Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

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To cite this article: Dalia Štreimikienė, Tomas Baležentis, Artiom Volkov, Erika Ribašauskienė, Mangirdas Morkūnas & Agnė Žičkienė (2022) Negative effects of covid-19 pandemic on agriculture: systematic literature review in the frameworks of vulnerability, resilience and risks involved, Economic Research-Ekonomska Istraživanja, 35:1, 529-545, DOI: 10.1080/1331677X.2021.1919542

To link to this article: https://doi.org/10.1080/1331677X.2021.1919542

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Published online: 18 Jun 2021.

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ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2022, VOL. 35, NO. 1, 529–545
https://doi.org/10.1080/1331677X.2021.1919542

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ABSTRACT
Covid-19 pandemic provided many negative effects on world economies and people around the world. The covid-19 creates many threats to sustainability of agriculture sector which is very sensitive because of food supply security needs. First of all, it is necessary to analyse and comprehend the immediate consequences of current pandemic on agricultural and food systems in order to develop necessary actions. The risks, vulnerability, resilience and systemic shifts of agricultural systems need to be better understood in order to adapt to covid-19 pandemic. The aim of this paper is to analyse the negative impacts of covid-19 on agriculture and food systems by applying vulnerability and resilience approach by treating covid-19 like global disaster. The concepts of 'vulnerability', and 'resilience' which dominates disaster studies historically initiated after the World War II were applied to systematise literature review. The main input of this paper is systematization and grouping of the main measures to enhance resilience of agriculture systems in the face of covid-19 pandemic based on recent scientific studies published in 2020. The future research guidelines are also provided based on conducted systematic literature review.

ARTICLE HISTORY
Received 28 January 2021
Accepted 13 April 2021

KEYWORDS
Vulnerability; resilience; covid-19 pandemic; impact; framework; agriculture; risks

JEL
Q01; Q1; Q18

1. Introduction

The severe covid-19 world pandemic started in 2019 and resulted in immediate, serious human health issues around the world. Quarantines and other restrictions have been implemented to combat pandemic and these measures are expected to remain in place for many weeks and months. Vaccination may provide some help but many risks are still obvious and impact on all sectors of economy is detrimental (Horner, 2020; Patrinley et al., 2020).

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There are many other world-wide efforts aiming to control the pandemics by restraining movement and interactions of people causing negative economic effects linked also with functioning of agriculture systems responsible for food supply (Siche, 2020; Timilsina et al., 2020). The covid-19 creates many threats to sustainability of agriculture sector which is very sensitive because of food supply security needs. There are also many secondary damaging outcomes of the covid-19 pandemic on sustainability of agricultural systems across the world. There is huge decrease in demand for eatery and commercial food services, labour restrains, handling and production capacity of food and other agricultural products that have influence on farmers output reduction (Brewin, 2020; Ceballos et al., 2020; Cranfield, 2020; Poudel & Subedi, 2020). Quarantine measures reduced labour availability for such important farming activities like sowing vegetable crops, picking fruits etc. (Bochtis et al., 2020; Adhikari et al., 2021; Bisht et al., 2020; Cortignani et al., 2020). With the deepening of economic crisis cause by world pandemic, these impacts might be even more serious for agricultural sectors.

The consequences of the world covid-19 pandemic on agriculture sector around the world require immediate and long-term actions. First of all, it is necessary to analyse and comprehend the immediate consequences of current pandemic on agricultural and food systems in order to develop necessary actions, therefore, the risks, vulnerability, resilience and systemic shifts of agricultural systems to adapt to the current situation need to be better understood (Boughton et al., 2020; Cattivelli & Rusciano, 2020; Darnhofer, 2020; Diesner, 2020; Gunther, 2020; Henry, 2020).

Therefore, in this paper the consequences of the world covid-19 pandemic on agriculture and food systems were investigated by applying vulnerability and resilience approach. These concepts 'vulnerability', 'resilience' are the major theoretical concepts that are dominating, disaster studies historically after the World War II (Proag, 2014). As covid-19 pandemic can be treated as real disaster, this framework might be useful in dealing with the effects of covid-19 on agriculture sector. The current scientific literature on covid-19 impacts on agricultural sector was analysed by applying vulnerability and resilience assessment framework. The main input of this paper is systematization and grouping of the main measures to enhance resilience of agriculture systems in the face of covid-19 pandemic based on recent scientific studies published in 2020.

The rest of the paper is structured in the next way: Sec. 2 introduces data and methods including conceptual framework; Sec. 3 discusses results of literature review; Sec. 4 provides generalization of literature review findings; Sec. 5 concludes and develops future research directions.

2. Methods

2.1. Conceptual framework

The word disaster refers to a abrupt and unpredicted catastrophe notwithstanding of number of people, countries or the entire world effected. The current world covid-19 pandemic can be treated as disaster or happening having huge potential to create many losses. This can be defined as well as a hazard or the overall cradle of danger.

The definite expose of specific valuable things for people to a hazard is defined as a risk. The risk is usually being treated as the probability of loss. Therefore, the covid-19 pandemic is a disaster and a realization of hazard.

Vulnerability is being characterized as the degree to which a system or it's constituent may respond harmfully in the face of hazardous event or disaster. The vulnerability concept allows to evaluate the risks connected to the physical, social and economic consequences resulting from disaster to the system or it's components (Proag, 2014).

Concepts of resilience in scientific literature (Moench, 2009) can be grouped according hard and soft resilience definitions. The hard resilience can be described as the direct strength of systems when they are placed under the definite pressure under disaster. Therefore, in case of disaster, resilience can be defined as an inverse of fragility. The rising of resilience of a systems can be achieved by implementing enhancement measures aiming at reduction of probability of system collapse in the face of disaster. So, with the increase of resilience of the system, the level of damage for a certain intensity of the hazard, tend to reduce. The concept of soft resilience is linked to the capacities of the systems to absorb and recover from the hazardous events without encountering ultimate deviations in the systems functions or/and arrangement. This is linked to adaptive capacity of the system therefore defines the capacities of the system to adapt to the consequences of disaster.

As both concepts of resilience are valid in case of covid-19 impacts on agriculture, in this paper the hazards and risks created by covid-19 to agricultural systems need to be defined, following the analysis of exposure of agricultural systems to physical, social or economic hazards and related vulnerability of agricultural systems to these hazards. The resilience of the agricultural systems then will be addressed by assessing absorptive, adaptive and restorative capacities of the agricultural systems in the context of covid-19 pandemic based on various studies recently conducted around the world.

2.2. Collecting, preparing and analyzing information

We carried out a systematic literature review in order to consolidate the literature on covid-19 impact on agriculture. This method is distinguished by a well-documented, replicable and clear search mechanism that is driven by a theoretical interpretation of the related phenomenon and enhances the efficacy of the analysis process. To classify essential publications we applied our conceptual framework in literature search as well. For finding documents related to covid-19 impact on agriculture in terms of risks, vulnerability and resilience of agricultural systems, we have identified the following search terms and their combinations: 'covid-19', 'agriculture', 'resilience', 'vulnerability', 'risks': in all field in CA Web of Science database. We searched for these academic databases released across the year, including 2020, to cover the full spectrum of scientific papers. Except sources not related to the covid-19, as well as excluding duplicate articles in individual searches, we selected 50 documents for analysis from the 343 sources found. In order to find as many studies on these issues as possible, a snowballing technique was applied in the next step. While analysing the content of publications found during the search, those appropriate for analysing this article were also reviewed. Additionally, 30 relevant papers were found. The main findings of literature review performed are provided in results section.

3. Results of systematic literature review

3.1. Hazards and risks of covid-19 in agriculture systems

Based on literature review, the analysis of covid-19 pandemics effects on agriculture sector can be grouped into farms resilience, agriculture goods supply and demand, labour regulation, food security and safety, overall economic and social consequence and international trade issues. (Cranfield, 2020; Darnhofer, 2020; Jámbor et al., 2020; Siche, 2020; Villulla, 2020; Zarei & Rad, 2020). The analysis of these covid-19 effects is performed based on risk, vulnerability, resilience framework defined above.

The covid-19 can be treated as disaster associated with hazards and risks. Though, a disaster is a apprehension of hazard, there is no universally concept and agreement among scholars about the scale of hazard to be qualified as a disaster, however covid-19 pandemic can be treated as disaster taking into account overall negative impacts and risks occurred around the world and the number of deaths totalling to almost 2 billion. Thus, based on universal definition of hazard following conceptual framework provided above for our analysis, the main hazards and risks linked to covid-19 impacts on agriculture sector are given in Table 1 based on scientific literature review.

As one can see from Table 1, farmers, rural communities and the most valued issue for them are the main points of reference in assessing risks of agricultural systems in the face of covid-19 pandemics.

Table 1. Hazards and risks of covid-19 for agricultural systems.

Hazards	Risks	References
Farmers and rural communities	Deaths, diseases, health problems; stress and trauma for people and their family and relatives	Abrams & Szefler, 2020; Hossain et al., 2020; McDonald et al., 2020; Poudel & Subedi, 2020; Singh et al., 2020
Goods and services	Losses of agricultural products, waste of food.	Brewin, 2020; Cortignani et al., 2020; Harris et al., 2020; Henry, 2020; Richards & Rickard, 2020
Environment	Negative impact on soils, eocystems, losses of flora and fauna	Huynh et al., 2020; Lal, 2020b; Lal et al., 2020; McDonald et al., 2020; Rahim & Rahim, 2020; Saadat et al., 2020; Zambrano-Monserrate et al., 2020
Economic development of the agriculture sector	Food export and import break, economic crisis, break in agriculture sector development; bankruptcy of enterprises, loss of income, unemployment, poverty, inequality.	Ahmed et al., 2020; Barcaccia et al., 2020; Barichello, 2020; Martin, 2020; Mitaritonna & Ragot, 2020; Neef, 2020; Nicola et al., 2020; Phillipson et al., 2020
Social implications	Overall food insecurity and hunger	Deaton & Deaton, 2020; Dudek & Myszkowska-Ryciak, 2020; Kent et al., 2020; Laborde et al., 2020a, 2020b; Lal, 2020a; Lal et al., 2020; Neff, 2020; Niles et al., 2020; Owens et al., 2020; Torero, 2020; Wolfson & Leung, 2020; Zavaleta-Cortijo et al., 2020

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First of all covid-19 has created risks associated with deaths, diseases, health problems, stress and trauma for rural people like to other population groups. Several studies provided (Abrams & Szefler, 2020; McDonald et al., 2020; Poudel & Subedi, 2020; Singh et al., 2020) in depth-review of these hazards for farmers and rural communities including case of suicide of farmers (Hossain et al., 2020).

The covid-19 has impact on losses of farmers goods, especially fresh vegetables, fruit and milk products. These losses were associated with restrictions imposed by countries for movement and interactions, labor losses as well as demand reduction due to closure of restaurants, hotels etc. (Cortignani et al., 2020; Harris et al., 2020; Henry, 2020; Richards & Rickard, 2020).

Negative impact on soils, ecosystems, losses of flora and fauna are anticipated as major hazard to environment due to covid-19 pandemic (Huynh et al., 2020; Lal, 2020b; Lal et al., 2020; McDonald et al., 2020; Rahim & Rahim, 2020; Zambrano-Monserrate et al., 2020).

There are many risks identified by scholars (Ahmed et al., 2020; Barcaccia et al., 2020; Barichello, 2020; Martin, 2020; Mitaritonna & Ragot, 2020; Neef, 2020; Nicola et al., 2020; Phillipson et al., 2020) for break of economic development of agriculture sector due to pandemic linked to food export and import break, bankruptcy of enterprises, loss of income, unemployment, poverty, inequality. As pandemic has far reaching influence on international relationships going outside the agriculture sector, including export restrictions limiting global agricultural products and food trade as well as market access. Agriculture sector is very interconnected. All see ports and airports that were shut down or massively diminished capacity of freight for agricultural goods can provide for significant disruptions in global supply chains including food and agriculture goods (Ivanov, 2020).

However, most of the studies analysing the impact of covid-19 on agriculture stressed food insecurity issues like the main consequence of covid-19 disaster by linking them also with negative health impact to population (Laborde et al., 2020a, 2020b; Leddy et al., 2020; Neff, 2020; Poudel & Subedi, 2020; Singh et al., 2020); poverty and social exclusion (Adhikari et al., 2021; Kent et al., 2020; 2020; Marcus et al., 2020; Niles et al., 2020). Studies carried out in developing Asian countries like India, Malaysia, Nepal (Adhikari et al., 2021; Bisht et al., 2020; Cattivelli & Rusciano, 2020; Ceballos et al., 2020; Harris et al., 2020; Kumar et al., 2020a, 2020b) indicated that lockdown had huge negative effects on attainment of Sustainable Development Goals (SDG) linked to food and nourishment, i.e. SDG1 and SDG2, especially in least developed and developing countries due to the deficiency of actions to sustain food production and ensure food safety and supply security. Food supply security is the key issue as food supply disruptions may cause severe consequences to people around the world (Torero, 2020). It is necessary to highlight, that food distribution channels in majority of world countries due to covid-19 pandemic have been highly interrupted by providing negative influence on the most vulnerable people.

Studies highlighted that during covid-19 pandemic the limited capacities of supermarkets to rapidly restock following unprecedented demand increase due to the panic buying. There were also a big losses of fresh food like vegetables, fruits and dairy products due to inability by farmers or agricultural entities to carry them from production sites to local markets or logistic problems linked to delivery of agricultural products to supermarkets in local cities (Aldaco et al., 2020; Diesner, 2020; Morone & Imbert, 2020; Naughton, 2020; Unger & Razza, 2018).

3.2. Vulnerability of agricultural systems to Covid-19 pandemic

The concept of vulnerability suggests combination of risk with ability to handle the negative consequences of disaster. Vulnerability of agriculture systems can be defined as the degree to which an agricultural system, or it's constituent can respond harmfully in the face of a hazardous event or disaster (Handmer & Dovers, 2009).

For example, people can be 'vulnerable' if access to specific resources at various levels is the furthermost critical issue in maintaining secure livelihood or retrieving successfully from a hazardous event. The people having good access to main resources such as financial capital, various management tools, knowledge, know-how and necessary equipment are able to recover most rapidly and with least consequences for them in the face of disaster. However, the most vulnerable people in most cases which are not able to maintain secure livelihood or recover are the poorest one, having little choice and access to finances, tools, equipment, knowledge etc. (Proag, 2014). Exposure of farmers and rural communities to a different hazards' caused by covid-19 and linked vulnerability analysis areas are provided in Table 2.

As one can see from Table 2 all hazards of covid-19 pandemic can be grouped to physical, economic, social and environmental hazards and corresponding vulnerability traits of these hazards exposure in agricultural sector. The studies dealing with covid-19 pandemic influence on agriculture can also be systematized according to linked vulnerability analyses performed.

Comparing information provided in Table 2 with information provided in Table 1 where covid-19 hazards were associated to risks, one can notice that the major difference of qualifying hazards in both tables are linked to the areas of analysis. In Table 2 hazards are linked to vulnerability analysis of farmers and rural communities in addressing the similar risks encountered by agricultural systems.

Physical hazards of covid-19 linked to agriculture sector are linked to physical assets and also includes the potential losses and waste of food as well as well as other agriculture infrastructures necessary to livelihood of rural communities. These physical hazards provide for physical vulnerability analysis which aims to assess the risk confronted by critical facilities, which are necessary for the performance of rural communities in covid-19 pandemic situations, such as emergency services, transport, communication infrastructure and performance and other vital services. There are several studies (Barcaccia et al., 2020; Chen et al., 2020; Darnhofer, 2020; Henry, 2020; Siche, 2020; Zhang, 2020) dealing with physical hazards and associated vulnerability of farmers and rural communities. The food supply chain is a net linking the agricultural systems including farms with the consumers, covering production, packaging, supply and distribution as well food storage all being crucial for food safety and security (Chen et al., 2020). Due to social isolation people flood the supermarkets providing for serious shortage of certain goods, therefore, the food supply chain systems must be properly maintained to ensure food security. This food supply chain depends directly on infrastructure and it's maintenance.

Table 2. Exposure of farmers and rural communities to a different physical, social and economic hazard caused by covid-19 and vulnerability analysis areas.

Hazard	Vulnerability analysis areas	References
Physical hazard	Physical vulnerability relates to physical assets and also covers the possible losses and waste of food as well as well as other agriculture infrastructures necessary to livelihood of rural communities. The main vulnerability analysis includes examination of the major risks encountered by critical facilities, necessary for the safe operations and proper performance of rural communities in covid-19 pandemic, like emergency and other vital services and logistics, communication and transportation infrastructures etc.	Barcaccia et al., 2020; Brewin, 2020; Chen et al., 2020; Darnhofer, 2020; Diesner, 2020; Henry, 2020; Richards & Rickard, 2020; Siche, 2020; Zhang, 2020
Social hazards	Social vulnerability relates to the most vulnerable groups of society in rural areas The most vulnerability analysis should address the risk encountered by the most vulnerable groups include low income and pour people, old handicapped, lonely woman, children and livestock	Abrams & Szefler, 2020; Ahmed et al., 2020; Dudek & Myszkowska-Ryciak, 2020; Laborde et al., 2020a, 2020b; Leddy et al., 2020; Marcus et al., 2020; Neff, 2020; Owens et al., 2020; Poudel & Subedi, 2020; Singh et al., 2020; Zhang, 2020
Economic hazards	Economic vulnerability relates to the losses in economic assets and processes of agricultural systems The main vulnerability analysis needs to address the risk of destruction of physical and social infrastructures including the costs of repair or substitution as well as loss of agriculture production, unemployment risks, risks to vital services and income disparities	Adhikari et al., 2021; Ahmed et al., 2020; Barcaccia et al., 2020; Richards & Rickard, 2020; Bisht et al., 2020; Ceballos et al., 2020; Cortignani et al., 2020; Darnhofer, 2020; Horner, 2020; Kentikelenis et al., 2020; Laborde et al., 2020a, 2020b; Martin, 2020; Mitaritonna & Ragot, 2020; Neef, 2020; Nicola et al., 2020; Phillipson et al., 2020; Poudel & Subedi, 2020; Pu & Zhong, 2020
Environmental hazards	Environmental vulnerability analysis should examine the risk of destruction of soil, losses of fauna and flora.	Huynh et al., 2020; Lal, 2020b; Lal et al., 2020; McDonald et al., 2020; Rahim & Rahim, 2020; Saadat et al., 2020; Villulla, 2020; Zambrano-Monserrate et al., 2020

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Social hazards are very important for social vulnerability dealing with covid-19 impact on the most vulnerable groups of society in rural areas like low income and pour people, alone women with children, handicapped persons, old people and livestock. The covid-19 has the most severe impacts on these groups of people. The most studies (Dudek & Myszkowska-Ryciak, 2020; Leddy et al., 2020; Marcus et al., 2020; Neff, 2020; Owens et al., 2020) dealing with social issues of covid-19 in agriculture have highlighted the negative impact of food risks to pour people and homeless people as well as negative health consequences to most vulnerable people groups (Abrams & Szefler, 2020; Poudel & Subedi, 2020; Singh et al., 2020). Some authors (Ahmed et al., 2020; Laborde et al., 2020a, 2020b) noticed that poverty and food insecurity is expected to grow dramatically due to Covid-19 pandemic.

Economic hazards were addressed by most of studies (Barcaccia et al., 2020; Cortignani et al., 2020; Horner, 2020; Kentikelenis et al., 2020; Nicola et al., 2020; Phillipson et al., 2020) and these are mostly linked to examination of the possible losses in economic assets and processes of agricultural systems. The economic vulnerability analysis deals with the risks of destruction of physical and social infrastructures and related cost of repair, linked losses of agriculture products and income losses due to labour restrictions and shortages (Darnhofer, 2020; Pu & Zhong, 2020; Richards & Rickard, 2020), unemployment risks (Ceballos et al., 2020; Cortignani et al., 2020; Martin, 2020; Mitaritonna & Ragot, 2020; Neef, 2020); risks to vital services and income disparities (Adhikari et al., 2021; Ahmed et al., 2020; Bisht et al., 2020; Laborde et al., 2020a, 2020b; Poudel & Subedi, 2020).

Environmental vulnerability analysis should examine the risk of destruction of soil, losses of fauna and flora and addresses environmental hazards of covid-19. The main studies in this area deal with damages to soil (Huynh et al., 2020; Lal, 2020b; Lal et al., 2020; Zambrano-Monserrate et al., 2020) and influence on pollution (McDonald et al., 2020; Villulla, 2020) including reduction of GHG emissions.

The performed analysis of physical, social, economic and environmental vulnerability of agriculture sector exposed to covid-19 hazards allows further to systematize studies based on analysis of measures to increase resilience and mitigate vulnerability of agricultural systems to covid-19 pandemic.

3.3. Resilience of agriculture systems to Covid-19 pandemic

The agriculture system resilience depends on three main capacities which are inbuilt in agriculture systems: absorptive, adaptive and restorative capacities (Vale & Campanella, 2005).

Absorptive capacity of the systems can be defined as endogenous feature of the system which reveals the capability of the defined system or structure to absorb the disruptive effect of specific disaster. Adaptive capacity of the system is dynamic ability of the system to change endogenously and to adapt successfully to the consequences of disaster. The restorative capability of the system is the capability of the system to recover after disaster. This capacity is linked to dynamic activities by various bodies which are exogenous to the system (Proag, 2014).

In Table 3 absorptive, adaptive and recovery capacities of agricultural systems and recovery efforts are thoroughly described.

As one can see from Table 3, the absorptive, adaptive and restorative capacities of agriculture systems are systematized based on efforts required and time frame required to takeover with negative effects of covid-19 disaster.

Absorptive resilience capacity of agricultural systems is endogenous and linked to absorbing the influence of system disorder with little effort immediately in face of disaster like covid-19. The example of absorptive capacity or resilience can be the availability of food storage that can be used to ensure food supply security under various restrictions which might cause food supply disruptions under covid-19 pandemic (Galanakis, 2020; Roy, 2020; Zarei & Rad, 2020). The studies stressed the need for better food self-sufficiency due to the bans of food exports from foreign countries. In Malaysia, the covid-19 outbreak provided the assessment of resilience of country agriculture systems, as particularly effected was the Malaysian paddy industry. Malaysia imports over 30% and the rise of the prices for rice during pandemic was alarming.

Table 3. Resilience capacities of agriculture systems in face of covid-19 pandemic.

Main components Capabilities	Impact on agriculture systems		
	Absorptive	Adaptive	Restorative
The main features of capacities	Acts immediately in face of disaster by absorbing the negative impacts of system with small or no effort.	Necessary actions taken after the disaster, to ensure the recovery of the system	Capability of the agriculture system to be repaired easily after disaster
Examples	Food Storage that can be used to ensure food supply security under various restrictions which might cause food supply disruptions	New business options for farmers under various restrictions like electronic commerce and contactless deliveries	Governmental subsidies to cover losses of farmers encountered during pandemic due to fresh food loses or labor shortages
Required efforts	Automatic absorption of negative impacts	Just internal efforts are necessary	Often external efforts are necessary
Time frame	Vital just in the initial phases of food supply disruption	Important just during initial phase of disruption of food supply	It short term the repair of the system is not possible
References	Galanakis, 2020; Roy, 2020; Zarei & Rad, 2020	Adnan & Nordin, 2020; Bhavani & Gopinath, 2020; Cattivelli & Rusciano, 2020; Henry, 2020; Lal et al., 2020; Sukhwani et al., 2020; Zimmerer & de Haan, 2020	Boughton et al., 2020; Kentikelenis et al., 2020; Petetin, 2020; Pu & Zhong, 2020; Timilsina et al., 2020

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Adaptive resilience capacity of agriculture systems is related to internal actions taken after the disaster, to go for recovery and to adapt to covid-16 impacts. The example can be new business models (Adnan & Nordin, 2020; Bhavani & Gopinath, 2020; Henry, 2020; Lal et al., 2020) and supply chains modifications, urban-rural partnerships and other innovations (Cattivelli & Rusciano, 2020; Sukhwani et al., 2020; Zimmerer & de Haan, 2020) implemented by farmers to deal with various restrictions imposed by the government.

Restorative resilience of agriculture system is linked to exogenous efforts like governmental or international subsidies channeled to cover losses of farmers encountered during pandemic due to reduction of food demand, fresh food loses or labor shortages (Boughton et al., 2020; Kentikelenis et al., 2020; Petetin, 2020; Pu & Zhong, 2020; Timilsina et al., 2020).

Several studies conducted in various countries stressed that family-based subsistence farming systems provided for better results comparing to market-based commercial framing systems during covid-19 pandemics (Bisht et al., 2020; Boughton et al., 2020; Cattivelli & Rusciano, 2020; Zimmerer & de Haan 2020).

The conducted analysis of literature on covid-19 outbreak impact on agriculture in the risk-vulnerability-resilience framework allowed to define and group the main measures and policies necessary to increase resilience of agriculture systems to global pandemic summarized in next section of paper.

4. Synthesis and discussion of results

There are various ways to increase resilience of agricultural systems to covid-19. The systematic literature review of recent studies dealing with covid-19 pandemic impacts on agriculture systems allowed to define and systematise the main actions targeting enhancement of resilience.

The measures to enhance the resilience of unofficial food supply chains using agrobiodiversity and such social innovations as the authorisation of social groups in providing cooperation of urban and rural communities were found as very effective in some South American nations, as the disturbances caused by the global covid-19 pandemic highlighted the importance of agrobiodiversity to increase the resilience of unofficial food chains (Zimmerer & de Haan, 2020).

Though restrictive measures against the increase of covid-19 infection have serious negative effect on workforce in agriculture sector and food safety, the study by Bochtis et al. (2020) assessed the influence of covid-19 on agricultural labor in US and suggested several strategies to address these risks. The occupations in agriculture sector having the highest risks were identified and measures to protects workers were identified for these professions. Several control measures were identified as very relevant to increase the resilience of agriculture sector and safeguard farmers were proposed like physical distancing, protection equipment and hygiene.

Pulighe and Lupia (2020) proposed to enlarge farming activities, to ensure farming in the urban sites to enhance resiliency of food systems delivering fresh products to urban areas and several measures of management of urban and natural resources were elaborated. Some authors (Bhavani & Gopinath, 2020; Lal, 2020a; Sukhwani et al., 2020) argue that after pandemic food supply will not be able to match local demand. The innovative farming measures to enhance resilience of food supply systems are still vital in most cases. Though, innovative farming measures will not be able to ensure fully food supply safety, it will provide for shaping more resilient food supply systems for the future (Gunther, 2020).

The reduction in food security during covid-19 contagion is caused by reduced capacity of special agencies that provides important food social safety nets for vulnerable groups of population. Such institutions like food banks and school feeding programs have problems during covid-19 pandemic due to various restrictions imposed by the governments aiming to control pandemic, therefore state support is necessary to establish safety nets and to protect food supply chains during the covid-19 disease and afterwards (Boughton et al., 2020; Hobbs, 2020; Petetin, 2020; Timilsina. et al., 2020).

Another important issue is food waste management enhancement which is crucial during pandemic (Aldaco et al., 2020; Jribi et al., 2020; Morone & Imbert, 2020; Neumeyer et al., 2020).

Labour availability problems in agriculture sector were very obvious during covid-19 pandemics, as labour was constrained in many countries due to imposed quarantines and there are losses of workforce due to covid-19 deaths and illness. Taking into account, that in livestock and horticulture farms, the planting and harvesting of crops requires a lot of labour taking into account seasonally, the actions for dealing with labour scarcities and creating safe working environments for workers and the community members are necessary to evade catastrophic outcomes for future supply systems during pandemics. It is important to ensure labour availability for agricultural systems or increase capacities of agricultural systems to adapt to situations of quarantines (Bochtis et al., 2020; Cortignani et al., 2020; Martin, 2020; Neef, 2020).

Table 4. Measures to enhance agriculture systems resilience.

	Enhancement measures	References
Technical measures	Various technical solutions aiming to enhance the level of functional performance of agriculture sector infrastructures. Usually the simple design of infrastructure has a bigger absorptive capability and it can be easier for such systems to adapt and it is easier to repair them. The measures like smart packaging system and other innovations in food supply chain can be good example.	Bochtis et al., 2020; Chen et al., 2020; Gunther, 2020; Henry, 2020; Hobbs, 2020; Lal, 2020a; Pulighe & Lupia, 2020
Organizational measures	Organizations and institutions in agriculture sector need to select a necessary recovery effort, considering available absorptive, adaptive, and restorative capabilities of the agriculture system. It is necessary to compare costs of recovery with the speed of recovery and to select relevant actions selected based on time of recovery. The new management approaches, innovations and entrepreneurship in farms and other agricultural entities are also very useful. Urban–rural partnerships, improved legal regulations of labor, international trade regulations can be good example.	Aldaco et al., 2020; Barichello, 2020; Bhavani & Gopinath, 2020; Bisht et al., 2020; Bochtis et al., 2020; Boughton et al., 2020; Cortignani et al., 2020; Diesner, 2020; Jribi et al., 2020; Laborde et al., 2020a, 2020b; Martin, 2020; Naughton, 2020; Neef, 2020; Neumeyer et al., 2020; Patrinley et al., 2020; Sukhwani et al., 2020; Zhang et al., 2020a; Zimmer & de Haan, 2020
Economic measures	The market prices act automatically and regulate demand for threatened agricultural goods during pandemic. Banning such price increases are negative impact on resilience as they diminish the absorptive and adaptive capabilities of system resilience provided by the market mechanisms, however economic support measures and state aid for farmers to survive during pandemic are useful.	Kentikelenis et al., 2020; Richards & Rickard, 2020; Roy, 2020; Timilsina et al., 2020; Villulla, 2020; Zhang, 2020
Social measures	The strong communities developed in rural areas can enhance the social resilience capacities of agricultural systems. Usually in the case of disaster and afterwards, neighbours pool their resources, survive during pandemic more easily and start rebuilding as government aid always come with delay.	Boughton et al., 2020; Cattivelli & Rusciano, 2020; Gunther, 2020; Hobbs, 2020; Morone & Imbert, 2020; Petetin, 2020; Roy, 2020; Timilsina et al., 2020; Zimmerer & de Haan, 2020

Source: Created by authors.

Food export restrictions have negative influence on current agricultural productivity and in future seasons as well. The suitable domestic substitutes can be found but this needs time. Countries try to explore more domestic ‘food sovereignty’ seeking to coupe with domestic food security linked to covid-19. These measures provide important implications for present globalized agricultural and food trading schemes (Barcaccia et al., 2020; Horner, 2020, Pu & Zhong, 2020).

Actions for enhancement of agriculture systems resilience to covid-19 can be grouped into technical, organizational, economic and social measures and summarized in Table 4.

As one can see from grouping measures aiming to enhance resilience of agriculture systems to covid-19 disaster, the organizational measures are dominant in recent studies dealing with covid-19 impacts on agriculture systems. Social measures were also found to be effective especially in developing countries.

5. Conclusions

The covid-19 pandemic has a big negative influence on agriculture sector. Food safety and security were greatly threatened due restrictions on mobility, interaction of people and reduced purchasing power of people. The most vulnerable groups of population were affected mostly. Therefore, the measures taken by governments to stop the spread of the Corona-19 virus, first of all influenced negatively global food supply systems.

The analysis of literature in the risk-vulnerability and resilience of agriculture systems in the face of covid-19 showed that the resilience of food systems needs to be enhanced by implementing technical, economic and measures. All these policies and measures first of all need to safeguard the health and food supply security of world population.

Technical measures aiming to improve the functional performance level of the infrastructure in agriculture sector are necessary to enhance physical resilience. Organizations and institutions in agriculture sector need to take necessary recovery efforts, considering the absorptive, adaptive, and restorative capabilities of the agricultural systems. It is obvious that the market forces via price mechanisms involuntarily reduce the demand of rare agricultural goods and match supply with demand during pandemic and the banning on such price increases has negative impact on resilience of agriculture systems by diminishing their absorptive and adaptive capabilities of resilience provided by the market price system. However, economic support and subsidies in face of economic losses of farmers allows to recover faster after disaster and are welcomed. The strong communities developed in rural areas can enhance the social resilience capacities of agricultural systems as strong communities pool their resources and survive during pandemic more easily and start rebuilding as government aid always come with delay.

Covid-19 pandemics just deepened prevailing economic and social inequalities around the people and differences in resilience of agricultural systems around the world as well as revealed the need for the enhancement of social nets dependent on income generation and stability of agriculture sector workers.

The current study has limitations as it aims to capture just general and fast effects of the covid-19 disaster on agricultural systems in the widest sense. The future research is necessary to investigate how various market disruptions of food supply affect small and larger scale farms, dependent on the volatile market prices and supply chains disruptions. The negative effects on food security need to be investigated further to define necessary changes in food systems to increase their resilience. Also, the wider impacts of covid-19 on other producers in different sectors, industries and regions need to be investigated. It is also necessary to explore father how the size of the farm, technological equipment available, production modes and practices provides for increase resilience of farms and what are the best policy measures for boosting resilience of agricultural systems.

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