



From Farm to Fork: Early Impacts of COVID-19 on Food Supply Chain

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COVID-19 pandemic has resulted in widespread global disruptions. While much is being discussed about the health and economic impacts, there has been a limited focus on the immediate food sector shocks and their related social implications in developing countries, especially when the farmer surveys cannot be conducted due to mobility restrictions in many countries. To overcome these challenges, this study uses news mining and content analysis of media articles published from February to April 2020, to assess the early impacts of the COVID-19 pandemic on the food supply chain and farm distress in India. It also presents the media perception of the impact of the pandemic and resulting policy measures using sentiment analysis, in addition to the cross-tabulation of results that show differential impacts across food supply chain components among different commodity groups and regions. The results show wide-scale impacts across different components of the food supply chain ranging from crop harvesting and processing, distribution and logistics to disruptions across food markets, as represented by 22, 11 and 30% of total articles, respectively. The impacts are also differentiated by commodity groups, with animal products having more trade and demand-side issues, logistic bottlenecks in fruits and vegetables and crops showing problems in labor availability and harvesting. Sentiment analysis of news items shows a spike in the negative sentiment immediately post the national lockdown, with relatively less negativity in subsequent weeks due to large-scale policy and community action. Sentiment classification along different indicators shows the highest negative sentiment for animal products (85%) in commodity groups, western states of India (78%) among different regions, and food supply (85%) and markets (83%) among supply chain components. Further, extreme weather analysis (using excess rainfall events) shows that farmers faced compound risks from the COVID-19 pandemic and extreme weather events in many parts of the country. The results highlight the importance of building resilient food systems, especially when the biotic and abiotic shocks are projected to increase globally due to many drivers including biodiversity loss and climate change.

Keywords: food, supply chain, COVID-19, market, producer, India, news mining

INTRODUCTION

COVID-19 declared as a pandemic by WHO is an ongoing global health emergency being faced by countries across the world. From its first emergence in China in December 2019, the disease has rapidly spread, infecting more than 157.36 million people globally and fatally affecting 3.27 million people as of 11th May 2021 (World Health Organization, 2021). The highly transmissible nature of the disease forced several countries to impose regulations related to social distancing, self-isolation and travel restrictions (Nicola et al., 2020). Implementation of a nationwide lockdown, including the closure of international borders and, in some cases, domestic borders was an instant and important measure adopted by most countries to control the spread of the virus. In countries with full lockdown, fears of a socio-economic and humanitarian crisis were highlighted as different sectors were negatively impacted (Abhishek et al., 2020; McKibbin and Fernando, 2020; UNDP, 2020).

Among other macro-economic impacts like poverty (Buheji et al., 2020) and trade (Maliszewska et al., 2020), food supply chain disruption was also an increasingly highlighted area of concern, especially for countries such as India that are largely comprised of small agricultural producers (Workie et al., 2020). Restricted access to markets and labor, along with reduced food demand were some of the key challenges in such places (FAO, 2020a; United Nations, 2020). Other global crises in the past such as the 2014 Ebola virus disease (EVD) epidemic, as well as the food price crisis of 2006–2008, also suggest similar patterns of supply chain disruptions in many countries (FAO, 2016, 2020b). However, given the wide scale of the COVID-19 pandemic, its socio-economic implications are expected to be more severe. These may range from increased food insecurity and malnutrition to a rise in poverty and inequality (Headey and Ruel, 2020; Laborde et al., 2020; Sumner et al., 2020).

The first official COVID-19 case in India was reported on 30th January 2020. Since then the Indian government announced a slew of measures to contain the spread of the disease and to manage the resulting impact of the same. On 12th March the government declared international travel bans and on 25th March, a nationwide lockdown was declared with mobility restrictions across the country. The resulting lockdown had an extensive impact on Indian agriculture across different commodities—from aquaculture (Kumaran et al., 2021) and fisheries (Avtar et al., 2021), to cereals (Balwinder-Singh et al., 2020) and vegetables (Harris et al., 2020). The lockdown resulted in supply chain bottlenecks for various agricultural commodities and affected agricultural supply and production. Several studies highlighting these trends utilized qualitative and quantitative surveys, remote sensing methods, modeling techniques and analysis of publicly available data. However, these methods are limited in their scope (both spatial and temporal), and surveys require substantial time and logistical resources to generate data. Further, the available literature does not highlight compound shocks faced by the farmers. In this paper, therefore, we utilize news mining as an innovative data collection methodology to analyze the immediate impact of COVID-19 on the Indian food supply chain. News mining is an upcoming tool that can generate

useful and actionable insights, especially for dynamic scenarios such as the ongoing pandemic (Buckingham et al., 2020; Jahanbin and Rahmanian, 2020; Sadman et al., 2021). In fact, recent studies have used media analysis to understand the impact of the COVID-19 pandemic on various sectors including public health and food (Bai et al., 2020; Thomas et al., 2020; Moriom Khatun et al., 2021; Suryadi, 2021). This study uses this tool for the following three objectives—(1) assessing early impacts of COVID-19 pandemic on different components and sectors of the food supply chain, (2) understanding the media perception of the impact of the pandemic and resulting policy measures using content and sentiment analysis and (3) analyzing compound risks (from the pandemic and extreme weather events) faced by supply chain players in the study period and identify the policy/community actions undertaken to overcome them.

DATA AND METHODS

Selection of Articles for Review

The selection and extraction of news articles involved multiple steps (Figure 1). Different keywords were used to search for the news articles in Google News. These keywords included a combination of words related to food supply and COVID-19 pandemic—COVID-19, pandemic, Corona, farmers, agriculture, agricultural producers, farm producers, consumers, food supply, agricultural supply chain, food supply chain, food demand. The “Selenium” package in Python was used to web scrap the articles from Google News. Only articles published in the English language were selected. The exclusion of regional language articles remains a limitation of this analysis. The initial search resulted in 6,568 news articles, for which the metadata was extracted including the Title, Date, Source, and a brief description of the article. These articles were screened for their relevance to the analysis, and duplicates were removed—resulting in a total of 2,361 articles, which were selected, and their full text was extracted. Out of this, all articles that referred to other countries (and not India) were excluded to get a list of 786 articles. This list was further refined to exclude articles that were not related to COVID-19 and food supply. A final subset of 335 articles was selected based on which the review was carried out. To focus on the immediate impact of COVID-19 (and resulting national lockdown in India on 25th March 2020), the entire analysis was conducted from 1st February to 6th April 2020, covering the first 2 weeks following the announcement of the national lockdown. There was no baseline data collected (number of articles published during non-COVID years), as the objective of the study was to assess impact of the COVID-19 pandemic on different components and sectors of food supply chain (and not a comparison of media analysis for baseline years and the COVID-19 pandemic). The duration of the temporal analysis and non-comparison with baseline data remains a limitation of the study.

Content Analysis Framework

The framework described in Figure 2 forms the basis of data collation and analysis of the selected articles. Figure 2 shows how

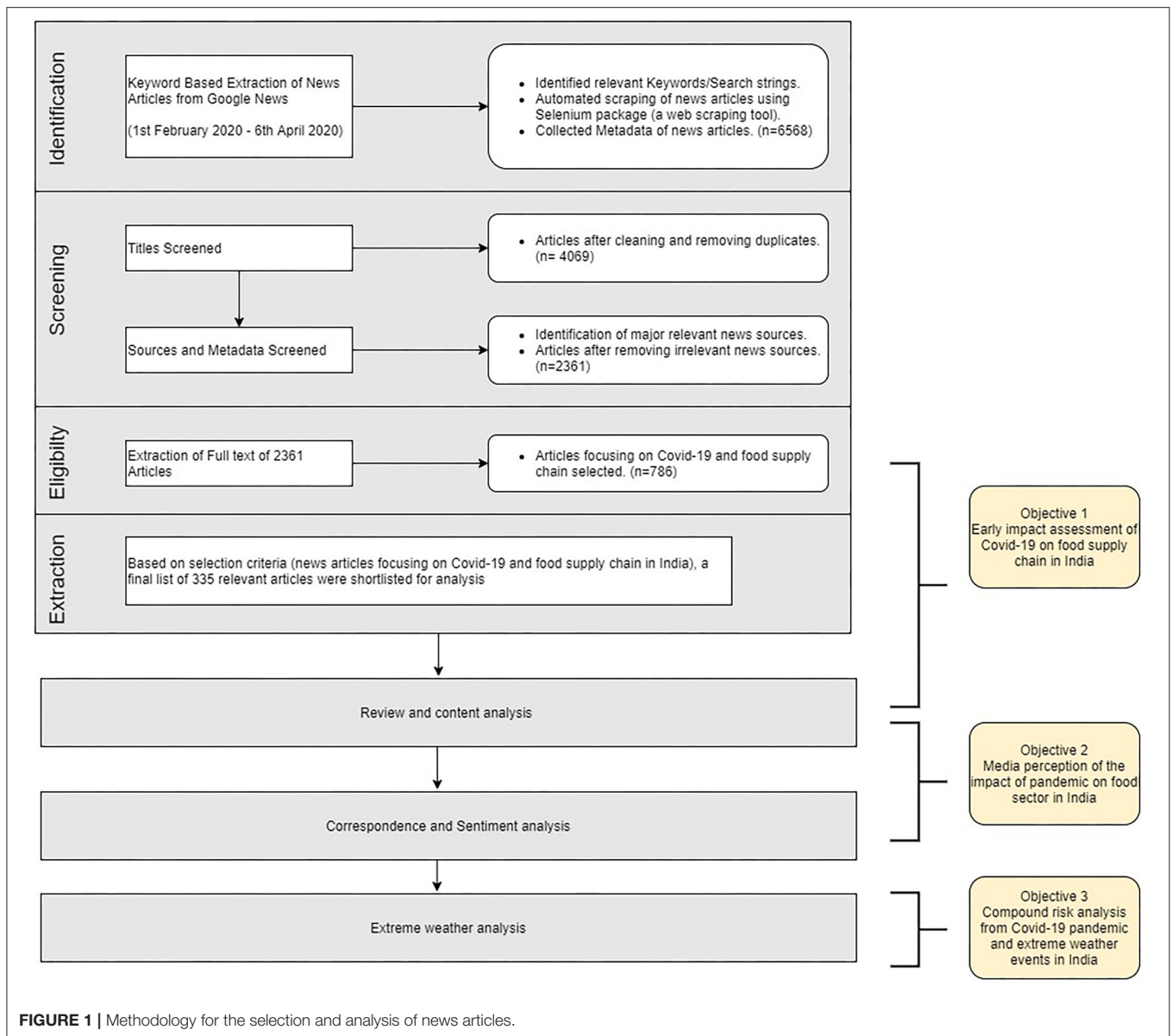
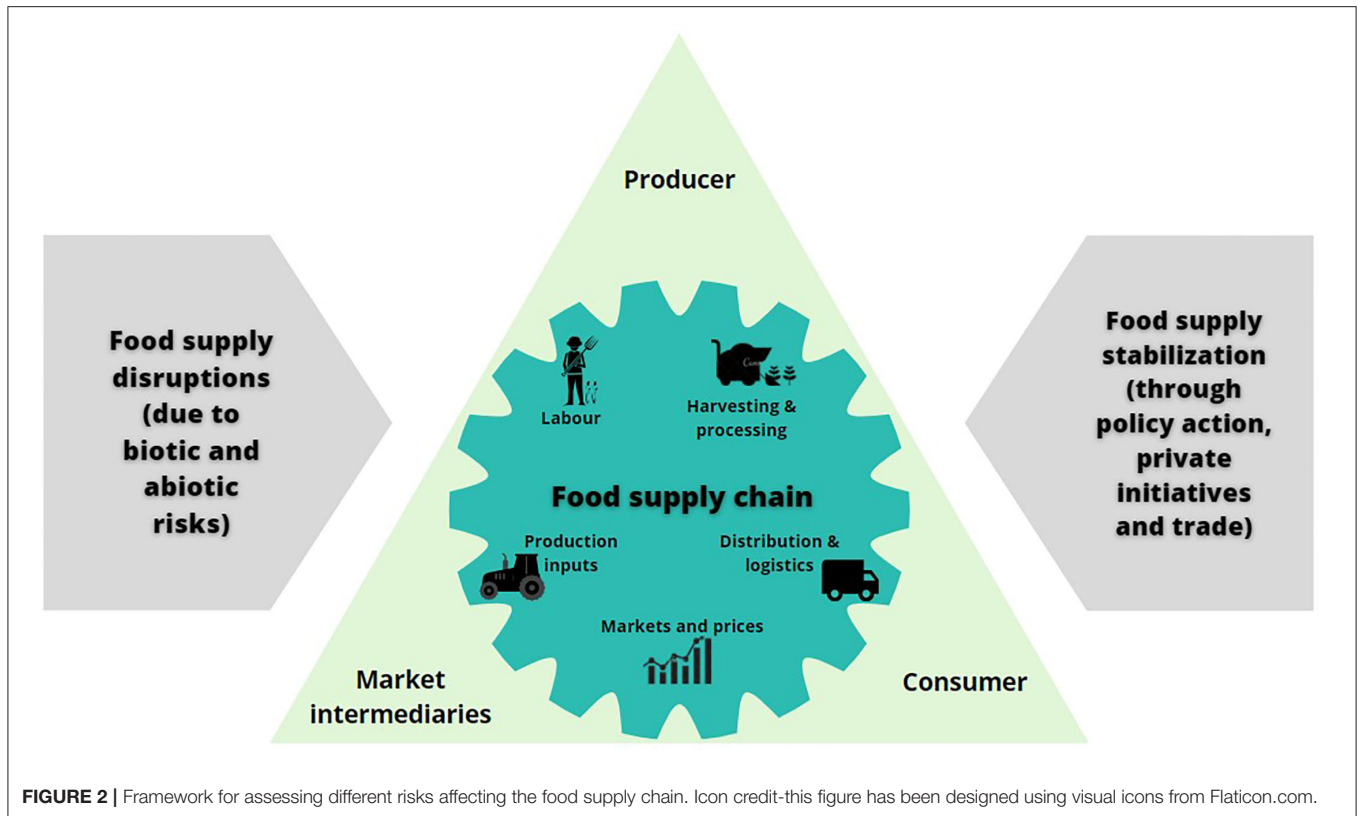


FIGURE 1 | Methodology for the selection and analysis of news articles.

food supply disruptions can be caused by both biotic and abiotic risks (in this case, the COVID-19 pandemic and extreme weather events, respectively). These risks affect different components of the supply chain including Labor (labor required for agricultural operations), Production inputs (seeds, fertilizers and pesticides), Harvesting and processing (harvesting operations and processing of different commodities, including post-harvest storage), Market and prices (farm, wholesale and retail markets, as well as price-related information for different commodities in these markets). These components affect different stakeholders of the supply chain—producers (farmers), market (market intermediaries) and consumers. To stabilize the food supply from the impact of different risks, public, private and trade-related actions are undertaken. The analysis presented in this paper is based on this framework—it assesses multiple risks that were

faced by the food sector in the given timeframe, how these risks affected different stakeholders and components of the supply chain, and finally, how these impacts were managed through public and private initiatives.

While collating information from the articles selected from the news mining, the authors read through each article in detail and started categorizing the articles based on the type of risks focused upon in the articles, the components of supply chain impacted and different stakeholders affected, and the measures undertaken, if any, to resolve supply chain issues. In addition to the supply chain components described (Figure 2), there were a few articles that focused on the entire food sector, resulting in two additional categories—Food supply (articles focusing on food distribution and food security in general, including food supply for migrant workers stuck in



many cities due to the lockdown) and Food demand (articles on food demand from different consumers). Information was also collected on different commodity groups, four exclusive categories for commodities included Food (articles where no specific commodity is mentioned or multiple commodities are mentioned), Crops (articles specifically related to arable crops like cereals, pulses, millets, oilseeds and other crops), Animal products (articles related to poultry, milk, fish and seafood) and Fruits and Vegetables. Additional information was also collected from the selected articles in the review, including the region/place focused upon in the news articles, the type of methods used and the date of publication.

Correspondence Analysis

A review of selected media articles, through the framework described above, helped in understanding the impacts of the COVID-19 pandemic on Indian agriculture. To further strengthen the qualitative insights, a correspondence analysis was also conducted on the full texts of the articles. Correspondence analysis is a quantitative exploratory technique, which helps in cross-tabulations and understanding the variation in the distribution of keywords across different commodities. This method is frequently used for qualitative analysis in social sciences (Brunette et al., 2018; Hjelldrekk, 2018) and has been recently used to understand the change in consumer perceptions and motivations toward food, after the COVID-19 pandemic (Laguna et al., 2020). For this study, the correspondence analysis was conducted using the WordStat software. The software first

identified keywords from the full text of the selected articles and then calculated the contingency tables (crosstabulations) using the frequencies of these keywords across different categorical variables (in this case, different commodity groups).

Sentiment Analysis

For the second objective of the study, sentiment analysis was undertaken to assess the sentiment of news during the pandemic. Sentiment analysis categorizes data based on the “sentiment” of the words used. These “sentiments” are based on semantics, semantic theory, feelings around the words used (adjectives), and, etymology and phrasing; based on which the text can be classified into different sentiment groups, for example—negative, neutral and positive (Jacobs, 2019; Saura et al., 2019). For example, negative words like “panic,” “frightened,” and “devastated,” which are mentioned across the article text are scored negatively, highlighting a negative sentiment. This analysis has been used by social science researchers to investigate research questions related to public opinion and perception (Soo et al., 2012), has also been used recently to analyze the public perception of quarantine guidelines as a result of the COVID-19 pandemic, in educational institutes (Pastor, 2020). For this study, a supervised learning model was trained with a 30% random sample using Monkey Learn, a widely used software for sentiment analysis¹. The model was trained by assigning sentiment categories manually on 102 articles (~30% of the total articles), which formed the

¹MonkeyLearn API Reference. from <https://monkeylearn.com/api/v3/>.

training set. The five categories were Negative, Negative: Neutral, Neutral, Neutral: Positive, and Positive; with values -2 , -1 , 0 , 1 , 2 , respectively. These sentiment categories represent a scale, where the extreme end is “negative” where the incidence of words with negative sentiments are high, and with “positive” at the other end of the spectrum where words used in the article have positive connotations. For many news articles, a mix of both negative and positive words was observed, and these were classified in the middle of the scale—negative: neutral (presence of both positive and negative sentiments, but the proportion of negative sentiments is higher), neutral (both positive and negative sentiments equally present), and neutral: positive (presence of both negative and positive sentiments, but the proportion of positive sentiments is higher). Each article was assigned a tag and was fed to a feature extractor where the text vectorization was performed. The resultant list of features was then fed to a machine learning algorithm and passed to a classifier model. The model was strengthened and validated by achieving an efficiency score of 70%, which means that the model was repeatedly trained till 70% of the articles in the training set were correctly classified by the machine learning algorithm, across all five sentiment categories. The final model thus developed was used to classify the dataset of 335 articles. The results are presented using the frequency of the articles (under each sentiment category) based on their sentiment classification. As an example, an excerpt from the text of a news article which was classified as “negative” is presented—*“Rumors in India that birds could spread the coronavirus are taking a massive toll on sales of poultry in the world’s second-most populous nation. The speculation is circulating on social media, according to B.S. Yadav, managing director of Godrej Agrovet Ltd., India’s biggest compound animal feed company. Industry-wide weekly sales have plummeted at least 47% to 35 million to 40 million birds in the past 3–4 weeks, while prices have slumped almost 60%, he said. “The damage is so severe that whatever we have done in the past seven months will be wiped out if the decline in sales continues for next 1–2 months,” Yadav said.”*

Extreme Weather Analysis (Excess Rainfall)

To assess compound risks (both biotic and abiotic risks) faced by the food supply chain actors, analysis was also undertaken to assess the weather events which occurred during the study period (February to March 2020). We restrict the analysis to precipitation, as these were the main weather events reported by farmers in the media. Extreme rainfall, heat stress and hailstorms are the major climatic risks faced during the winter cropping season in India, which adversely affects crop production, especially during the maturity and harvest stage of crops like wheat (Zampieri et al., 2017). Excess rainfall is known to cause significant harvest² and post-harvest losses (Bjerge and Trifkovic, 2018; Li et al., 2019). Satellite-based daily precipitation data was downloaded from the Climate Prediction Centre of the National Oceanic and Atmospheric Administration (NOAA-CPC) at 0.1-degree resolution (Rainfall-NOAA-CPC-RFE V2.0). The daily

²<https://indianexpress.com/article/india/heavy-rain-damages-standing-crops-over-4-5-lakh-hectares-6745312/>.

precipitation data was analyzed to calculate three indices to assess rainfall volume and distribution in the study months—cumulative monthly rainfall, number of rainy days in a month (number of days when rainfall is >2.5 mm, as defined by the Indian Metrological Department) and maximum 1-day rainfall in a month. These indices are used by several crop monitoring systems to track weather events and monitor crop progress (Fritz et al., 2019; van der Velde and Nisini, 2019; Aggarwal et al., 2020). By assessing all the three indices together, areas with excessive rainfall risk were identified. Next, a cropland mask was used to highlight areas with significant crop acreage. A threshold of 50% was used to mask non-agricultural areas (only pixels where crop area was more than 50% were used).

RESULTS

Content Analysis

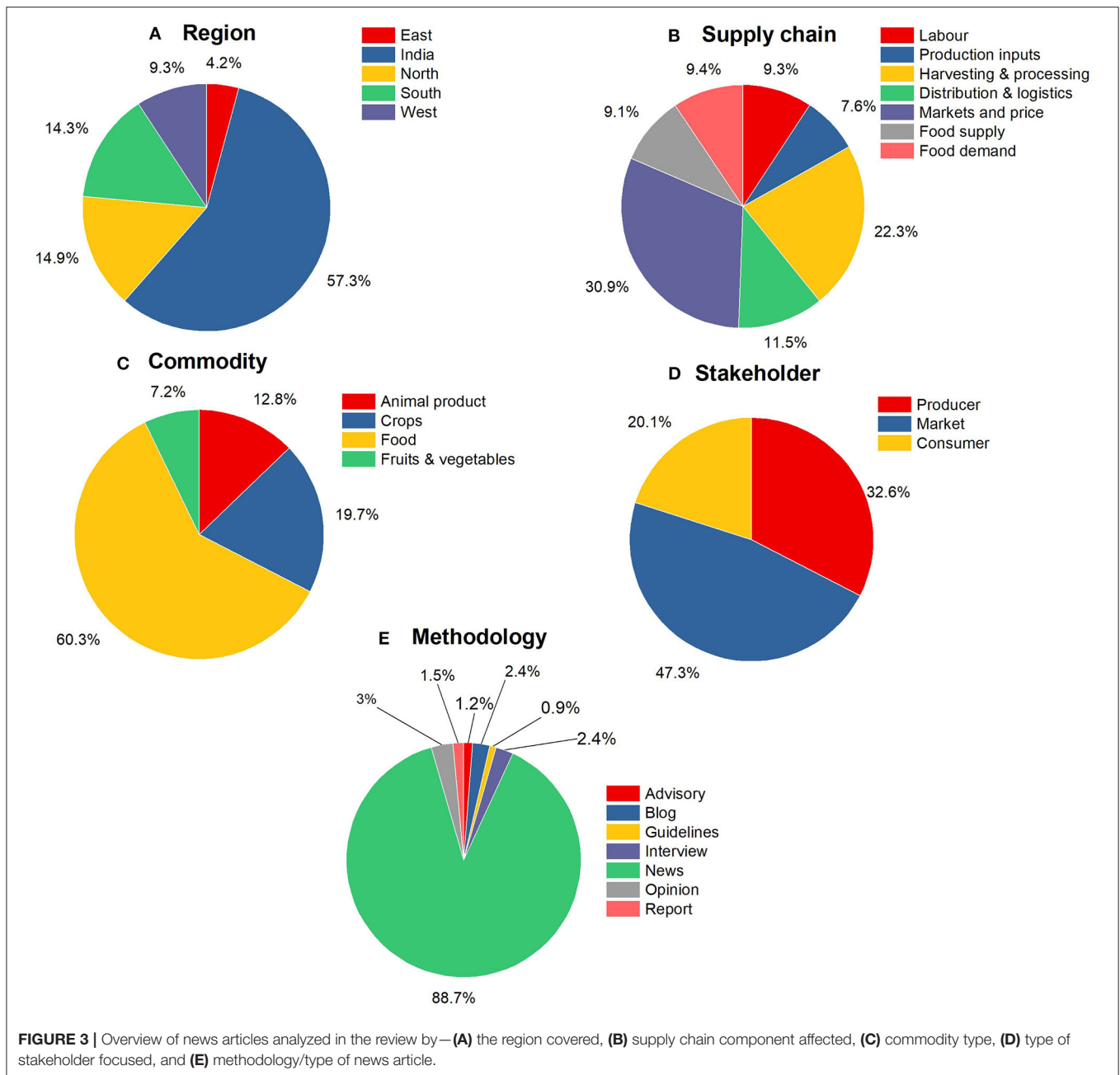
Overview of Key Trends

The news articles analyzed in this study were segregated into different groups to understand key trends (Figure 3). More than half of the news articles were nationally focused, followed by articles related to northern and southern parts of the country (state-wise distribution of news articles is given in Supplementary Figure 2). The news articles were also grouped based on the supply chain actors affected, with a third of the articles focusing on “Markets and price,” while only 7.6% of the articles focusing on “Production inputs.” Among different commodities, the highest share was of “Food,” with minimal focus on “Fruits and vegetables.” For different stakeholders, almost half of the articles focused on the market (intermediaries), followed by producers and consumers.

Out of the 335 articles reviewed, 66% of articles were published after the nationwide lockdown in the country. This is expected as media focus on food sector in the country increased after the national lockdown. However, a few exceptions in this trend were also observed for different sectors and components of the supply chain, for example, Animal Product (commodity) was the exception to this trend, with articles highlighting the commodity much before the lockdown (Figure 4). This was primarily driven by reduced export demand for poultry which began earlier in the year as the pandemic spread across countries, affecting international food trade. Post lockdown, the issues related to “Market and prices” increased, with the shutting down of wholesale and retail markets, increase in prices of different commodities across the country due to limited supply and panic-driven demand from consumers, and the closure of markets for mass sanitization. Logistics and Distribution challenges were also witnessed due to mobility restrictions from farms, warehouses and factories to wholesale and retail markets. Mobility restrictions, as well as labor shortage also affected labor intensive operations across the farms, storage and processing units, factories, transportation and markets.

Commodity and Theme-Wise Results

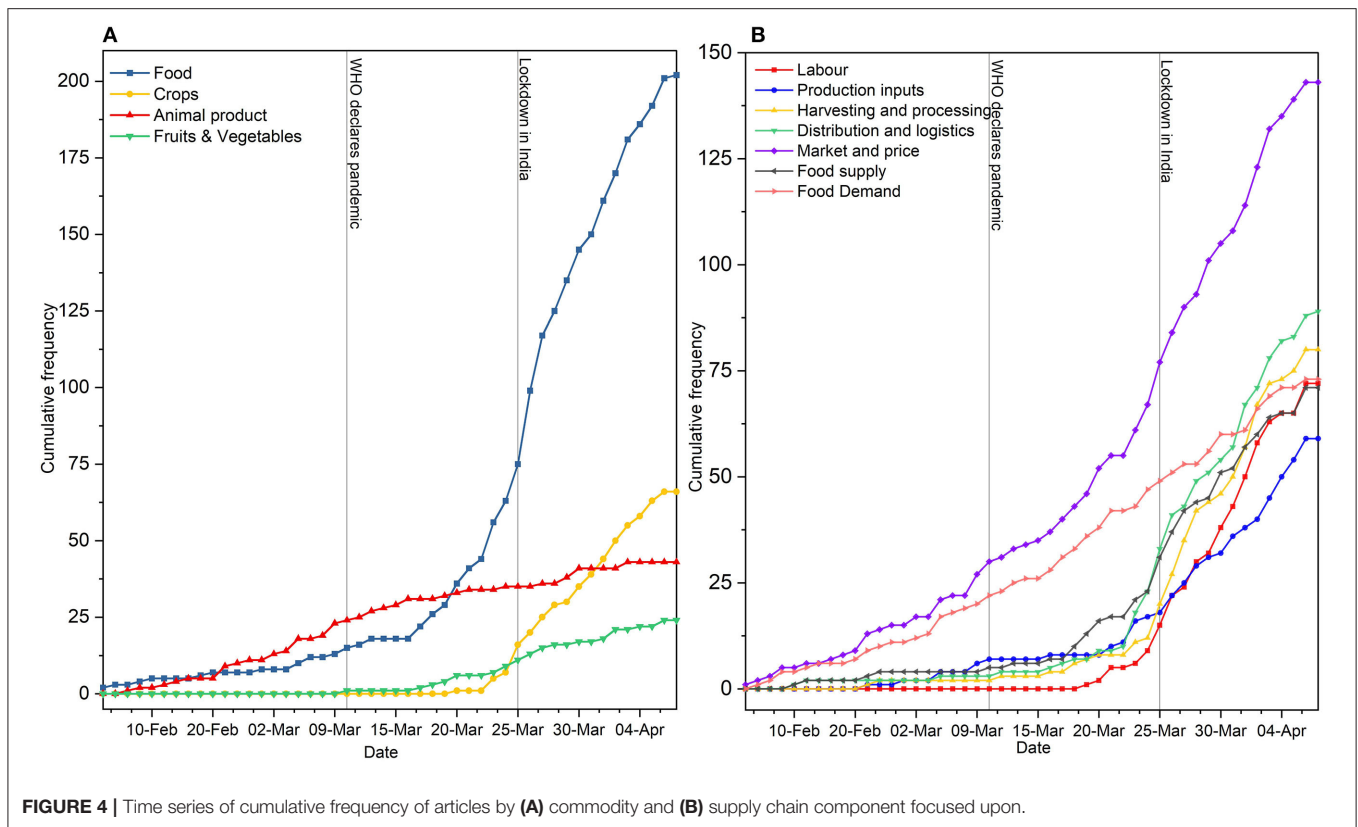
Figure 5 highlights the article frequency across the thematic areas and commodity group. About half of “Market and price” related disruptions were mentioned for the Food commodity.



For “Crops” commodity, harvesting and processing were the most affected operations, and many news articles reported labor shortage for harvesting of wheat crop in the northern parts of the country. This is also supported by literature—farmers in major wheat-producing states of Haryana and Punjab, contributing 60% to India’s wheat procurement (Directorate of Economics Statistics, 2018), were unable to meet their requirement of about 1.6 million laborers for harvesting (Sethi, 2020). Additionally, the news articles also reported limited availability and access to harvesting machines, which further caused bottlenecks in harvest operations. To tackle this, the government assured procurement of wheat from farmers while requesting them to delay the

harvesting by 2 weeks. In addition to this, storage of the harvested produce and limited accessibility to markets in rural areas for seeds and inputs for the next cropping season (summer crop) also emerged as an area of concern by farmers in the Northern and Southern regions of India, as reported by the news articles.

Impacts on “Animal Products” commodity were mainly related to poultry, with 80% of the total articles highlighting the decline in chicken prices as a result of reduced international and domestic demand (Kolluri et al., 2020; Rakshit and Basistha, 2020). The news articles highlighted that this market trend was driven by social media rumors about the spread of COVID-19 through birds which began earlier in 2020. Consequently,



consumer demand decreased by almost 50%, and chicken prices fell by up to 70% across the country, resulting in an industry-wide loss of INR 1,750 crore³ during January–February, as also reported in many articles (PTI, 2020a,b). Ex-farm gate prices fell from INR 100 to INR 35 a kilogram, while retail prices reduced from INR 180–200 to INR 100–150 a kilogram in the country in early March—as highlighted by the news articles in the review (IANS, 2020; PTI, 2020c). A few articles also mentioned a 64% decline in the wholesale prices of eggs (from INR 4.25 to INR 2.7 per egg) and 25% decline (by INR 5–7 per liter) in farm price of milk resulting from reduced demand by consumers for similar reasons (DHNS, 2020; Jha, 2020a).

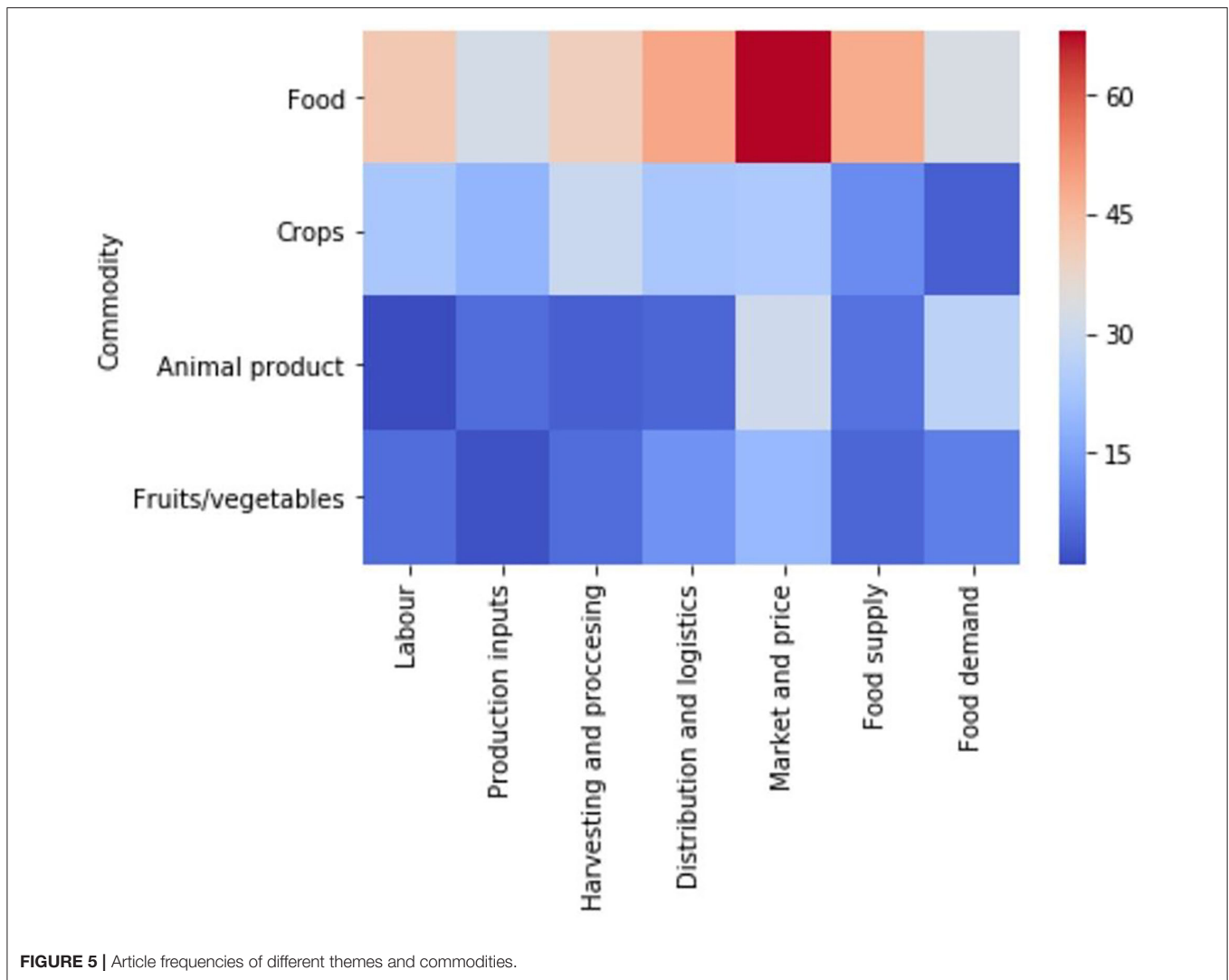
No clear pattern and trends were observed for food prices in other commodity groups. Shutting down of markets and international trade restrictions resulted in price volatility in some wholesale and retail markets for “Fruits and Vegetables” commodity in the country. Before the lockdown, a decline in export demand resulted in reduced prices for fruits and vegetables in some regions, for instance, a few news articles highlighted how farm-gate prices for grapes and bananas (in western and southern India) fell by 30% in the first 2 weeks of March. In addition to this, the news articles also mentioned reduced demand from bulk buyers including hotels and restaurants, also reduced wholesale prices for perishable vegetables by 15–20%. This trend is also supported by literature (Arya, 2020; Bera, 2020). On the other hand, there were reports

of spike in the retail prices due to panic buying from individual consumers during the lockdown in some cities. This price rise ranged from 50% in North India to 200–400% in South India for some vegetables following rumors of food shortage due to market closures (Express News Service, 2020; Staff Reporter, 2020). Wholesale prices, however, varied across regions and no clear trends were observed, as prices either increased as a result of lower market arrivals (North and Central India) or in a few cases, declined due to a fall in demand by consumers (North India). As a case study illustration, a 5-year (2016–2020) time-series analysis using secondary wholesale price data for potato crop for the same date (20th April) shows that the highest price rise was observed for the year 2020 when the price increased by 77% over the previous year⁴ (Supplementary Figure 3). The analysis is shown for the Azadpur market in Delhi, the biggest wholesale market in India.

The news articles, also reported diverse trends in farm-gate prices after lockdown (a decline in farm gate prices was observed in some regions) (Mukherjee et al., 2020). In these regions, supply chain bottlenecks caused the farmers to sell their produce at low prices (Jha, 2020b). The limited focus of media articles on farm gate prices, therefore, pointed to a possible under-representation of producer distress. A formal analysis of food prices for different commodity groups and supply chain components in India (farm gate, wholesale and retail prices) can help in understanding these patterns (Elleby et al., 2020; Höhler and Lansink, 2021).

³1 INR = 0.014USD (as of 22th January,2021); 1 crore = 10 million.

⁴<http://www.apmcazardpurdelhi.com/>.



Other than the supply chain disruptions, certain social concerns also emerged from the review. A key example was the closure of schools and consequently, the mid-day meal scheme, one of the largest government-sponsored school feeding programs of the world, and important food and nutritional safety-net for children in India (Singh et al., 2014; Alvi and Gupta, 2020). Consequently, the government implemented measures including at-home delivery of mid-day meals or food security allowance for the children. The lockdown also resulted in job and income losses of daily wage earners, migrant laborers, street vendors in urban areas resulting in food security and hunger issues in major cities.

Cross-Tabulation Using Correspondence Analysis

To further support the findings from the qualitative review of media articles on India, a correspondence analysis of the keywords was also conducted (Figure 6). These keywords were analyzed by commodity. To have a deeper understanding, the category of Animal products was further bifurcated into

poultry and fisheries. Correspondence analysis highlights the relationship strength between keywords and commodities by their angular placement. Some of the most closely associated words with “Food” commodity were “shops,” “markets,” “distribution,” “essential,” “relief,” and “credit.” Similarly, with “Fruits and Vegetables” it was “APMC,” “Mandi,” “Consumption,” “wholesale,” and “prices.” For “Cereals,” these words were “operations,” “transportation,” “harvesting,” “seed,” “wheat.” These keywords point to specific problem areas for different commodities. For “Food” commodity, the keywords related to supply or access to food, along with government action were most significant. For “Crops,” farmer and production issues like harvesting and logistics were highlighted and for “Fruits and Vegetables,” the concern was more on the market and consumer side. The positioning of these words also highlights the presence or absence of associations. Most of the words regarding government action are on the opposite side or to the right angle of commodities like Fisheries, Poultry and Fruits and Vegetables, indicating that most of the economic relief

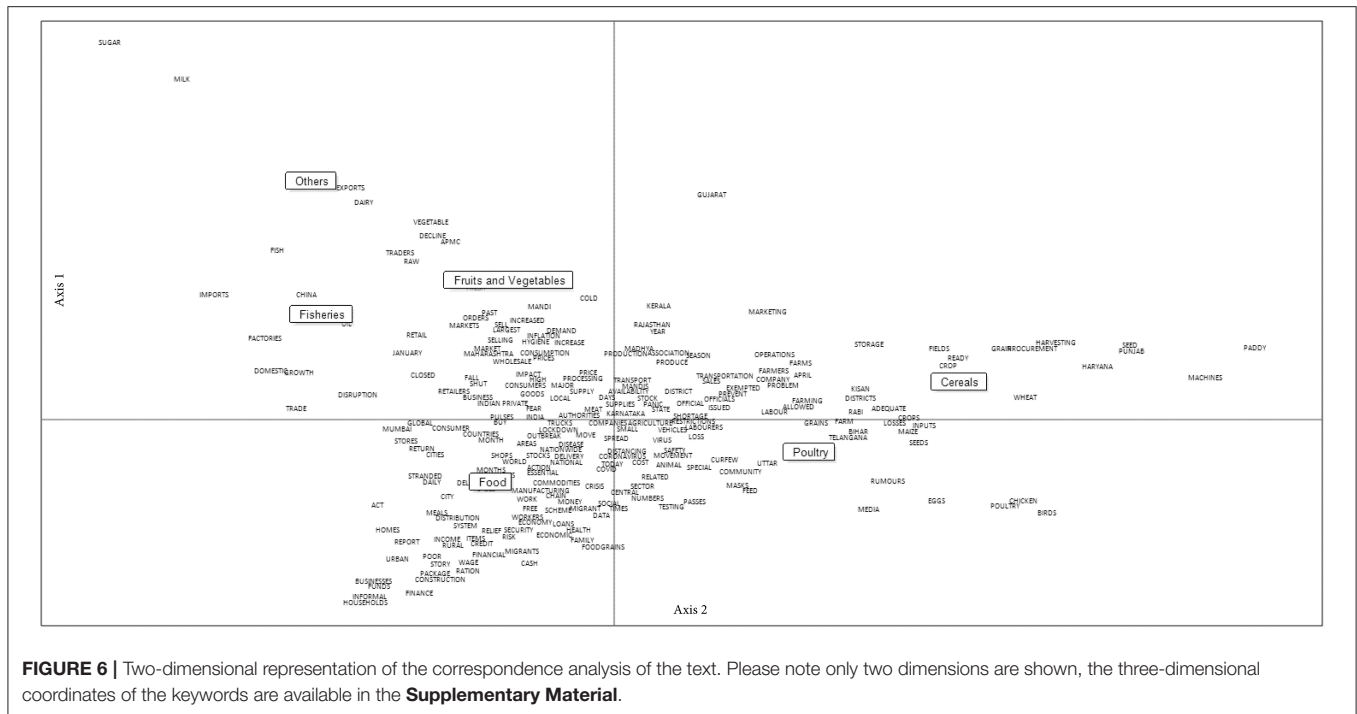


FIGURE 6 | Two-dimensional representation of the correspondence analysis of the text. Please note only two dimensions are shown, the three-dimensional coordinates of the keywords are available in the **Supplementary Material**.

packages were announced for either cereal crops or to ensure food supply in general. Similarly, words related to logistics and production which were strongly associated with cereals, have zero to negative association with poultry. This again highlights how the COVID-19 pandemic and the resulting lockdown resulted in different impacts for different commodity groups.

Sentiment Analysis

Sentiment analysis of the media articles in the review shows a significant increase in articles with overall negative sentiment, especially after the lockdown (Figure 7), which is expected. The trend, however, shows marginal improvement post lockdown due to several initiatives taken by the government and community relief efforts to address some of the challenges. Among them was the significant economic stimulus package of INR 1.70 lakh crores (approximately USD 23 billion) under the Pradhan Mantri Garib Kalyan Yojana (PMGKY) involving a direct cash benefit transfer along with food grain provision for two-thirds of the country’s population, which many news articles focused upon post-lockdown (Goyal, 2020).

The results from sentiment analysis by commodity highlighted the highest frequency of articles with negative sentiment for the “Animal Products” group. This was not just attributed to the significant losses incurred as a result of reduced demand but was also exacerbated by the lack of government relief measures for this group. High negative sentiment for “Fruits and Vegetables” was driven by panic-driven consumer demand as well as price volatility across markets. In contrast, the large scale relief measures announced by the government including cash transfers led to comparatively lower negative sentiment for commodity groups such as food and crops. Most

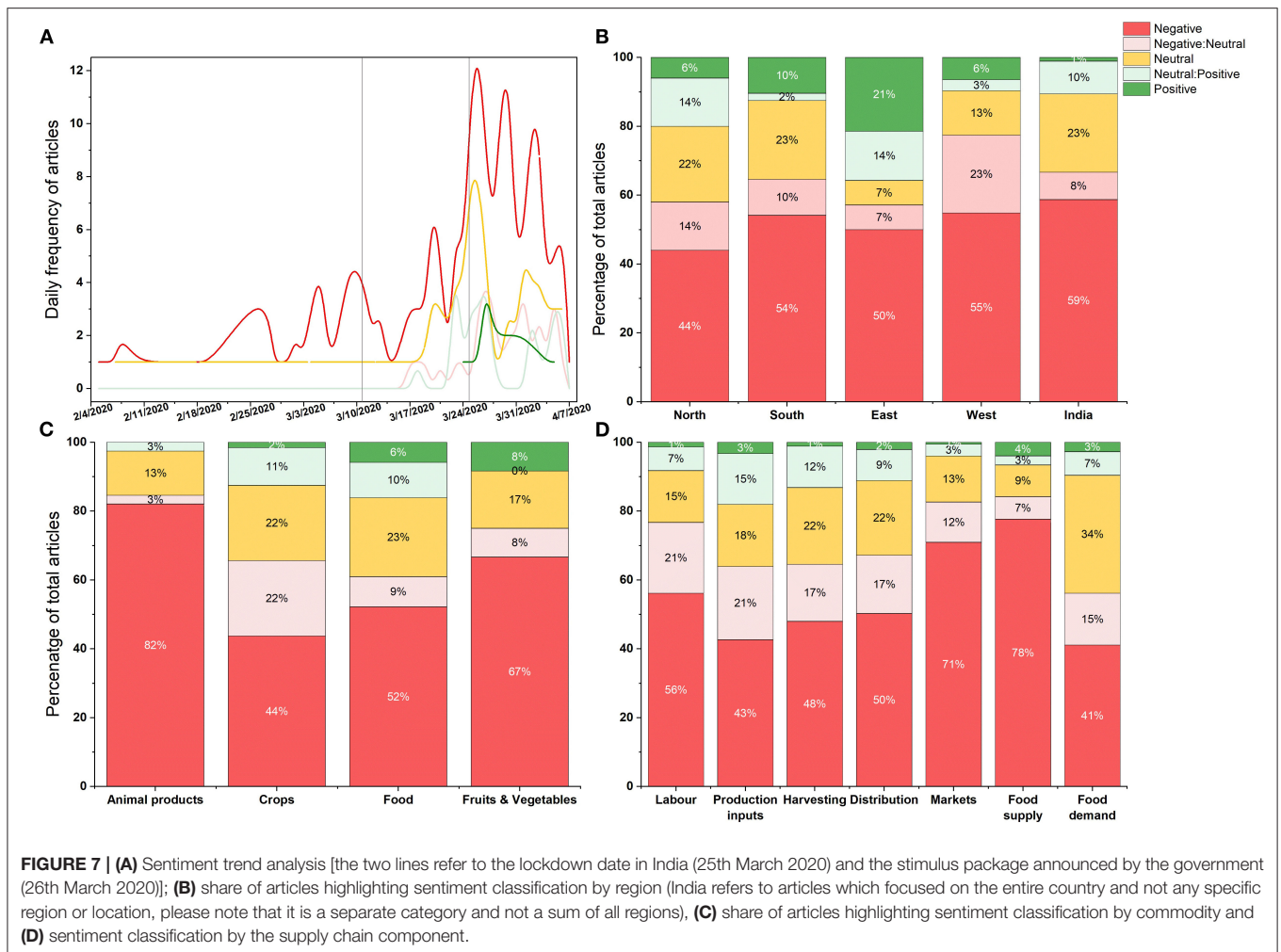
of the government relief measures reported in the news articles focused on crops (mainly cereals like wheat and rice).

Around 60% of the articles focused on India, were of negative sentiment and 23% were negative-neutral, highlighting an overall negative sentiment, as seen in the media articles. Among regions, over 50% of the articles from western and southern India had a negative sentiment, largely driven by a large share of “Animal Products” and “Fruits and Vegetables” articles from these areas. Comparatively lower negative sentiments were found for northern India, as most of the articles here focused on crops. The sentiment analysis by supply chain components also shows the highest negative sentiment for food supply (78%), followed by markets (71%) and labor (51%)—indicating these as the most affected parts of the food supply chain. Food demand was least affected with 41% of the articles with negative sentiment.

Compound Risks From COVID-19 and Extreme Weather Events

Media analysis highlighted compound risks faced by farmers over the study period. In addition to the impact of the COVID-19 pandemic, farmers also suffered extreme weather events. Phrases such as “loss of crops,” “delay in wheat harvesting,” “severely damaged,” “excess rainfall” in the media articles highlight how climatic stress affected the crop production in 2020, especially in the case of wheat and mustard crops in North India (Supplementary Figure 1). A private weather forecasting agency estimated economic losses up to INR 255 crores from unseasonal rain in the cropping season, affecting 650,000 farmers (Sangomla, 2020).

Results from extreme weather analysis (excess rainfall events) for the study period also highlighted these issues (Figure 8). Also

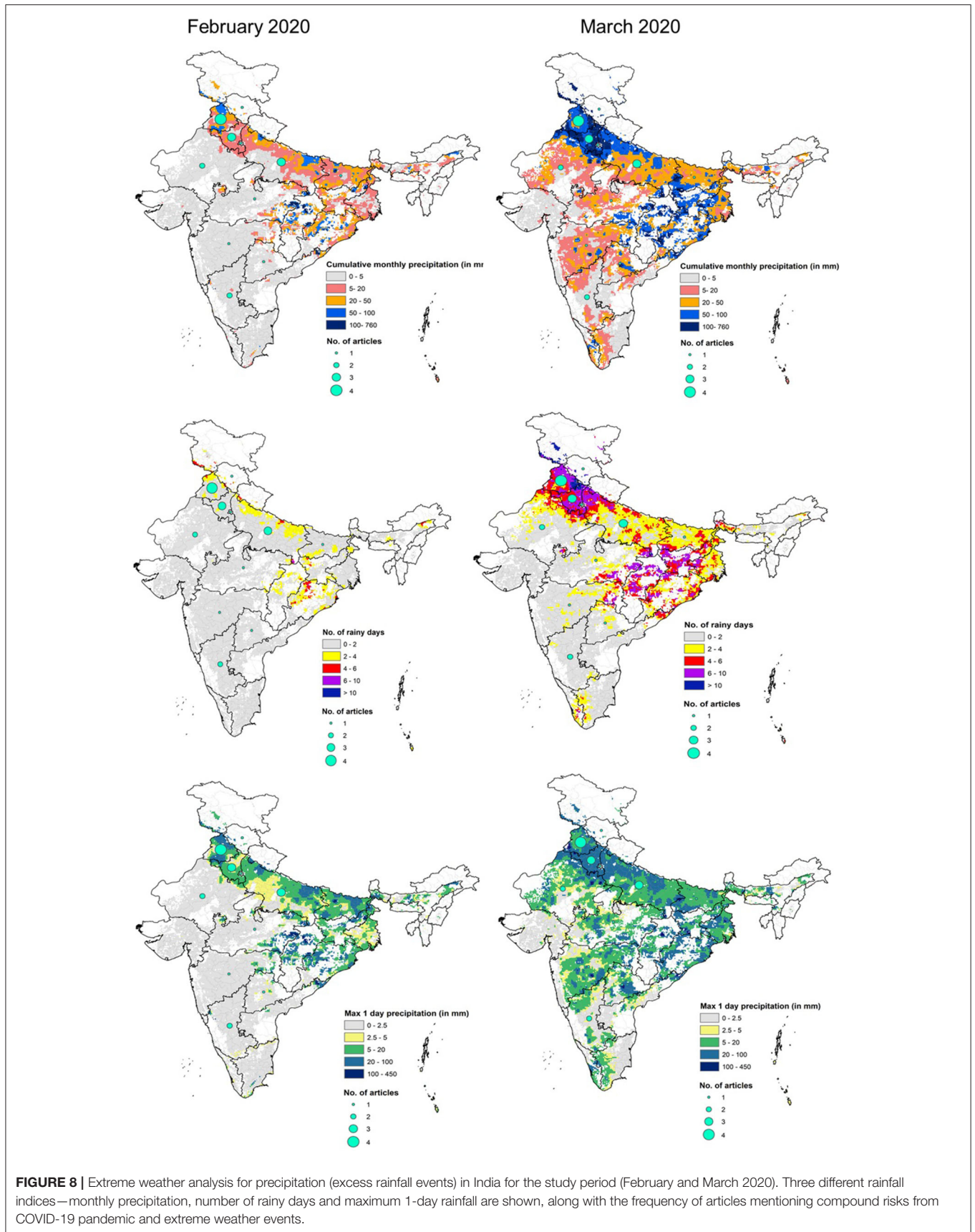


shown in the figure is the number of news articles in the state where impacts of COVID-19 and excessive rainfall events on the farming sector were both recorded. There were instances of very high rainfall (up to 750 mm) in March in northern and eastern India. This was observed especially in wheat-producing regions of Haryana, Punjab and Uttar Pradesh along with eastern states of Chhattisgarh, Jharkhand and Orissa. This is significantly higher than the normal rainfall received during this time (<https://mausam.imd.gov.in/>). These regions received rainfall volume of 100–750 mm in 6–10 days, with states like Haryana and Punjab witnessing up to 10 rainy days in March 2020. The high volume of rainfall over a span of few days has the potential to adversely affect the harvesting and maturing stage of crops, especially wheat, in the field through lodging and flooding (Mukherjee et al., 2020). The extreme rainfall risk in the study period was also shown by the maximum rainfall received in a single day (1-day maximum rainfall)—farms in Uttar Pradesh and Haryana received up to 100 mm of rainfall in a single day, while central states Chhattisgarh and Madhya Pradesh received 100–450 mm rainfall in a single day. Producers in those regions suffered

compound risks from both the pandemic and extreme weather during the same time, exacerbating their loss, as also reported by the news articles. The focus of the articles, however, remained skewed toward the COVID-19 impacts on the food systems, with limited attention on the compound effects (of both the pandemic and extreme weather) on the Producers.

Policy and Community Action

News articles highlighted many policies and community initiatives undertaken to help the farmers and other supply chain actors, and the different measures which were undertaken by local governments, private sectors and individuals to distribute food to those who were severely impacted. Apart from the national farm stimulus announced by the government, state governments issued health guidelines for farmers to be followed during harvesting and marketing operations with social distancing. Some state governments also created specialized disinfection tunnels before entry gates of certain food markets (ANI, 2020). Simultaneously, the government officials interviewed in the news articles, highlighted the availability of



enough food stock for the country's population to mitigate food insecurity fears. Apart from this, several private initiatives were also reported in the news media. In many places, consumers directly contacted farmers (through local farmers markets) and established localized food delivery networks, to overcome logistical bottlenecks. Private and development agencies also initiated food delivery services for migrant laborers during the lockdown.

DISCUSSION

The study highlights the immediate effects of the pandemic-induced lockdown on the Indian food supply chain by combining news mining techniques with content analysis tools. It highlights the key areas of disruption across different commodities and themes. A sharp spike in articles immediately after lockdown was observed (and expected), however different trends were noticed for commodity groups and components of the supply chain. Key areas of impact were Animal products and Fruits and Vegetables (commodity groups), and wholesale and retail markets, food distribution and logistics challenges (supply chain components) as well as concern over food supply and availability. On the other hand, despite agriculture being exempted from the lockdown restrictions, labor and input availability were observed as major bottleneck areas as reported by the farmers. The food supply chain in India is disorganized, fragmented and inefficient due to several challenges like small landholdings, lack of infrastructure like post-harvest storage and processing units, among many others (Parwez, 2016; Meena et al., 2019). These challenges further magnify the impact of both biotic and abiotic risks as mentioned in the news articles. This is especially true for perishable commodity groups like Animal products, Fisheries and Fruits and vegetables; which were found to be disproportionately affected in the media analysis than others. At the same time, these commodity groups play a significant role in the livelihood security of millions of farmers—India has the highest cattle population in the world, and a fast-growing fisheries sector (Islam et al., 2016). The fisheries sector in India provides livelihood support to 16 million people directly and 20 million people are supported by the livestock sector (<http://dahd.nic.in/about-us/divisions/statistics>). Most of these farmers are smallholders with a limited resource base (as also evidenced in the media articles), and the production is thus disorganized and scattered, thereby making the supply chains more vulnerable to shocks. The consolidation and organization through mutuals, formal and informal producer organizations can be one way to improve the efficiency of the supply chains (Meuwissen M. P. et al., 2019).

The scope of the study is temporally limited and does not allow an analysis of medium to long term trends. However, the analysis is aimed at providing immediate and short-term insights into the impacts of the lockdown on the food supply chain. The study results highlight the potential of this methodology to enable near real-time monitoring of farm distress. Additionally, the dis-aggregation of challenges by actors and categories, along with their interactions with each other, also provides a unique

opportunity to timely identify and address key issues within the food supply chain.

The current crisis, while disruptive, also necessitates a detailed assessment of existing preparedness and resilience of the food systems to adapt to multiple external shocks, including extreme weather risks. Results also highlight the extreme weather risks faced by producers in the country during the pandemic. The analysis shows limited attention to this issue, which could be due to the localized nature of extreme events as compared to the global impact of the pandemic. However, it can serve as a starting point to understanding the potential impacts and compound risks in near future. Further research is required to understand how multiple shocks interact within the food systems and impact different actors.

Drawing from this study's results, the following recommendations can help agrarian countries such as India, in recovering from the current crisis as well as to enable better planning for the future. First, incorporating a broad range of unforeseen risk factors is essential in food security planning. Our case study results show how farmers in India faced multiple risks from COVID-19 induced supply chain bottlenecks (including both production and market risks), and extreme weather events in a single cropping season. Concurrent risks have the potential to significantly affect farm production (Toreti et al., 2019) and agricultural operations for the subsequent cropping seasons, reducing farm resilience and creating poverty traps in smallholder economies. Integrating a resilience approach (which recognizes the role of different risks in food systems) in policy planning is an important research agenda (Meuwissen M. P. M. et al., 2019; Komarek et al., 2020; Davis et al., 2021). A combination of different risk management strategies including early warning systems (Krishnamurthy et al., 2020), ICT-enabled climate services (Born et al., 2021), climate-resilient agricultural technologies (Sarker et al., 2019) and insurance can play a crucial role in building farm resilience. Second, leveraging the strengths of local and regional knowledge systems and supply chains, and providing opportunities to further strengthen them can help in overcoming risks, in addition to promoting timely reforms for strengthening social and physical infrastructure for last-mile connectivity. This can also be achieved by pursuing blended finance mechanisms and engaging all stakeholders including government, private sector, local community organizations and international agencies to scale up socially inclusive measures for building more robust and efficient supply chains. Our results show how local food supply chains can innovate (for example, media articles highlighting how consumers engaged directly with farmers during lockdown) and their strengths can be leveraged to create supply chain resilience (Thilmany et al., 2021). There were also several examples of how collective action was able to reduce some of the supply chain disruptions in the country. Government agencies collaborated with farmer producer organizations in the state of Maharashtra by directly selling farm produce to consumers through social media, thus overcoming supply chain bottlenecks. Similarly, women groups also played a key role in providing food to the vulnerable social groups in urban as well as rural areas (Ragasa, 2020). Timely planned and forward-looking policy measures can support supply chain

resilience. For instance, India's post-pandemic stimulus measure aimed to address some of the disruptions caused by COVID-19 and further develop agricultural infrastructure to advance producer well-being. While this measure was in the form of a relief package and was thus a reactive policy, similar strategies if proactively implemented can help in strengthening the resilience of the existing food systems toward future shocks.

Last and most importantly, we combine multiple data sources and present a methodology that can be used for a rapid near-real-time assessment of farm distress. With significant advances in data sciences, we believe the use of social media and news mining methods have immense potential for application in agriculture and food systems. Multiple case studies have highlighted the use of social media analysis in climate sciences (Buckingham et al., 2020) and disaster management (Kryvasheyev et al., 2016; Kibanov et al., 2017; Cecinati et al., 2019). Future research agenda can focus on utilizing big data analytics for farm risk management, particularly localized weather events (like hailstorms, landslides, inundation, cloud burst and lightning-induced fire events, among others) which are difficult to monitor due to data scarcity (especially in developing countries) and cause significant farm distress (Prein and Holland, 2018).

CONCLUSION

The paper demonstrates a methodology where detailed and structured analysis of media articles helps in assessing the early impacts of the COVID-19 on the food supply chain. This can be used as an analytical tool by policymakers to develop a timely response strategy to deal with such unprecedented crisis events in future. Results also point to the need for targeted responses, as impacts vary across commodities, regions and supply chain actors. The results also show the emergence of compound and concurrent risks in agriculture, and appropriate policy measures are needed to overcome the same, especially in countries with smallholder agriculture. The COVID-19 pandemic has come as a sudden tipping point for food supply chains in many countries, where they are not only required to adapt, but also transform the

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way supply chains operate right from farm to fork. The above analyses and recommendations, therefore, provide important inputs to build better pathways to food security in the post-COVID-19 era.

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.

AUTHOR CONTRIBUTIONS

SV, NC, and PA conceptualized the study and designed the methodology. SV, MC, and NC worked on the analysis. SV and NC majorly contributed to the writing and editing of the manuscript and supervised the entire study. All authors contributed to the article and approved the submitted version.

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