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A Framework for Addressing the Twin Challenges of COVID-19 and Climate Change for Sustainable Agriculture and Food Security in South Asia

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Climate change has begun to ravage agriculture and threaten food security in many parts of the world. The novel coronavirus pandemic (COVID-19) has further disrupted agricultural activities and supply chains and has become a serious threat for public health. Like in many developing countries, South Asian farmers are now facing the double challenge of addressing the impacts of a changing climate and managing the disruptions caused by COVID-19. Despite growing concern, there is limited understanding of how climate change, public health, and COVID-19 interact, and of the possible pathways to achieving a climate-friendly recovery from COVID-19 to achieve food and nutrition security. In view of this, this paper explores the multifaceted challenges that farmers are now facing in South Asia due to climate change and the disruption caused by COVID-19 from the agricultural and food security lens. The analysis reveals that the complex interactions of COVID-19 and climate change have impacted all dimensions of food security. These interlinkages demand an integrated approach in dealing with food, public health, and climate change to harness synergies and minimize trade-offs between food production, public health, and climate mitigation. I present a framework to address the immediate challenge of COVID-19 and the longer-term challenge of anthropogenic climate change. Key elements of the framework include the strengthening health sector response capacities, strengthening of local and regional food systems, making agriculture resilient to pandemics, adopting flexible and smart approaches—including the implementation of climate-smart agricultural interventions on different scales, promotion of appropriate research and innovation, and the integration of short-term support to address the challenges of COVID-19 to build long-term productivity, and resilience of food systems by investing on natural capital. This framework would enable policy makers to choose the appropriate policy responses at different scales, to address these twin challenges of COVID-19 and climate change.

Keywords: COVID-19, climate change, food security, climate smart agriculture, COVID-19 smart food system, sustainable agriculture, South Asia, public health

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INTRODUCTION

Agriculture and food security are connected with both climate change and COVID-19 as healthy food and healthy environment are critical for dealing with COVID-19. Agriculture is the cornerstone of human society, providing not only food and nourishment, but also employment for millions of people all over the world. South Asia is considered as one of the highly vulnerable regions in the world to climate change (Bandara and Cai, 2014). A number of empirical studies indicate that climate change-induced yield losses in agriculture are becoming a serious concern (Bandara and Cai, 2014; Alvi et al., 2021). In South Asia, about 60% of the population depend on agriculture directly or indirectly. South Asian farmers have to feed over 20% of the global population with just 5% of the world's agricultural land (FAO, 2009; Rasul, 2021). Countries in this region faced multiple challenges of food insecurity and underdeveloped public health even before the COVID-19 pandemic. About 300 million people are still severely food insecure in South Asia (FAO, 2019) and ~36% of the children below 5 years of age in the region are stunted due to malnutrition, and 16% are acutely malnourished. South Asia accounts for about 40% of the world's stunted children (FAO, 2019).

Global warming has aggravated the existing challenges of food insecurity. The rising temperatures, changing rainfall patterns, and the accelerated melting of glaciers have posed a threat to agriculture and food security in South Asia (Lal, 2011a; Knox et al., 2012; Gupta et al., 2017; Lal et al., 2017). The main breadbasket of South Asia, the Indo-Gangetic Plains, faces huge challenges of climate change and water management (Rasul, 2014). To add to all this, the novel coronavirus has impacted agricultural operations, transportation, and marketing in South Asia, compounding the prevalent challenges of food and nutritional security, and public health (Balwinder-Singh et al., 2020; Pradhan et al., 2021; Rasul, 2021; Rasul et al., 2021).

South Asia also has poor healthcare systems. For every 10,000 people, there are 2.8 physicians in Afghanistan, 3.8 in Bhutan, 5.3 in Bangladesh, and 6.5 in Nepal, just a tenth of the number in developed countries. Even India—which has one of the strongest healthcare systems in the region—has only 7.8 physicians per 10,000 people (NTI, 2019; Rasul, 2020). Moreover, most of the South Asian countries face a desperate scarcity of public health and primary care facilities, and the magnitude of human suffering is huge. People also lack access to adequate food, and other basic facilities such as clean water, and sanitation and hygiene to name just a few.

Agriculture, food production, climate change, and public health systems are closely interconnected (Pradhan and Kropp, 2020; The Lancet, 2020) and impact each other in various ways. There are multiple pathways intersecting the COVID-19 pandemic, climate change, and agriculture and food security. The COVID-19 pandemic has underlined yet again that the food supply chain is vulnerable to any emergency, and cushioning it from shocks needs special preparation and planning.

Like many other developing nations, the challenges South Asian countries face is ways to make agriculture and food systems both climate smart and more resilient to severe shocks such as pandemics (Balwinder-Singh et al., 2020). The unprecedented challenges faced by humanity demand innovative strategies and approaches to agriculture and food systems that address both the coronavirus and climate challenges (Balwinder-Singh et al., 2020; HLPE, 2020; Rasul, 2020). The lessons emerging from the best practices that are being proposed provide an opportunity to use the disruptive forces of COVID-19 to accelerate the transition to more sustainable and resilient food systems and also contribute to mitigating climate change. Short-term measures to address the challenges of COVID-19 can be linked to increased agricultural sustainability and making food systems more resilient by investing in natural capital, and by incorporating ecological, economic, and social considerations in the production, distribution, and consumption of food (HLPE, 2020). While addressing health challenges should be prioritized in the short-term, in the long-term, government policies, and actions need to prioritize making agriculture sustainable and building healthy food systems (Rasul, 2020; Watts et al., 2020). Thus, policy choices need to focus on meeting urgent food and public health requirements, ensuring longer-term resilience, and sustainability in agriculture, and also taking into account the impacts of climate change.

Climate change and COVID-19 are the two major global crises. Despite the fact that all countries are affected by the COVID-19 pandemic and climate change, South Asian countries face a more difficult situation due to their large populations, inadequate health care facilities, high poverty, and malnutrition. While a number of studies highlighted that South Asia is one of the most vulnerable regions to climate change (ADB, 2017), COVID-19 has wreaked additional havoc in the region. India, Pakistan, Bangladesh, and Nepal are facing difficult challenges to control the spread of the virus. As of April 29, 2021, India had over 18 million COVID-19 cases (second after the United States), with over 200,000 deaths, and the number is growing every day. It is predicted that South Asia will account for over half of the people driven to poverty due to COVID-19 and resultant economic consequences (Sumner et al., 2020). Although South Asian countries are most vulnerable to the effects of climate change, they are less prepared to deal with COVID-19 and climate change. Despite growing concern, there is a limited understanding of how climate change, public health, and COVID-19 interact, and what are the possible pathways to achieve a climate-friendly recovery from COVID-19 to realize food and nutrition security? Under the changing climate, the challenges of food and nutrition insecurity, public health, and environmental degradation cannot be separated (Rasul, 2021). Agriculture is key to food and nutrition security and public health, as well as to the mitigation of climate change. This paper examines the twin challenges that farmers in South Asia are now facing in addressing the effects of climate change while also dealing with the disruptions caused by COVID-19. It contributes in better understanding the linkages between the two global crises of climate change and COVID-19, and highlights the need for integrated actions to address interconnected challenges and suggest a framework for addressing the two shared global challenges.

METHODS

This paper is based on secondary information through reviews and analysis of various literature including journal articles, review papers, media, and government reports. As the main objective of this research is to develop a framework to tackle the twin challenges of COVID-19 and climate change, this study has been guided by two broad research questions: (a) What policy and institutional mechanisms are needed to tackle the twin challenges of COVID-19 and climate change to make agriculture and food security public health friendly? (b) Can a framework be developed to address these twin challenges? While literature on climate change and agriculture and food security has grown globally, the understanding of the link between COVID-19, climate change, food security, and public health is limited, particularly in South Asia (Rasul, 2021).

Collection of Literature

To collect the relevant documents, I started searching with relevant keywords. The search string terms included combinations of "challenges of COVID-19 and climate change," "COVID-19 and climate change for agriculture and food security in South Asia," "COVID-19 smart," "climate smart agriculture," and "framework." Literature search was limited between 2008 and 2021. I started the search with Scopus. As many journal articles do not touch upon the COVID-19 and climate change, I expanded the search to Google Scholar and ResearchGate and also considered gray literature including government and international agency reports, and media reports. For collecting additional literature, I used a snowball approach. This has resulted in 2,810 documents. These documents were analyzed on the basis of inclusion and exclusion criteria. The main criteria for inclusion were (a) COVID-19 and climate change, (b) agriculture and food security, (c) South Asia, and (d) publication in English. The main exclusion criteria were (a) literature that is not directly related to COVID-19 and climate change, (b) literature that is not related to, or deal with, agriculture and food security, and (c) literature that is not published in English. To assess the relevance, I first examined the titles and abstracts and found 238 articles that were suitable. However, after a detailed study of the 238 documents, I found that only 115 articles are suitable for a detailed analysis. Finally, 115 documents were studied in detail, analyzed, and used in the study, which provided the basis for developing a framework.

DYNAMIC IMPACTS OF COVID-19 AND CLIMATE CHANGE ON FOOD SYSTEMS: A CONCEPTUAL FRAMING

The COVID-19 pandemic and climate change affect agriculture and entire food systems in multiple ways, ranging from the production and processing of food, to its distribution and consumption. The complex interactions of COVID-19 and climate change have impacted all six dimensions of food security, namely, food availability, access, stability, utilization, agency, and sustainability (HLPE, 2020). It may be mentioned that the HLPE *Global Narrative* report recently added two more dimensions of food security—agency and sustainability.

COVID-19 and climate change both have an effect on agriculture and food systems, but the nature and mechanisms by which they do so differ (Béné, 2020; Pradhan and Kropp, 2020; Rasul, 2021). While the effects of COVID-19 are immediate, propagate quickly, and pose a high risk, the effects of climate change are long-term, build slowly over time, and pose a long-term threat to agriculture, human health, and well-being. The impacts of climate change on agriculture are manifested through different ways, including higher temperatures, variability in rainfall and precipitation, and associated extreme weather events—droughts and floods and pests and diseases (IPCC, 2019). Additional effects come through accelerated melting of glaciers and changes in snowfall patterns, rising sea-levels, and increased heat stress (Hock et al., 2019; The Lancet, 2020). Climate change also has an impact on public health by increasing heat stress, facilitating the spread of infectious diseases, and causing extreme weather events (Springmann et al., 2016; The Lancet, 2020; Watts et al., 2020). Increased rainfall and prolonged drought expose people to a number of pathogenic bacteria, parasites, mycotoxins, and viruses (Rose and Wu, 2015), which have significant impacts on human health and labor productivity particularly on children's nutritional status, growth, and development (Guerrant et al., 2013). Furthermore, a number of studies hypothesized that rising CO_2 levels in the atmosphere would have an impact on the nutritional status of various crops, and thus effects on human nutritional status (Myers et al., 2015, 2017). Myers et al. (2015) found that increased CO_2 concentrations resulted in lower zinc and iron concentrations in all C3 grasses and legumes.

On the other hand, COVID-19 has profound implications for all dimensions of food security (Workie et al., 2020). The associated lockdowns, restrictions on physical movement, restrictions on transport, and the closure of restaurants, food stalls, shops, and malls affected food production, transportation, processing, marketing, and consumption (HLPE, 2020; Schmidhuber and Pound, 2020; Workie et al., 2020). They have caused labor shortages, disrupted supply chains, affected harvesting, cultivation, post-harvest management, transportation, processing, and the marketing of agricultural products. Labor-intensive crops, particularly horticultural products such as fresh fruits and vegetables, have been affected badly. Supply chains for agricultural inputs, such as seeds and fertilizers, have also been affected by the lockdowns (Arouna et al., 2020; Pu and Zhong, 2020). COVID-19 can also affect food safety, particularly dairy and poultry products where risks of contamination are higher for COVID-19 during production, transportation, sale, and consumption, and increases risks to public health (Shahidi, 2020). Moreover, the generation of waste—both medical and household—has increased considerably due to COVID-19. Higher generation of household waste and particularly medical waste has adverse effects on environment, air, water, and human health by polluting the natural environment in the long run. The complex interactions of COVID-19 and climate change on food security

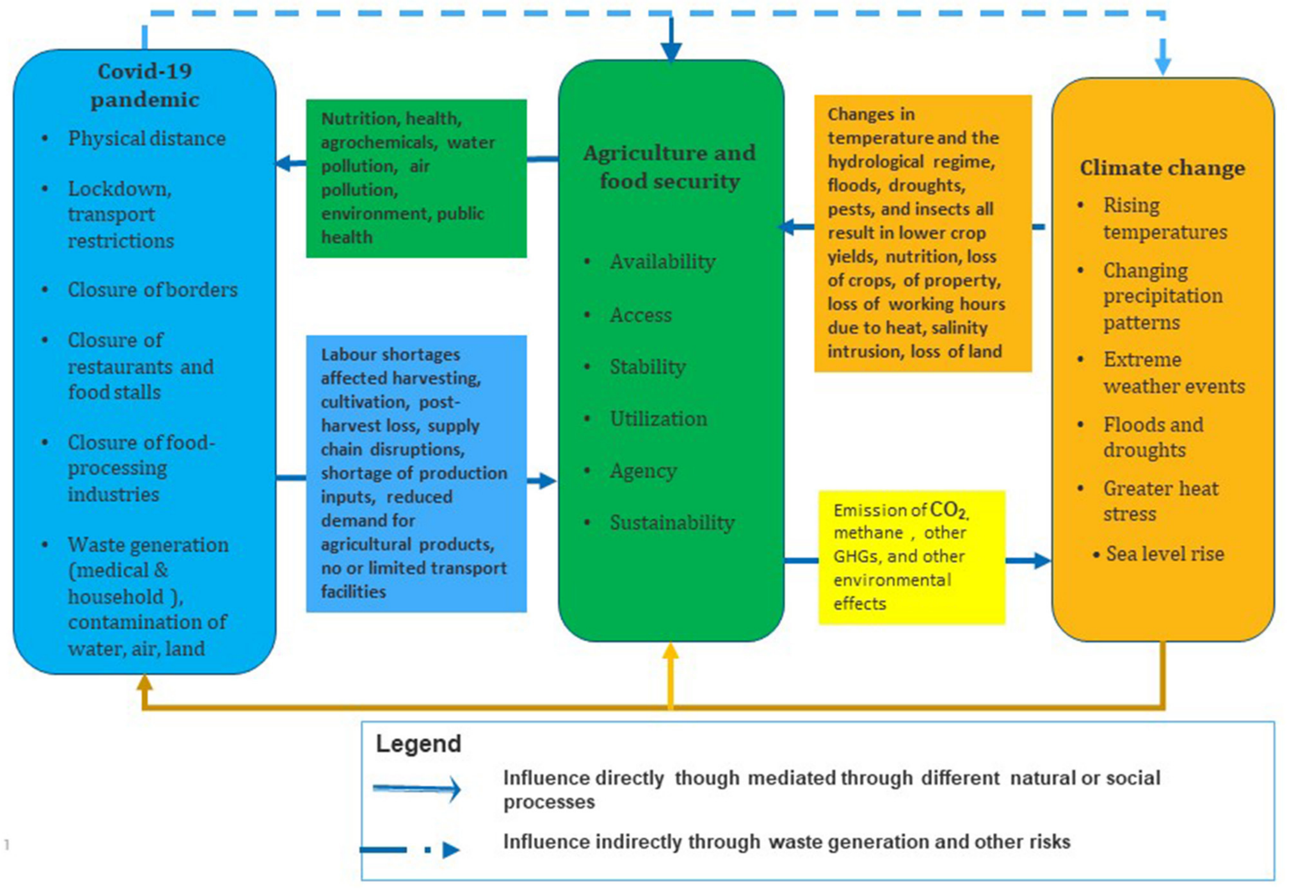

FIGURE 1 | Dynamic interactions between COVID-19, climate change, and agriculture and food security in South Asia.

and food systems and their multiple pathways are presented in **Figure 1**.

So, whereas climate change mostly affects the availability, stability, and sustainability of food security, the COVID-19 pandemic has affected all the six dimensions of food security and food systems mentioned above. In particular, the COVID-19 pandemic has underlined certain imperatives in food security and food systems—public health, nutrition, and food hygiene. Because of COVID-19, public health and nutrition have become more important than ever before. It is no longer enough to only think about how much is produced, but also what to produce, and how to produce it. Human actions that have an effect on the Earth's atmosphere often lead to health problems. Agricultural production, which affects the environment eventually affects human health and well-being (The Lancet, 2020). Additionally, agriculture is one of the few major sectors in South Asia (and indeed the world economy) from which all the three main greenhouse gases (GHGs)—carbon dioxide, methane, and nitrous oxide—emanate significantly (Gupta et al., 2017). COVID-19, climate change, and agricultural systems are interlinked in many ways. The changing climate has already affected the underlying social and environmental determinants of health at the global level [World Health Organization (WHO), 2015; Watts et al., 2020]. In many situations, increased food production comes with increased environmental degradation, such as air pollution, water pollution, and GHGs emissions, which affects public health and increases costs in health (Watts et al., 2015), which in turn affects agriculture and food production (Gupta et al., 2017). On the other hand, environmental friendly agriculture and food system can mitigate GHGs emissions and improves public health, while enhancing productive capacities and potential in the future (Pretty et al., 2018). Because of these interconnections, dealing with food security in the context of the pandemic and climate change necessitates an integrated approach. Food security, public health, and climate change cannot be addressed effectively and sustainably unless food, public health, and climate change are addressed together (Rasul, 2020). Given the aforementioned interconnections, it is clear that food security, public health, and climate change need to be addressed in an integrated manner in order to maximize synergies and minimize trade-offs between food production, and climate adaptation and mitigation (Béné, 2020; Rasul, 2021).

EFFECTS OF CLIMATE CHANGE IN AGRICULTURE AND FOOD SECURITY IN SOUTH ASIA

Climate change can affect agriculture, food security, and human health and well-being in a variety of ways (Fanzo et al., 2017; Watts et al., 2018). Climate change is affecting the fundamental basis of agriculture including food production, stability, and availability, through changes in temperature and rainfall, water availability, hydrological regimes, and by intensifying the frequency of floods, droughts, and heat stress (Mbow et al., 2019). Crop yields depend largely on climatic conditions. For instance, temperature rise by 1°C can reduce yields of wheat by 5–10% (Asseng et al., 2015). According to the Intergovernmental Panel on Climate Change (IPCC), there will be an increase of 0.88–3.16°C in average temperatures by 2050, and an increase of 1.56–5.44°C by 2080 in South Asia (IPCC, 2007). Other studies have also reported major changes in temperature (Mbow et al., 2019). Along with changes in temperature, precipitation patterns is also likely to change. It is projected that winter rains are going to be lesser, while summer rain is likely to increase (IPCC, 2007). Less rainfall in the winter when water is critical for agriculture and food production, with increased rainfall in summer rainy season with high intensity and frequency are likely to lead to extreme weather events such as floods, droughts, heat waves, increased storms, cyclones, and other natural disasters. Other studies suggest that precipitation patterns are changing, and it is apprehended that these changes will become stronger and less predictable in the future (Huss and Hock, 2018). Higher temperatures reduce crop yields through increased evapotranspiration, reduced soil moisture, and by creating favorable conditions for weed and pest infestations. Scientists apprehend that climate change may alter the patterns of the southwest monsoon in South Asia, the timings of its onset and withdrawal, and water availability for agriculture and food production in the future. Changes in precipitation patterns increase the chances of crop failure and reduce crop yields in rain-fed areas. Global warming is also likely to increase the prevalence of pests and plant diseases, and the pest resistance of crops, which will also affect yields.

Temperature rise have also accelerated the melting of glaciers in the Hindu Kush Himalaya region. According to the IPCC's *Special Report on the Ocean and Cryosphere in a Changing Climate*, most glaciers in the Hindu Kush Himalaya (HKH) will reach "peak water" discharge by the middle of this century, after which the peak water runoff is likely to decline in almost all glaciers (Hock et al., 2019). In most HKH river basins, with significant glacier melt contributions, annual glacier melt runoff is projected to increase until roughly the middle of the century followed by steadily declining glacier runoff thereafter (Huss and Hock, 2018; Nie et al., 2021). The accelerated melting of Himalayan glaciers will affect downstream areas in a number of ways. Initially, the availability of water will increase, though the increase will occur during the summer and monsoon seasons, and is likely to affect people, with more severe flooding and damage to property. However, as the glaciers shrink further over time, water supply will gradually decrease, particularly during the dry season when water is most needed for food production. This will affect agriculture and food security in large parts of South Asia, including the Indo-Gangetic Plains, which is the bread basket of South Asia (Hock et al., 2019; Rasul, 2021). Growing evidence suggests that future changes in different components of the cryosphere will adversely affect irrigated agriculture in South Asia, particularly in the river basins such as the Indus, Ganges, and Brahmaputra. A growing number of field-based local studies report that many high-elevation areas of the HKH region are already experiencing water shortages and uncertainties that are impacting agriculture and food security considerably (Rasul and Molden, 2019; Rasul et al., 2019).

Effects of Climate Change on Crop Yields in South Asia

IPCC Special Report on Climate Change and Land (IPCC, 2019) indicates that crops in many regions, including South Asia, are negatively affected by precipitation declines (Iizumi et al., 2017; Ray et al., 2019) in the absence of irrigation development. A number of crop-specific simulation and projection analysis demonstrate the effects of climate change on the yields of four major crops globally—wheat, rice, maize, and soybean (Bandara and Cai, 2014; Asseng et al., 2015; Wang et al., 2018; Yadav et al., 2021). Although projections vary depending on the methodology, a number of projections have indicated that the yields of many crops will decrease in South Asia with increasing temperatures. A number of projections conclude that the largest declines in yields will be in cereal crops such as wheat and rice, the main staples in South Asia (Knox et al., 2012; Bandara and Cai, 2014; Anwar, 2019; Aryal et al., 2020). Climate change may affect different crops differently and different areas in different ways. While some crops may be affected negatively, others may be affected positively. Different projections results vary widely. Based on the review of 52 studies, Knox et al. (2012) estimates a mean change in yield of all crops in South Asia, by ∼8% by 2050; particularly the yield reduction of maize and sorghum can be 16 and 11%, respectively. In these studies, the CO_2 fertilization is not taken into account. Crop yields in rainfed agriculture may be affected more significantly in some South Asian countries (Lal, 2011a,b).

Other studies corroborate these declines in future yields. According to a study conducted by the International Food Policy Research Institute (IFPRI), climate change in South Asia will result in a 50% decrease in wheat yields, a 17% decrease in rice yields, and a 6% decrease in maize yields by 2050, compared with the levels in 2000 (IFPRI, 2009). While certain crops' yields are likely to decline, climate change may have a positive impact on some others. Rice yields, for example, may rise in Bhutan, Sri Lanka, and Pakistan (Bandara and Cai, 2014). In Sri Lanka and Pakistan, the rice yield may be increased by 6 and 7.5%, respectively. However, there are a number of uncertainties in different assessments. The general agreement is that the climate change will lead to yield decrease in most parts of South Asia, and the overall impact on agriculture and crop yield is more likely to be negative with increasing temperature (IPCC, 2014) as detrimental temperature effects overcome the positive effects of CO_2 (IPCC, 2019). Climate-related threats to food security are expected to increase with 1.5°C global warming and increase even further with 2°C global warming (IPCC, 2018). If the average annual temperature rises by 3°C by 2080, there will be a 10% net reduction in cereal production in South Asia (Knox et al., 2012).

Besides impacting crop yields, climate change is also expected to affect areas suitable for a range of crops and shift crop suitability in different regions in South Asia. For instance, different climate change scenarios predicted that wheat and maize production areas in Pakistan would decline by 30–35 and 23–36%, respectively, by 2070 (Khubaib et al., 2021). Similarly, in Bhutan, it is projected that rice production areas in all major rice-growing areas of Paro, Wangdue, Punakha, Tsirang, Dagana, Trashigang, Trashi Yangtse, and Samtse are likely to shrink in the projected future climate (Chhogyel et al., 2020). However, more systematic research is necessary to better understand the impacts of climate change on crop suitability and crop area.

Reduction in crop yield and crop area are likely to have significant consequence for food security, nutrition, and public health in South Asia, as well as the global community, because South Asia is both the largest producer and consumer of rice and wheat (Myers et al., 2014; Rasul, 2021). Reduced wheat and rice production in South Asia could destabilize the global food market and threaten global food security. As agriculture is vital in South Asian economies, the effects of climate change could have far-reaching consequences for food security (Cai et al., 2016).

Climate Change Is Intensifying Floods and Droughts

Agriculture and food security is highly dependent on hydrological conditions and water availability. Meeting growing food demand depends on the availability of water resources in adequate quantity in the right time. In addition to its effects on crop yields, climate change is also expected to affect hydrological conditions and increase extreme events such as floods and droughts (IPCC, 2014; Hock et al., 2019). According to the Global Climate Risk Index, South Asia was the most affected by disasters between 1999 and 2018. Of the world's total population exposed to climate change-related disasters each year, 64% live in South Asia. Climate disasters have significant economic and social consequences in the region. Between 1990 and 2019, more than 1,000 climate-related disasters affected 1.7 billion people in South Asia, causing more than US$ 127 billion in damages [Global Centre on Adaptation (GCA), 2020]. According to the World Bank, climate change could push 62 million South Asians into extreme poverty by 2030; floods alone could cost an estimated US$ 215 billion annually by 2030 [ADB, 2017].

In the last 30 years, climate-induced disasters affected 1.7 billion people in South Asia and cost US$127 billion in damages [Global Centre on Adaptation (GCA), 2020]. Floods also affect water availability and other infrastructures such as irrigation canals, dams, and transportation necessary for food production. Growing evidence suggests that flood frequency and severity are rising in South Asia and can affect agriculture and food security unless appropriate adaptation and mitigation measures are taken in a timely manner. Floods in the Indian state of Bihar in 2008, attributable partly to glacial melting in the Himalayas due to global warming, affected 4.4 million people, inundated 290,000 hectares of land (Costello et al., 2009), and destroyed 225,000 houses [World Health Organization (WHO), 2008].

Higher temperatures and less rainfall during the dry season (in winter and pre-monsoon) increase the likelihood of droughts. Droughts that last longer and floods that occur more frequently as a result of climate change are exacerbating the region's food and water protection problems, as well as the human population's suffering (Kirsch et al., 2012; UNOCHA, 2014). All the major river basins of South Asia are categorized as "high drought severity." Droughts have occurred at least once every 3 years in India and Pakistan over the last four decades; Bangladesh and Nepal also experience frequent droughts. It has been estimated that natural disasters have killed 5,308 people and affected 1.3 billion people in the region between 1975 and 2015, causing total damage of USD 37.4 billion (EMDT, 2018). With increasing variability in rainfall and precipitation patterns in South Asia the risks to rain-fed agriculture increase considerably (Lal et al., 2017).

Climate Change's Effects on Public Health and Disease in South Asia

A growing body of literature suggests that climate change has already had an impact on some aspects of human health and will continue to do so in the future, particularly in low- and middle-income countries [World Health Organization (WHO), 2014, 2015; The Lancet, 2020; World Economic Forum, 2020]. Climate change can affect human health and well-being directly and indirectly. The direct health effects are physiological effects such as respiratory and cardiovascular disease, as well as injuries, death, and mental illness caused by extreme weather such as droughts, floods, heatwaves, storms, and wildfires. The spread of climate-sensitive infectious diseases, as well as other effects caused by ecological changes as well as changes in air quality, water quality, food, and water security, are its indirect effects [World Health Organization (WHO), 2015]. Like other developing countries, changes in temperature and precipitation, and water-induced disasters caused by climate change have important health effects in countries in South Asia (**Table 1**). The impacts on health are likely to be intensified through indirect pathways such as the spread of vector diseases, food and water insecurity, undernutrition, displacement, etc. The increased incidence of waterborne diseases (such as diarrhea, cholera, and typhoid), vector-borne diseases (like malaria, dengue, and visceral leishmaniasis, more popularly known as kala-azar), and zoonotic diseases (such as leptospirosis, Nipah virus, and encephalitis) have been found to be associated with changes in temperature, precipitation, humidity, and the El Nino Southern Oscillation (ENSO) cycle, and disasters such as floods and cyclones (UNDP, 2016; Adve, 2020). It is reported that a temperature increase of 1°C increases diarrheal incidence rates by 5.6% in developing countries (Hashizume et al., 2008). Climate change increases health risks by creating favorable conditions for the spread of climate-sensitive infectious diseases, particularly water-, food-, and vector-borne diseases (Watts et al., 2015; Adve, 2020; The Lancet, 2020). An article in the journal *Lancet Infectious Diseases* affirms that dengue is perhaps the most important of the emerging infections likely to be affected by climate change (Pandey and Costello, 2019). The incidence of malaria and dengue fever has increased in various parts of South Asia (UNDP, 2016; Sen et al., 2017). In Bangladesh, the incidence of dengue and malaria has increased considerably in recent years. Malarial parasites are detected nowadays even in high-altitude, mountainous areas in Bhutan, India, Nepal, and Pakistan due to increased temperatures. The incidence of dengue fever is also increasing in Bhutan and Nepal [World Health Organization (WHO), 2006], which was not the case some years earlier.

Extreme climatic events such as floods, droughts, and cyclones amplify existing public health challenges in South Asia. For instance, the prevalence of diarrhea, a water-borne disease responsible for 38% of the under-five child mortality in South Asia, and largely caused by a shortage in the availability of safe drinking water (UNDP, 2016), will intensify due to climate change. The IPCC's Fourth *Assessment Report* projects that East, South, and South East Asia will see an increase in morbidity and mortality from diarrheal diseases associated with floods and droughts that are influenced by climate change (UNDP, 2016). Heatwaves are also increasing in some parts of South Asia due to global warming. In India, 1,300 died as a result of heat waves in 1988 and 3,000 people died in 2003, respectively (Confalonieri et al., 2007; Watts et al., 2020). Heat stress also reduce agricultural worker's capacity to work and productivity (Nag et al., 2009; Sahu et al., 2013; Kjellstrom et al., 2016).

A number of other studies indicated that morbidity and mortality from water-borne and vector-borne diseases are expected to rise in South Asia in the future as temperatures rise and severe weather events become more common (ADB, 2017). South Asia is expected to be the region most affected by the health effects of climate change by 2050 (**Table 1**). This is further exacerbated during COVID-19 because of the poor access to safe water, sanitation, and hygiene. The burden of infectious diseases often falls disproportionately on the poor and on women.

TABLE 1 | Climate-related health risks in South Asian countries.

Countries	Climate-related health risks
Afghanistan	• Increased occurrence and risk of waterborne diseases such as cholera, typhoid, diarrhea, and ascariasis as well as vector-borne diseases like malaria and leishmaniasis. • Increased risks of morbidity and mortality due to extreme cold, heat stress, extreme events, and water and vector borne diseases.
Bangladesh	• Increased occurrence and risk of water borne diseases, diarrheal, dysentery, typhoid, and vector-borne diseases like dengue fever, chikungunya, and leishmaniasis. • Increased risks of deaths, injuries, and psychosocial stress due to extreme weather such as floods, cyclones, storm surges, droughts, heat waves, and sea-level rise. • Increased risks of respiratory diseases due to poor air quality in urban areas and damage to coastal healthcare facilities.
Bhutan	• Increased risks of vector-borne diseases including malaria, dengue fever, Japanese encephalitis, and chikungunya, (particularly in the southern lower elevation regions) as well as waterborne diseases. • Increased risks of injuries and death due to glacial lake outburst floods, landslides, and flash floods.
India	• Increased occurrence of vector-borne diseases such as malaria, dengue fever, Japanese encephalitis, leishmaniasis, as well as waterborne diseases. • Increased injuries, deaths, and psychosocial stress due to extreme weather events. • Increased risks of respiratory diseases due to poor air quality as well as morbidity and mortality of heat stress and mental illness. • Damage to costal healthcare facilities.
Maldives	• Increased incidence and risk of vector-borne diseases like dengue fever, chikungunya, scrub typhus, Zika virus infection as well as waterborne diseases such as diarrhea, and typhoid. • Increased risks of injuries, death, psychological stress, damage to healthcare facilities due to storm surges, tsunamis, heavy rains and floods, tidal waves, and sea level rise.
Nepal	• Increased incidence and risk of vector-borne diseases such as malaria, chikungunya, dengue fever, lymphatic filariasis, and Japanese encephalitis, Zika virus as well as water-borne diseases, such as diarrhea, dysentery, typhoid, and amoebiasis. • Increased risks of injuries and death, and mental illness due to glacial lake outburst floods, landslides, and flash floods.
Pakistan	• Increased incidence of vector-borne and waterborne diseases like diarrhea, dysentery, and typhoid. • Increased risks of injuries and death due to glacial lake outburst floods, landslides, flash floods, and mental illness. • Increased risks of morbidity and mortality due to extreme weather and heat stress. • Damage to costal healthcare facilities as well as intrusion of saline water.
Sri Lanka	• Increased incidence and risk of vector-borne diseases such as malaria, dengue fever, and heat related diseases as well as water-borne diseases—such as diarrhea, dysentery, and typhoid. • Increased risk of morbidity and mortality and damage of health care facilities due to increased storm surges, tsunamis, heavy rains and floods, tidal waves, and sea level rise.

Hashizume et al., 2008; World Health Organization (WHO), 2014, 2015; ADB, 2017; Sen et al., 2017; Dhimal et al., in press.

COVID-19, AGRICULTURE, FOOD SECURITY, AND PUBLIC HEALTH

The impact of COVID-19 on agriculture and food security is complex and many of the consequences are yet to be identified and fully understood. Because of limited mechanization and high labor intensity in agriculture, the impact of COVID-19 on agriculture has been significantly greater in South Asia compared with developed countries. Over half of South Asia's labor force is directly or indirectly involved in agriculture for sustenance. South Asian countries initially implemented stringent policy measures to halt the spread of coronavirus. Economic activity has been halted, travel has been prohibited, the movement of goods and services has been restricted, and cross-border movement has been halted in order to contain the virus (Abhishek et al., 2020; Balwinder-Singh et al., 2020; Laborde et al., 2020; Rasul et al., 2021).

Labor, the primary input into agriculture, has been quarantined, borders have been closed, and national, regional, and global supply chains have been disrupted (Balwinder-Singh et al., 2020; Rasul et al., 2021). While physical distancing and lockdowns are critical for saving people's lives, these measures have significantly affected agricultural operations, with millions of migrant farm workers unable to work (Suresh et al., 2020). Farmers in South Asia are heavily reliant on migrant workers (Babu et al., 2020; Balwinder-Singh et al., 2020). These disruptions have had an impact on agricultural activities and supply chains, including the marketing, transport, distribution, and consumption of agricultural goods and agricultural inputs in South Asia. This has huge economic implication. For instance, the potential economic loss of India's wheat and rice-growing states of Punjab and Haryana in 2020 could be around US$ 1.5 billion due to delayed planting because of shortages of labor (Balwinder-Singh et al., 2020). Even where farmers have been able to hire agriculture workers, physical distancing measures have slowed operations and disrupted planting and sowing in many countries in South Asia (Babu et al., 2020; Balwinder-Singh et al., 2020).

Since the pandemic struck during the planting and harvesting seasons of many crops, including wheat, paddy, fruits, and vegetables, the pandemic wreaked havoc on agriculture in South Asia. For instance, in Bangladesh, farmers faced difficulties in transporting potatoes to cold storages, and harvested watermelons to markets due to transport bans. The Food and Agricultural Organization of the United Nations stated, "The agricultural sector in Bangladesh has faced several challenges during the COVID-19 crisis. The country's export of tropical fruits seems to have been hampered by the crisis. In addition, substantial issues arose during the countrywide lockdown, when *Boro* rice needed to be harvested, which accounts for more than half the national rice production. With public transport not functioning, the seasonal laborers required for harvesting could not reach the fields (FAO, 2020)."

Agriculture was also affected due to the sudden unavailability of inputs such as seeds, fertilizers, and fuel. For instance, in Bangladesh, paddy cultivation was affected by the scarcity of diesel (van Bodegom and Koopmanschap, 2020). Similarly, in India, farmers across 43 districts have indicated insufficient seed availability for the kharif crop in 2020 (PRDAN, 2020). Indian farmers faced challenges in getting agricultural inputs (such as seeds and fertilizers) even though they are normally provided by the government. In Pakistan, agricultural products and agricultural inputs were stopped at different locations for a month or more due to transport restrictions, resulting in the price hike of different food items (van Bodegom and Koopmanschap, 2020). The lockdown also affected other occupations in rural areas. Particularly, migrant farm workers have faced extreme difficulties during the COVID-19 lockdown in different countries in South Asia (ICIMOD, 2020).

COVID-19 has disrupted food transportation and supply chains in different parts of South Asia. In India, the value chains of fresh produce, such as vegetables, fruits, eggs, meat, and fish have been affected most due to the lack of transport facilities and the shortage of storage capacities (van Bodegom and Koopmanschap, 2020). The prices of farm products collapsed because of transport restrictions and market disruptions. For example, farm prices for wheat in India have fallen significantly due to a lack of transportation facilities to transport the harvest to markets (Dev and Sengupta, 2020). Similarly, demand for poultry has decreased sharply. Even as farm produce prices fell, ordinary people in most countries in the region faced higher food prices and even food shortages due to a decline in purchasing power caused by widespread job losses.

The situation was further aggravated by restrictions on cross-border trade. Fearing food shortages, a few cereal-exporting countries limited their exports. This weakened trust in global and regional food markets. Trade in agricultural inputs such as chemical fertilizers, seeds, and farm equipment was also hampered by border restrictions. The imports of food from neighboring countries were limited or banned because of the closing of borders. The decline in trade in food and farm inputs affected the availability of food in remote areas. Food security in remote mountain areas of Nepal was affected because people depend on food transported from lower altitudes and the plains, such as the Terai (van Bodegom and Koopmanschap, 2020).

These interruptions in food supplies led to price hikes in food-importing countries such as Afghanistan, Bhutan, the Maldives, and Nepal. For instance, in Afghanistan, food prices initially increased by 30% in Kabul when its border with Pakistan was closed; wheat flour prices nearly doubled in March 2020 (Amani, 2020). It also placed severe costs on fragile economies. Although restrictions on the limits of Afghanistan-bound transit containers have recently been lifted, and Afghanistan's exports to Pakistan were resumed recently, the demurrage and detention charges, which are, on average, USD 150 per day per container was quite substantial. On an average, an additional cost of USD 15,000 was incurred for a container stranded at the Karachi port since the first week of March (Rahim, 2020). This applies to thousands of stranded containers; the loss and damage to the Afghan economy has been huge.

COVID-19's Impacts on Food and Nutrition

COVID-19 also has disrupted logistic arrangements, food transportation, and supply chain in different parts of South Asia. Because of transport restriction and market disruptions, prices of farm products collapsed, and farmers had to sell the harvested products at a very low price. While prices of farm products have declined, the consumer price of many essential food items have increased in almost all the countries during the initial outbreak of the COVID-19 (UNICEF, 2020). During the lockdowns, most of the South Asian countries experienced higher prices of food items and even shortage of food due to supply chain disruption, which is likely to worsen household consumption and nutrition (UNICEF, 2020). According to a survey conducted in Bangladesh in April, 47% of respondents in urban slum areas and 32% in rural areas reported reducing their food consumption (Hossain et al., 2020). The most significant decreases in consumption occurred in more nutritious foods such as dairy products, meat, fish, eggs, fruits, and vegetables (UNICEF, 2020). Reduced intake of nutritious foods would have a negative effect on health and wellbeing, which have a consequence on child health. It is apprehended that food insecurity, combined with disruptions in health systems, could result in between 5,400 and 28,100 additional deaths of children under the age of 6 in Bangladesh over a 6-month period (Roberton et al., 2020).

The situation was further aggravated by the restriction of cross-border movement of goods and trade (Rasul et al., 2021). In Afghanistan, for example, wheat and cooking oil prices increased by nearly 15 and 9%, respectively, while wheat flower prices increased by nearly 13% in March 2020 in Pakistan (World Bank, 2020). Food prices also rose in Bangladesh in the days following the announcement of the lockdown measures, while in Bhutan price of meat, fruits, and vegetables increased due to the restriction of cross-border movement of goods (World Bank, 2020). Meeting food and nutritional needs has been difficult for many of South Asia's poorer households due to rising food prices combined with widespread job and livelihood losses during the lockdown. Poor households have been forced to cut back on their food spending, even borrowing money or using their savings to do so. Many poor households have been pushed to reduce their expenditure on food items which have compromised their nutrition. According to a study conducted by the United Nations University, the COVID-19 pandemic will push 16 million people in South Asia into extreme poverty (Singh, 2020). According to preliminary estimates, COVID-19 has pushed an additional 20% of Bangladeshis into poverty (PPRC-BIGD, 2020). To make matters worse, the global economic downturn is likely to cause international migrant workers to return home, causing many South Asian countries' critical foreign remittances to dry up. This will have a further negative impact on millions of people's ability to purchase food.

More than 7 million Afghan children are at risk of going hungry as food prices rise as a result of the lockdown (Farmer, 2020). This has long-term consequences—stunting, wasting, and the underdevelopment of their cognitive capacities. In India, a recent post-lockdown study by PRADHAN conducted in 12 states showed that 50% of rural households are eating less than usual, and 68% of households have reduced the number of food items in their meals (Hindustan Times, 2020). These effects will be felt unevenly, disproportionately affecting South Asian countries, as in this region a large number of people work in informal sector and already suffering from poverty and malnutrition, and will exacerbate the existing vulnerabilities and inequalities. IFPRI has projected that 316 million people may fall below the international extreme poverty line of $1.90 per day (Laborde et al., 2020).

TACKLING THE TWIN CHALLENGES OF COVID-19 AND CLIMATE CHANGE

COVID-19 and climate change are two global crises, and both are shared global challenges. The COVID-19 pandemic has posed a huge risk to human security and prosperity, even as climate change continues to affect South Asia. The coronavirus is still spreading, and there has now stronger mutant strains emerged in India and other South Asian countries. Even as the recent reports of impending vaccines have been encouraging, it is difficult to predict when they will be administered to the hundreds of millions in South Asia who need them, and there is uncertainty by when the coronavirus will be contained. In South Asia not even 2% of the population are vaccinated. Some reports apprehend that it may take over 2 years to inoculate 75% of the population of South Asia.

The unprecedented challenges posed by COVID-19 demonstrated that transformative change, and a food system approach is necessary, which call for urgent and decisive actions to ensure food and nutritional security, an uninterrupted movement of agricultural products including daily necessities such as milk, eggs, vegetables, fruits, fish, etc., and to save people's lives and livelihoods. To deal with the health threat posed by COVID-19 and climate change, comprehensive coordination mechanism is required so that coordinated response can be launched efficiently and effectively [World Health Organization (WHO), 2017; Rasul, 2020]. Strengthening the response capacity and building capacity of the health sector is central to the response mechanism. Increased investment is necessary in health system, organizations, and health personnel to improve access, performance, and quality to strengthen response capacity of the health sector. While strengthening capacity of health sector is central to public health, without nutritious food, we cannot achieve health security and escape from the COVID-19 pandemic (Torero, 2020). This demands integration and alignment of public health with broader national plans including agriculture and food security and *vice versa* (World Health Organization (WHO), 2018). Though expanding the social safety nets for the extreme poor is an immediate need to assure basic income and food access to rural and urban poor, the long-term strategy and innovation needs to adopt measures that mitigate future pandemic challenges (Gilligan, 2020). This will require the promotion of healthy, sustainable food systems (Neff et al., 2015; Béné, 2020), and innovation and transformative approaches toward food production, public health, and climate change to achieve multiple benefits (Rasul, 2020). The first step could be developing appropriate guidelines and protocols for the protection of health of workers related to agriculture production, transportation of agricultural inputs and outputs, and processing and marketing of agricultural products. These guidelines can vary by type of production such as crop and livestock, production, processing, transportation, and marketing.

When the outbreak of the pandemic is over or slows down, it is necessary to take on board both the COVID-19 pandemic and climate change together, although approaches and strategies to tackle each may vary. From a food systems perspective, the COVID-19 pandemic and climate change are integrated; as has been shown above, they largely adversely affect different components of the food system (HLPE, 2020). COVID-19 and health risks, and food systems need to be addressed in an integrated manner. Food and agriculture are driving forces shaping the public's health. Poor diet, as well as a lack of micronutrients in diets, pose a serious threat to human health and increase the risk of morbidity (Watts et al., 2020). Addressing them jointly has the potential to improving public health and environmental and climate benefits. Innovative strategies and approaches, however, are needed in designing policies, programs, and projects that address both the coronavirus and climate crises to make them both climate and COVID-19 pandemic smart, although COVID-19 pandemic is an immediate risk and requires a rapid response. For instance, shifting subsidies from fossil fuels to water efficient irrigation system can provide co-benefits of increased food production with reduction of GHGs emission (Gulati et al., 2018). Similarly, providing children with fresh, healthy meals and building their interest in eating fruit and vegetables can improve nutritional status while benefiting local farmers (Watts et al., 2015, 2020). Adopting sustainable land management practices can also generate co-benefits of increased food production while reducing environmental effects (Meybeck et al., 2012; Pretty et al., 2018; Damerau et al., 2020). Considering this important role of nutrition in immune system and public health, producing nutritious food in a climate and public health-friendly way is critical for addressing the triple challenge of COVID-19, public health, and climate change (Guerrant et al., 2013; Myers et al., 2015, 2017). Options that contribute to improved food security and reduce air and water pollution and mitigate climate impacts generate co-benefits for both COVID-19 pandemic and climate mitigation and thus are COVID-19 and climate smart (IPCC, 2019). Restoration of ecosystem can also help regulation of zoonotic disease like COVID-19 (Everard et al., 2020).

Covid-19 pandemic has shown us that "no one is safe until everyone is safe" in this interdependent world. Hence, regional and global cooperation is also necessary to address the cascading effects of COVID-19 and climate change (Barrett, 2020; ILO, 2020). We need to learn to maintain physical distance in order to keep ourselves safe while also promoting trade, cooperation, and healthcare. Withdrawing trade barriers, while maintaining safeties and hygiene can ensure food and nutrition security is a smart way to deal with COVID-19 and other pandemics (Barrett, 2020; Cappelli and Cini, 2020; HLPE, 2020). The countries of South Asia must act collectively to fix the disrupted agricultural supply chains. They must create favorable conditions to make the agriculture sector more attractive, especially to the young labor force, while implementing other reforms such as fast-track investments in technology and logistics (ILO, 2020). The COVID-19 pandemic demands policy innovation, coordination, and synergies at the national and subnational levels and smart strategies that address both COVID-19 and climate challenges. Orchestrate short-term measures to achieve long-term goals in order to address the immediate challenges of employment generation and achieving long-term goal of green recovery by investing in natural capital to improve the long-term productivity and resilience in the region. No matter what challenges need to be addressed in the short-term, government policies and actions should take into account the need for sustainability in the long-term both in public health and the environment (Blay-Palmer et al., 2020). Thus, policy choices should focus both on resolving the urgent needs regarding food and health, and on ensuring long-term resilience and sustainability in agriculture, while taking into account the impacts of climate change (HLPE, 2020). I present below the key components of the framework to tackle the twin challenges of COVID-19 and climate change (**Figure 2**), in the agrarian context in South Asia. Different components of the framework support each other and contributes to achieve broader goals of resilient food system.

Strengthening Health Sector Response Capacities

Strengthening the health sector's capacity to prepare for and manage shocks such as pandemics is critical for dealing with pandemics such as COVID-19 and health emergencies [World Health Organization (WHO), 2015; Djalante et al., 2020]. It is, thus, vital to prepare emergency plans and build the capacity of healthcare workers and other health system functions so that a coordinated response can be taken effectively and efficiently to save people's lives and operating food production and transportation safely (Raina et al., 2020). In the health sector, it is critical to develop awareness and skills, as well as emergency preparedness and response, and to integrate risk prevention and emergency preparedness services into health sector planning (Raina et al., 2020). Supporting health systems and enhancing health protection against COVID-19 and other health threats requires healthy food, water, and sanitation (Myers et al., 2017). This exemplifies the critical interdependencies that exist between health and food, as well as water and sanitation. It is thus necessary to improve disease surveillance, take coordinated actions and strategic alignment of plans and actions across health, food, water, and sanitation sectors (Neff et al., 2015; Rasul, 2020; Watts et al., 2020; Rasul and Neupane, 2021).

Making Agriculture Resilient to Pandemics

Strengthening Local and Regional Food Systems

The COVID-19 pandemic has taught us that an emergency can arise unexpectedly and make food supply chains in South Asia highly vulnerable. As food is fundamental for human existence, it is essential to plan for emergencies such as a pandemic and other disasters, and set up appropriate crisis management structures and protocols for dealing with emergencies (Béné, 2020; Blay-Palmer et al., 2020). This planning would need to cover the integration and coordination of food value chains, from production and transportation, to the processing, marketing, and retailing of food products (Altieri and Nicholls, 2020; Béné, 2020; Blay-Palmer et al., 2020; HLPE, 2020; Fan et al., 2021). It would include balancing the local, regional, and global food supply chains. **One** important strategy would be strengthening local and regional food systems to promote self-sufficiency, and have shorter supply chains so as to reduce the reliance on global supply chains (Baudron and Liegeois, 2020; Béné, 2020). For example, to enhance food production and provide employment to the jobless due to the COVID-19 pandemic, the Government of Bhutan has launched an initiative to promote agriculture in urban and peri-urban areas. The Government extended different types of support to utilize the uncultivated land to grow vegetable and other crops to ensure food security [Bhandari, 2020; RGoB (Royal Government of Bhutan), 2020]. It is also important to strengthen the digitalization of farming, and ensure improved hygiene along with strengthening food safety management systems, and stringent quality standards in manufacturing to contain the possible spread of diseases and protect the health of agriculture and supply chain workers. Governments at different levels need to support smallholder and

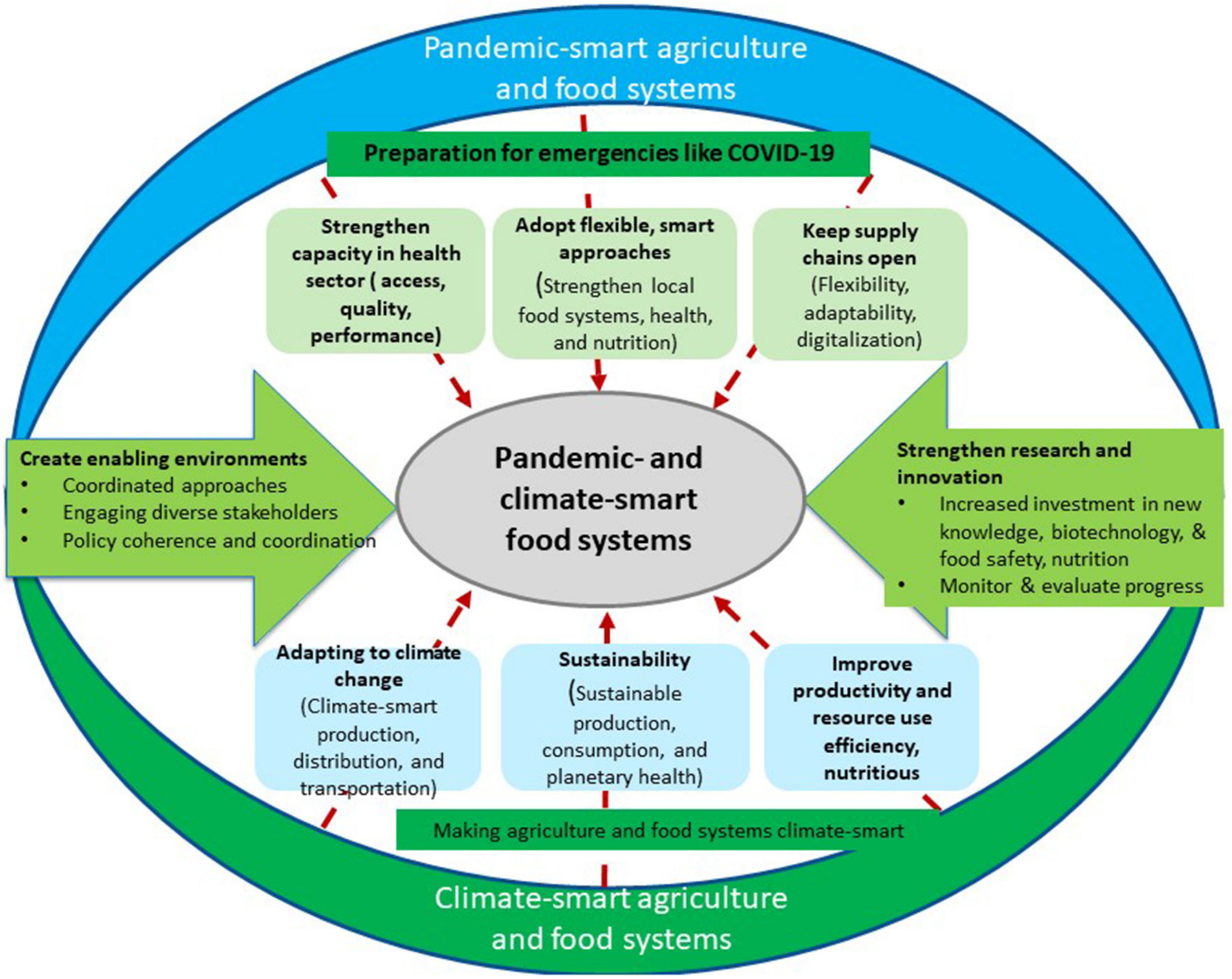

FIGURE 2 | Framework to tackle the changes of COVID-19 and climate change.

family farming, and small and medium enterprises along the food chain to ensure their viability to augment a broader social resilience (Darnhofer, 2020; Henry, 2020; HLPE, 2020).

Strengthening Social Safety Nets

It is also important to strengthen social safety nets to protect vulnerable communities. Adequate emergency food aid should be provided wherever possible, integrating such public distribution with local and regional procurement of food (Hepburn et al., 2020; HLPE, 2020; ICIMOD, 2020). Special attention needs to be given to support the most vulnerable populations, including children and women, wherever supply chains are severely disrupted. Food assistance programs that offer adequate access to healthy food, and not just sufficient calorie intake, should be designed (Barrett, 2020; ICIMOD, 2020).

Adopting Flexible, Smart Approaches

It is necessary to adopt smart approaches to ensure that normal food production continues. This can be done by maintaining physical distancing and following safety procedures, including incorporating the necessary health and safety measures as well as an increased flexibility in sourcing labor, labor mobility, and working time (Cappelli and Cini, 2020; Henry, 2020; Hepburn et al., 2020). For example, increasing the number of shifts or changing the working hours where possible will ensure that there are fewer workers in a farm at the same time. Similarly, agricultural products or inputs could be transported during off time such as night and weekends. To enhance better health and nutritional outcomes, unhealthy foods should be discouraged and nutritious and healthy food ought to be incentivized. Where possible, human workers could be replaced with machines without depressing employment opportunities of local workers (van Bodegom and Koopmanschap, 2020). For instance, it has been reported that in order to overcome labor shortages during the harvesting of paddy, the Government of Bangladesh provided subsidies to buy harvesters (ICIMOD, 2020). This will reduce the overdependence on food imports, as supply disruption during the crisis is often aggravated by measures to restrict exports during a crisis (van Bodegom and Koopmanschap, 2020). Home gardens and urban agriculture can also prove more resilient to shocks and disruptions and ensure access to more varied and nutritious food for the urban poor (Lal, 2020). Sustainable fisheries and aquaculture provide important sources of nutrition and are also crucial for livelihoods and employment generation (Bennett et al., 2020; Love et al., 2020).

Keeping Supply Chains Open and Functional During the Pandemic

The authorities need to develop special channels and standard operational procedures to ensure the movement of food and agricultural inputs during the pandemic to ensure that supply chains are kept open and functional (Barrett, 2020; Reardon and Swinnen, 2020). For example, the Government of Bangladesh made special arrangements to ensure the transport of agricultural workers during the paddy-harvesting period (FAO, 2020; ICIMOD, 2020), which helped to reduce crop damage. Local organizations, institutions, and platforms ought to be strengthened. Local and sub-national value chains ought to be promoted, including agricultural self-sufficiency, such as home gardening (HLPE, 2020; van Bodegom and Koopmanschap, 2020). Governments should invest in enhanced territorial market infrastructure at the local, regional, and national levels, and support more diverse and resilient distribution systems, including shorter supply chains, and territorial markets. Another important strategy to cushion against shocks is a diversification in the sources of imports, and not relying on a single source with a view to minimize fragility if there are supply disruptions (Henry, 2020; van Bodegom and Koopmanschap, 2020).

Prioritizing Climate-Smart Agricultural Interventions at Different Scales

Adaptation to Climate Change

To minimize the impacts of climate change on agriculture and food systems, an appropriate adaptation plan with concrete measures is necessary, which reinforces mutually. In identifying adaptation measures, special attention needs to be paid to public health and conservation of natural resources vital for food production as well as to improving farmers' livelihoods and adaptive capacities (Beddington et al., 2012; Meybeck et al., 2012; HLPE, 2019). It is important to identify integrated options that create synergies between food systems and public health, and reduce trade-offs between food and climate mitigation such as reducing food loss and food waste (Beddington et al., 2012; Watts et al., 2015, 2020). Governments ought to develop the appropriate policy and strategies, and provide technical and institutional support and incentives to farmers and community to adopt the right, sustainable solutions including appropriate cropping patterns, agronomic management, and sustainable use of resources, including conservation of ecosystems and reduction of fossil fuels (Meybeck et al., 2012; Shepon et al., 2018; Bhatt et al., 2019; Everard et al., 2020).

Improving Sustainability

Sustainability is one of the key dimensions of food security. The excessive use of agrochemicals and the unsustainable use of groundwater and energy have contributed to high GHG emissions, water pollution, air pollution, water scarcity, energy scarcity, the loss of biodiversity, and grave impacts to human health (Dholakia et al., 2013; Gould, 2018; Pretty et al., 2018; Aryal et al., 2020; Hussain and Qamer, 2020; Fan et al., 2021). It is critical to enhance sustainability in agriculture and build resilience in the production, processing, and trading of food to minimize GHG emissions and optimize the management of water, air, soil, and ecosystems essential for production of food in sustainable manner and supplying of healthy nutritious food for public health (Pretty et al., 2018; Bhatt et al., 2019; Barbier and Burgess, 2020).

Improving Productivity and Resource Use Efficiency in Agriculture and the Food System

Governments in South Asia ought to increase investment in agriculture and the food system in general to improve efficiencies, including resource use efficiency, in every aspect of the food system to increase productivity, reduce yield gaps, and conserve resources (Beddington et al., 2012; Pretty et al., 2018). Choosing locationally suitable cropping patterns and appropriate agronomic measures, including crop rotation and multi-cropping practices can improve land-use efficiency and crop productivity while generating environmental co-benefits by decreasing dependence on chemical fertilizers and fossil fuels (Bhatt et al., 2019; Tenzin et al., 2019).

Creating an Enabling Environment

Conducive agricultural policy environment is required for managing shocks and vulnerability, as evidenced in rapid response mechanisms. Governments ought to create enabling environments through a greater alignment of policies, financial investments, and institutional arrangements. To create conducive environment for transformative change, it is necessary to ensure coordinated planning and prioritizing activities that support multiple objectives (Pingali, 2012; Rasul, 2020). Policies should also address risks along the food chain (including those faced by small-scale food producers), including storage, post-harvest losses, and food safety risks (HLPE, 2020). They ought to develop and strengthen nutrition-enhancing food, agriculture, and forestry policies that simultaneously contribute to climate change mitigation (Myers et al., 2017). They can do so by adopting the appropriate practices, developing enabling policies, and institutions, and by mobilizing the necessary finances toward these ends. Government should also support value chain actors to build their capacities to maintain supply chain operation during COVID-19 and other pandemics while maintaining safety and security so that they can adequately respond to any future pandemic and other challenges.

Strengthening Research and Innovation

Research and innovation are essential inputs toward increasing the efficiency and resilience of food systems, and are part of the basis for sustainable agriculture and food security (Beddington et al., 2012; Henry, 2020). Governments ought to fund improved research, knowledge, and innovation to develop and support agriculture and food systems that meet nutritional requirements, strengthen public health, and are also climate-friendly in their capacity to conserve resources, protect ecosystems, and reduce greenhouse gas emissions. Research efforts are also required to improve agricultural management and practices for sustainable intensification, to increase crop resilience to climatic variability, droughts, and salinity in soils, and to identify appropriate adaptation and mitigation practices that enhance food system productivity without degrading the environment. The outputs of research, such as of drought- or heat-resistant crop varieties, also ought to reach farmers widely and quickly. This needs the strengthening of agriculture extension programs to promote innovative public health and environment friendly agri-food system.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

GR: conceptualization, data collection, writing, and revising.

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