of i) Cooperatives Model (Bangladesh Milk Producers' Cooperatives Union Ltd. (Milkvita), ii) Private Milk processing Model, iii) Self production - Processing -Marketing Model (recent trend of Corporate Dairy Farm). The milk produced by the dairy farmers (located in rural, peri-urban and urban) end up to the consumers (Rural and Urban Consumers) in a distinct channel. The total milk is marketed through formal (1.7%) and informal channels (98.3%) according to DLS (2021) while according to IDRN (2021) the formal processing is 2.4%. This is much lower than the available literature or news published in the newspaper which might be true as there is no research available on processing profile in Bangladesh. The import represents 8% (as Milk Equivalent) to the total milk production of the country.

The milk produced by the farmers are marketed by both formal and informal marketing chains. In the formal sector, the milk delivered to the processors is only 2.4% against the global level delivery to the formal processors, which stands at 68%. This is much lower than comparison with India, Pakistan and Sri Lanka (60% milk is delivered). There are more than 12 processors, which collect milk from dairy farmers and processes into further dairy products. There is a recent tendency of growing corporate farms which produces and processes themselves. The top three milk collection agencies in Bangladesh are Milk vita, PRAN Dairy Ltd. and BRAC Dairy and Food Ltd; producing 1.1% of the total milk production in Bangladesh in 2021. The rest of the processors (in total 12) process 0.6%. The top 3 processors have 64% share of the formal milk marketing in Bangladesh.

Milk Vita, a booming business cooperative enterprise, has been collecting milk from 3084 primary village cooperative societies and subsequently processing and distributing the milk throughout the nation. Milk Vita built a network of almost 1,34,728 primary member farmers in 33 milk producing areas of 41 different districts of the country (Khaleduzzaman et al., 2021). The total milk collection by Milk Vita per year is 43 695 ton/year). At the same pace, PRAN Dairy Ltd. a sister concern of the PRAN-RFL Ltd. is the second largest processor in Bangladesh who collect and process 42,460 ton/year. The third processor is BRAC Dairy and Foods Ltd. who collect 41,600 ton/year.

Looking into the formal chain, pasteurized milk and Ultra High Temperature (UHT) milk, contributes to the major share of the total formal market. There is an increasing trend towards milk products (Butter, cheese, flavor mixture, sweet, chocolate). The manufacturing of powder milk during the peak season of the year (November to April) also drives the milk processing and milk supply in the country. The milk price is based on the fat percentage, although there are some other criteria for whether the milk is accepted or not, which are lactometer reading and some physical properties. The milk price based on the more holistic indicators is missing. Within the existing value chain activities, there is weak linkage between farmers and processors, the quality is very poor where there is no control as well as lack of awareness is distinct. Traceability is another key challenge for the growth of the formal sector. The farmers are afraid of delivering milk to the formal processors and try to maximize the opportunity to deliver their milk to the informal sector.

Informal sector

The informal milk marketing fall into household consumption (9%) and niche marketing (close to farm, nearby market and/or bazar, neighbor) which represents (25%). The major player in the informal market is the Sweetmeat processors and Goala (52%). It is also notable that small scale producers also process milk which is about 1.2%, particularly curd, yoghurt and local Chanan (similar to cheese). The informal sector is highly volatile in terms of availability, price and quality. There is no quality check except some physical evaluation by the consumers. This is the key point for intervention where it might be needed to standardize the milk price with the quality and there should be regulatory body for controlling this. This, once applied, benefit the consumers and might be the way to increase the trust between the farmers and consumers.

The milk collected in both formal and informal market are distributed to the consumers through retailers (in case of formal market) and directly by farmers to the consumers or/and farmers to middle men. There is limited research on milk demand and consumption in Bangladesh. However, the IFCN database for Bangladesh refers to the consumption of the milk at farm household level is 9% (1.08 million ton) per year. The milk price varies among national, formal and informal sector, where the farm gate and consumer milk price in the formal sector is 42 BDT/kg (0.4 USD/kg) and 74 BDT/kg (0.8 USD/kg), respectively. The same goes for informal sector 48 BDT/kg (0.55 USD/kg) and 58 (0.6 USD/Kg), respectively. The market coverage and distribution of the formal sector is limited only to the capital city, city corporation and municipalities areas and district level, which might need to be extended to the rural areas.

3.2.2 Beef Value Chain

Due to increasing demand for meat, beef fattening has become an important business for smallholder farmers in Bangladesh. Cattle and buffalo constitute a major proportion of livestock in agribusiness. Total meat intake in Bangladesh has been increasing significantly over the years, with a yearly growth rate of 26.51% per year (World vision, 2017). Meat production has steadily been growing from 1.26 million metric tons in fiscal year 2009-2010 and has multiplied more than seven times to 8.44 million metric tons in fiscal year 2020-2021 (DLS, 2021). Popular breeds for cattle production in Bangladesh are Red Chittagong, Pubna, Munshiganj, North Bengal grey, Red Sindhi, Sahiwal and Holstein Frysian cross cattle (DLS, 2021).

Table 4. Beef value chain study so far done in Bangladesh, along with their focus

SL No.	Context of the Value Chain	Key focus	Authors	Year
1	A Study on Beef Cattle Marketing in Bangladesh	Marketing channel	Nabi	1998
2	A Study on Beef Cattle Marketing in Bangladesh	Beef cattle marketing	Hossain and Chanda	2002
3	Beef Value Chain Study in Bangladesh	Smallholder production system, Value chain analysis, Strategies for sustainable livelihood	Hasanullah	2013
4	Value Chain Analysis of Beef Cattle in Selected Areas of Northern Bangladesh	Value chain actors, functions and relationship	Sarma et al.	2017
5	Value Chain Assessment at National Level for World Vision Bangladesh	Value chain, Assessment of regulatory environment, SWOT analysis	World Vision	2017
6	The dairy and beef value chain in Bangladesh: Diagnostics, investment models and action plan for development and innovation	Value chain, Opportunities for investment, Action plan for the development of the value chain	FAO-UNIDO	2019
7	Analysis of the beef value chain in Bangladesh - Towards a strategic action agenda for the Dhaka city corporations	Marketing channel, Food system	Kok, et al.	2021

Beef cattle production or to be precise beef cattle fattening has become popular in Bangladesh, especially in small scale farm level (Ahmed et al. 2010; Baset et al. 2003; Kamal et al. 2019). However, the profitability level of beef cattle production is not very promising due to various reasons, such as unscientific production system, fluctuation of feed and other input price and most importantly improper marketing channel (Ahmed et al. 2010; Kamal et al. 2019). The existing traditional marketing channel of beef cattle majorly consists of beef farmers or fatteners, traders or middle men or both and consumers (Figure 5). However, direct selling of beef cattle from farmers to consumer hardly occurs. Additionally, import from neighboring countries (India, Nepal and Myanmar) of beef cattle especially during Eid-ul-Adha is another minor component of traditional beef marketing channel. Although importation of beef or meat from outside Bangladesh is gradually slowing down recently.

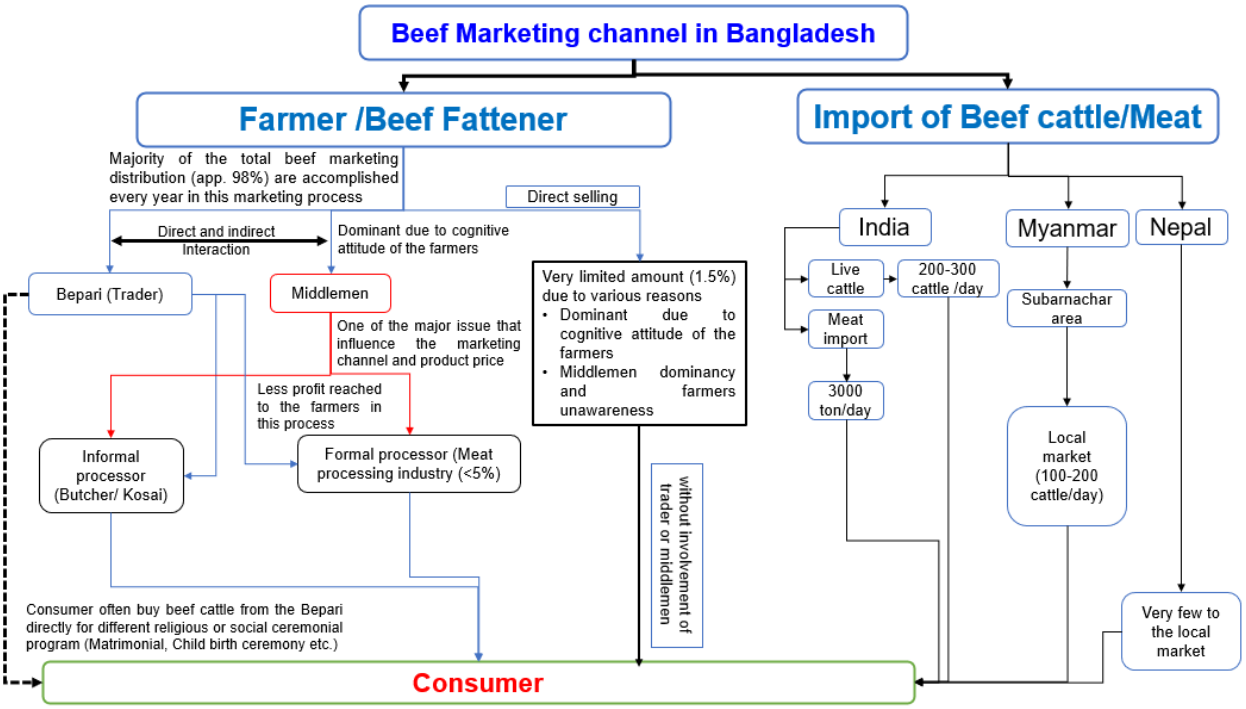


Figure 5: Existing beef marketing channel in Bangladesh

Production

Particularly the smallholder cattle farmer supply fattened beef cattle to the market. The smallholder producers have a strong tradition of rearing 3-4 beef cattle by stall feeding (Sarma, 2017). In this system of production, the farmers usually use beef cattle after the final phase of their primary purposes leading to very high cost of production at the final stage of fattening period. There are only a few middle and large-sized farmers completely involved in the bull fattening system (FAO-UNIDO, 2019). Most of the farmers prefer to raise healthy indigenous bulls due to high demand of such breeds in the markets.

Processor slaughtering and butchering

Majority of the meat is processed by the informal processor (butcher). The primary processing work includes de-hiding, quartering the whole carcass and transport to clients (butchers, hotels, and/ supermarkets etc.) (Sarma, 2017). Butchers and hotels process the meat into different retail food commodities. Supermarkets also further process the meat for their retail outlets.

Distributor network

The trade of fattening bulls mostly depends on cattle traders. Apart from being sold directly to butchers, farmers sell bulls to small or large-sized traders. The middle men like baparies/traders purchase these beef cattle from farmers of different areas, town, and villages and then transport and sell these bulls in urban cities.

Consumers

The requirement of meat consumption is 120 gm/ capita/ day, but the availability is 136.18 gm/capita/day (DLS, 2021). Finally, consumers buy the beef directly from butchers or value-added beef product from hotel and restaurants, who buy the beef cattle either from producers/ farmers or traders.

3.2.3 Horticulture value chain

The horticulture sector in Bangladesh produces around 3.2 million metric tons/year. The total production of vegetables in Bangladesh is about 2.5 million tons, which is far below the required 11 million tons to feed its population (USAID, 2011). Statistics indicate that, with the current population boom in Bangladesh, 12.60 million tons of vegetables will be required to feed its estimated population of 172.90 million in the year 2020 (FAO, 2021). The review of the horticultural products (fruits and vegetables) value chain study in Bangladesh that were completed so far (within ten years, only consider the significant one) is depicted in Table 5, in order to provide their focus.

Table 5. Horticultural value chain study so far done in Bangladesh along with their focus

SL No.	Context of the Value Chain	Key focus	Authors	Year
1	Improving the Marketing System Performance for Fruits and Vegetables in Bangladesh	Marketing system, Safety and quality, Marketing cost, Price variation	Hasan an Raha	2013
2	Agricultural Value Chains in the Feed the Future Zone in Bangladesh: Baseline Study	Value chain, Economics of value chain	Akhter et al.	2015
3	Value System Analysis of Vegetable Supply Chain in Bangladesh: A Case Study	Value chain, Cost and price movement of value chain	Karim and Biswas	2016
4	The Vegetable Supply Chain of Bangladesh: Is it capable to meet the requirements of international trade?	Supply chain, International trade	Hasan and Naim	2017
5	Mango value chain analysis and detection of post-harvest problems at farmer and trader levels	Value chain, Postharvest lost detection	Rahman	2018
6	Profitability of mango marketing in different supply chains in selected areas of Chapai Nawabganj district	Marketing channel, Problems in marketing	Miah et al.	2018
7	Value Chain Analysis of Mango in Bangladesh	Mapping of mango value chain	Ahmed et al.	2019
8	Value Stream Analysis of Fresh-Cut Vegetables in Bangladesh	Value chain, Marketing margin and value addition	Salam et al.	2020
9	Analysis of the mango value chain in Bangladesh - Towards a strategic action agenda for the Dhaka city corporations	Marketing channel, Food system	Kok, et al.	2021

Primary vegetables production of Bangladesh increased from 1.14 million tonnes in 1971 to 7.14 million tonnes in 2020, growing at an average annual rate of 4.03% (WDA, 2021). It is an almost fivefold increase in a span of ten years and is not an easy task. However, we are far behind the expected level to fulfill daily requirement for fruits and vegetables. Lack of adequate varieties, non-availability of quality seeds, inadequate crop protection measures, high cost of production, seasonality and various natural calamities are some of the major deterrents to fruits and vegetable production and damages in different regions of Bangladesh (Figure 6).

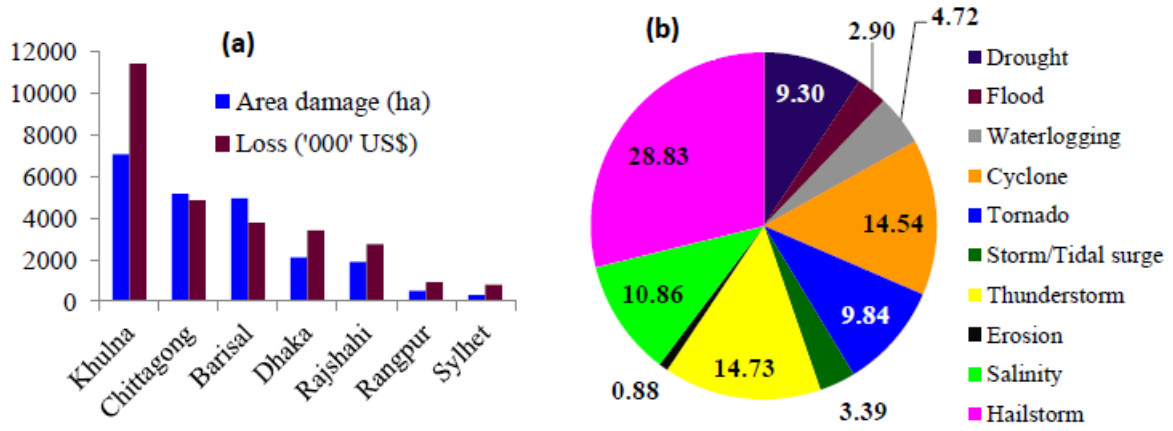


Figure 6. Constraints of production and damages of fruits and vegetables in different regions in Bangladesh (Biswas et al., 2021)

Bangladesh is blessed with many horticultural crops. More than 100 types of vegetables, 70 types of fruits, and 60 types of spices are produced in the country. Major vegetables include potato, tomato, brinjal, cabbage, cauliflower, aroids, pumpkin, bottle gourd, cucumber, pointed gourd, bitter gourd, hyacinth bean and yard long bean. In case of fruits, banana, pineapple, papaya, jackfruit, mango, guava, lemons, pummelo, litchi and jujube are important (Figure 7). Major spice crops are chilli, onion, garlic, turmeric and ginger. Some of the popular flowers are rose, gladiolus, tube rose, dahlia, chrysanthemum, marigold, night jasmines and belly. The total cultivated area of horticultural crops is about 0.69 million hectare which is about 5% of the total cropped area (BBS, 2018). Over the years, the performance of the horticulture sector has improved. Yields and production of fruits and vegetables have shown considerable progress. For example, growth of yield has contributed to 75% and 79% of growth of tomato and potato production respectively between 2012 and 2018 (Biswas et al., 2021). However, the overall yields of fruits and vegetables in Bangladesh is still far below international standards.

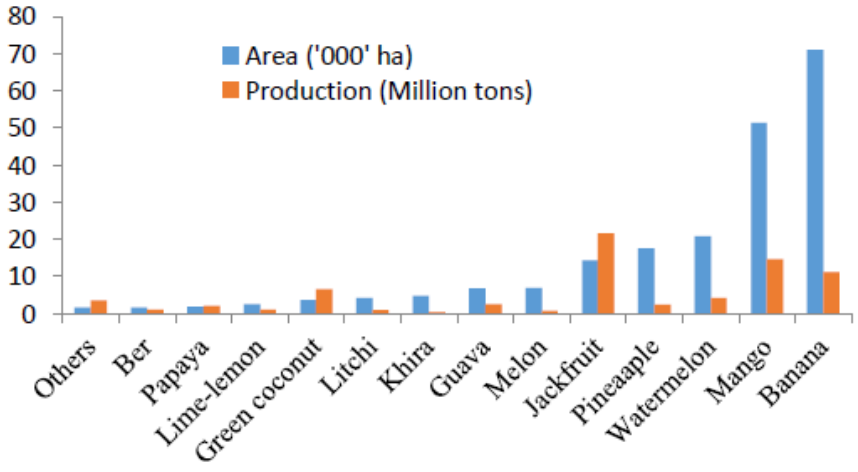


Figure 7. Area and production of major fruits in Bangladesh (Biswas et al., 2021)

Although Bangladesh has accomplished food security, household nutrition security will depend upon the per capita consumption of balanced nutritious food. It is essential that resource poor communities secure affordable and safe food that is nutritionally rich. The nutrition security

can be seriously impacted if the food produced is not safe to be consumed or treated for post-harvest processing needs.

3.2.3.1 Existing horticulture value chain in Bangladesh

Existing value chain mapping gives a clear understanding of the sequence of activities, the key actors and the relationships involved in the horticultural value chain. Several categories of traders known as middlemen are involved in the value chains of horticultural products (fruits and vegetables) in Bangladesh. In most cases, marketing involves local traders (foria), commission agents/large traders (aratdar), wholesalers, and retailers (Figure 8). The intermediaries play a vital role to make a proper connection between the producer and consumers, but too much involvement of intermediaries in the supply chain can cause an unequal price margin for both the producer and the consumers and also creates a long-awaited supply chain which is not appropriate for perishable products like fruits and vegetables (Karim and Biswas, 2016).

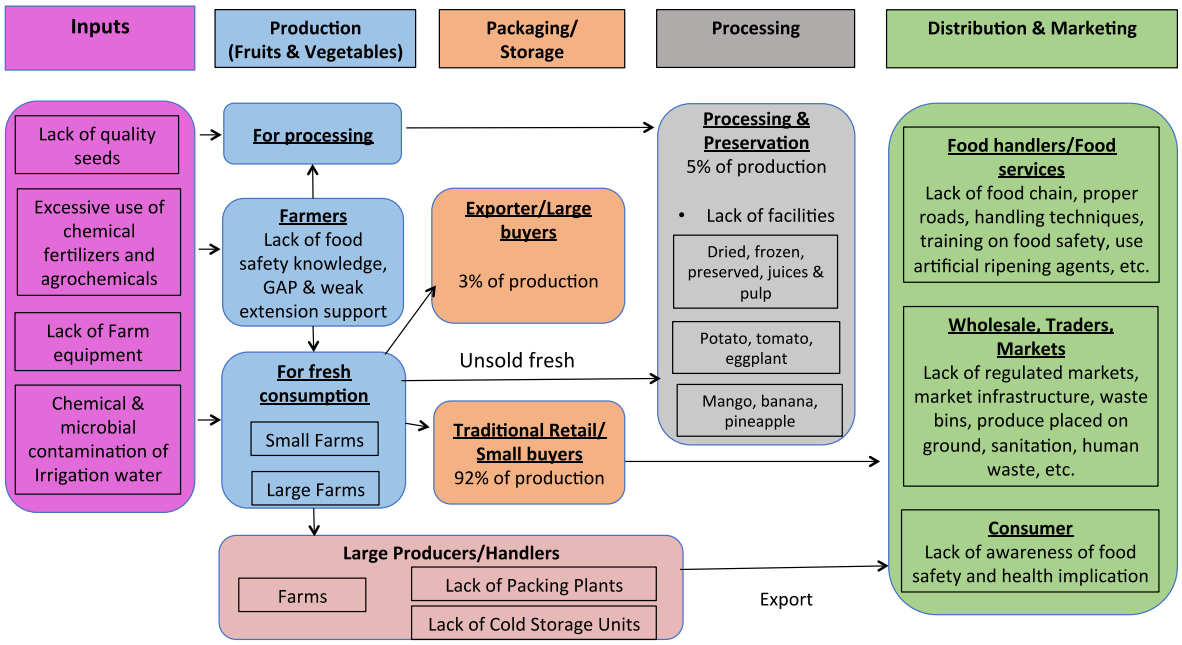


Figure 8. Horticulture Value Chain in Bangladesh

The whole value chain involves different stages such as inputs, production (fruits and vegetables), packaging/ storage, processing and distribution/ marketing. Among the total production, 92% of horticultural produce is used for the fulfilment of the local demand. From the remaining amount, 5% is used for processing and preservation, and 2% is purchased by the large buyers for exporting. The value or quality of vegetables will decrease rapidly once they are harvested and will keep decaying when being delivered. Thus, the timely production and delivery of perishable foods significantly affect the supplier's revenue. So, a simply understood and properly structured supply chain is much needed for a successful vegetable production flow (Karim and Biswas, 2017).

3.3 Challenges on food quality, safety, wastage and greening the value chain

The value chain analysis and its description in the previous sections are now assessed to understand and identify the challenges and to see which and to what magnitude the different sector has been facing challenges related to quality, safety and wastage as well as greening value chains.

3.3.1 Challenges of the Food Value Chain

Looking into sector wise challenges (dairy, beef and horticulture), the challenges fall under five common framework which are depicted in Table 6.

Table 6: Common Challenges Framework of the Food sector

SL No.	Challenges	Framework
1	Input use for sustainable production	The rampant use of inputs such as antibiotics, pesticides, growth hormones, inorganic fertilizer, heavy metals, water quality are directly affecting the food safety and quality. The carbon and water footprint are also challenges while the input system is not controlled by efficient use of the inputs in the production system
2	Management practices	Management practices substantially affect the food quality, safety and food loss. The manual versus mechanization, inefficient handling process, knowledge level, skill and appropriate health practices are key challenges for greening the value chain
3	Distribution system	Equipment and testing facility, robust cold chain technology, capacity building, inspection and monitoring, might be other ways of the challenges that are linked with value chain efficiency for greening the farms.
4	Consumer perception	Consumer perception towards low-cost products rather than paying for high-cost green products, may pose as a major challenge for producers who are willing to adopt the green concept. Adoption of the green concept at farm level would increase the cost per unit of production which ultimately will be added to the consumers price
5	Economics of the value chain	Input price, outprice, are also substantial challenges that prevent achieving food quality/safety and the green element

The common challenges are then extended to the sector for describing the key challenges and finding the proposed recommendations to tackle those challenges.

3.3.2 Challenges in Dairy Sector

The dairy value chain deals with the process of milk production from the farm to consumption and entails the challenges in the various level of the value chain. The challenges that the DVC are confronting, are stated below:

3.3.2.1 Challenges related to input use for sustainable production

i) Lack of appropriate Feeds and Feeding to the Dairy Cows

The feeding to the dairy cows, particularly providing balanced ration, manipulation of the feeds in the ration and cost of the feeds, are highly influencing the productivity, profitability and reduction of enteric emission from the cows. Till today, a number of studies has been done focusing only on the nutritional requirement and the balanced ration formulation, however majority of the studies did not focus on the optimization of the balanced ration of both nutrient

and cost and environment. The study done by Akter et al. (2022), for the first time introduced Integrated Dairy Feed Optimization Model (IDFOM), which has the capacity to address the nutritional requirement of the dairy cows, its costs, possible ways for cost optimization, sensitivity analysis and whether any cost reductions affect the productivity. The next challenge for this model is to integrate the factors that lead the model to formulate the ration focusing the emission per kg Dry Matter of the ration.

ii) Lack of awareness of milk loss, quality and safety control

Regarding milk wastage and milk loss, IFCN farm analysis estimates that 3% of the total milk produced at farm level is wasted, while there is no research on exact loss in the upstream link (milk delivery from farm to processor: in the processing plant, distribution and consumer's place). An estimation was made based on expert opinion that a total of 1.5% milk is lost during processing to consumption. The estimated economic loss against this loss is enormous.

A recent field survey and transect survey revealed that the typical dairy farm allocates milk to the different marketing agencies; high fat milk goes to the formal processors and low fat and milk from early lactating cows goes to the informal sector. This is the key challenge for constant milk sourcing by the processors. This implies that milk that is sold to the informal market are not confirming to the minimum quality standards, as there is no price policy against quality. The farmers take this benefit and opt to adulterate their milk in different ways to increase the volume to get higher return, as the volume is the basis for milk payment in the informal market. Since the informal market share is over 90% of the total milk in Bangladesh, it is of utmost important to implement a strict milk pricing policy considering the quality of the milk in the informal market. This would increase the consumers trust on the quality of the milk and in turn enhance milk consumption. The other quality parameter such as protein, lactose, somatic cell count and total bacterial count and presence of heavy metals as well as detergents, is not possible to test both in the formal and informal sector, which is a key threat for consumer's health and public health issues.

The awareness by farmers and other stakeholders within the dairy value chain for quality and safety control are highly driving the overall quality of the milk production. The milk handling, udder management, cow care and utensils used in the dairy farms are not up to the mark and farmers are relatively less educated on this. The recent covid-19 pandemic has even further aggravated the issues which might pose to apply strict hygiene and sanitary control. Some of the farmers do not have the knowledge on the safety precautions while milking the cows, storing the milk in buckets and transportation to the market or processing plant. Both personal and utensil safety is highly important for keeping the milk safe at farm level, which are under challenges due to lack of awareness from the farmers.

iii) Lack of traceability of Carbon footprint and water footprint

The actions, actor and activities and related data within the DVC are not highly lacking and but there is a lack of transparency. For making the dairy sector green and keeping the milk safe and of high quality, it is important to track the records/data flow both on-farm and on-farm activities. Therefore, the lack of traceability of the of the activities that are linked with carbon emission and water use in dairy systems are putting the dairy sector under serious environmental threats and acts as negative motion for greening the dairy sector.

3.3.2.2 Challenges related to Management Practices

The management practices are sought for important indicators for any agricultural operation for ensuring the food quality, safety and food loss. The Bangladesh dairy sector is mostly operated manually, where the milk is exposed to various health and contamination factors and this has a negative influence on the quality and safety. The knowledge level of the farmers is also lagging far in regards to reaching modern management systems. Although the degree of automation is taking place in the dairy system of Bangladesh, this is mostly practiced in the recently establishing corporate farms and to some extent, the business farms only. The lower productivity of milking cattle and smaller herd size (with an average herd size of 2.7 cows per farm) is the key challenge for introducing the mechanization in dairy in Bangladesh. Inappropriate management system is, therefore, also driving negatively towards greening of the dairy value chain.

Regarding the issue of a green concept, this is recent and value chain actors are yet to fully focus on this. As there is still an agenda on increasing milk production to meet the rising demand and reaching to self-sufficiency, intensification is in practice which is not supporting the green concept yet. The recently on going LDDP project is looking for climate smart and technology driven solutions and focusing on increasing productivity, which is a good attempt for a green concept.

3.3.2.3 Challenges related to the distribution system

i) Weak linkage and poor market access

Moving toward the dairy value chain, the challenges are manifested into: i) Weak market linkage: Farmers – Processor; ii) Processors-Consumers: consumers are out of the link and highly ignored; and iii) No formal and written agreement and iv) farmers are not linked with a high value milk market. The challenges within the informal dairy value chain include:

ii) Sudden Quota

Many of the farmers face challenges of accepting a sudden quota system to deliver the milk to the formal processors. This unwritten quota system has heavily driven the processor's market demand. From field observation, it was found that processors mostly pose a quota during the afternoon milk collection, which is a significant economic loss for the farmers, as the milk not delivered during the afternoon, find no alternative way to sell the milk

iii) Unregulated activities of the Middlemen (Goala)

The involvement of the Middlemen (in Bangla most commonly known as "Goala") pose serious challenges as this group exploits the farmers in terms of quality, quantity and price. However, due to poor access to the market by the dairy farmers the middlemen even become a very dependable source of milk selling. The study done by Sharna et al., (2020) clearly revealed that milk price paid by the Middlemen is lower than the usual processors but they still have constant access to delivery of the milk. The quality, safety and hygienic precautions come under serious threat with these middlemen, as this group of people are highly profit driven and focus mostly on the milk collection and cannot provide any support services to the dairy farmers.

3.3.2.4 Consumer Perceptions

The consumer perception toward low-cost product rather than the high-cost green product will be a major challenge for the producers who are willing to adopt the green concept. Adoption of the green concept at farm level would increase the cost per unit of production which ultimately will be added to the consumer's price.

3.3.2.5 Economic Challenges in Dairy Value Chain

The dairy economics play a key role in defining the value chain actors, activities and strategies for ensuring the profitability, sustainability and climate-resilience for future expansion which lead to safe and quality milk production, processing, distribution and marketing. Looking at the value chain perspectives from an economic point of view, the DVC are confronted with challenges:

i) All High Dilemma

In relation to economics of the dairy production and marketing, the Bangladesh dairy sector is facing challenges of "All high dilemma" in dairy sector and dairy farms. The Bangladesh dairy stakeholders face the dilemma of all 6 high (6H),

a. high milk price,
b. high cost of milk production,
c. high feed price,
d. high consumer milk price,
e. high carbon emission and
f. high-water footprint.

The first case is expected while the other cases are unexpected and act as barrier for dairy development. The greening of the value chain, thus, depends on lowering 5H (Low CMP, FP, CP, CF, WF) and high 1H (MP). Since the milk price is already 1.5 times higher than the global price, it will be further difficult to expect higher milk price, rather the only way is to reduce the cost of milk production. To reduce the cost of milk production, the feed cost is the ultimate target as the feed costs represents the highest cost item in the total cost of milk production (18-82%) (Hemme et al., 2014). The questions remain on how can a dairy farm be green (reduction of the greenhouse gas emission and water footprint) without compromising milk yield and cost of milk production.

Milk price at farmers level is comparatively low in the North-west region (Nilphamari, Panchgarh, Gaibanda, Kurigram, Dinajpur) and varies from 20-25 BDT/kg milk from March to June and from 40-45 BDT/ kg during September to November. In contrast, the price is comparably high in the western and eastern region of the country (Patuakhali, Barishal, Khulna, Jashore and Sylhet). The milk price is 80-90 BDT/kg during March to June and 90-100 BDT/kg during September to November. Linked with global milk price and feed price, Bangladeshi milk price is 41% higher than the global milk price and feed price is 41% higher than global feed price. The high milk and feed price drives the Bangladesh dairy farmers out of getting benefits of the competitive advantage.

The milk price plays a key role for food quality as with the current regulations of Bangladesh Standard and Testing Institute, (except fat pecentage and lactometer reading), there is no price

modeling based on the quality of the milk. This influences the quality and safety of the milk negatively. In this regard, 2019 the Bangladesh dairy sector was characterized with a quality scandal due to the research published by one report from the University of Dhaka (IDRN, 2020). The report revealed that all Bangladesh formal sector milk contains lead, detergent and other adulterants which made shrinkage to the dairy market. The sales volume decreased by 40% and the milk delivered to the processors was also decreased by 35%. This incident has been treated as a key lesson for farmers and dairy processors as well as consumers which implies that the food safety and quality is well connected with the entire value chain functions.

The greening of the dairy value chain is driven by farming practices which is lined with the emission of greenhouse gas and water footprint. Within the farming practice, the feeds and feeding and improvement management practices contributes to more than 90% of the greenhouse gas emission and water footprint all over the world including Bangladesh (Hagemann et al., 2011 and Sultana et al., 2015). Feed production alone (on-farm and purchase) contributes to 90% of the greenhouse gas emission (especially the enteric methane emission) and water footprint.

ii) No rules and regulation regarding quality and price

In Bangladesh quality standards for milk set by the Bangladesh Standard and Testing Institute (BSTI) are not conforming to the quality with price level. The quality of milk is only tested while the farmers deliver their milk to the formal processors (e.g. Milkvita, PRAN Dairy Ltd. BRAC Dairy and Food Ltd. and Akij Dairy Ltd.) and hence it is possible to imply some quality standards and regulations for price setting. However, the milk that is sold informally (sweetmeat, niche market, neighbour and other small and medium enterprise for processing milk into dairy products) is not possible to test; rather the milk is sold based on volume only. Thus, those consumers are worse off as the farmers adulterate their milk by increasing volume through addition of water. Since more than 90% of the milk is sold through an informal channel, the significant number of the consumers are not getting quality milk with the price they are paying. Back to the formal channel, only fat percentage and specific gravity (lactometer reading) are used for the quality estimation. To increase the quality standards, more variables, like protein, lactose, Solids-not-Fat (SNF) are necessary to be included in the price model, which are does not exist yet. There is a need for some initiatives to develop a model that considers the price variation according to the number of quality parameters.

3.3.3 Challenges in Beef Value Chain

Beef marketing channel or value chain system in Bangladesh is still in a very rudimentary stage. Therefore, there are many prospects that can be achieved in the future. However, it is very complicated due to the abovementioned challenges and many more. Unlike the dairy value chain, the beef value chain actors, functions, context are quite different which entails different challenges. The beef sector is highly unorganized, although there is a trend for increasing number of professional beef farm. The transition of beef fattening toward beef farming poses more challenges than the dairy sector as the number of brokers, traders, middlemen is much more prevalent in the beef value chain. A brief overview of the challenges the beef production and its chain are facing are described below:

3.3.3.1 Challenges related to input use for sustainable production

- There is an unawareness or lack of knowledge of farming and about beef marketing among the farmers. Therefore, involvement of different growth promoting harmful agent in the production of beef cattle and involvement of notorious middlemen in the marketing distribution make the beef value chain ineffective and unsafe at the same time.
- Beef meat price is usually fixed by the middlemen or trader syndicate. Most of the time, farmers have no saying in this price fixing process.
- No feeding standard and beef balanced ration formulation is available which prevent the farmers to use balance feed input for increasing production.
- The use of steroid hormone is most common for fattening the beef cattle, which however, are highly restricted by the government. However, the implementation of the government regulations on banning the antibiotic and steroid hormone are not fully in practice at farm level.
- Currently, application of green value chain is highly difficult without a definite policy and control from Government regarding beef cattle production and beef cattle marking in Bangladesh. In addition, increasing awareness of farmers, reductions of involvement of numerous middlemen and increasing involvement of collaborative meat processing industry will provide extra strength towards green value chain application in the existing or newly established beef value chain in Bangladesh.

3.3.3.2 Challenges related to Management practices

- Most of the beef fatteners are seasonal and lack knowledge and skill on beef cattle production. The management practices are very poor as they mainly focus on the general rearing practices.
- Animal welfare is extremely poor, and no attention is taken for the safety and comfort of the of animal

3.3.3.3 Challenges related to Distribution system

- Farmers are often diluted by the traders and the middlemen during selling of their cattle, due to presence of interaction between trader and middlemen.
- There is no definite policy toward running a beef value chain or marketing channel in Bangladesh. Therefore, the market is fluctuating more frequently in different areas of Bangladesh.
- Less involvement of industrial or private meat processing industry is another major problem in Bangladesh.

3.3.3.4 Challenges related consumers perception

- The consumers are not well connected with the beef value chain, as consumers have limited influence on the beef cattle purchase as well as beef meat purchase
- The Butchers (Traditional meat processors) are dominating in the country and they never fulfill the preference of the consumers. They rather exploit the consumers in terms of weight and quality (mixing more inedible bones into the meat), thus, the consumers-butchers relationship is highly untrustworthy
- The price of the meat is high for the consumers and have no impact of the consumers preference on the meat price

3.3.3.5 Challenges related to economics

- The meat price and beef cattle price is increasing over the last decades which was instigated due to the ban of the importation of Indian Cattle from 2014 onwards since the Modi Government has come into power. This has in another way created an opportunity for a high economic return to the beef farmers but the beef farmers are not in a position to exploit this opportunity
- There is very limited research on beef economics which is a key challenge for new entrepreneur development
- No investment model is available for beef farming

3.3.4 Horticulture Value Chain

Although 3.2 million metric tons of horticultural crops are produced each year, 38% of those crops are lost after harvest (Hassan, 2010). Bangladesh is facing problems with food contamination, pests, diseases, lack of seed quality, lack of suitable processing technology, and poor market linkage. In addition, the small farmers engaged in horticulture production in Bangladesh suffer economic losses due to lack of high yielding varieties and hybrids; post-harvest technologies; food safety issues and processing facilities. Among them the food safety issues affect marketable produce, human health and food quality resulting from high chemical and microbial content and also due to unhygienic production and storage facilities.

Horticultural products especially fruits and vegetables are vital for the daily diet as these contain micronutrients (vitamins and minerals), fibers, proteins and bio-functional components. Consumption of fruits and vegetables are vital for a diversified and nutritious diet. Dietary diversification through horticultural food intake can be seen as a sustainable approach to fighting micronutrient malnutrition. This will require a environmentally friendly value chain, reduction of food loss and waste and access to and consumption of a variety of safe horticultural produce. The horticulture value chain is another domain of agriculture which has a very strong and vast marketing network in Bangladesh. The development of horticulture, particularly fruits and vegetables are very promising. The development of this sector, however, is counteracted with several challenges which are stated below:

3.3.4.2 Challenges related to input use for sustainable production

- Shortage of timely inputs especially seeds, fertilizers, and irrigation water and farm equipment cause tremendous loss of horticultural production in Bangladesh. To increase crop production, farmers buy chemical fertilizers with a higher price and use that in the soil, which in turns reduces fertility and destroys the condition of the soil.
- In addition, to reduce the incidence of diseases and pests infestation, farmers excessively using agrochemicals (Herbicides, Fungicides, Pesticides) which are very unsafe and hazardous for the environment and human health. Ultimately these causes are reducing the sustainability in horticultural production systems in Bangladesh.

3.3.4.3 Challenges related to Management Practices

- The management is highly sensitive as the harvesting, transportation to the market destroys the product

3.3.4.4 Challenges related to the distribution system

- **Poor handling and transportation:** Farmers can sell their products to the foria or consumers at local the market or bring them to the wholesale markets. Sometimes farmers contract out fruit orchards and/or vegetable fields during the flowering stage to the foria, aratdar, and/or wholesalers who provide loans to the farmers over the course of production. When sold to the foria, fruits and vegetables are assembled, sorted, graded, and sometimes cleaned before handing over to the aratdar. The most common vehicle to transport fresh produce is an open truck. Most of the time, they are overloaded with different types of products, resulting in spoilage and loss of quality of the products. There is hardly any vehicle customized to transport fruits and vegetables; sometimes they are transported with many other things including poultry and dairy in the same vehicle.
- **Lack of storage facilities:** Cold storage is hardly used in the wholesale markets of Bangladesh. In most cases they are owned by the aratdars and used for potato, spices, and imported fruits only. According to Bangladesh Cold Storage Association, the country had 428 cold storages with an estimated capacity of 5.5 million metric tons in 2019. Out of the total cold storages, 30 were public, and operated by Bangladesh Agricultural Development Corporation with an estimated capacity of about 0.05 million metric tons while the rest were privately owned. The number of private cold storages is increasing over time.
- **Improper packaging, preservation and inadequate processing facility:** Fruits and vegetables are packaged before shipment using local materials. In most cases such packaging fails to preserve the freshness and quality of the produce. Very limited preservation and processing facilities are another cause for postharvest losses and wastes of fruits and vegetables in Bangladesh. Very limited amount of food processing and value addition occurs, although it can effectively reduce high post-harvest losses
- **Lack of distribution and marketing facility:** The aratdar arranges or negotiates sales for the sellers on a commission basis. He often acts as a wholesaler and owns stalls in the wholesale markets. The wholesaler buys from the aratdar at the wholesale market and sells to the retailers. The retailers sell to consumers at their retail shops and to street vendors. Supermarkets also buy from some wholesale markets. They also buy directly from farmers through contract farming. Supermarkets are a growing business in Bangladesh. Their share in the total fruits and vegetable market is small but growing. Different local retail companies are operating through their own supermarkets and planning for expansion. Some international retailers are also planning to start operations in Bangladesh.

3.3.4.5 Consumer Perceptions

- The consumer trust on the horticulture sector is negative, as many of the consumers believe that fruits and vegetables are produced with a high level of pesticide and herbicide at the dose much higher than it is recommended
- In relation to fruits, either imported or locally produced, the addition of formalin versus health is a huge discussion in the country. Even with government high level initiatives, the consumers do not appear to be in a comfortable space

3.3.4.6 Economic Challenges

- The cost of production of the vegetables are very high and not many economic studies are less available on the cost-effective production
- The price on the other hand is also high and many of the consumers are not able to keep up due to such prices
- The seasonal variation of the price is significantly higher which negatively influences the motivation of the entrepreneur on investing on horticulture.

3.3.5 Proposed actions and recommendations for greening value chain along with food safety, quality, and food loss

The existing value chain and their challenges lead us to find the ways to ensure the food safety, quality, food loss and finally greening the value chain. In this case, ways and approaches are recommended for dairy, beef and horticulture value chain.

3.3.5.2 Proposal for Greening Dairy Value Chain: Food safety, quality and food loss

The green dairy as we already demonstrated in the previous section is a relatively new concept; the proposed options for greening the dairy sector need to include the following action points:

- Change in the input use, particularly fertilizers, roughage feed to more concentrate feeds
- The farm should be monitored for enteric methane emissions and attempts should be taken to reduce emissions at cow level and farm level
- The manure management should be in a way that prevents emission directly to the open air
- The milk transportation should be done in a large volume in order to reduce the number of vehicles transporting milk, since the transportation causes higher emission
- A training tool package for increasing awareness for farmers, processors and distributor on safety and hygienic practices and milk loss on dairy, needs to be developed and introduced at all kinds of farms
- The concern on the negative public health on how to do the activities of the one of the chain (e.g., dairy farmers) affect the entire value chain's safety and quality
- Traditional system of milking should be avoided and there is a need to introduce mechanization to the farm
- Proper guidelines and its application must be embedded at the farm level for antibiotic use and must follow the withdrawal period of the milk from marketing, after use of such antibiotics
- All kinds of illegal practices must be discouraged through tough penalties
- Clear communication and exchange of knowledge amongst all the stakeholders in the value chain

3.3.5.3 Proposal for Greening Beef Value Chain: Food safety, quality and food loss

- Farming practices and feeding practices with more roughage needs to be changed and a shift is required towards a more balanced ration. Hence, proper guidelines on feeding practices must be introduced.

- In the beef value chain, live cattle movement is a significant source of emission and the cattle transportation should be done within minimal ways, for example, to increase the vehicle size to include more live cattle than traditional ones
- The manure management should include ways that avoid emissions to the open air
- The use of water should be highly efficient
- The use of steroids for increasing the growth of the beef cattle must be excluded

3.3.5.4 Possible ways for Greening Horticultural Value Chain in Bangladesh: food safety, quality and food loss

- Greening the horticulture value chain and horticultural interventions to enhance food safety at farm level combined with extensive nutrition and food safety education can offer a long-term food-based strategy to control and eliminate micronutrient malnutrition in the resource poor people. To address this issue, we need to fulfill seven key objectives: crop yield improvement, seed delivery system, post-harvest technology, food safety and adoption of GAP, food processing and value addition, market linkage and extension education
- **Minimization of challenges and gaps through greening horticulture value chain**

  i) Seed Delivery System
  ii) Green management practices for sustainability
  iii) Effort to ensure minimal soil disruption
  iv) Introduction of cover cropping
  v) Optimization of plant nutrient
  vi) Optimized Plant Genetics
  vii) Ensure Labor Efficiencies
  viii) The Logical Use of Protected Culture
  ix) A Logical Balance of Fresh, Frozen and Canned Output
  x) Attempt to increase Crop Yield
  xi) Food safety and adoption of GAP
  xii) Harvesting at the right time
  xiii) Application of mechanization in post-harvest process, even manual, awareness and safety guidelines must be followed
  xiv) Packaging and well guided transportation system must be ensured
  xv) Good storage and safe technology (freezing with sufficient cooling system)
  xvi) Food processing and value addition should be taken
  xvii) Good distribution and marketing practices
  xviii) Research and Extension and marketing
  xix) Consumer awareness should be ensured

The Bangladesh agriculture backdrop is constrained by weak extension systems which seriously impacts transfer of suitable technologies to the farmers. While extension is an important element of each of the objectives mentioned above, revamping the system is considered to be key and is therefore addressed separately under this objective.

3.3.6 Proposed Action Points: Synthesis of the proposed recommendations

To make the recommendations into action points for possible applications at field level to increase the safety, quality, reduction of the food loss and ultimately to ensure the greening the sector, using all of the proposals (as stated above), a matrix of the summary of the recommendations are plotted against those challenges to fit three sectors into five key areas of the challenges, which are depicted in the Table 7.

Table 7: **Proposed action points**

Challenges	**Recommendations**		
	Dairy	**Beef**	**Horticulture**
Input use for sustainable production	• Input use change for reducing the enteric methane emission and overall greenhouse gas emission • Change in water use to reduce the water and increase the water use efficiency and water footprint • Feed Ration changes where feeds like grass and straw might be limited • Strict regulatory policy and guidelines on the antibiotic use for dairy cows • Awareness program for the farmers and veterinary service providers for following guidelines • Manure and slurry management need to improve • Less inorganic fertilizer uses in fodder production	• Zero use of Growth Hormones (e.g., steroid) • Following strict guidelines for antibiotic use	• Strict guidelines and policy for pesticide, herbicide and inorganic fertilizer use • Reduce the use of inorganic fertilizer and use at least a certain percentage of organic fertilizers
Management practices	• Transition from manual to automated milk handling (adapted to the local conditions) and its economic justification is highly recommended • All equipment used in the dairy farm must be cleaned and sterilized where applicable	• Hygienic management during pre- and post-slaughter conditions • Meat handling in the traditional system needs to be transformed with a standard hygienic way • Selling meat from open point at bazars (market) needs to be changed	• Agricultural Practices for fruits and vegetables farming need to be done using improved practices • Improved transportation (especially using standardized cooling van) system
Distribution system	• Optimization of the vehicle use to minimize transportation related emission	• Minimize transportation for beef cattle	• Well packaging (airtight) to keep the product fresh and safe

Challenges	Recommendations		
	Dairy	**Beef**	**Horticulture**
	• Cooling system with heat stabilizer to standardize the temperature of 4 degree • Highly insulated transportation vans should be introduced	• Meat import and distribution channels should be modernized using temperature regulated cool vans	
Consumers perception	• Consumers need to be concerned and willing to purchase the greener produced milk	• Consumers need to be concerned and willing to purchase the greener produced beef	• Consumers need to be concerned and willing to purchase the greener produced fruits and vegetables
Economics of the value chain	• Green production should be acknowledged in a price policy (greener product should get higher prices compared to traditional products)	• Green production should be acknowledged in price policy (greener product should get higher prices compared to traditional products)	• Green production should be acknowledged in price policy (greener product should get higher price compared to traditional products)

3.4 Catalogue of green/climate friendly solutions

3.4.2 Strategies for the food sector's green value chain

Agri-food Value Chain is a strategic partnership/a collaborative venture that links producers, processors, marketers, food service companies, retailers and supporting groups such as shippers, research groups and suppliers to increase the competitive advantage and create value for the final consumer. Furthermore, it involves a series of activities that create and build value at every stage from agricultural production, manufacturing, processing, distribution to consumption. Developing the green food value chain will deliver higher economic value, environmental sustainability, food security, safety and quality along the value chain. The food sector based on the agricultural output is depicted in Figure 9. Agriculture is a significant contributor to climate change and a substantial portion of emission comes from the activities of value chain actors at different levels. Greenhouse gas (GHG) emissions from on-farm production (i.e., within the farm gate) and related land use change contribute about one-fifth to one-quarter of total emissions from all human activities (IPCC 2019). Alhough the rate of emission is varies from one agricultural sub-sector to another sub-sector. The value chain activities are also heterogeneous. Therefore, the contribution is even more striking for individual gases. For instance, crop and livestock production within the farm gate contributes more than 50% of the methane (CH4) and 75% of the nitrous oxide (N2O) emissions from human activity globally (FAO 2020).

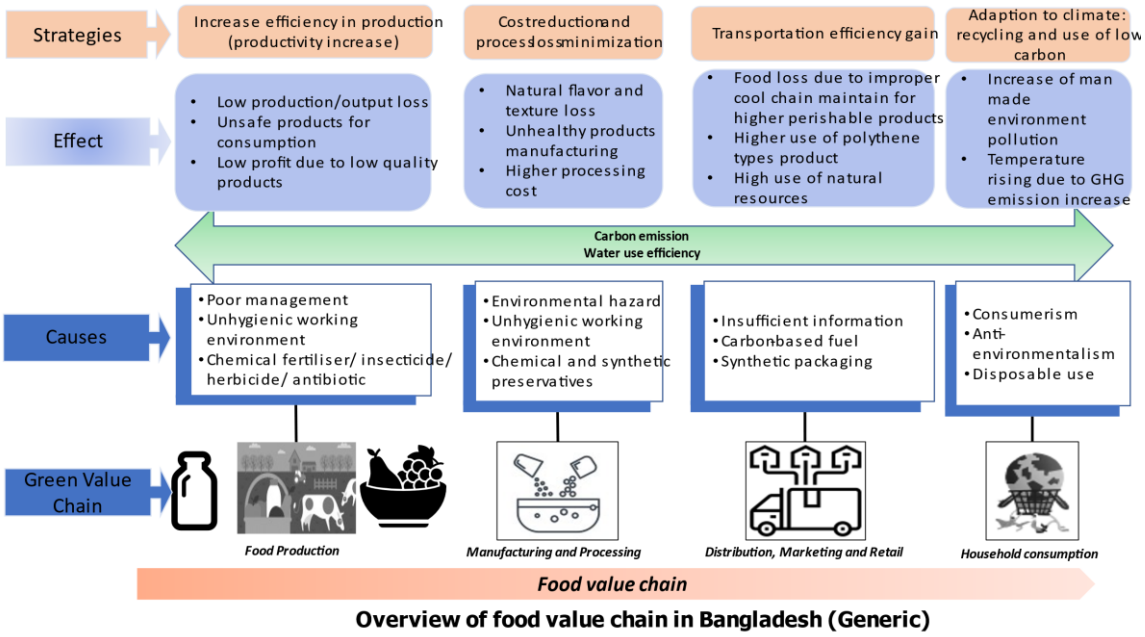


Figure 9. Generic and concept of greening the food value chain

The first and second stage of generic food value chain is the production, manufacturing and processing of food/ fibres. Increased use of production inputs, such as mineral, fertilizer, poor management practices, use of excessive insecticide/pesticide/herbicides have made Bangladesh agriculture more greenhouse gas (GHG)-intensive. Recent estimates report that the global food production must increase by 70% to meet the projected food demand of the estimated 9 billion global population by 2050 (CTA-CCAFS, 2011). The majority of agricultural GHG emissions occur at the primary production stage (Pathak et al., 2010) due to

the use of agricultural inputs, farm machinery, soil disturbance, residue management and irrigation. These practices are used to increase yields and improve harvests.

Rosenzweig et al (2020) estimated that the food system generates 20% - 40% of the anthropogenic emissions from all economic activities. These large contributions further highlight the potential of food related GHG mitigation strategies, providing impetus for innovative approaches in food supply chains, consumption and waste processes in connection with farm and landscape level mitigation (Smith et al 2014, Niles et al 2018). Consumerism (both for agricultural and non-agricultural items) is also equally sued for the uncontrolled and unmanaged emission and climate change effect. Therefore, it is recognized that dietary choices and consumption patterns are critical to reduce food system emissions, through their impact on supply-side activities (Dalin and Outhwaite 2019, Hayek et al 2020). We have to maintain the food supply to feed the huge population of the country alongside the need to think about the emission and the severe strike of climate change. As a consequence, moving towards a green value chain will provide a safe and quality product, an environmentally friendly production eco-system and open an avenue of gaining more profit from a niche market segment of the consumers. It is also evident that the circular economy will have a greater impact on the carbon emissions reduction and lessen the climate effect on human/animal livelihood.

3.4.3 Proposed catalogue of green/ climate friendly solutions

Green value chains are a promising way to address food safety challenges, loss and climate vulnerability. It can be done through considering the economic issues such as profitability, cost reduction and revenue generation but also addressing the social and environmental issues including creating jobs and conserving the environment. Green value chains also have global implications. Public bodies, institutions and private companies should be aligned to green the agricultural value chain and allocate further resources to reduce costs and to become more socially responsible and environmentally friendly. Table 8 summarizes some of the economic, social and possible environmental impacts that result from green value chains.

Table 8. Possible impacts of green agricultural value chain

Strategy	Economic impact	Social impact	Environmental impact
Optimize material use	Less waste (cost)	Less health hazards	Reduced solid waste and pollution
Reduce inventory	Less space and energy consumption	No relocation and social disruptions	Reduced pollution, build up areas and emissions
Reduce over production	Fewer resources used for production	Less over-consumption	Energy savings
Reduce transport	Less fuel consumption	Less health risks	Reduced emissions

Source: ESCWA Adapted from Ma and others, 2010.

The indicators are optimized material use, reduce inventory, reduce over production and reduce transport. Reduce over production has a conflict of interest to consumerism concept, therefore, following the catalogue to moving green value chain requires to accept the mentality of anti-consumerism or less consumption. There are some clear findings that show that markets cannot do it alone in terms of greening food value chains. There is a need for not only green demand and raised awareness among consumers but also the long-term perspective and investment required from other market players such as manufacturers, middlemen, processors, the government, etc. to provide support for greening food value chains.

3.4.4 Evaluation of the proposed interventions

Evaluation of various interventions strategies for optimizing the greening value chain, food security, food safety and food wastage for dairy, beef and horticultural products are discussed below:

3.4.4.2 Input use for sustainable production

Moving towards green value chains require greater sustainability and resource-use efficiency (*more efficient in using less land, water, energy and inputs*) among agricultural sub-sectors to increase productivity and incomes, ecosystems and reducing greenhouse gas emissions through implementing the circular economy concept. All interventions have a strong positive effect on greening the value chain. Not following the guidelines of antibiotic use, insecticide/ pesticide use and inorganic fertilizer use are the major hidden/ explicit reasons of sub-standard level of food safety/quality and deviation from greening value chains.

3.4.4.3 Management practices

A range of different management practices are inclined with the production of each product and many agricultural value chain participants are involved in the process. Efficient use of input resources, hygiene management during pre-and -post handling, pollution prevention, use of clean and sterilize equipment, waste minimization and recycling are the major interventions of management practices which are related to production and distribution system of the product. The practices can be labelled as green by creating generic, less expensive and lighter packaging; using biodegradable packaging made from recycled material; sorting recyclable materials as specifically as possible; working with experts to reduce/eliminate packaging whenever feasible and recycling material to reduce waste and environmental impact (Kushwaha, 2010).

3.4.4.4 Distribution system

Greening agricultural value chains can initiate significant savings by reducing packaging, using energy more efficiently, removing harmful chemicals from production processes and improving logistics, which increases the overall quality, though it leads to less quantity. An increase in the quality of agricultural raw products is believed to generate more income and ensure a better quality of life (ESCWA, 2014). By becoming more efficient in those ways, firms that have greened their supply chain have also become more competitive and more resilient to crises.

3.4.4.5 Consumer's perception/ awareness

Consumer awareness is the biggest driver to green agri-food value chains. The government, private sector and farmers are the primary stakeholders for production, management and supply of nutritious foods but the success of these products depends upon the ultimate stakeholder i.e., consumers (Kaswan, 2018).

3.4.4.6 Economics of the value chain

As global climate change issues receive increasingly more attention, the government has gradually increased the environmental awareness of consumers by promoting learning and accelerating the spread of green technologies (Meng et al. 2021). Green product innovation depends on an understanding of market demand, as well as sustainable business operations

(Ling et al. 2013). Greening the value chain may lead to higher prices of the products, leading to losing part of the demand of consumers who are more price sensitive. Consumers tend to pay more attention to certain attributes of products when making purchase decisions, therefore, to create the consumers' perception/ awareness towards safe, quality and environmentally friendly products, a reasonable and acceptable pricing policy is necessary.

3.4.5 Impact analysis of the proposed interventions and catalogue for green / climate solutions in relation safety, quality and food loss: Dairy, Beef and Horticulture Value Chain

Using the interventions, finally a matrix of catalogue is developed for each of the value chains, in order to take those interventions to the field level to make the sector as green, safe, quality full and less loss occurring.

3.4.5.2 Matrix of catalogue for greening the Dairy Value Chain

The transition from traditional to green following the concept of the Rio Marker and also evaluating the existing dairy value chain, the Catalogue for Dairy Value Chain is depicted in Table 9.

Table 9: Catalogue of green/ climate friendly solutions for dairy value chain

Challenges	Interventions	Food Safety	Food Quality	Food wastages	Greening value chain
Input use for sustainable production**	Reduce the enteric methane emission	+	+		+++
	Increase the water use efficiency and water footprint				++
	Change the feed ration		++		+++
	Guidelines on the antibiotic use	+++	+++		+++
	Develop awareness program	+++	+++	+++	+++
	Improve manure and slurry management				+++
	Use of less inorganic fertilizer in fodder production	++	+		+++
Management practices	Transition from manual to automated milk handling	+++	+++	++	++
	Use of cleaned and sterilized equipment	+++	+++		+++
Distribution system	Optimization of vehicle use	+	+	+	+++
	Cooling system with heat stabilizer	+++	+++	+++	+
	Introduce highly insulated transportation van	+++	+++	+++	+
	Improve last mile delivery system	+++	+++	+++	+++
Consumers perception	Consumers need to be concerned and willing to purchase greener produced milk	+++	+++	+++	+++
Economics of the value chain	Green production should be acknowledged in pricing policy	+++	+++	+++	+++

Note: +++ indicates High Impact, ++ indicates Medium Impact, + indicates low Impact

***For dairy only, a case study on reduction potential of the emission from dairy using input change as intervention is depicted in detail using Partial Life Cycle Analysis of the International Farm Comparison Network (IFCN) Carbon footprint and Water Footprint methodology to show how greening is possible in one hand but on the other hand, how the greening associates with increase in cost of milk production in Appendix 2. The same can be done for beef and horticulture, if the required data is available.*

3.4.5.3 Matrix of catalogue for greening the Dairy Beef Value Chain

The value chain activities in beef sector are complex and less explored. Based on our findings, the Catalogue for greening he Beef Value Chain is depicted in Table 10.

Table 10: Catalogue of green/ climate friendly solutions for beef value chain

Challenges	Interventions	Food Safety	Food Quality	Food wastages	Greening value chain
Input use for sustainable production	Zero use of the Growth Hormone (e.g., steroid)	+++	+++		++
	Follow strict guidelines for antibiotic use	+++	++		++
Management practices	Improve manure and slurry management				+++
	Hygienic management during pre- and post-slaughter conditions	+++	+++		+
	Introduce standard hygienic meat handling procedure	+++	+++		+
	Modernize open market meat selling point	+++	+++	+	+
Distribution system	Minimize transportation for beef cattle				+++
	Use of temperature regulated cool van throughout meat distribution channel	+++	+++	+++	+
	Improve last mile delivery system	+++	+++	+++	+++
Consumers perception	Consumers need to be concerned and willing to purchase greener produced beef	+++	+++	+++	+++
Economics of the value chain	Green production should be acknowledged in pricing policy	+++	+++	+++	+++

Note: +++ indicates High Impact, ++ indicates Medium Impact, + indicates low Impact

3.4.5.4 Matrix of catalogue for greening the Dairy Horticulture Value Chain

The Horticulture Value Chain is very broad and this sector comprises of quite a number of fruits and vegetables which makes this sector more complex than beef and dairy. However, this study has come up with a very concrete catalogue focusing mostly on very common fruits and vegetables which is depicted in Table 11.

Table 11: Catalogue of green/ climate friendly solutions for horticulture value chain

Challenges	Interventions	Food Safety	Food Quality	Food wastages	Greening value chain
Input use for sustainable production	Follow the guidelines and policy for pesticide, herbicide and inorganic fertilizer use	+++	+++		+++
	Reduce the use of inorganic fertilizer and use at least a certain percentage of the organic fertilizer	++	++		+++
	Increase the use of green water				+++
Management practices	Application of Good Agricultural Practices (GAP)	+++	+++	+++	+++
	Improve transportation (especially using standardized cooling van) system	+++	+++	++	+++
Distribution system	Use of green packaging materials	+	+		+++
	Reduce the postharvest losses of fruits and vegetables	+	++	+++	+++
	Improve the last mile delivery system	+++	+++	+++	+++
Consumers perception	Consumers need to be concerned and willing to purchase greener produced fruits and vegetables	+++	+++	+++	+++
Economics of the value chain	Green production should be acknowledged in pricing policy	+++	+++	+++	+++

Note: +++ indicates High Impact, ++ indicates Medium Impact, + indicates low Impact

4. Conclusion and way forward

This study has brought the results on the existing status of the food sector, its challenges and the way forward by deep diving to dairy, beef and horticulture sector. The results revealed that transitioning from existing value chains to green value chains require changes in the entire value chain. The major emphasis is on the production system where the changes in the input use, cost estimation for such changes and related emission and water use directly influence the greening of the value chain. The food safety, quality and food loss in dairy, beef and horticulture were also revealed based on the available information but for quantification of the actual loss in the various segment, the value chains need to be further expedited. At the same pace, the findings on the quality and safety of the dairy, beef and horticulture are multi-sectoral and multi-stakeholders' task based, which not only requires the changes in the production system but also requires the policy decisions, which needs to be aligned. The implication of this study can be aligned to the strategic goal of the Danish Government who eventually would like to fully green Denmark and secondly would like to extend the cooperation to the international scale, which includes Bangladesh. Based on this, the possible way forward to upscale the findings of this study are:

The agriculture and food sectors (Dairy, Beef and Horticulture) rely on a finite supply of land, water and energy to meet food demand; hence, misusing and degrading these supplies can lead to a serious economic crisis not only for the agricultural sector but also for the entire economy (ESCWA, 2014). However, there are some significant focus issues than can provide for some form of greening of the food value chains:

- Inaugurate public-private partnerships, which in some cases provided private investments in greening and markets for green products
- Organization and coordination of producers and consumers and strengthening the linkage among all stakeholders with transparent and goal oriented functional dynamics in the chain; this is expected to open up the avenue of working for greening the agricultural value chain
- Identifying the services (feed and nutrition, breeding, health, extension and knowledge-based networking) that would enhance sustainability and quality within the chain
- Evaluating market risk and the value of market opportunities, adopting specific standards and quality certifications that could lead to premium products and access to niche markets
- Identifying areas where cooperation with firms performing similar activities in the chain could increase efficiency and effectiveness (namely, marketing, procurement, management or logistics)
- Taking a system and network perspective including the life cycle approach which includes ecosystems
- Access to international markets has encouraged greening
- Promoting networking to bring all of the key stakeholders in a single platform to establish the knowledge pool for dissemination to the wider audience

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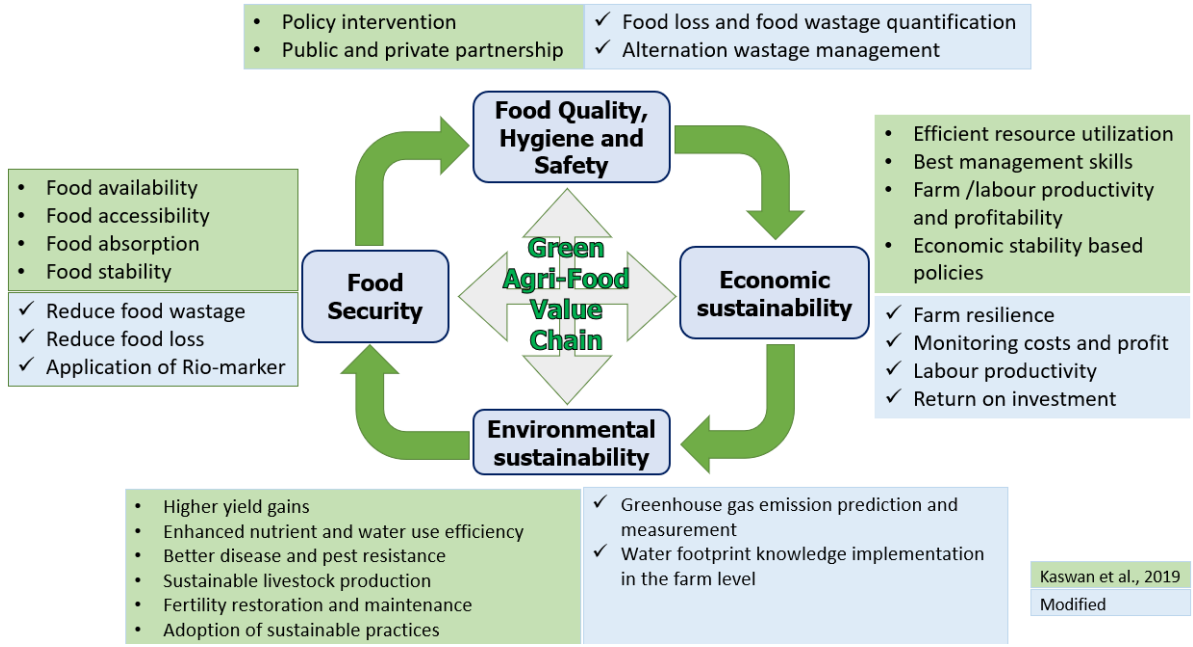
Appendix 1: Conceptualization of the Green Value Chain Application apply to our study

The green value chain concept is a systematic approach incorporating environmental support, guideline and policy to greening the food value chain (OCED, 2012). Kaswan et al. (2019) developed a framework for a green agri-food value chain, which is shown in Figure 1. Four components (environmental sustainability; food security; food quality, hygiene and safety and economic sustainability) are interrelated and interdependent to develop the green agri-food value chain. None of them can be out of focus/can stay behind the scenes to achieve the sustainable green food value chain. "No compromise with environment" - a time driven need, green value chain needs should not compromise the quality of environment/ecosystem so that it remains equally capable of supporting the future generations too. This can be attained by coordinated efforts for achieving higher nutrient and water use efficiency, insecticide/pest control through integrated approaches, sustainable production practices and greenhouse gas measurement and reduction at farm and value chain levels. It should be noted that overlapping or conflicting balances among profitable and environmental goals restrain the fulfilment of the goal.



Appendix Figure 1: Component of the Green food value chain (Adapted and further modified from Kaswan et al. (2019)

Economic sustainability is a part of the green agri-food chain and the farmers should be able to earn profits continuously by proper management of all adverse situations including unpredictable weather and pest outbreaks. The basic philosophy behind the economically sustainable agriculture includes better viability and pliability of farm economy in the long run, farm management skills, better resource utilization and conservation of the natural resources. Farm and labour productivity are key input systems of farming that need to be boosted with efficient management skills in order to open up the avenues for higher monetary returns (Winiewska, 2011). Employing crop diversification, natural resources conservation

technologies, livestock-crop integration, critical analysis of market trends, harnessing the government subsidies on fertilizers and engaging the family members in off-farm activities for side income etc. can enhance greener footsteps towards a green food value chain.

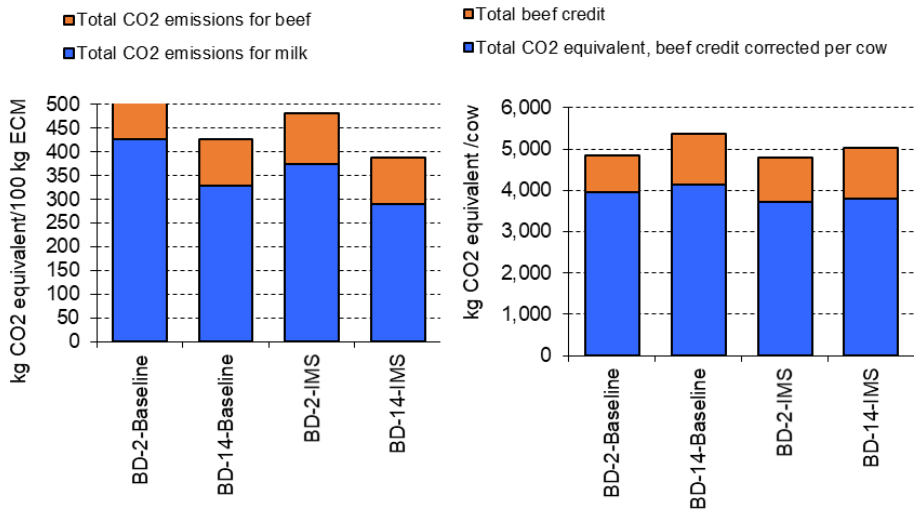
Food security is defined by the availability and accessibility of an ample amount of nutritious foods to live a healthy life (FAO, 2016). It is usually framed in four dimensions: food availability, food accessibility, food utilization/absorption and food stability. Bangladesh is self-dependent in cereal food production as per the statement of the government. However, the agri-food policies in the present context are not encouraging the health, safety and nutritional concerns of its consumers throughout the value chain. The studies on the food chains indicate the varying effects exerted by the changing policies on creation of healthier food environments for the society (Gomez and Ricketts, 2013). Hence, advanced levels of studies need to be carried out for pinpointing the effect of food chain shifts on health and nutrition (Popkin, 2014). Food waste reduction and alternation (implementing circular economy) reduce the harmful emission and excessive use of scarce natural resources which will make the agri-food value chain greener. In addition, the policy makers should include the processing, marketing and consumption criteria for better implementation of the green agri-food value chain model.

Appendix 2: Case of Dairy for Green/ Climate Friendly Solutions

Considering the above facts, the total greenhouse gas emission reduction and water footprint toward greening dairy farms simulation model results on both baseline farms and simulated farms on total carbon footprint and water footprint. It has been done to derive some action points for future interventions toward achieving green dairy farms.

A. Farm Simulation Results on Greenhouse emission

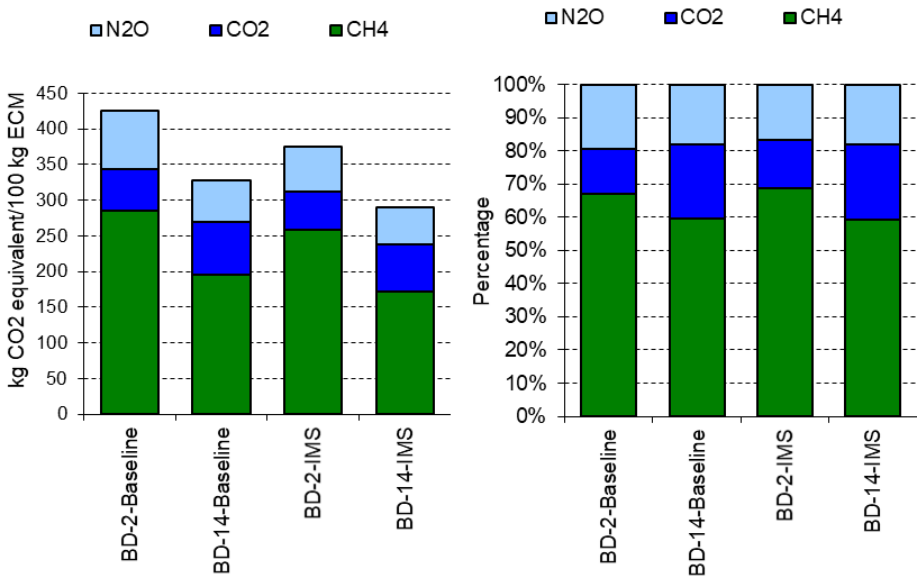
The total greenhouse gas emission per 100 kg Milk ECM and per cow (kg CO_2 equivalent) are depicted in Appendix Figure 2. The total CO_2 emission for beef is 96 for BD-2-Baseline farms, 98 for BD-14-Baseline and 108 for BD-2-IMS and CO_2 emission for milk is 426, 328, 375 for BD-2-Baseline farms, BD-14-Baseline and BD-2-IMS respectively. The GHG emissions per cow for BD-2 baseline is 3949 kg which is reduced to 3730 kg CO_2 equivalent. The Appendix Figure 2 shows that due to improved farm management system, an overall decrease in greenhouse gas emission by 8% for HH farms and 9% for FF farm was possible where for dairy this reduction is further increased to 12% (for HH) and 11% (FF). In case of beef cattle production, the FF still reduced emission by 2% but for HH farms, the emission increased by 12%. This implies that dairy is highly responsive to the total interventions toward achieving greening dairy farms.



GHG emissions per 100 kg milk ECM GHG emissions per cow

Appendix Figure 2 GHG emissions per 100 kg milk ECM and per cow

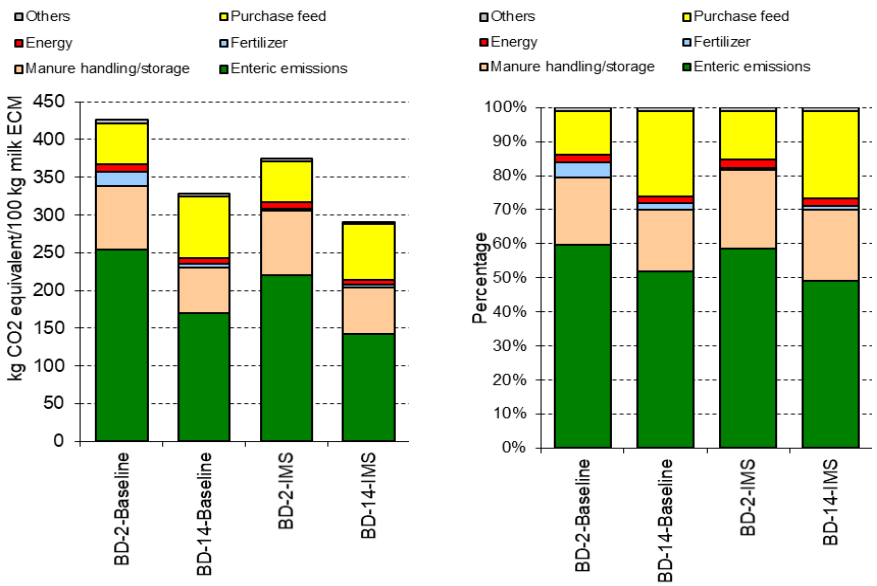
Looking into emission per farm and/cow level, both dairy and beef cattle have potential to reduce emission. The overall decrease through intervention were 6% for HH farms and 9% for FF farms. For dairy, the decline is 12% and 11%, for HH and FF farms, respectively.



Emissions by gases per kg milk SCM Emission by Gases: proportion

Appendix Figure 3: Emissions by gases and proportions per kg milk ECM

The main GHG gases CH_4, CO_2 and N_2O emissions are highest in BD-2-Baseline farm, which is almost 285 for CH_4, 83 N_2O and 58 CO_2 and the lowest gas is produced from BD-14-Baseline farms (Appendix Figure 3). According to the report of Gerber et al. (2010), the GHG emissions from the dairy herd, including emissions from deforestation and milk processing were estimated at 1,969 million tonnes CO_2-eq. [±26 percent], of which 1,328 million tonnes [±26 percent] are attributed to milk, million tonnes [±26 percent] are attributed to milk, 151 million tonnes [±26 percent] to meat production from culled animals and 490 million tonnes [±26 percent] to meat production from fattened animals.



Emissions by activities per kg milk ECM Emission by activities: proportions

Appendix Figure 4: Emissions by activities and proportions per kg milk ECM

Appendix Figure 4 shows the simulation model results on both baseline farms and simulated farms on total carbon footprint in metric and percentages form from energy, manure handling/storage, purchase feed, fertilizer, enteric emission and other sources. The detail emission reduction possibility through improvement in the management are depicted in the Appendix Table 1. The emission on various activities of the dairy farm and different ways clearly revealed that the most important gas within the greenhouse gas emission is CH4 and NO2. According to gas types, the interventions supported to reduce the enteric methane emission which has very slight decreased from 230 kg CH4/farm to 225 kg CH4/farm (for small, HH) but substantial decrease from 1562 kg CH4/farm to 1381 kg CH4/farm (for large, FF).

The most potent gas for contributing to the highest level to the greenhouse gas emission is N2O. Due to improved management, similar like CH4, N2O is also reduced. Both direct N2O emission (on-farm) and indirect N2O emission (off-farm) were reduced which reveals good prediction for substantial decrease in the emission as the N2O contributes to 12 times higher CO2 equivalent than CH4. Unlike CH4 and N2O, CO2 is less likely to contribute to the reduction of the emission. Since this has lower impact on the overall emission, this might be less significant. Genetic selection for feed efficiency, heat tolerance, disease resistance, and fertility can augment selection for milk yield in reducing enteric CH4/ECM with the potential of 9 to 19% reductions (Knapp et al. 2014).

The value chain management and its actors are highly influenced by the milk marketing system. So far, the value chain study on the dairy sector was mostly on how to milk has moved farm to consumers but our approach is based on the milk marketing system-based value chain which in one hand, have the capacity to trace the milk and on the other hand, how the concept of green could be applied to the farm level. With this approach from production to the consumers - all are well linked

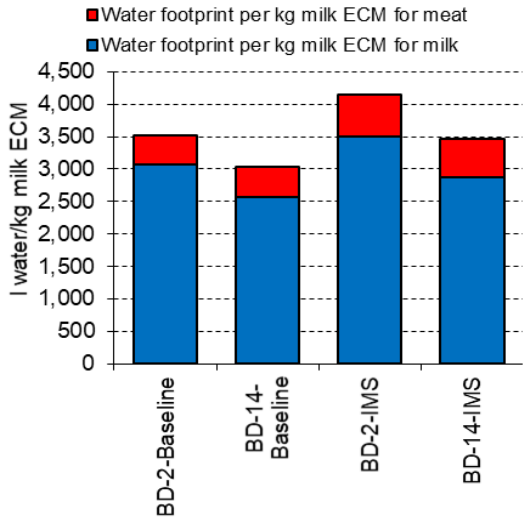
Appendix Table 1: Emission reduction possibility of the dairy farm using the Greening concept

Gas emission	Unit	BD-2-Baseline	BD-14-Baseline	BD-2-IMS	BD-14-IMS
Methane emissions					
CH4 enteric emissions	kg CH4/farm	230	1,562	225	1,381
CH4 slurry emissions	kg CH4/farm	28	235	39	293
Total CH4 emissions	kg CH4/farm	259	1,797	264	1,674
In CO2 equivalent	kg CO2/farm	6,469	44,933	6,611	41,860
Beef credit	kg CO2/farm	1,186	10,300	1,473	10,383
CO2 equivalent per 100 kg milk SCM	kg CO2/100 kg milk	285	196	258	173
Nitrous oxide emissions					
Direct N2O emissions	kg N2O/farm	4.8	28.1	4.2	26.7
Indirect/off-farm N2O emissions	kg N2O/farm	2	17	1	16
Total N2O emissions	kg N2O/farm	6	45	5	42
In CO2 equivalent	kg CO2/farm	1,885	13,460	1,607	12,664
Beef credit	kg CO2/farm	346	3,085	358	3,141
CO2 equivalent per 100 kg milk SCM	kg CO2/100 kg milk	83	59	63	52
Carbon dioxide emissions					
Direct CO2 emissions	kg CO2/farm	218	1,468	233	1,522
Indirect/off-farm CO2 emissions	kg CO2/farm	1,099	15,379	1,147	14,501
Total CO2 emissions	kg CO2/farm	1,317	16,847	1,379	16,023
Beef credit	kg CO2/farm	242	3,862	307	3,974
CO2 equivalent per 100 kg milk SCM	kg CO2/100 kg milk	58	73	54	66
All gases in CO2 equivalent					
Total CO2 equivalent	kg CO2/farm	9,672	75,240	9,598	70,547
Total CO2 equivalent	kg CO2/100 kg milk	521	426	482	387
Direkt/on-farm CO2 emissions	kg CO2/100 kg milk	437	310	406	281
Indirect/off-farm CO2 emissions	kg CO2/100 kg milk	85	116	76	105
Total CO2 equivalent per cow	kg CO2/cow	4,836	5,374	4,799	5,039
Total beef credit	kg CO2/farm	1,773	17,247	2,138	17,499
Total beef credit per 100 kg milk SCM	kg CO2/100 kg milk	96	98	107	96
Total beef credit per cow	kg CO2/cow	887	1,232	1,069	1,250
Total CO2 equivalent, beef credit corrected	kg CO2/farm	7,898	57,992	7,460	53,048
Total CO2 equivalent, beef credit corrected per 100 kg milk SCM	kg CO2/100 kg milk	426	328	375	291
Total CO2 equivalent, beef credit corrected per cow	kg CO2/cow	3,949	4,142	3,730	3,789

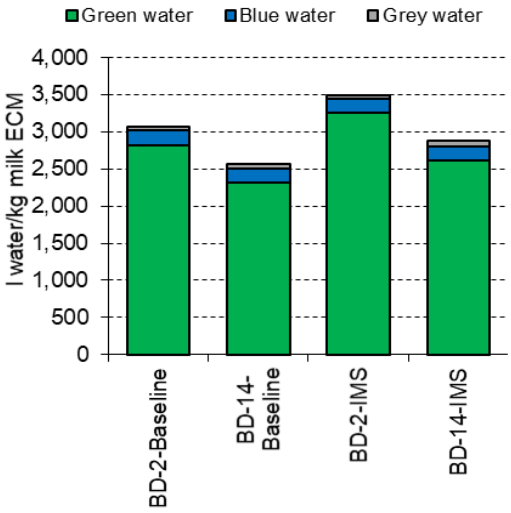
B. Farm Simulation Results on Water footprint

Structural change towards intensification has been observed in the dairy farming in Bangladesh which causes increased use of input (i.e., purchased feeds, farm mechanization, fodder production, fertilizer, etc.) to produce more milk. This will have direct effect on water use. Water will be similar to "Oil" in 2050. The water use is an environmental sustainability indicator and is based on how efficiently water is used to produce a unit of milk. In 2050, there

will be a need to double the amount of milk than now and hence will require double the amount of water. In contrast, the water availability is decreasing, and rate of pollution is increasing.



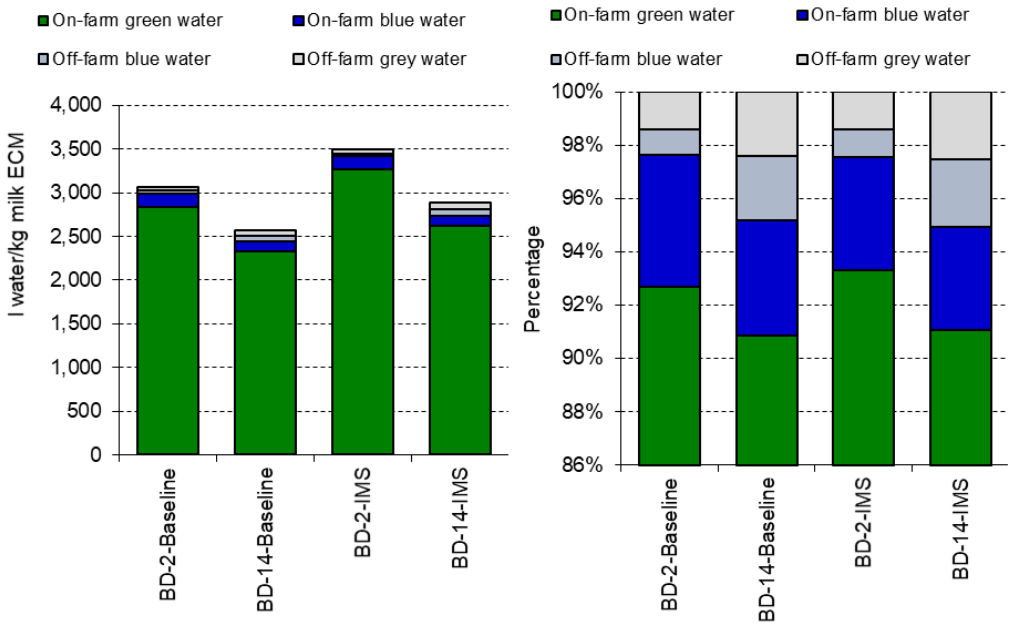
Water footprints per kg milk ECM



Green, blue and grey water footprint per 100kg milk ECM

Appendix Figure 5: Water footprints per kg milk ECM and green, blue and gray water footprint

Appendix Figure 5 show the water footprint per kg ECM and types of water use. The amount of water uses in BD-2 (3063 kg/ per kg milk ECM) and BD-14 (2567 kg/ per kg milk ECM) is lower compared to the improved management system respectively. Though the amount of water is increasing, the excess water is coming from green water which has less environmental cost. The major driver for water use is the use of water through feed (~98%) and only ~2% water is used as drinking and service water. The amount of water used is higher through concentrate than roughage because growing cereals requires more water (fourth times higher), due to the fact that cereal is highly water intensive than forage (Sultana et al., 2014 and 2015). According to WFN (2012), water requirement leads to questionable results and uncertainty towards sustainable production and consumption of good and/or services in local pertinence. For instance, it is referenced worldwide that approximately 1000 litres of water are required to produce one litre of milk (WFN, 2012). This is attributed to poor understanding of water use without knowledge in the context of local pertinence.



On-farm and off-farm water contribution

Share of on-farm and off-farm water contribution

Appendix Figure 6: On-farm and off-farm water contribution and share

Water usage in the dairy sector is considered an integral part of agricultural water resource management. Appendix Figure 6 show the on farm and off farm water contribution. Majority of water contribution is from green water (almost 93%) and less than 5% water comes from blue water. However, small-scale production farm (BD-2) needs more water requirement/kg of milk as they rear small number of animals with low productivity than large scale typical farming system (BD-14) with high productivity. The scenario is the same for baseline and improved management system.

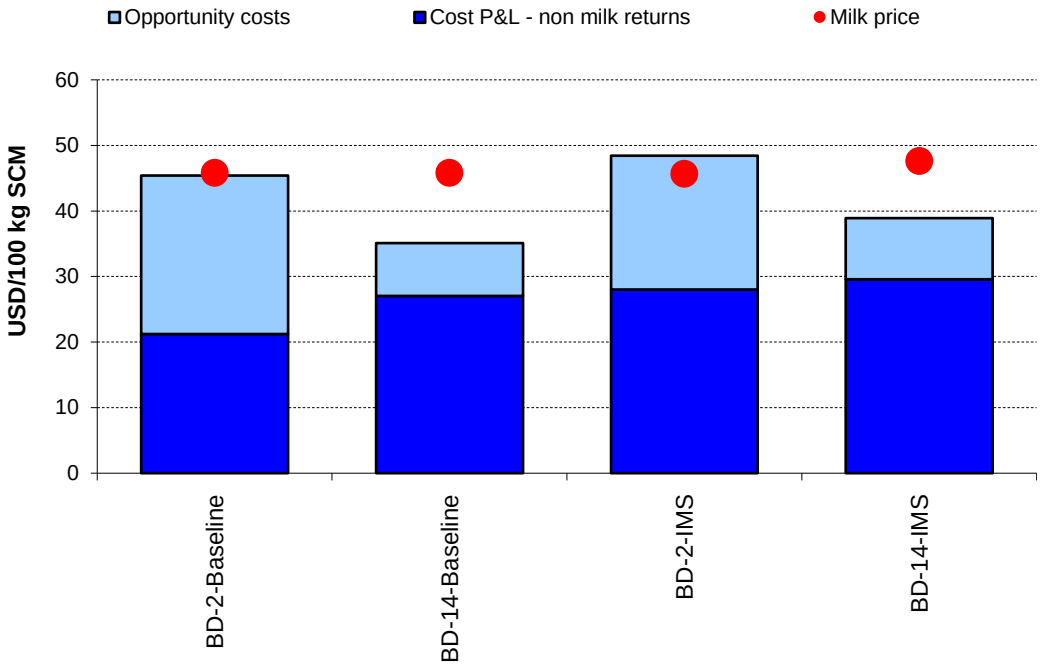
C. Sustainability and Resilience of the Simulated Farm

The reduction strategy of the greenhouse gas emissions through input changes are highly potential, however, there is no impact on productivity and economic performance of the dairy farm. On the other hand, the sustainability is important to continue the dairy farm operation. The sustainability has four dimensions, social, economic, environment and institutional. From the perspective of green, food safety, quality and food loss in a dairy farm, the TIPICAL model has capacity to demonstrate those indicators. The four indicators are used for the sustainability and greening dairy farms: the cost of milk production only (COMPO), Financial Performance, liquidity of the dairy farms and operating profit margin (Uddin et al., 2020)

D. The cost of milk production towards achieving Green dairy farms

The cost of milk (raw) production for the average farm type (BD-2) and large farm type (BD-14) was 50 USD/100 kg (42.5 BDT/kg) and 38 USD/100 kg (32.3 BDD/kg), respectively. The milk (raw) price for those typical farms was 40.8 BDT/kg. This implies that all of the small-scale typical farms are outpaced and has no competitive advantages on the global market. The small-scale farm type represents 82% of the total farm type available in the country and produces 63% of the total country milk production (IDRN, 2021). The ECM milk price is 45.4,

35.2, 48.4 and 38.9 USD/ 100 kg respectively for BD-2 and BD-14 farms at baseline and IMS level (Appendix Figure 7).

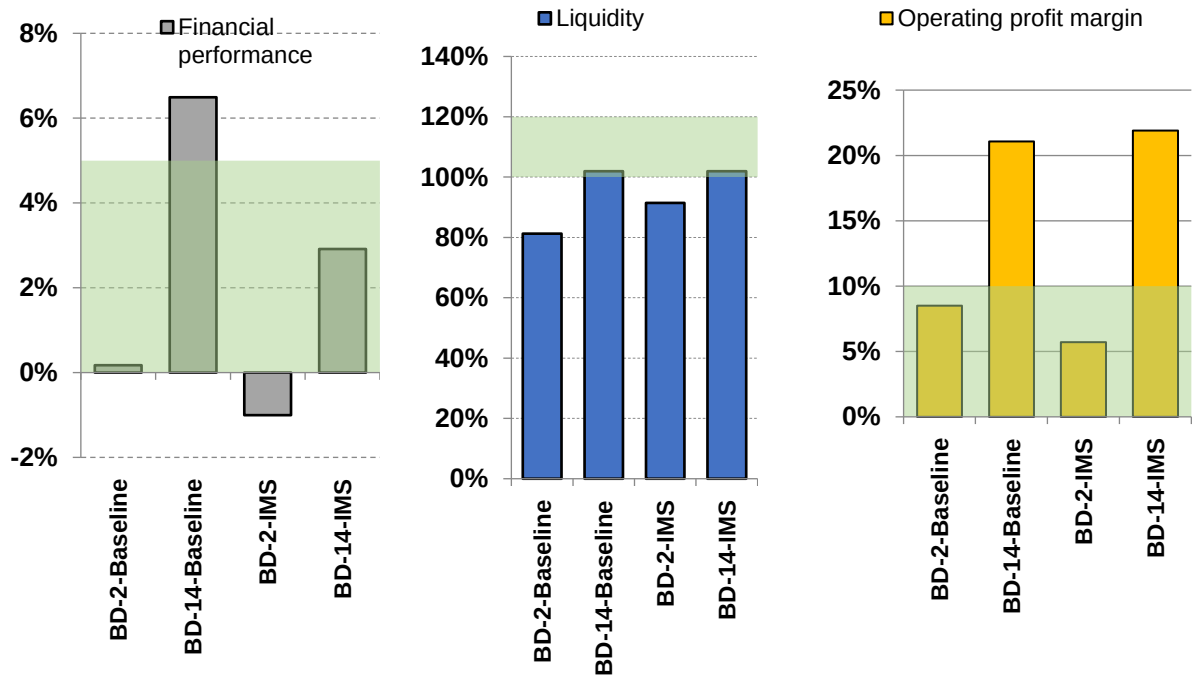


Appendix Figure 7: Cost of milk production considering opportunity cost and non-milk returns.

The opportunity costs (for own land, labour and capital) marked as light blue was the highest for BD-2 farm and the lowest for BD-14 farm. This implies that farmers put substantial family labour input to the dairy farms as long as the farms stays smaller but once the farms start to get bigger, hired labour takes place. The cash costs (marked as dark blue) are found for the highest for BD-14 farms and the lowest in BD-2 farm (Appendix Figure 7).

E. Farm Resilience toward the greening of dairy farms

Farm resilience to the input changes for greening the dairy farms are a way forward for sustaining the dairy sector. The results on the baseline farms and simulated farms are depicted in Appendix Figure 8. The financial performance and liquidity are decreased due to implementation of the greening objective while the positive operating profit margin is achieved, which could be used as a driving force for the farmers to adopt the greening objectives.



Financial performance Financial performance Financial performance

Appendix Figure 8 Financial performance, Liquidity and Operating profit margin of dairy farm

Based on the potential of reducing greenhouse gas emissions through input changes, the cost is increased per kg while all kind of gasses - methane, carbon dioxide, nitrous oxide decreases and the operating profit margin increases. However, the water footprint, financial performance and liquidity is negatively affected. This implies that the quality of the input, feeding balance ration, farmer awareness and farm practices need to improve and these are highly important in making the dairy sector green.