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Pandemic or Environmental Socio-Economic Stressors Which Have Greater Impact on Food Security in the Barishal Division of Bangladesh: Initial Perspectives from Agricultural Officers and Farmers

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Abstract: The COVID-19 pandemic and subsequent protectionary lockdowns have had a dramatic impact on agricultural production globally. Barishal division is the 'grain-basket' of Bangladesh and a main rice cultivation centre within the country. This study captures perspectives on the environmental socioeconomic stressors impacting primary production in the coastal region of Barishal, and the impact of the first wave of the global pandemic. In our methodology, a cross-sectional survey is carried out amongst agriculture officers and farmers focusing on land management practices, environmental stressors, and the consequences of the pandemic on winter crop harvests and wet season production. A total number of 234 people participated, of which 31 were agriculture officers and 203 were farmers. Government officers completed an online questionnaire, while farmer responses were collected through Focus Group Discussion. The results show that despite the lockdown, 76% of responders claimed that they had harvested more than 80% of the cultivated winter rice. Other crops, such as fruits and vegetables, were less successfully returned. Despite food production pressures, land capacity was not fully utilised, with a significant/notable proportion of fields left fallow, principally due to periodic flooding events that sufferer concurrently from soil organic matter depletion. Upazila, not severely waterlogged, had salinity problems to contend with. While transportation restrictions and labour shortages were key constraints arising from the impact of COVID-19 on both agricultural production and post harvesting (processing, distribution, and utilisation). Current storage facilities for perishable produce, such as fruit, were found to be lacking, which further compounded access to such food items. The COVID-19 pandemic shocked agricultural productivity and food supply within the Barishal division. However, despite managing to return a successful rice harvest during the lockdown, it was found that the pre-existing environmental stressors arising from cyclones and flooding continued to be the primary threat to agriculture, even during a global pandemic. Our findings have been used to inform management options to increase resilience in the region.

Keywords: COVID-19; climatic events; agriculture; food security; Barishal

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1. Introduction

Epidemics impact negatively on food security. For example, after the Ebola outbreak in Guinea, Liberia, and Sierra Leone in 2014, rice prices increased by more than 30% [1].

Elevated costs arise, due to the disruption of supply chains and/or diminished agricultural productivity, for example, rice production/output in Guinea dropped by 20% during the Ebola outbreak [2,3]. Unlike other recent epidemics, which were relatively localised events, the impacts of the COVID-19 pandemic for farm-food trade and food security resonated deeply throughout the world [3–8]. Many countries implemented widespread and severe restrictions on the movement of their people, with some enforcing stay at home orders and curfews [6,9]. The rapid implementation of "lockdowns" meant that there was little provision in terms of advanced warning and preplanning, which exacerbated shocks on food production, distribution, and access [4,6,10,11]. However, countries dependent on manual labour for crop cultivation, which includes Bangladesh, were particularly vulnerable. With important agrarian zones facing severe labour shortages associated with the collapse of transport infrastructure, combined with travel restrictions [4,6]. For many workers in these countries, the lockdown periods resulted in an absolute loss of income, with many households borrowing money from friends and family or forced to take out personal loans [12]. In addition to the stresses placed on the purchasing power of lower- and middle-income households, export-import restrictions between and within countries further stifled trade and incomes. A key consequence of this was the unavailability of vital agricultural products, such as seeds and fertilisers [6,13]. The culmination of all these factors, meant that for many, the quantity and quality of food items consumed were significantly impaired [12].

Barishal (formerly known as Barisal), is one of the coastal divisions of Bangladesh located in the south-central part of Bangladesh. Approximately 80% of the Barishal region is used to cultivate rice [14,15], and as such, the region is a significant contributor to the national food security strategy [14]. Single Transplanted Aman (T. aman), or monsoon rice, is the dominant crop in the Barishal region [16]. Other important crops include pulses (predominantly mung bean), vegetables, fruits, spices, and nuts. With coconut cultivation being prevalent behind beaches. The production potential, however, of the agricultural sector in Barishal is limited by a series of significant environmental stressors, such as flood-cyclones, waterlogging, salinity, and soil organic matter depletion [16,17]. As a coastal division, with an elevation of just 1.22 m above sea level and with numerous river tributaries, the region is and has been historically prone to prolonged flooding, cyclones, and storm surges [18–20]. Among the six districts of the Barishal division, Bhola, Barguna, Patuakhali are the most cyclone vulnerable, but all districts have suffered extensive crop damage, especially in the recent spate of cyclones, which included Amphan (2020), Bulbul (2019), Fani (2019), Roanu (2016), Aila (2009) and SIDR (2007) [21] (Table S1). The spread of urban conurbations, road construction, and bridge culverts have either destroyed or modified canals within Barishal, slowing down the dispersion of floodwaters. Despite rice being a semi-aquatic crop, heavy and persistent flooding is a major productivity constraint globally [22,23]. Singh et al. [24] documented that around 22 million hectares of the world's rice fields are over flooded annually, which threatens the food security of more than 100 million people. Predictive models based on sea level rises and storm incidences suggest coastal communities, such as Barishal, will experience "much more difficult futures" [25]. However, there is currently a paucity of information on the damage to agriculture that exists, due to cyclones, sea level rises and flooding specifically for the Barishal region, and what protectionary measurements should be prioritised moving forward to mitigate the impact.

During the COVID-19 pandemic of 2020, Barishal also experienced tropical cyclone 'Amphan', which caused significant damage and prolonged flooding. Hence, the crop production system of this region had to endure the devastating impacts of a trio of significant pressures (preexisting soil health problems, cyclone climate hazards, and now a pandemic). This culmination of factors presented a unique opportunity to assess agricultural perspectives on the relative importance of such stressors, and better understand the strengths, weaknesses, and overall resilience of the agricultural food production systems of Barishal. Therefore, a cross-sectional survey targeting local agricultural officers and

farmers was accomplished in the region to capture initial perspectives on the success of the winter crop collection, post harvesting (processing, distribution, and utilisation) and wet season planting across a ca. 6-month period, while simultaneously assessing the interplay of preexisting edaphic constraints and seasonal cyclone damage, during the onset of the COVID-19 pandemic. In this study, we specifically considered/investigated the following:

1. Baseline land use and cropping regime characteristics;
2. Prioritisation of abiotic/edaphic hazards constraining crop production;
3. COVID-19 and climatic event disturbances/perturbations;
4. Postharvest and socioeconomic impacts.

Main findings from the survey were then used to inform the development of a conceptual model for understanding and managing crop production, harvest, and postharvest vulnerabilities for mitigation planning for future national and/or regional lockdown events, while contending with continuing pressures arising from abiotic and climate hazards.

2. Materials and Methods

2.1. Survey Design

The questionnaire was developed to comprise three themed sections and consisted of 34 questions consisting of multiple-choice and open answer responses. The first section focused on the general cropping regimes and the potential problems affecting the cropping systems. It was comprised of nine questions, and examples included 'how much land has been cultivated for rice?'; 'if there were any land remaining fallow for any season?'. The second section consisted of fifteen questions, focused on capturing the detailed impact of COVID-19 on crop production phases. These included which stage of the crop cultivation cycle was affected by the pandemic, how much crop was harvested, the fate of the crop, and whether farmers could make a profit, or to what extent the economic losses were. The third section focused on environmental challenges. These questions set out to prioritise which abiotic and edaphic factors were most impacting crops. Here eight questions probed whether the pandemic, or the preexisting environmental (edaphic/climate) stressors had a greater effect on crop production. The questions were presented in both English and Bengali languages.

2.2. Partner Organisation and Selection of Participants

The survey was carried out in collaboration with the Department of Agriculture Extension (DAE) of the Government of Bangladesh and Queen's University Belfast, Northern Ireland, United Kingdom. Two different categories of responder were:

2.2.1. Upazila Agriculture Officers (UAO)

There are 42 Upazilas (lowest tire of administration) from six districts in Barishal. A UAO is responsible for the agricultural accountability of an Upazila and provides crop/field management and policy guidance. They have an in-depth overview of general soil/crop health, production/harvest trends, as well as specific issues, across the network for multiple smaller farming communities within their jurisdiction. They received the survey questionnaire via email and responded through Microsoft Forms. Several attempts were made through emails and phone calls to reach all of the UAOs from the 42 Upazilas: A total of 31 UAOs (74%) returned their responses.

2.2.2. Farmers

Here participants were interviewed by associates of the University of Barishal in Focus Group Discussions (FGD). This approach was used for a number of reasons: (a) Capture of responses within a narrow temporal window as possible, to better harmonise the data responses, which would not have been achieved with email communication or one-to-one telephone surveys. (b) purposes of speed and efficiency [26] which enables a larger cohort to be surveyed [27], (c) focus groups are a tried and tested method of farmer engagement, and as such, farmers are more likely to participate and engage rather than commit to a one-on-

one interview/survey [27–31], (d) because FGD settings are documented to facilitate better reflective responses especially those relating to daily life activities, i.e., observations that could otherwise be taken for granted [26]. However, FGD's also have shortcomings, and the open nature of the discussions can introduce biases [27]. For example, discussions can be dominated by strongly opinionated individuals. This was controlled for in several ways. Firstly, the questions were screened to ensure they were neither sensitive nor controversial to answer. They were also framed on topics that the groups were highly familiar with, and the FGD facilitators were provided with training prior to engaging with participants. The term farmer in our survey represented three socioeconomic sub-groups, being a land-owner farmer who lease their lands to the tenant farmers (19%), land-owner and also farmer (i.e., who works in their own fields) (53%) and tenant farmer (27%). To avoid hierarchical biases relating to social-economic stratification, FGD facilitators were specifically briefed to be receptive to this and foster engagement from all participants [26]. They interacted with a total of 203 farmers across different Upazilas. These group discussions are presented as representative and unbiased information captured from specific Upazilas. Due to transport restriction and prolong rain events, farmers in remote areas could not be reached.

2.3. Ethical Approval

The Faculty of Medicine, Health and Life Sciences Research Ethics Committee of the Queen's University Belfast (QUB) reviewed and approved the survey questionnaire. We sought approval from the Director-General of DAE, Bangladesh. After obtaining permission from both QUB and DAE authority, we circulated the questionnaire among the responders. The consent of the participants was sought after the elucidation of the aim and focus of the survey.

2.4. Data Collection and Analysis

The survey was conducted between 14 July and 20 August 2020 (see Table S2). The responses were collected through Microsoft forms. The scores from answers to the questions were transformed into percentages, and figures are prepared using the infographic maker Canva, and the maps are produced using Arc GIS software.

3. Results

Results are organised to present: (a) Edaphic and environmental stressors, (b) the impact of the COVID-19 pandemic, and (c) the combined effect of the aforementioned on crop production in the region.

3.1. Edaphic and Environmental Factors

3.1.1. General Cropping Practices

Respondents were asked about current cropping practices, area coverage of principal crops, the ratio of cropped land and fallow land, and the reasons behind the land being left fallow. Approximately 72% of respondents claimed that more than 80% of the land is used for rice cultivation in their jurisdiction (Figure 1a). However, in some Upazilas, namely, Barishal city corporation, Nesarabad, Dumki, only 50% of the agricultural land resource is used for rice cultivation. Pulses, followed by fruits, leafy vegetables, spices, root vegetables, and nuts, are the most popular and extensive crop cultivation practices after rice (Figure 1b). Amongst pulses, mung bean is widely cultivated in the Barishal region during the winter season. In addition to winter vegetables, a wide range of summer vegetables are also grown on some high lands (low in percentages), or in the backyard of the household areas, some purposefully landscaped grounds (Sorjan/ridge and dike practice), and in floating garden practice. The majority (65%) of respondents said they grew less than 30% fruits and vegetables in their jurisdiction. Only 8% said they produced more than 60% fruits and vegetables. The production frequencies of rice, fruits, and vegetables are shown in Figure 2. Both the agricultural officers and farmers indicated that the crop cultivated depended on several factors: (a) Which crop is most profitable, (b) which grows

best with the climate, and (c) meets local demand. A range of fruits and vegetables grown in Barishal are presented in Tables S3 and S4.

3.1.2. Climatic and Environmental Stressors

Despite Barishal being the second-largest cropped area in Bangladesh (cropping intensity 178% in the year 2016–2017) [14], 20% of land remains fallow in 45% of the Upazilas (Figure 1c). In 30% of the Upazilas, the cropped land to fallow land ratio is 70 and 30. Both respondent groups, UAOs, and farmers, pointed to multiple reasons, such as waterlogging, soil salinity, labour shortages, and lack of organic matter (OM), for land being fallow (Figure 1d). A similar observation has been reported by FAO [17] that riverbank erosion, exposure to cyclones and storm surges, risk of heavy/late rainfall, torrential rain drip, and the remoteness of southern parts of the region from urban markets are key limitations of this area. The potential threats for crop production are presented in Table 1 and Figure 1d.

From our survey data (Figure 3), we found that flood prone Upazilas in Barishal are experiencing low soil organic matter issues, as well as a labour shortage problem. Upazilas, which experience waterlogging less infrequently, are nevertheless suffering from a soil salinity problem.

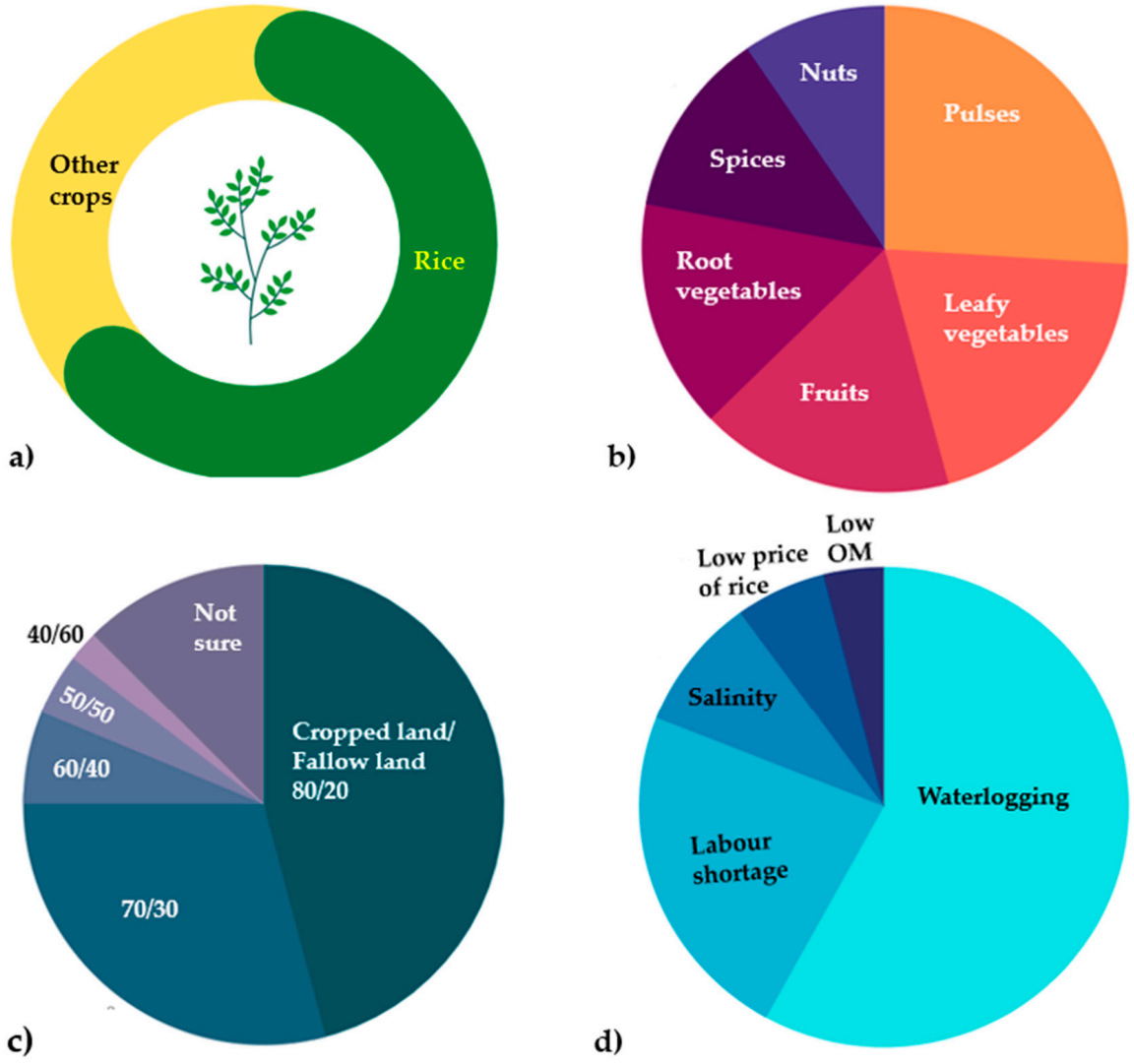

Figure 1. (**a**) Ratio of rice and other crop production in Barishal; (**b**) other popular crops; (**c**) ratio of cropped land and fallow land; (**d**) potential reasons for fallow land. (All the responses are presented as percentages).

3.2. Impact of COVID-19 Pandemic

On 8 March 2020, the first COVID-19 case was confirmed in Bangladesh by the Institute of Epidemiology, Disease Control and Research (IEDCR) [32]. To prevent the spread of viral infection among the mass population, the Government of Bangladesh announced a 'general holiday with restrictions on movement' effective from 26 March 2020 [12]. This coincided with the harvest time for the 'rabi' dry season crops [33]. Hence, it was anticipated that crop production would face serious damage because of the lockdown and travel restrictions. We asked participants at which stages of the production-cycle of rice, vegetables, and fruit they felt were most significantly impacted by the pandemic (Figure 4a). For rice, 74% of respondents said that harvesting was most affected compared to other cultivation stages. Their answers were also similar for both vegetables and fruits. Respondents were asked about whether harvest time scheduling was maintained. The majority (52%) claimed that they could harvest their crops on time and as planned (Figure 4b). However, 42% did say that they had harvested their products with a delay, while 6% said they had completed their harvesting earlier. Delays in harvesting were noted because of some of the protectionary measures of the pandemic, such as travel bans and transportation restrictions. Forty-two percent of respondents reported that they faced a labour crisis during harvest time, due to transportation restrictions (Figure 4c). The labour crisis in the Barishal division resulted in delayed harvesting, which is mentioned as a reason for yield loss by 25% of respondents. Travel bans and transportation restrictions also disadvantaged the buying and selling facilities of crops, mostly fruits, and vegetables. Ten percent of respondents stated that low market prices and lack of transportation caused perishable product spoilage. Nevertheless, 76% of respondents indicated that they could harvest more than 80% of their winter rice. This was in stark contrast to vegetable and fruit farmers—58% were unable to harvest more than 80% of vegetables in their jurisdiction. While for fruits, 57% of them ensured they harvested more than 80% of fruits (Figure 4d).

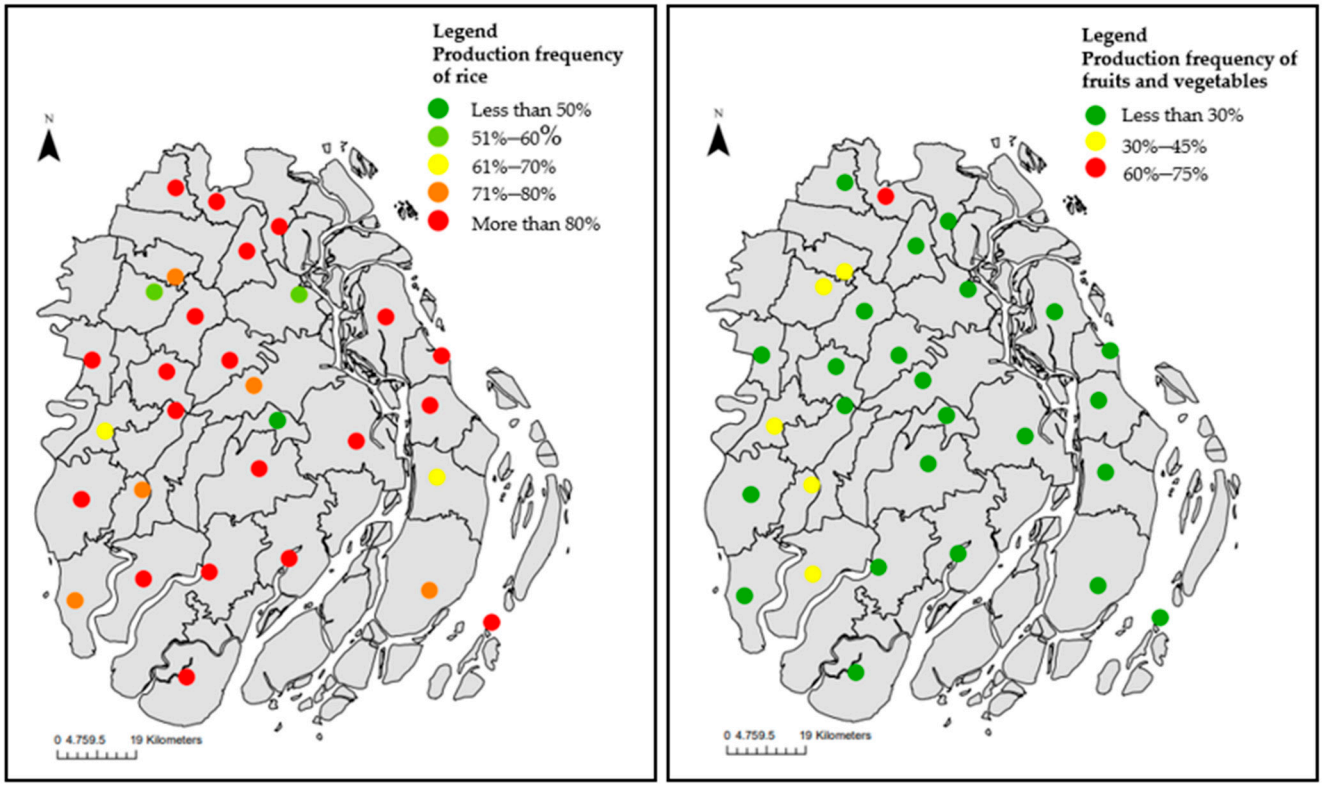

Figure 2. Production frequency of rice, fruits, and vegetables cultivation in the Barishal division.

Table 1. Potential threats for crop production in Barishal as summarised from participant responses.

Waterlogging—68% of the responders stated that waterlogging is a crucial problem for crop production in Barishal in recent years. Water can remain above the soil surface for 4–6 months. The problem is severe in Agailjhara, Banaripara, Burhanuddin, Dumki, and Wazirpur Upazilas. The difficulty with flooding/water logging is that the monsoon rice cannot be cultivated in those lands.
Salinity—17% of the respondents said salinity is another reason for which land remains fallow in the dry season. These responses are mostly from coastal Upazilas. Several places in Barishal are affected by low to moderate salinity and the places near the coast are highly saline. For example, Kalapara, Taltoli, Patharghata, Mathbaria.
Labour shortage—14% of the survey respondents said that some land remains fallow, due to labour shortages. Barishal Sadar, Jhalkati Sadar, Nesarabad- in these Upazilas, crop production gets hampered, due to labour availability.
The low price of rice—8% of the survey respondents claimed that in some seasons, due to the low price of rice, farmers lose interest in cultivating rice for that particular period.
Soil organic matter depletion—respondents, especially the farmers, emphasised a lack of organic matter as one of the main factors contributing to low yield.

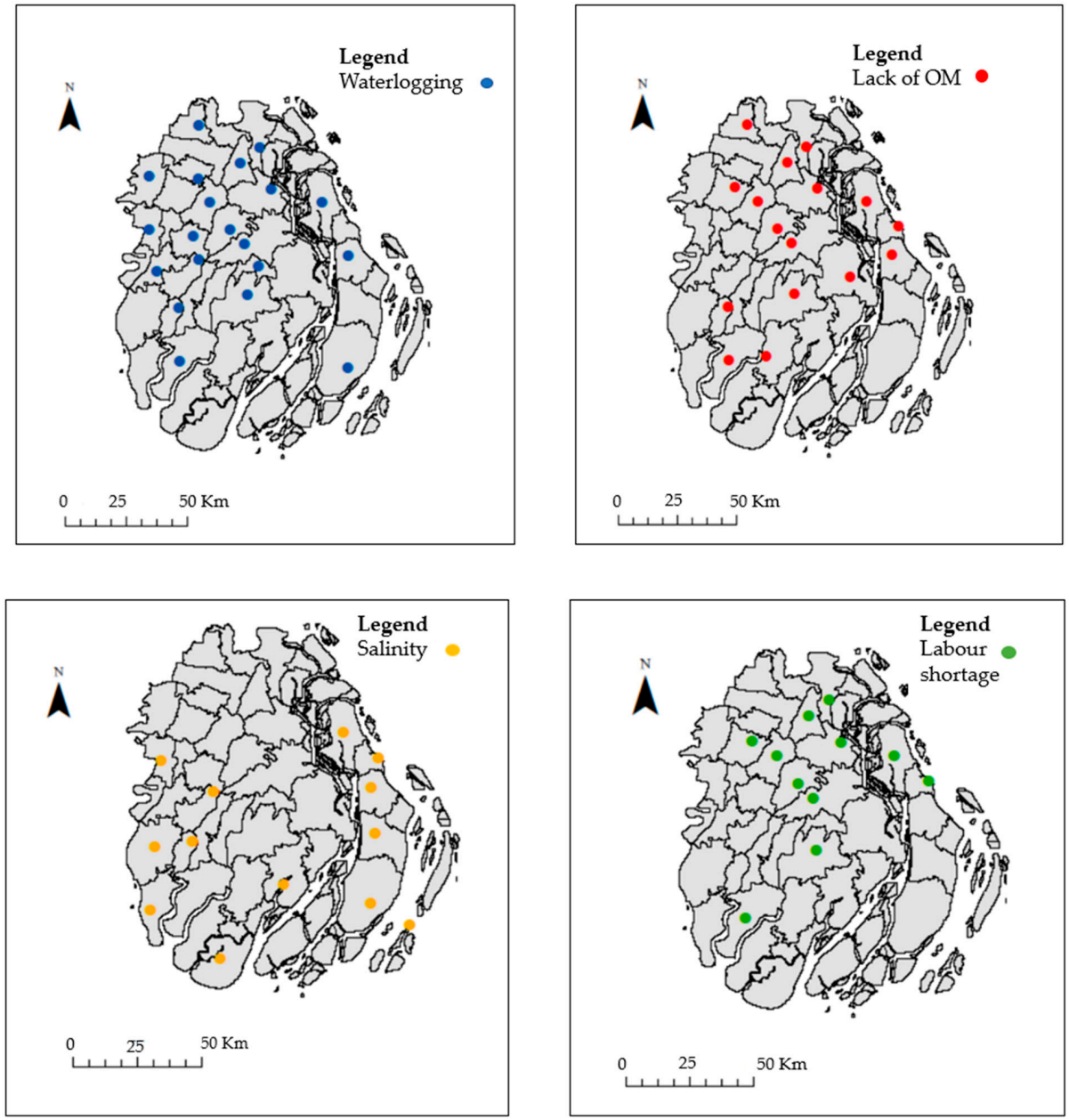

Figure 3. Abiotic and socioeconomic issues that affect crop production in different Upazilas of the Barishal division.

Respondents were asked whether they had proper storage facilities for the harvested products. Eighty-five percent said they do not have appropriate storage facilities to preserve perishable products for future use (Figure 4e). In one regard, marketing facilities were severely hampered, i.e., farmers could not sell their produce in the markets, due to lockdown, and in others, participant highlighted difficulties with storage facilities (Figure 4f); as such, farmers had no choice, but to sell their produce at a lower price than the cost of production.

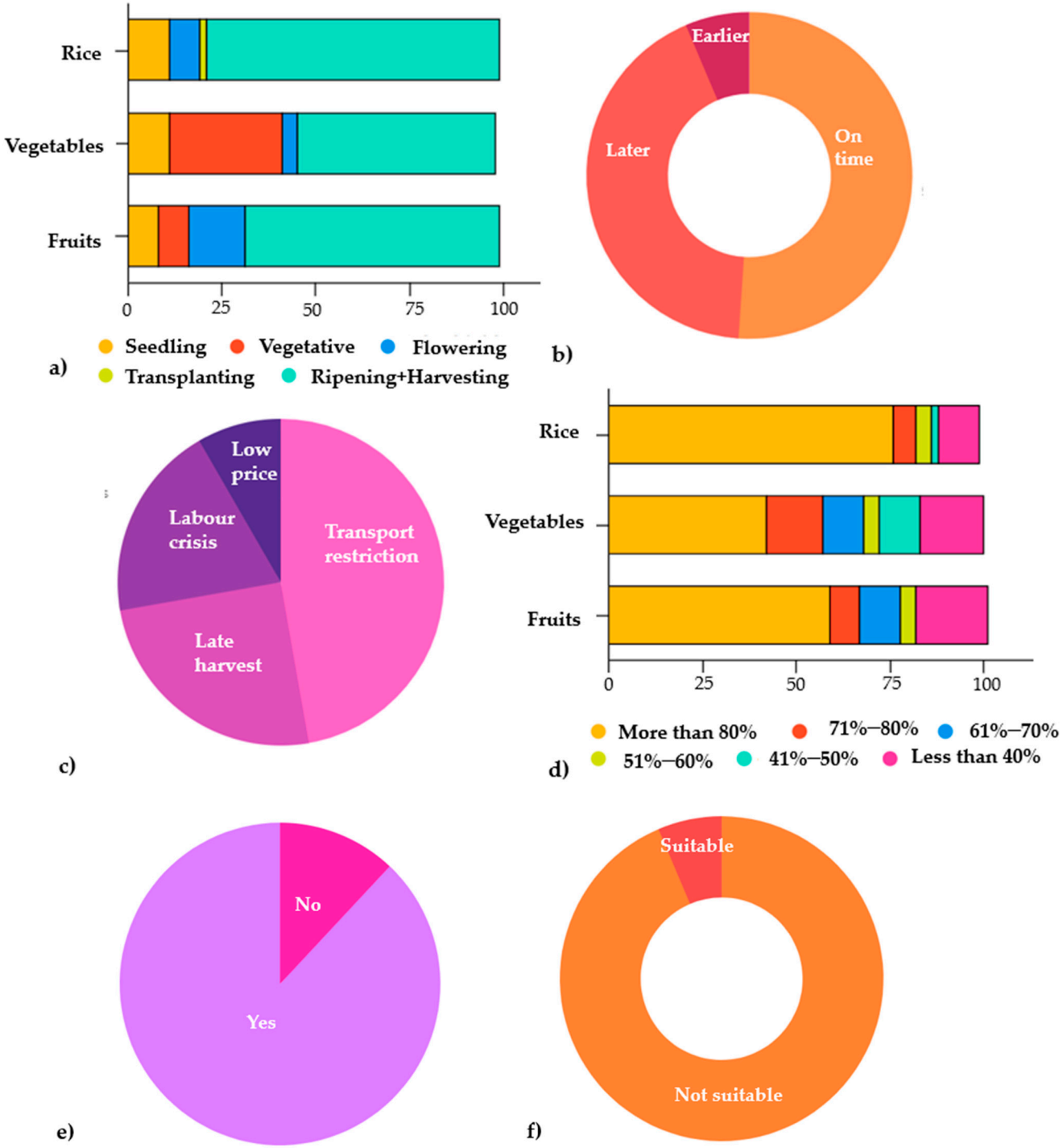

Figure 4. (**a**) Life cycle stages affected by the pandemic; (**b**) harvest time during the pandemic; (**c**) consequences of the pandemic affecting crop production; (**d**) harvest frequency of crops; (**e**) availability of storage; (**f**) suitability of storage. (All the responses are presented as percentages).

Fifty-five percent of responders claimed that farmers in their areas sold their products without any economic profit because they had no other option available to them. Thirty-one percent reported selling harvested crops with profit, and 12% of them faced product spoilage (Figure 5a). Respondents were asked to categorise the impact of the pandemic on harvest procedures on a scale of '1 to 5' (1 signifying 'None' to 5 'Very highly impact' accordingly) (Figure 5b). Twenty-nine percent reported that the pandemic had a medium impact on crop harvest, while 27% claimed it has a low, and 23% a high impact. For example, some people who faced economic losses selected high impact, while others who could harvest more than 80% of the rice and sold it with minimum profit selected medium or low impact. Sixty-eight percent of the survey respondents agreed that the Government provided seeds and fertilisers as incentives (Figure 5c); hence, they could continue crop production despite the pandemic and subsequent financial losses. Nine percent of participants stated that the Government would buy all the crops and other agricultural products.

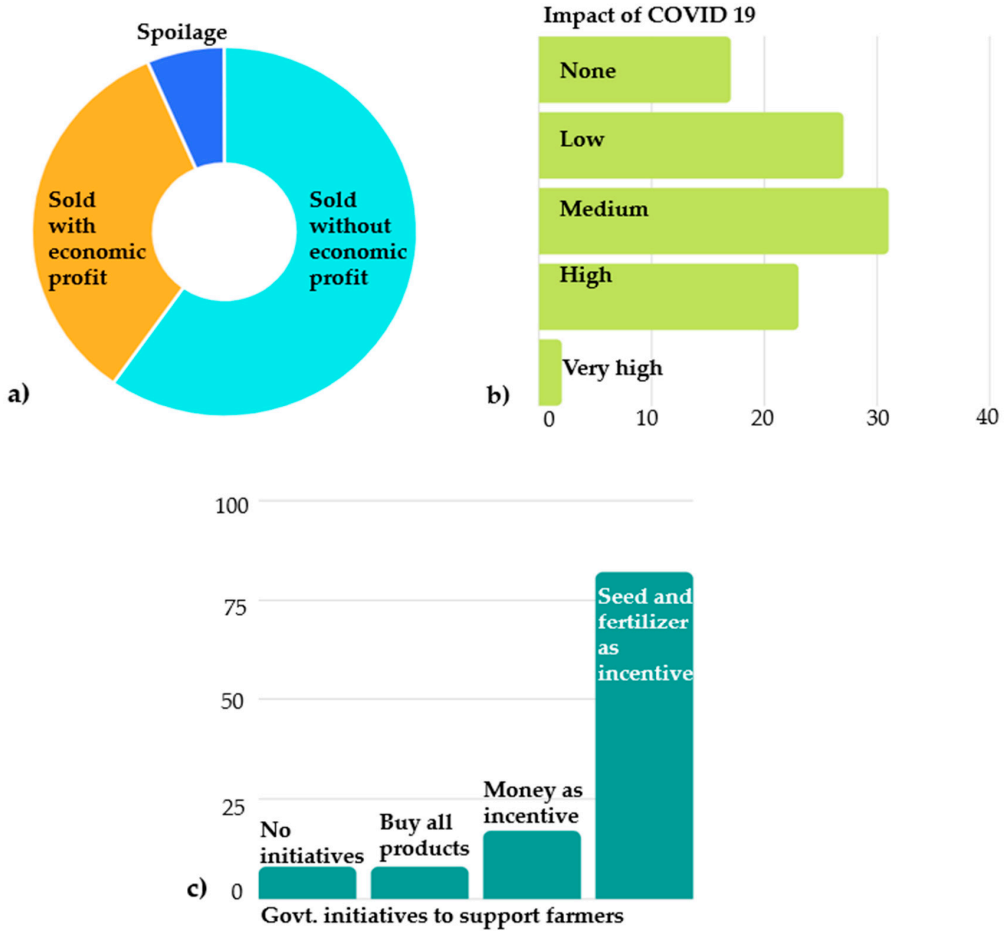

Figure 5. (**a**) Aftermath of the pandemic on crop production; (**b**) impact of the pandemic on the harvest of crops; (**c**) initiatives taken by the Government of Bangladesh during the pandemic. (All the responses are presented as percentages).

For example, some people who faced economic losses selected high impact, while others who could harvest more than 80% of the rice and sold it with minimum profit selected medium or low impact. Sixty-eight percent of the survey respondents agreed that the Government provided seeds and fertilisers as incentives (Figure 5c); hence, they could continue crop production despite the pandemic and subsequent financial losses. Nine percent of participants stated that the Government would buy all the crops and other agricultural products.

3.3. Combined Impact of Climatic/Environmental Stressors and the COVID-19 Pandemic

The first tropical cyclone of 2020, Amphan, reached Bangladesh on the 20 May and caused widespread devastation [21]. This "super cyclone" wreaked havoc across low-lying/coastal areas especially, with a five-meter (16-foot) storm surge, heavy precipitation, and strong winds (up to 260 km/h) [21,34]. The cyclone affected crops on some 176,007 hectares of land in 17 coastal districts [35]. Heavy downpours continued as the aftermath of the tropical cyclone caused flooding in several districts, which extended into the first week of June 2020 [34]. Furthermore, Bangladesh endured its worst flooding in a decade with persistently heavy monsoon rains [36]. The downward pressure of upstream flows, heavy rains, storm surges, and tidal bores caused local rivers to rise above their respective danger levels in the southern region, including Barisal city. This prolonged flood submerged some 159,000 hectares of agricultural land in 37 districts of the country, affecting more than 1 million farmers, according to the Ministry of Agriculture of Bangladesh [37]. In three phases, the flooding damaged various crops, including Aus, Aman, jute, and vegetables worth BDT 1323 crore (ca. £110 million GBP) in the country [38].

Crop production in the Barishal region is inherently vulnerable to climate events; this was also demonstrated from our survey questions. Respondents were asked whether they had experienced any other issues impacting crop production while also experiencing the effects of the pandemic simultaneously. The majority (72%) identified climatic hazards as a significant problem. Amongst the climatic hazards, cyclones (53%) mostly hit the winter crops, followed by floods (32%) and uneven rainfall (15%) (Figure 6a). Participants categorised the impact of climatic events on crop production on a scale of 1 to 5, signifying 'No impact' to 'Very High Impact,' respectively. Forty-two percent of them claimed that climatic events had a medium impact, and 34% said they had a high impact on crop production (Figure 6b).

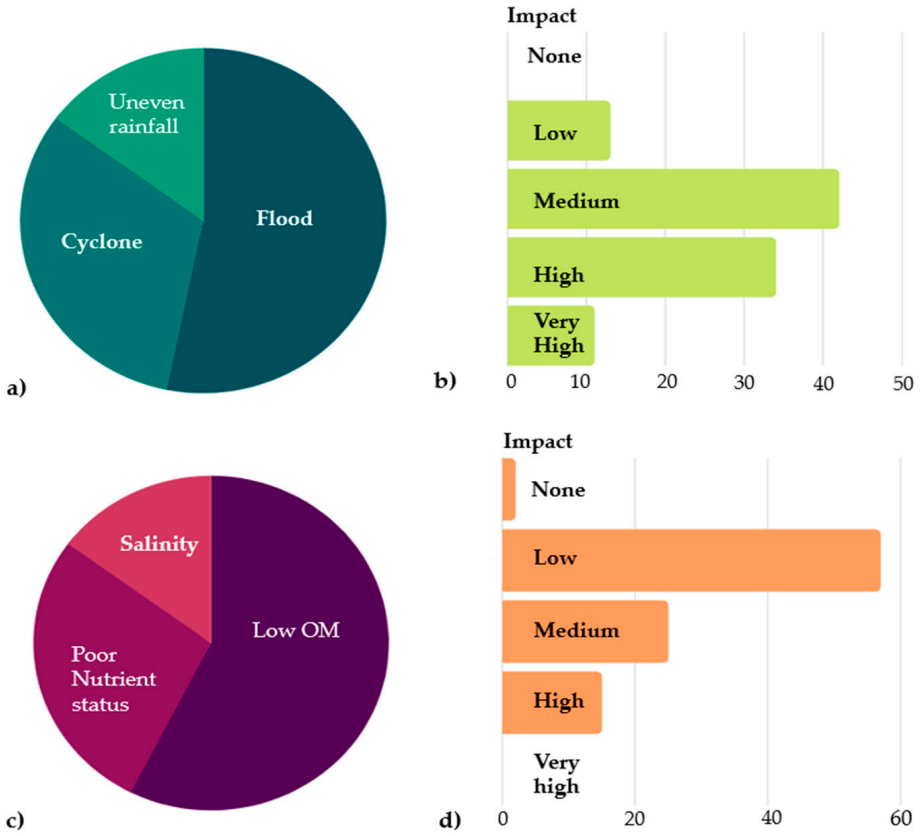

Figure 6. *Cont.*

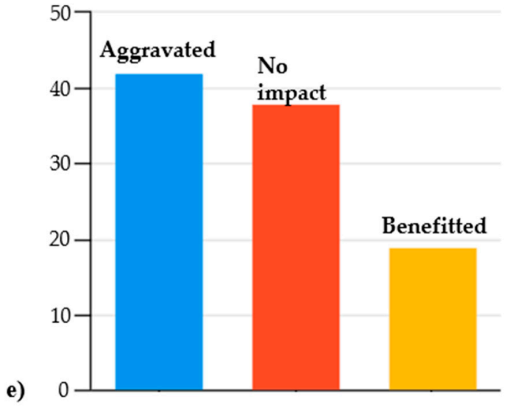

Figure 6. (**a**) Climatic events occurring during the pandemic; (**b**) impact of climatic events on crop production; (**c**) soil problems during the pandemic; (**d**) impact of soil problems on crop production; (**e**) combined impact of the pandemic and abiotic hazards. (All the responses are presented as percentages).

Although the impact of cyclones and flooding was mentioned profoundly in the survey, a number of soil-related problems were also identified by farmers in terms of impairing crop cultivation. Amongst which, soil organic matter depletion was reported by 57% of participants; low nutrient status of soil by 28%, and 15% noted soil salinity as a problem (Figure 6c). The respondents categorised the impact of soil problems on a scale of 1 to 5, where 57% said the soil-related issues had a low impact and a quarter of the respondents said those issues had a medium impact on the crop cultivation (Figure 6d).

Climatic events are recurring phenomena, whereas soil health issues are mostly a longer-term factor that can impair agricultural practices to differing extents. However, the outbreak of the COVID-19 also affected the agriculture sector. We asked participants whether the pandemic had a combined impact with the prevailing abiotic hazards on agriculture. Fifty-three percent of participants said that the occurrence of the pandemic had exacerbated the negative impacts created by existing climatic hazards (Figure 6e). However, some of them said there was no such combined impact; but rather, the cyclone and subsequent flooding damaged their standing crops in the fields more than the impact of the pandemic itself.

4. Discussion and Management Options

Our survey revealed the potential problems for crop production in the Barishal division. These production constraints can be arranged under three major themes. They are as follows:

1. Climatic and environmental stressors;
2. Socioeconomic and infrastructural pressures;
3. Constraints arising from the COVID-19 pandemic.

They affected the agri-food sector, due to yield loss, disruption of product marketing, i.e., selling and buying, and caused price increases and/or economic imbalance amongst farmers, sellers and consumers. All these factors culminate in food insecurity for the region [39]. Appropriate initiatives should be taken to manage and mitigate the impact of such production constraints to ensure food security and agricultural resilience for the people of the Barishal division (Figure 7). We discuss and present management options.

4.1. Climatic and Environmental Stressors

Abiotic hazards for the agricultural sector in Barishal include cyclones, flooding/waterlogging, salinity, and low soil organic matter content. Climate change has altered meteorological patterns, causing drought and heatwaves, whilst intensifying tropical cyclones and floods, particularly in coastal belts [40]. Cyclones in Bangladesh predominantly occur in the pre-

and post-monsoon season, between April–May and October–November. The Barishal region encounters cyclonic storms every 2–3 years, and they affect crops, cause financial insecurity, and uncertainty amongst the farming community [21]. Both dry season and wet season crops in the Barishal region are highly vulnerable to damage by such cyclones. Flooding and waterlogging persist after cyclones or heavy monsoon rain events as a result of poor drainage. The main vulnerability to rice production from excessive rainfall and prolonged flooding is with transplanting of Aman (T. aman), which accounts for 46% of the total rice paddy area of Bangladesh [41] and is the major crop of Barishal. This weakness was acutely evidenced in the exceptional flooding in 2020 [42].

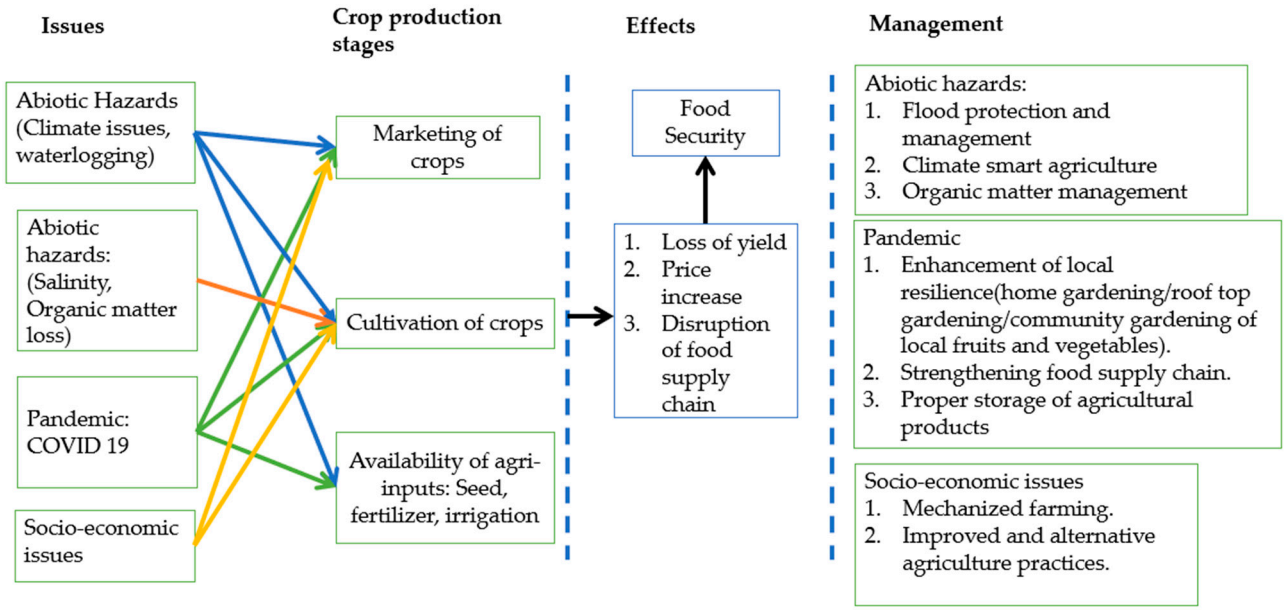

Figure 7. A conceptual framework model for understanding and managing crop production/harvest/postharvest vulnerabilities in the Barishal division based on perspectives from the initial 6-months of the COVID-19 pandemic.

Saline water intrusion in the Barishal division occurs, due to tidal inundation, storm surges, and sea-level rise. Soil salinity is a particular problem for dry season crops. Whereas, in the wet season, salinity levels are less problematic, due to diluted and wash-out effects from the monsoon rains. Our survey data revealed that several Upazilas are affected by soil salinity (Figure 3) to varying magnitudes. Those Upazilas with the most fallow land, due to salinity include Patharghata, Pirojpur, Kalapara and Taltoli. Worryingly, salinisation is predicted to advance 8 km further north in the country by 2030, further reducing available land for farming [43,44]. As such, increased importance should be placed on monitoring saline ingress to better understand and potentially mitigate against the early signs of salinity on crop production in the Barishal region.

Low soil organic matter content and nutrient status are long-term issues in Barishal. This is in part due to intensive cultivation practices, i.e., repeated rice cultivation in the same fields for prolonged periods with no crop rotation cycle [45–47]. Additionally, in wetland soils, flooding causes carbon and nutrient 'wash-out' because low redox potential changes the mobility of organic matter [48]. Farmers are guided to use organic manure to replenish the soil, nevertheless, the use of organic manure is not widely practised in all Upazilas of Barishal, due to comparatively low livestock densities.

Management for Climate and Environmental Stressors as follows.

4.1.1. Flood Mitigation

Recently, the Government of Bangladesh announced the 'Bangladesh Delta Plan 2100' [49]. This 'mega plan' [50] incorporates several strategies for flood protection and includes dredging of riverbeds [51]; excavation/re-excavation of canals [51]; early flood

warning [50]; restoration, redesign, and modification of existing embankments [51–53]. However, previous attempts to create protection against flooding, such as riverbed dredging, and the establishment of embankments, has not been entirely successful. To some extent, these approaches (e.g., riverbed dredging) resulted in negative impacts on the hydromorphological environment [53], and a lack of embankment maintenance contributed to significant flood related losses [54]. Brammer [55] propounded that "the main obstacles to protecting Bangladesh against floods from Brahmaputra, Ganges, Meghna rivers are economic and institutional." Hence, flood management planning should be built on studying the environmental conditions of each flood prone area, assuring the suitability of planning for the designated area [55,56].

The following are potential mitigation options for flood prone and waterlogged areas of Barishal:

- Excavation and dredging of canals: Barishal is intertwined with numerous canals which have been populated by human settlements over the years. Alongside this is infrastructure, such as impervious surfaces, roads, culverts, which impact overland flows and drainage hydrology [57]. Local wetland rehabilitation, particularly the reconnection of the wetlands and canals, can be beneficial to the water storage capacity of low-lying coastal regions [58].
- Installation of pump drainage: Pump drainage [55,59,60] can be an effective solution in several Upazilas in Barishal where crop cultivation is threatened, due to waterlogging. This mechanical rainwater or floodwater removal from low-lying agricultural fields would enable them to be put back into cultivation.
- Establishment of embankments with regulators: Regulators/floodgates on embankments could help in the Barishal region to control the inflow or outflow of floodwater [55]. Hence, people there can choose to use the monsoon floodwater for the benefit of winter crops.
- Introduction of flood and storm/cyclone tracking apps: Flood forecasting and early warning systems have facilitated farmers over the years [51]. Based on river monitoring and precipitation records, an early warning notification is sent to the DAE, which is then relayed to farmers [51]. However, this information could be communicated faster, more directly and to more people with the help of phone hosted flood tracking apps. Storm/Cyclone tracking apps can also be introduced so that farmers can take necessary preparation for the protection of crops. For example, the warning could enable early harvesting or the addition of soil-plant protection, such as mulch. It is of immense importance to ensure that support reaches all farmers to save cultivated crops.

4.1.2. Adopt Climate Smart Agriculture

To protect food security from the vulnerability of climatic crisis, the Department of Agriculture Extension (DAE) advocated farmers on the coastal belt adopt strategies of Climate Smart Agriculture (CSA) [43,61]. There are several CSA practices popular among the farmers of Kalapara Upazila [18,61], for example floating bed agriculture, Sorjan (raised bed), submergent varieties of crops, and salt-tolerant varieties of crops. However, CSA practices need to be introduced and extended to other Upazilas of Barishal.

- Floating Bed Agriculture: An ancient practice of wetland farming during the monsoon, where aquatic plants are used to build rafts, on which vegetables and other crops are grown [62], (Figure S2). This is a popular practice in some (<30%) Upazilas of Barishal and is predominantly used for seedling propagation [43]. The main benefit from this practice is that farmers can grow multiple crop seedlings in one season, while minimising the risk of complete crop failure, due to excessive rainfall [43]. Nevertheless, further research is needed for the practice to be extended to waterlogged prone areas where the use of floating bed agriculture as an adaptive strategy for crop cultivation could be used during the monsoon. The other benefit associated with the

used floating beds is as organic compost for subsequent return to soils, providing organic matter and nutrient replenishment.

- Sorjan (Ditch and Dyke): A technique of raised beds (see Supplementary Material) used for vegetable and crop cultivation with furrows, or trenches [43]. It helps farmers to protect crops from tidal submergence [43] (Figure S3). This practice could also be extensively adopted in flood prone areas. Sorjan is also successfully used in saline prone areas to protect the crops from salt effects.
- Use of submergence and salt-tolerant cultivars: Farmers are already adopting the use of submergence and salt-tolerant varieties for the management of critical issues like flooding, and salinity [18,43,61]. However, there are several genomic and anthropogenic factors that regulate the success of such varieties. For instances, several of the submergence tolerant varieties that have been released so far (BRRI dhan 51, BRRI dhan 52, Binadhan-11, Binadhan-12) could not survive complete submergence and prolonged flooding of 3–4 weeks which is still not helpful for most farmers [63]. Besides, specialist plants, highly adapted to extreme conditions, cannot often match the production of high yielding varieties. Furthermore, traditional plant breeding approaches are often lengthy because it usually takes approximately 15 years to provide the farmer with access to improved seeds [43]. Here, fast-breeding initiatives and gene editing technologies have a potential role to play [63].

4.1.3. Maintain and Build Soil Organic Matter Content

Soil organic matter in Barishal could be improved through crop rotation, the enhanced use of inorganic fertilisers and organic manures, and tillage methods for soil conservation [63]. Research is needed to develop cost-effective and implementable mitigation measures/practices to help improve soil health and status. In addition, control measurements for flooding may also help to reduce organic matter loss from the agricultural fields.

4.2. Socioeconomic and Infrastructural Pressures

Labour shortages and the low market value of rice have resulted in economic inequalities. Due to the low price of rice, farmers cannot directly afford to seek help from others nor employ workers during the harvest time. Therefore, agriculture as a source of employment is perceived as an economic burden, and as such, farmers become less interested in crop cultivation than the alternative, more lucrative incomes [64,65]. These drives significant rural-urban migration: Many young adults move into city areas to seek work in the textile industry, for example. This pattern is becoming a national crisis within Bangladesh as the rural economy struggles and is threatened by an increasing labour shortage, due to rural-urban migration. Management options include the introduction of:

4.2.1. Mechanised Farming

The use of farm machinery could help to alleviate the manual labour crisis [65–67]. In a few places of Barishal, mechanical agricultural practices are not new [65,66], e.g., tractor driven seed and fertiliser drill, and axial flow pump for irrigation. Their adoption can reduce the necessity for manual labour and its associated cost, save time, and reduce postharvest grain losses [65]. In a study conducted in Wazirpur Upazila of Barishal district, Ali et al. [65] found that rice harvesting losses can reach as low as 5% or 2% using mini-combine and reaper machinery, respectively, when compared to traditional labour harvesting. Yet, it is not widely practised in all agricultural farms in Barishal. Moreover, this machinery are an expensive investment for rural farmers in Bangladesh. The Government of the country should help farmers in this regard by providing incentives for the procurement of mechanical farm inputs. Furthermore, banks or other private sectors could also provide loan support to farmers [66].

4.2.2. Improved and Alternative Agriculture Practices

This survey revealed that some lands are not cultivated, due to economic reasons. Typically, this is most prominent during Kharif 1 (May–June) season, due to the low price of rice. Research should be focused on determining the reasons for the drop in the market price of rice during this period and take the necessary actions to improve the issues. Subsidy provision to farmers so that they can pay for the production cost of the rice would help. Here diversification of agricultural crops could also better balance temporal fluctuations in rice price and may have co-benefits for soil health and organic matter.

4.3. Constraints Arising from the COVID-19 Pandemic

The pandemic has impacted agricultural production from several perspectives: From crop cultivation, crop marketing, as well as the food supply chain, and the preservation of crop products. Nevertheless, the extent of the impact was different across the Upazilas of Barishal (Figure S1).

Crop cultivation involves several stages, among which ripening and harvesting of crops in Barishal were the most affected by the pandemic. The effect on cultivation stages resulted principally from the labour crisis as the crop cultivation in Barishal is still extremely labour intensive [65,66]. The unaffordability of mechanised reaper and harvesters makes the harvesting process labour dependent [68]. At the same time, many landless poor currently rely on this source of seasonal employment, and there is some economic migration within Upazilas and districts aligned with the agricultural season [69]. However, during the pandemic, this was significantly disrupted, due to COVID-19 protectionary measures, such as transport restrictions, and secondly, the fear of infection. This manifested in both a concern from the workers and host communities not wanting outsiders to join them. This led to a dramatic shortfall in labour during the harvesting of winter crops [10]. As a result, in many cases, crop harvesting was delayed.

Despite the constraints, rice, among all other crops, was successfully harvested, while fruits and vegetables received less priority. Rice harvest was supported by the Government of Bangladesh via the DAE. This prioritisation of rice harvesting [70], over other crops, is because rice is the primary cereal for the Bangladeshi population. However, it is essential to keep in mind that, balanced diets, micronutrient supplementation, and nutrition surveillance are essential for combating health-related issues like the emergence of coronavirus, or other diseases [7,71]. Murphy et al. [72] reported that in developed countries, such as New Zealand, UK, and Ireland, fruits and vegetable' intakes significantly increased during the pandemic. Hence, fruit and vegetable supply chain management must be a focus area for the next growing season, as well as the major cereal crop, rice.

Many farmers claimed that their perishable agricultural products could not reach the big cities and became spoilt, due to transport restrictions. Furthermore, because consumers were also movement restricted within lockdown, many farmers had to sell their products in their local markets with no or minimum profit. This is despite a backdrop of product scarcity and countrywide price spikes. This breakdown in supply chain function has been similarly reported in other countries. For example, in the USA, during the pandemic, the temporary closure of some meatpacking plants increased the price of meat by 4.4% and other alternative protein sources like eggs by 16% in April 2020 [73].

To support the farmers, as well as consumers, the Government of Bangladesh had aimed to buy 8 lakh (8×10^5) tonnes of boro paddy during the procurement period from 26 April to 15 September. Yet, it could only manage to purchase 2.2 lakh tonnes of paddy, falling short of the target by 72.5%. This failure is because the millers and farmers were less interested in supplying the grains to state storages because of the soaring prices of staple food [74].

Ceballos et al. [5] found that, in Haryana (a state in the Northwest of India), the existence of storage facilities resulted in farmers not having to sell their wheat at lower prices, while in Odisha, losses were much more severe because of the limited access to the quality storage. Similarly, limited storage facilities in the Barishal region were a

disadvantage to farmers. Transport restrictions, due to the pandemic impaired logistics and the access of rice, fruits and vegetables to markets could have been minimised if there were suitable storage facilities.

Management Options for Pandemic Related Constraints as follows.

4.3.1. Enhancement of Local Resilience

Increasing local agricultural resilience to crisis' like the COVID-19 pandemic is critical [75,76]. Agricultural production systems can be converted to mechanised farming systems so that labour supply limitations are no longer a barrier. Mechanised harvesting has already started in different parts of Bangladesh; its widespread establishment can reduce the risk of labour shortages in times of such crisis [65,66]. Moreover, where mechanised farming cannot be operated, manual labour should be provided with the maintenance of proper health guidelines and personal protective equipment to avoid the spread and transmission of the virus [4]. In addition, people who lost their jobs in the pandemic, can also be employed in the farming system who are willing to help in this regard [66].

Barishal being a geographically low-lying region, is challenged with respect to the cultivation of fruits and vegetables. However, to enhance the local resilience to supply shortages, there are strategies that can be taken to increase the cultivation of fruits and vegetables within the local community of Barishal. Floating bed cultivation in the flood prone areas, 'Sorjan', community gardens and roof top gardens should be encouraged, if possible, even incentivised, in an effort to cultivate more fruits and vegetables all the year round.

4.3.2. Strengthening the Food Supply Chain

Transport of agricultural products should always be uninterrupted with proper safety measures [3,4,66]. Staggered/rotation working hours can be implemented to ensure an efficient transportation flow of food products from farming areas to market/urban locations [4]. Safety protocols should be taught and enforced strictly to avoid the spreading of infection. Besides, robust monitoring should be conducted to check with the prices of commodities within local and national market, retailers. Hence, the unpleasant incidence of price increase and food supply chain crisis can be avoided. While at the same time, the Government should have a stronghold in equitable regulation of the market price for both the seller and consumer.

4.3.3. Establishing Adequate Storage Facilities

Improved storage infrastructure and capacity can ensure the protection/increased shelf-life of food for the entire population, which provides food security and can buffer against supply shocks [4].

Management options and their co-benefits for agricultural resilience in Barishal are summarised in Table 2.

Table 2. Summary of management options and their co-benefits for agricultural resilience in Barishal.

Management Option	Climate and Environment			Pandemic	Socio-Economic	
	Waterlogging	**Salinity**	**Low Organic Matter**	**COVID-19**	**Human Nutrition**	**Economy**
1. Flood mitigation						
a. Excavation and dredging of canals	++	~	+	~	+	++
b. Installation of pump drainage	++	~	+	~	+	++
c. Establishment of embankments with regulators	++	~	+	~	+	++
d. Introduction of flood and storm/cyclone tracking app	++	~	+	~	+	++
2. Adopt Climate Smart Agriculture						
a. Floating bed agriculture	++	~	++	++	++	++
b. Sorjan (Ditch and Dyke)	++	++	+	++	++	++
c. Use of submergence and salt tolerant cultivars	++	++	+	+	++	++
3. Maintain and build soil organic matter content	-	~	++	~	++	++
4. Mechanized farming	+	+	+	++	+	++
5. Improved and alternative agricultural practices	~	++	+	++	++	++
6. Enhancement of local resilience	~	~	~	++	+	++
7. Strengthening the food supply chain	~	~	~	++	+	++
8. Establishing adequate storage facilities	~	~	~	++	++	++

Benefit (Major)	++
Benefit (Minor)	+
Neutral	~
Negative	-

5. Conclusions

This cross-sectional study revealed significant insights for the food production system in Barishal in light of the COVID-19 pandemic, and against a backdrop of challenging and extreme climatic events. Our approach, although not as comprehensive as the annual agricultural census, which provides the most in-depth/detailed perspective, is faster and a more flexible platform for gauging information on cross-discipline/themes bridging soil-plant impacts along with supply chain and environmental socioeconomics. Our results are encouraging in that during the start of the pandemic agricultural returns and food security disruptions associated directly with COVID-19 were not as severe as was initially perhaps feared. The impact of the first wave of the COVID-19 pandemic on crop production in Barishal has been viewed as moderate by respondents. This is because, critically, farmers were able to attain a relatively successful rice harvest. However, it is important to stress that we are not diminishing the severity of the COVID-19 pandemic in this region, rather hailing the success and resilience of the DAE and the farming communities in general during this initial 6-month period. However, this is only part of our findings, and the disruption identified from vulnerabilities associated with preexisting/prevailing environmental pressures, such as climate change/soil health and especially flood and cyclone damage alongside food supply chain resilience, are highly concerning.

At the time of writing, the continuing battle against the pandemic is very different to 12-months ago in Barishal. In April 2020, the averaged 7-day COVID infections were ca. 400, during the same period in 2021, it peaked at ca. 7000 [77]. Reduced access to market facilities, due to transportation restrictions brought economic losses to farmers. This was compounded by a shortage of suitable storage facilities for harvested produce. Many farmers have been left significantly weakened, having made either a financial loss or only just broken even. This negatively impacts the ability to prepare for future cropping cycles /harvests, for example, seed and fertiliser procurement. As demonstrated (Figure 7; Table 2), there are solutions to some of these stressors, but many of these rely on 'people power', either in the form of working the land, maintaining or enhancing catchment hydrology, processing/storage of harvests, and transportation of goods. Our study identified labour as being a major constraint even at the start of the lockdown. Mechanisation and technologies are another management strategy but are difficult to implement quickly, especially during a national health crisis. All these vulnerabilities are cumulative—a poor fruit and vegetative harvest, for example, has consequences for following seasons, initially financially and environmentally, as well as potentially from a human health perspective. The cyclone season in April 2021 has been subdued, but the threat of future major storms remains ever-present. Cyclones will bring damage to the Barisal division. Key questions now are: (a) When, where and how bad will future climate impacts be? (b) What have been the cumulative effects of these problems, since the pandemic began? (c) What will be the human response and ability to ensure agricultural and food supply chain resilience in the wake of a devastating peak in COVID-19 infections within the region?

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13105457/s1, Figure S1: The COVID 19 pandemic impacted Upazilas of Barishal Division, Table S1: Previous cyclone frequencies in Barishal region since 2007, Table S2: Time frame of the survey within the cropping period of Bangladesh during the pandemic COVID 19, Table S3: Common fruits grown in Barishal, Table S4: Common vegetables grown in Barishal, Figure S2: Floating bed agriculture practised in Barishal, Figure S3: Sorjan (Ditch and dyke) practised in Barishal.

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