The Koronivia Joint Work on Agriculture: Towards a more sustainable and resilient agriculture to foster post-COVID recovery and prevent future pandemics

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Executive summary

The COVID-19-induced pandemic has resulted in a multidimensional crisis that has aggravated pre-existing social and economic inequalities worldwide, revealed vulnerabilities of agri-food systems and called for attention to the interconnectedness of human, animal, and environmental health. In view of the twenty-seventh session of the Conference of the Parties (COP27) of the United Nations Framework Convention on Climate Change (UNFCCC), which will take place in November 2022 in Sharm El-Sheikh, it is urgent to consider, discuss and address the interlinkages between agriculture and the (re-)emergence of zoonotic diseases with risks to become pandemics in a context of rapid climate change, habitat loss, growing threat against biodiversity and increasing globalization and population movement.

The UNFCCC Koronivia Joint Work on Agriculture (KJWA) constitutes a unique opportunity to discuss policies and action related to climate change and agriculture that acknowledge the interlinkages between human, environmental, and animal health. This report summarizes how current topics of the UNFCCC Koronivia Joint Work on Agriculture (KJWA), such as livestock management, manure management, soil (land-use), and socio-economic dimensions are relevant not only to address and adapt to climate change but also in the context of zoonotic pandemics. We explain how current trends and patterns related to these four topics (such as unsustainable food production practices and consumption patterns or growing globalization) are not only contributing to and exacerbating climate change, but also pose a threat of zoonotic outbreaks and pandemics. Based on the disruptions triggered by COVID-19 on agri-food systems and available scientific evidence, we also describe how these trends and patterns simultaneously make agri-food systems highly vulnerable to the ecological and socio-economic disruptions caused by climate change and global pandemics. All in all, the evidence presented in this study highlights the strong interlinkages and overlaps between climate change and pandemics and the vulnerabilities and contribution of agri-food systems to both threats, thus calling for a stronger and more explicit consideration of the topic of zoonotic diseases and pandemics in the climate discussions, especially those related to agri-food systems.

KJWA provides an excellent opportunity to do so, as conclusions and future topics are to be discussed at the COP27 in November 2022. This publication encourages policy-makers to adopt post-COVID transformative and comprehensive approaches aimed at building the resilience and sustainability of agri-food systems. This will require the design and implementation of changes in

production practices and trading, distribution and consumption patterns with a view to a systemic transformation that recognizes the interconnection between animal, human and environmental health, and ensures food security and socio-economic justice. These changes would not only contribute to a successful recovery from the COVID-19 pandemic but will help build long-term resilience to climate change and future zoonotic pandemics.

Acronyms and abbreviations

AMR	Antimicrobial resistance
COVID-19	Coronavirus disease 2019
CH4	Methane
CO2	Carbon dioxide
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gases
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
KJWA	Koronivia Joint Work on Agriculture
N2O	Nitrous oxide
SFA	Sustainable Food and Agriculture
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UN FSS	United Nations Food Systems Submit
OECD	Organization for Economic Co-operation and Development
OIE	World Organization for Animal Health
SDG	Sustainable Development Goal
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization

Glossary

Climate change: change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods (UN, 1992).

Emerging infectious disease: infectious diseases whose incidence in a population occurs for the first time, has increased abruptly in a population, spread to new geographical areas within the recent past or threatens to increase in the future (WHO, 2005). Many emerging diseases are zoonotic in origin (WHO, FAO and OIE, 2019).

Agri-food systems: systems that encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and food industries, and the broader economic, societal and natural environments in which they are embedded (von Braun *et al.*, 2020).

Pandemic: the worldwide spread of a new disease (WHO, 2011). For the present document, we only consider pandemics originating from zoonoses.

Resilience: the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2018).

Zoonosis (or zoonotic disease): an infectious disease that has jumped from non-human animals to humans (WHO, 2020a).

1 Introduction

1.1 Climate change and agriculture

Human-induced climate change (hereafter "climate change") caused by the emission of greenhouse gases (GHG) is one of the major crises facing humanity. According to the Intergovernmental Panel on Climate Change (IPCC), climate change is already affecting global and regional climate patterns in multiple and diverse ways (IPCC, 2021). These changes include an increase in global surface temperatures and increasing heat extremes but also changes in rainfall, winds, snow and ice, and coasts and oceans (IPCC, 2021). The effects of climate change are not only unprecedented but also increasing and intensifying and to some extent irreversible (IPCC, 2021). Therefore, urgent action is needed to improve and promote the agri-food systems adaptive capacity and take GHG mitigation measures.

Climate change is and will continue to impact our lives in a number of ways, including the basis for our wellbeing: food. The effects of climate change on agri-food systems will be strongest for agriculture given its high sensitivity to climate parameters such as water and temperatures (Vermeulen, Campbell and Ingram, 2012). The effects of a changing climate on agriculture are highly complex and will vary across regions (Schmidhuber and Tubiello, 2007). For instance, while the increasing temperatures could have positive impacts on agricultural production in higher latitudes, these gains may be counteracted by the increase in the frequency of extreme events such as heatwaves, droughts, or flooding (references in Schmidhuber and Tubiello, 2007). In drier areas, climate change will result in increased livestock mortality, reduced livestock productivity, and reduced crop yields and a suitable area for cultivation (references in Schmidhuber and Tubiello, 2007). Temperature rises will also expand the range of agricultural diseases and foster their ability to survive winter and attack spring crops (Schmidhuber and Tubiello, 2007). Similarly, contamination with mycotoxins and bacteria such as *Listeria* or *Salmonella* will likely increase with rising temperatures and increase heat extremes leading to spoilage and bacterial damage (Binns *et al.*, 2021; FAO, 2020a).

In this context of growing climate change impacts on agricultural production and food generation, physical and financial access to food can be limited, therefore increasing food insecurity in different areas of the world. This supports the argument in favour of a holistic approach being taken when addressing climate change in agri-food systems in order to improve adaptive capacities of the populations and increase their resilience, livelihoods, food sovereignty, and social protection.

Similarly, policy-making and incentives to mitigate or adapt to climate change could better integrate socio-economic dimensions, when it comes to trade-offs with agriculture production and food security. This is for example the case when a large increase in biofuels as a substitute to fossil fuels is envisaged as a mitigation scenario, as this could in fact increase competition with food production for land (Stechow *et al.*, 2015).

At the same time, the agri-food production systems are an important contributor to the emission of multiple GHG (IPCC, 2021; Lynch *et al.*, 2021). Food related emissions have contributed to 19-29 percent of total global anthropogenic GHG emissions (Lynch *et al.*, 2021; Vermeulen, Campbell and Ingram, 2012) but more recent publications report contributions of 21-37 percent (Mbow *et al.*, 2019). Within agri-food systems, agriculture is the major source of GHG emissions (Vermeulen, Campbell and Ingram, 2012). Most notably, agricultural activities generate around half of all anthropogenic methane (CH4) and three-quarters of nitrous oxide (N2O) emissions (Mbow *et al.*, 2019). It is also an important contributor of carbon dioxide (CO2) emissions via direct and indirect mechanisms, but these are harder to quantify (Lynch *et al.*, 2021). When considering the contribution of agriculture to climate change, it is important to acknowledge its role in land-use change and deforestation, through which agriculture is estimated to contribute to the emission of 7-14 percent of annual global GHG emissions (OECD, 2016).

These figures are likely to continue increasing in the coming years (Vermeulen, Campbell and Ingram, 2012; Wollenberg *et al.*, 2016). IPCC urged countries to implement policy interventions on environmental agricultural impacts for example on GHG emissions to achieve IPCC's mitigation recommendations (IPCC, 2019). Nevertheless, the development and enforcement of climate policy for agriculture is lagging far behind other sectors such as energy or transport, for which price-based policies related to CO2 emissions are already in place (Leahy, Clark and Reisinger, 2020). At the same time, between 2000 and 2018, the global climate finance in the agriculture and land-use sector has dropped, moving from an average of 45 to 24 percent (Buto *et al.*, 2021). Consequently, agricultural and agriculture-related emissions will become the largest contributing sector of surplus emissions in the future, given that other sectors are projected to reduce their emissions to the maximal extent by 2030 (see references in Wollenberg et al., 2016). Failing to reduce emissions from the agriculture sector will compromise our ability to achieve global targets (Leahy, Clark and Reisinger, 2020; Wollenberg *et al.*, 2016). Resources, such as finance, capacity-building and technology transfer, are required for scaling up practices that lead to long-term sustainability of the agri-food systems (UNFCCC, 2021c). Sustainable and resilient agri-food systems will secure the income and livelihoods of those involved along the food chain and improve food security resulting in social and environmental benefits (UNFCCC, 2021c).

1.2 The Koronivia Joint Work on Agriculture

The recognition of strong interlinkages between climate change and agriculture led to the adoption of decision 4/CP.23 on the Koronivia Joint Work on Agriculture (KJWA), the so-called Koronivia Decision (UNFCCC, 2018). KJWA was adopted in 2017 at the twenty-third Conference of the Parties (COP23), supreme decision-making body of the United Nations Framework Convention on Climate Change (UNFCCC).

Under the leadership of the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) and Subsidiary Body for Implementation (SBI), and in conjunction with ten Constituted Bodies of the Convention, countries agreed to work together in addressing issues related to agriculture and climate change. The development and implementation of KJWA is closely followed as an observer by the Food and Agriculture Organization of the United Nations (FAO), the specialised UN agency for food and agriculture. It supports countries via webinars, workshops, and expert meetings to generate and disseminate knowledge, and facilitate exchange on how to implement the Koronivia decision. Following a series of workshops on agriculture under the Convention organised until 2016, six elements were identified as a basis to start the work:

(a) Modalities for implementation of the outcomes of the five in-session workshops on issues related to agriculture and other future topics that may arise from this work;
(b) Methods and approaches for assessing adaptation, adaptation co-benefits and resilience;
(c) Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management;
(d) Improved nutrient use and manure management towards sustainable and resilient agricultural systems;
(e) Improved livestock management systems;
(f) Socio-economic and food security dimensions of climate change in the agricultural sector.

The Koronivia decision was adopted before the Coronavirus Disease 2019 (COVID-19) outbreak and does not explicitly integrate the issue of zoonosis and pandemics. However, the COVID-19 induced pandemic has had an unprecedented impact in all aspects of our societies including agri-food systems, and access to food, highlighting inherent vulnerabilities to global shocks and strong interlinkages and similarities with other ecological crises such as climate change and biodiversity loss. Furthermore, pre-existing conditions related to social protection or structural inequalities have been seriously affected and aggravated. At the same time, it is important to consider that this situation creates an opportunity and momentum to transform our agri-food systems towards increased sustainability, resilience, and justice in a context of increasing global socio-economic and ecological crises.

The KJWA process constitutes a unique opportunity to expose the relevance of these interlinkages in international discussions on agriculture and climate change. It is also an occasion to advocate for a more sustainable and resilient agriculture in view to facilitate a quicker recovery in the short-term and avoid long-term additional costs and crises. It is crucial to include and engage all actors involved along the food chain while focusing on those communities in situations of higher vulnerability, such as Indigenous Peoples, women, youth, and people with disabilities.

1.3 Purpose and methodology

The purpose of this research is to expose the numerous interlinkages between agriculture, climate change, and pandemics based on the review of scientific evidence and demonstrate the need to consider these interlinkages in policy-making and actions for policy implementation, in general and specifically in the context of KJWA.

This study is structured as follows: we start by justifying the relevance of considering pandemics in the context of KJWA by summarizing the interlinkages between pandemics and four of the six KJWA topics. We conducted this in two sub-sections. First, we discuss the links between agricultural practises and the (re-)emergence of zoonotic outbreaks and pandemic. This section deals with the KJWA elements of livestock management, manure management, and soil, with a larger perspective on land-use. Second, based on the case of the COVID-19 pandemic, we continue by highlighting the stressors that pandemics cause over socio-economic and food security dimensions on top of the ones already experienced through climate change. Considering all this, we follow with a reflection and discussion on the importance, need and urgency to take action to build more resilient and sustainable agri-food systems in COVID-19 recovery plans.

2 Interlinkages between pandemics and the Koronivia Joint Work on Agriculture topics

2.1 Agricultural practises and pandemics

2.1.1 Livestock management

Livestock plays a key role in food security and nutrition and its production can represent an important contributor to household income and national economies (Molina-Flores, Manzano-Baena and Coulibaly, 2020; Uwizeye *et al.*, 2021). However, livestock production practices can be a driver of zoonoses with pandemic risk that threatens animal and human health worldwide.

Livestock animals can act as intermediate or amplifier hosts of pathogens (e.g., viruses, bacteria or parasites) originating in wildlife and pass them to humans (Layton, Choudhary and Bean, 2017). For instance, detection of Nipah virus in domesticated pigs was associated with close interaction with bat fruits, natural hosts of the virus (Pulliam *et al.*, 2012). Subsequently, there was a further transmission from pigs to humans (Bonilla-Aldana *et al.*, 2021). The higher the interaction between humans and animals, in particular wildlife, the more opportunities for microorganism exchange and risk for zoonotic pathogen spill-over (FAO, 2021n). This interaction is being intensified by accelerating deforestation for agriculture expansion that is triggered not by a lack of agriculture land surface but rather land mismanagement. (UNFCCC, 2021d).

The transmission of zoonotic agents between animals and humans can occur indirectly by inhalation (wind spread/ environmental contamination) or ingestion (food or water-borne), or directly via conjunctiva or being beaten or injured by animals (Goering *et al.*, 2013; WHO, 2020a). However, many are transmitted through vectors, that is, other living organisms, like flies, mosquitoes or ticks, that pass pathogens from infected animals to non-infected humans or other animals (EFSA, 2017).

In fact, most human pathogens are zoonotic in origin (Jones *et al.*, 2008), and are responsible for over 2.5 billion cases of illness and 2.7 million deaths a year worldwide (FAO, 2018a). Cross-species transmission of infectious agents occurs in those areas where wildlife, livestock, diseases' vectors and humans are in close contact (WHO, 2021a). Consequently, occupations that imply frequent and close animal-human contact like veterinarians, cullers, farmers or abattoir workers have a great exposure to animal-borne pathogens (Klous *et al.*, 2016; Leroy *et al.*, 2004; McDaniel *et al.*, 2014).

Several cases of zoonoses' transmission in occupational settings were reported in Denmark, the Netherlands, the United Kingdom of Great Britain and Northern Ireland, Germany, the United States of America or China (Klous *et al.*, 2016). Similarly, there is evidence of Ebola and the human immunodeficiency virus (HIV) transmission from bushmeat handling and trade in the African continent (Peros *et al.*, 2021). There is also a non-occupational exposure to zoonotic agents in those facilities where humans live close to their livestock (Klous *et al.*, 2016). For instance, in Viet Nam, avian influenza transmission was associated with backyard poultry keeping (Thorson *et al.*, 2006), and so as in Cambodia, Egypt and China with other infectious diseases (Klous *et al.*, 2016). This proximity increases the likelihood for pathogen transmission from animal reservoirs to humans. Additionally, as a result of the worldwide consumer demand for animal-source foods or plant-based products such as soya, avocado or palm oil (OECD and FAO, 2021), interfaces between livestock, wild animals and humans are increasing because of the need to convert forested land for farmland expansion, an issue addressed later in section (2.1.3) on Land-use (soil). Between 2021 and 2030, it is projected that crop production, which represents 60 percent of total agricultural production, will increase by 22 percent and livestock by 19 percent (OECD and FAO, 2021).

Livestock intensification contributes to enhancing greater food security by maximizing animal production and responding to population growth and consumption habits (FAO, 2021a). However, this practice may carry certain risks. Intensification of livestock production puts at risk animal health as this practice elevates the risk of zoonosis' propagation between animals (FAO, 2020c; Gilbert *et al.*, 2021), as animals are kept under conditions of high population size and density (Jones *et al.*, 2013), as well as from animals to humans since it implies higher interaction. Intensive livestock production has led to the following four negative consequences (Espinosa, Tago and Treich, 2020): (i) increased scale of disease impact, (ii) immunosuppression of intensively farmed animals, (iii) risks of contamination for animals and humans living outside of farms, and (iv) disease spreading risks associated with transportation. It should be pointed out here that international livestock and animal-source foods' cross-border flow around the globe, if not controlled, is negatively contributing to the transboundary spreading of infectious diseases and consequent pandemics of high impact for both animals and humans, such as brucellosis, bovine tuberculosis, parasitic illnesses, anthrax or bovine spongiform encephalopathy (BSE) (FAO, 2021g). In fact, current globalisation patterns are increasing the risk for diseases caused by pathogens of zoonotic origin to become pandemics. Recent pandemics caused by diseases like bovine spongiform encephalopathy, avian influenza or swine flu are expanding the occurrence of outbreaks in wider geographic locations as more people, animals, plants and agricultural products move within and between countries (FAO, 2017a). For example, according to the World Organization for Animal

Health (OIE), Lumpy skin disease, a disease historically reported only in African and Middle East countries, has been reported since 2020 in China, Nepal, Myanmar, Sri Lanka, Viet Nam and Bhutan (OIE, 2021).

Livestock intensification can also lead to antimicrobial resistance's (AMR) transmission between and from animals to humans (Gilbert *et al.*, 2021) due to the inadequate use (misuse or overuse) of antibiotics for animal production and the following increased presence of resistant pathogens in animals, humans, food and the environment (water, soil and air) (Nguyen *et al.*, 2020). AMR threatens the effectiveness of available treatments for common infectious diseases resulting in prolonged illness, disability and death (FAO, 2016; O'Neill, 2016). Attention should be drawn to the fact that AMR has not only been reported in livestock worldwide (Fu *et al.*, 2021; Khan *et al.*, 2021; Nikkhahi *et al.*, 2021; Vaneci-Silva *et al.*, 2022) but also in wildlife animals (Torres *et al.*, 2021). This fact alerts that AMR is spreading rapidly in the environment (UNEP, 2021).

At the same time and as evidenced during the COVID-19 pandemic, livestock practices do not only contribute but can also be disrupted by zoonotic pandemics. During the current pandemic, livestock production and post-production activities were affected by movement restrictions enforced to mitigate the virus spread (Ani *et al.*, 2021; Augeraud-Véron, Fabbri and Schubert, 2021; Middendorf *et al.*, 2021). Access to animal feed, inputs (vaccines and medicines for veterinary use) and services (food and animal welfare control), and national and international transport of live animal and animal food promptly dropped (FAO, 2020b).

2.1.2 Manure management

Animal manure is a natural substance directly obtained from livestock production and employed as an organic fertilizer (FAO, 2019a). This substance improves soil fertility and quality, and increases crop yields' production (FAO, 2019b; Rayne and Aula, 2020). Manure application to soil is an ancient practice that results in healthier soils by increasing soil's organic matter content (FAO, 2018c). As a result of this practice, soils are capable of retaining water and nutrients, store carbon, limit water and wind erosion, foster micro-biodiversity and increase productivity, as well as hold three times as much carbon as the atmosphere (FAO, 2020h). Despite manure's benefits for improving and maintaining soil health, excessive manure applications or inefficient manure storage practises before application to fields carry some inherent risks in relation to the spread of infectious agents (FAO, 2018c).

Pathogenic microorganisms coming from animals can survive, persist and be transmitted to humans and the environment and subsequent contamination of crops (Millner, 2014). Survival of zoonotic agents in manure has been documented by different researchers. For instance, a study demonstrated the persistence over time of *Clostridium botulinum*, a bacterium whose toxins cause botulism in both humans and animals, in poultry manure after a farm botulism outbreak in France (Souillard *et al.*, 2020). Another study detected viable pathogenic microorganisms in manure for periods up to 21 months in the United States of America (Zhao *et al.*, 2001). In Cambodia, presence of zoonotic agents in manure were associated with manure's management practises that potentially represented sanitary- and environment-hazards (Ström *et al.*, 2018).

Manure is considered an important factor of AMR's propagation too (Checcucci *et al.*, 2020) since antimicrobials are mostly not metabolised and antibiotic residues, antibiotic-resistant bacteria and antibiotic resistance genes are excreted to the environment (Marshall and Levy, 2011).

Cross-contamination from manure to humans may occur either directly when handling and processing manure or indirectly when manure's zoonotic agents contaminate food, water and the environment (Milinovich and Klieve, 2011). To prevent contamination and reduce pathogen's level, manure is treated through different methods such as composting, air drying or anaerobic digestion[1] (Gannon *et al.*, 2014). According to the above, manure mismanagement poses potential risks not only to humans, but also to animals and the environment.

2.1.3 Land-use (soil)

Deforestation, alongside replacement of natural vegetation by crops, are anthropogenic activities that lead to habitat and biodiversity loss, and promote the occurrence of new transmission channels as human-livestock-wildlife-environmental interfaces are expanded (FAO, 2020g; Jones *et al.*, 2013; Karesh *et al.*, 2012; Lindahl and Grace, 2015). Therefore, this context is more likely to favour opportunities for and exposure to zoonotic pathogens with pandemic potential increase from animal reservoirs to humans. A main driver of deforestation in many parts of the world, particularly in tropical and subtropical countries, is conversion of forested land by mostly export-oriented cattle ranching and cultivation of soya, avocado and oil palm, in response to the increasing demand for these commodities and their consumption patterns (FAO and UNEP, 2020; de la Vega-Rivera and Merino-Pérez, 2021). Approximately, 77 percent of deforestation and natural habitat conversion is triggered by agricultural expansion (FAO and UNEP, 2020). Higher incidences of Nipah virus in

[1] Process of digestion by microorganisms in conditions of absence of oxygen.

Malaysia, West Nile Virus in North America, Haemorrhagic fever with renal syndrome viruses in Asia, Europe and North America, and Lyme disease in Central Africa were linked to land-use shifts for agricultural purposes (Pongsiri *et al.*, 2009).

Climate change also has a role in this as climate-driven shifts, such as land and water scarcity, precipitation variability, extreme weather conditions or temperature increase, will aggravate these phenomena as insects and animals that carry zoonoses will be displaced among new ecosystem habitats (FAO, 2020a). In fact, climate change in conjunction with habitat fragmentation, which is the division of continuous habitat into isolated and smaller fragments (FAO and UNEP, 2020), is already altering migration patterns of wild animals among new areas and with them, their diseases (Rivera-Ferre *et al.*, 2021). As an example, Gilbert, Slingenbergh and Xiao (2008) have predicted that birds would start new migratory flyways and Newcastle diseases, avian influenza or cholera will expand their area of incidence.

Lal (2020) listed the following agricultural activities that contribute to intensified interaction between animals and humans: (i) in-field voluntary and intentional burning, (ii) excessive plowing and inundation by irrigation, (iii) indiscriminate use of chemicals and (vi) inappropriate use of natural resources. Besides, human encroachment into forested areas and development of urban settlements create new spots for mosquito breeding, increasing the exposure to vector-borne disease such as malaria or dengue (Rulli *et al.*, 2017; Whitmee *et al.*, 2015). Since 1940, 50 percent of zoonotic disease that emerged in humans, a proportion that may increase if agriculture expands and intensifies, are associated with land-use change, food and agricultural industries (Rohr *et al.*, 2019). Intact forest lands have been replaced for agricultural purposes, during the last decades. For instance, in Myanmar, from 2002 until 2016, 43 percent of 4 028 300 hectares of forested land moved to agricultural production (Schmid, Heinimann and Zaehringer, 2021).

Habitat loss and fragmentation is also one of the main drivers of biodiversity loss (IPBES, 2020), which is associated with increased risk and incidence of infectious diseases. Studies show that agriculture is the largest threat to the Red List of Threatened Species (Kehoe *et al.*, 2017). About 8 800 wild animal species are being used for human food consumption (FAO, 2020g). Furthermore, over 18 500 species are believed to be threatened with extinction because of agriculture (UN FSS, 2021a). The decline of biodiversity is considered a potential driver of emerging infectious diseases (Augeraud-Véron, Fabbri and Schubert, 2021; UNEP, ILRI and CGIAR, 2020) and poses a serious risk for zoonotic outbreaks. This is because high biodiversity can buffer against disease transmission from wildlife to humans via several mechanisms such as (Keesing, Holt and Ostfeld, 2006). (i) reducing the population density of a critical natural reservoir for pathogens; (ii) reducing the population density of arthropod vectors for pathogens; and (iii) reducing encounter rates between vectors and reservoirs or among reservoirs. Evidence for the reduction in disease risk facilitated by high biodiversity (named as the dilution effect) has been observed for instance for West Nile virus and Hantavirus and has also been studied for Lyme disease (Ostfeld, 2017; Ostfeld and Keesing, 2017; Pongsiri *et al.*, 2009).

2.2 The impacts of pandemics on socio-economic and food security dimensions of agri-food systems

The COVID-19 pandemic has highlighted the vulnerabilities of the social and economic dimensions of current agri-food systems to the impacts of pandemics (Mardones *et al.*, 2020). Even though a thorough and robust assessment of the impacts of the COVID-19 is limited by their complexity, the still scarce data available (Laborde, Martin and Vos, 2021), and the fact that they are still unfolding; it is important to understand in which ways global pandemics interact with food security and other socio-economic dimensions of agri-food systems.

Even before COVID-19, food insecurity was threatened by disruptions in supply chains and severe hunger was rising due to various causes such as climate change and other global challenges such as economic inequality or social discrimination (Tarra, Mazzocchi and Marino, 2021). However, the COVID-19 pandemic has exacerbated global food insecurity worldwide, especially affecting vulnerable households in high, middle, and low-income countries (Shahzad *et al.*, 2021; Smith and Wesselbaum, 2020).

The impacts of the COVID-19 pandemic on food security resulted from a combination of factors. On the one hand, lockdowns and mobility restrictions affected people's food security through a limitation in physical access to their land, natural resources and local markets (Béné, 2020).

But food security has also been affected by the economic disruptions resulting from the COVID-19 pandemic, through higher food prices and reduced incomes. High food price inflation at the retail level, generated by the supply disruptions, has higher consequences on low, middle and high-income countries, where people spend a larger share of their salaries on food than the population in high-income countries (WB, 2021a). The current crisis has also impacted farmers, agricultural workers and Indigenous Peoples. Beyond being unable to produce food for themselves, they often could not supplement this lack by buying nourishment due to their small economic capabilities and disrupted supply chains. Evidence from a survey launched in 48 countries during the COVID-19 pandemic shows a significant number of people reducing their food consumption (WB, 2021d).

Beyond impacting health, reduced calorie intake may threaten the cognitive development of young children. Also, data provided by the United Nations (UN) report on the State of Food Security and Nutrition in the World (FAO *et al.*, 2021a) warns about the increase in people going hungry in the first year of the pandemic. According to the document, around 118 million more people were facing chronic hunger in 2020 than in 2019. Moreover, the World Food Programme (WFP) estimates that 272 million people are at risk of becoming acutely food-insecure in the countries where this organization operates (FAO *et al.*, 2021a).

Another important consequence of the pandemic concerns the socio-economic impact on agricultural employment. Although the proportion of people working in the agriculture sector has historically declined over time, it remains the second greatest source of employment after the service sector, employing about 1 billion people globally (Roser, 2013). The importance of the sector in terms of employment is notably higher in countries of the Global South, where employment in the agriculture sector represents over two thirds of the total employment (Roser, 2013). However, these percentages become even larger if we consider the entire agri-food system, which also encompasses jobs in the food industry.

According to the Organization for Economic Co-operation and Development (OECD), the COVID-19 pandemic has triggered one of the worst job crises since the Great Depression (OECD, 2020a) including job losses and salary reductions. Although the recessionary effects of the COVID-19 pandemic seem to be strongest in non-agricultural sectors (Swinnen and Vos, 2021), this does not mean that the pandemic has not been detrimental for those working in the agriculture and food sector. In fact, the widespread informality and large share of migrant workers in the sector has put many farm workers in a position of high vulnerability. While specific data on the impact of COVID-19 on informal workers is still lacking, preliminary research suggests that they have been more likely to lose their jobs or suffer severe income losses during lockdowns (WB, 2021b). These consequences can be devastating for informal workers as they are largely excluded from government and formal support programs and tend to have low incomes that limit their ability to cope with income shocks (WB, 2020). The same holds for migrant workers, who may have been highly affected by the restrictions on domestic and international travel such as border closures (Larue, 2020). The mobility restrictions affecting migrant workers have contributed to labour shortages in many countries of the North and South, disrupting agri-food systems from the base (OECD, 2020b). Besides, combined disruptions along the food chain have put a strain on farm incomes, which may have been compounded by reduced off-farm salary (OECD, 2020c).

At the same time, the agriculture sector has the potential to serve as a safety net for crises affecting food prices and off-farm employment. The potential of farms as safety nets has been already recognized by the WB (Zaveri *et al.*, 2021) and has been exemplified during the COVID-19 pandemic with the reported return of urban migrants to rural areas of the Global South. This trend has also led to a general increase in urban agriculture, where sustainable urban farms are supporting the local agri-food system in response to COVID-19 (FAO, 2021e). In this context, many countries are re-examining the role of agriculture and integrated rural and urban development as a long-term viable strategy to emerge from the current crisis, create jobs and absorb expanding job creation for more robust and sustainable economic recovery (FAO, 2020i). For many in the Global South, agriculture and related sectors in their villages remain an informal safety net, a source of income if a crisis shuts down the principal livelihood in urban areas (Zaveri *et al.*, 2021). Evidence from various countries has shown the ability of smallholder production for home consumption as a way to reduce food insecurity during food-price crises (de Janvry and Sadoulet, 2011). However, the potential for agriculture as a safety net requires people in vulnerable situations to have access to land and this is limited in countries where agricultural land and production is in hands of a few large-scale producers (de Janvry and Sadoulet, 2020).

Support of safety nets (food-based, cash-based or voucher-based) have been one of the most relevant public instruments applied by states to buffer the economic impacts of the pandemic on individuals and households, proving to be highly effective in securing access to food by the most vulnerable (UN FSS, 2021f). At the same time, the global economic recession generated by pandemics and restrictive measures to contain it has also impacted the government's capacity to provide social protection for those most affected by the crisis (FAO, 2020d). Even though the international fora, such as the G20, offered to freeze the debt service for most developing countries, the poorest countries still faced difficulties to provide social protection for their populations. For example, according to the UN data, African countries alone need USD 100 billion to finance their health and safety net response (Lawrence, 2020).

Another important challenge connected with this current crisis that has also affected food security indirectly concerns access to education, which has been strongly reduced by the impact of the COVID-19 pandemic. For example, according to the World Bank, at the peak of the pandemic, 45 countries in the Europe and Central Asia region closed their schools (WB, 2021c). School closures affected meal programmes in high and low-income countries. The WFP estimates that 370 million children lost their access to their school meals due to COVID-19 restriction measures. But where maintained or implemented, they have proven very successful at ensuring food access to people in most vulnerable situations (UN FSS, 2021m). In some cases, the WFP has organized alternative school lunch arrangements to close the gap, in other occasions government and international organizations could not arrange different programs, exacerbating the financial burden of families to feed their children (Moseley and Battersby, 2020a).

Gender inequalities within agri-food systems have also been aggravated by the pandemic (CGIAR, 2020). The gender dimension of agri-food systems is an important element in low-, middle- and high-income countries. Due to certain social roles, women and girls have been often the first to see their food serving decreased while they would need special attention for nutrition purposes (FAO *et al.*, 2020). Additionally, women suffered a higher risk of domestic violence due to the lockdown measures (WHO, 2020b) Restrictions increased insecurity, harassment, and violence, especially faced by women in urban and rural areas (IADB, 2020). Moreover, women are likely at greater risk of exposure to COVID-19 due to their caregiving activities for the sick, children and the elderly. The phenomenon may have implications for food production processing and trade (Moseley and Battersby, 2020a) and more in general for food generation (FAO, 2021h).

The COVID-19 pandemic has also exacerbated the pre-existing inequalities and disparities affecting Indigenous Peoples and youth, who are particularly exposed to external pressures that threaten their livelihoods, cultures, identities and rights (FAO, 2021i). According to the report provided by UN Special Rapporteur on the rights of Indigenous People, Francisco Calí Tzay, Indigenous Peoples are among those most harshly affected by the pandemic (OHCHR, 2021). The UN Special Rapporteur stressed how the current outbreak has created an unprecedented challenge around the globe where Indigenous Peoples are left behind. In particular, involuntary containment policies used to mitigate the virus, paired with the denial of Indigenous land and self-determination rights have worsened the conditions of these categories already impacted by the disruption of local and traditional economies mainly based on agriculture. According to literature, Indigenous Peoples have seen their ability to sustain themselves strongly impacted due to the lack or limited access to land and natural resources, loss of livelihood and the disruption of local economies (FAO, 2021j). One of the most relevant examples concerns various Indigenous Peoples in Latin America. For instance, during the pandemic, Indigenous Peoples in Guatemala faced malnutrition at twice the rate of non-Indigenous Peoples (Mazariegos, Kroker-Lobos and Ramírez-Zea, 2020). Similarly, a number of Amazonian tribes across Peru, Brazil and Ecuador are suffering food insecurity due to unequal access to state support (Nanda, 2020). At the same time, Indigenous Peoples are in especially vulnerable situations in the face of the job crisis of the agricultural sector during the pandemics.

3 Towards a more sustainable and resilient agri-food systems

The COVID-19 pandemic has exposed the multiple vulnerabilities of agri-food systems to shocks and has raised awareness about the interdependence between human, animal, and environmental health. As explained in this report, zoonotic pandemics and climate change share many similarities and are closely interlinked, especially when considered in relation to agri-food systems. On the one hand, they are both important disruptors of agri-food systems and are predicted to increase and intensify in the future. On the other hand, current agri-food systems are important contributors to the intensification and increase in frequency of both threats. This suggests not only that there may be common approaches for simultaneously addressing the challenges that climate change and zoonotic pandemics pose on agri-food systems but that action and policies in the post-COVID era must follow integrative approaches that acknowledge the interlinkages between these two threats.

One Health is an example of a collaborative, multisectoral, and transdisciplinary approach to designing and implementing programmes, policies, legislation, and research that can help to build a better understanding of these interlinkages and address the intertwined challenges that climate change and pandemics pose on agri-food systems and food security (FAO, 2022; OIE, 2022). The One Health approach is supported by the Triparted organisations (FAO, WHO and OIE)[2] and recognizes that the health of humans, domestic and wild animals, plants, and the wider environment are closely linked and inter-dependent (FAO, 2022; OIE, 2022). It does so by mobilizing multiple sectors, disciplines and communities with the aim of fostering human well-being and tackling threats to public health and ecosystems (FAO *et al.*, 2021b)

Similarly, the KJWA also emerged from the realization that there were important interlinkages between climate change and agriculture and that there was a need to integrate both topics in policy discussions. As such, this constitutes a unique platform to integrate One Health approaches to the design and implementation of post-COVID-19 policies and actions.

It is important to emphasize that policies and actions for COVID-19 recovery must expand beyond recovery and use the opportunity, momentum, and lessons created by the unprecedented disruptive nature of this crisis to recover and transform how we feed the world. Agri-food systems were already failing to deliver safe and nutritious food for all before the pandemic. Moreover, they were altering the climate and adversely impacting the ecosystems on which they relied, thus compromising future wellbeing and its potential to deliver its intended outcomes in the future.

[2] As of 2020 the United Nations Environment Programme (UNEP) joined the Triparted organisations and together established the One Health High-Level Expert Panel, which provides guidance on One Health-related matters to governments and political visibility on this subject (UNEP, 2020).

Therefore, returning to business as usual is not an option and incremental adjustments will not be enough to respond to the climate, environmental, human health and social and economic, as well as food security challenges that we face today (UN FSS, 2021k). The actions presented below comprise a series of potential considerations and activities to help build a pathway towards the required transformation of sustainable, resilient, and inclusive recovery.

3.1 Resilience and sustainability

The IPCC defines resilience as "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation" (IPCC, 2018). Resilient agri-food systems are those capable of meeting the objectives of food security in all their dimensions (economic, ecological, and social), even in the face of multiple, unpredictable drivers of change (Hodbod and Eakin, 2015). In the event of a crisis, resilient agri-food systems should be able to withstand the shock or adapt to it by making incremental adjustments in the system (Béné, 2020). However, resilient systems should also be able to intentionally transform after major crises make the current system untenable (Folke, 2006).

Managing resilience requires an acknowledgement of the complexity inherent to agri-food systems, including interactions between social and ecological dimensions from local to global scale (Folke, 2006). Recognition of these complex relationships has notorious implications for management for resilience including the need for collaborative governance, integrated approaches, and alignment of policies and plans across sectors and countries (UN FSS, 2021n). Managing resilience also highlights the need to move away from exclusively reactive responses for recovery after a shock and the need to build capacity for anticipation and preparedness in advance (i.e., Béné, 2020). Eventually, managing for resilience will entail a moving away from short-term optimisation strategies (Hodbod and Eakin, 2015) to ensure food supply with sustainable practises and achieve long-term food security.

A sustainable agri-food system is a system that ensures food security and nutrition for all in a way that economic, social and environmental bases are not compromised for future generations (FAO, 2018b). Therefore, sustainable agri-food systems comprise economic sustainability (profitable throughout), social sustainability (broad-based benefits for society) and environmental sustainability (positive or neutral impact on the environment).

In view to support the 2030 Agenda, particularly Sustainable Development Goal (SDG) 1 (No poverty), SDG 2 (Zero hunger), and SDG 10 (Reduced inequalities), through the transformation to more efficient, inclusive, resilient and sustainable agri-food systems, FAO included in its Strategic Framework 2022-31 the *four betters*, which interconnect the economic, social and environmental dimensions of agri-food systems (FAO, 2021f):

- *Better production*, which aims to ensure sustainable and resilient agri-food systems.
- *Better nutrition*, which seeks to achieve food security.
- *Better environment*, which has the purpose to protect, restore and promote sustainable use of terrestrial and marine ecosystems while fighting against climate change.
- *Better life*, which seeks to reduce inequalities to promote inclusive economic growth.

3.2 Changing agricultural practices

Livestock is one of the major contributors to climate change and, as already shown, an important driver of zoonosis. Acknowledging the current demand for animal-source foods worldwide, livestock agri-food systems need to be transformed towards more sustainable, productive and resilient systems (FAO, 2021k) while preventing the (re-)emergence and spread of zoonotic diseases, and their environmental impact. As an observer to the KJWA process and to feed the discussions on the topic related to livestock, FAO formulated five actions to achieve resilient and low carbon livestock systems, which are referred as healthy livestock systems (FAO, 2020c):

- Action 1: boosting efficiency of livestock production and resource use;
- Action 2: intensifying recycling efforts and minimizing losses for a circular bioeconomy;
- Action 3: capitalizing on nature-based solutions to ramp up carbon offsets;
- Action 4: striving for healthy, sustainable diets and accounting for alternatives;
- Action 5: developing policy measures to drive change.

The actions cover topics such as animal production, health, feeding or human nutrition towards helping countries in achieving a balance between production of animal-source foods and minimising livestock system's environmental impacts. According to the UNFCCC, livestock management systems have the capacity to be highly adaptive and resilient to climate change (UNFCCC, 2021a). By improving livestock's sustainability and animal health, it results in a reduction of GHG emissions in the livestock sector while achieving long-term climate objectives.

Based on the United Nations Food Systems Submit (UN FSS), there are three cluster solutions to be addressed and implemented in this sector (UN FSS, 2021b): (i) fast scaling of best practises, technology and management, (ii) grazing for soil, climate and people, and (iii) aligning production and consumption. The first one lists best practices and innovative solutions that are now already being applied to secure sustainable livestock systems (UN FSS, 2021c). These practices include the application of technologies to reduce enteric CH4 and monitor animals' health and wellbeing, or initiatives that convenes different actors along the food chain such as agriculture and agri-food system related associations and representations, grassroots organizations, academia or UN bodies to work together. In line with this cluster solution, FAO and Climate and Clean Air Coalition (CCAC) with the support of the Global Research Alliance on agricultural greenhouse gases (GRA) participated in a project which aimed to reduce enteric CH4 emissions and emission intensity, increasing ruminant productivity through adopting best practices (FAO, 2021d). The second cluster refers to practices that aim to restore ecosystems, mitigate global warming, and enhance food security (UN FSS, 2021d).These include harvesting of grassland plants to sequester carbon like grasses and legume forages, extensive pastoral grazing or provision of technical assistance, training, monitoring tools for farmers, agricultural workers and Indigenous Peoples. It should be pointed out here that those communities are the most vulnerable situations and the first to experience climate change effects (FAO, 2021k). The last cluster shows solutions to optimize and align consumption and production in order to ensure healthy diets and that food production stays within planetary boundaries' (UN FSS, 2021e).

Those solutions include the livestock industry resizing towards more equitable distribution and consumption of animal source foods, shift towards regenerative, agroecological farming systems, supporting a Just Transition approach and adopting good standards of farm animal welfare. Transition from intensive to extensive livestock-based agri-food systems is also recommended, not only for the exposed reasons in this document but also to restore and protect grasslands, shrublands and savannahs, and thus conserving existing biodiversity (UN FSS, 2021a).

Although animal-source foods are important sources of high-quality nutrients and contribute to prevent and end undernutrition, their high consumption in some regions, particularly red meat and processed meat, increases risk of diet-related non-communicable diseases and implies environmental impacts (FAO and WHO, 2019). Hence, to achieve sustainable healthy diets, consumption of small amounts of red meat is recommended to improve health outcomes along with increasing intakes of plant food (fruits, vegetables, legumes, nuts and whole grains). Shifting from animal- to plant-based diets also contributes to dropping down global GHG emissions coming from agri-food systems (FAO and WHO, 2019). Enforce carbon pricing on an international level is another mechanism to minimize emissions and hence achieve higher levels of reduction (YOUNGO, 2021).

AMR is a central part for future pandemic preparedness. Prudent use of antibiotics in food production is key to effectively reducing AMR (UN FSS, 2021g) and building resilience in the agri-food sector by limiting the emergence and spread of AMR (FAO, 2021l). It is estimated that drug-resistant infections may cause a global economic damage similar to the 2008 financial crisis and a loss of 3.8 percent of world's annual GDP by 2050 (WB, 2017).

Agriculture, linked to both deforestation and habitat conversion, is a serious cause of biodiversity loss and compromises the agri-food system resilience and sustainability. As evidenced, pathogen spill-over is more likely to happen where forested lands have shifted for agricultural purposes. However, through agriculture itself, this situation can be driven towards another direction. Soil management along with nutrient and manure management are considered as core elements for climate-resilient and sustainable food production (UNFCCC, 2021a).

Sustainable soil management is key for maintaining soil health, fertility and production, and hence meet the food demands in areas of the world where it is more needed as well as to ensure ecosystem well-functioning and stability (FAO, 2017b). One of the most usual deficiencies in degraded soils is the lack of organic matter (FAO, 2018c). Contrary to synthetic fertilizers, which are fully inorganic, application of animal manure to cropland restores, improves and maintains soil health by increasing soil's organic matter and providing the essential elements required for plant growth (Teenstra, Andeweg and Vellinga, 2016). For this reason, manure's field application strengthens soils for being more fertile, sustainable and resilient to climate change (Teenstra, Andeweg and Vellinga, 2016).

While manure application is an important pillar for agriculture, emissions of GHGs, manly N2O, CH4 and CO2, can be realised to the environment because of microbial activity during manure's treatment (composting, drying or digestion), storage or after spreading to land (IPCC, 2007), resulting with adverse consequences for the environment. It is estimated that the overall nitrogen losses derived from manure is about 40 percent (IPCC, 2006). In view to the present and foreseen trend of higher demand for livestock-derived foods, livestock production is expected to expand and with it, animal manure. Although there are different manure managements systems, the main measure to prevent and mitigate GHGs emissions is closing the nutrient cycle by recycling and conserving manure's nutrient content in the field for carbon sequestration, soil fertilisation and crop production (Gerber *et al.*, 2013; Petersen *et al.*, 2013). Integrated farming systems, which integrate cereals and protein crops, mixed field cropping or mixed crop-livestock, such as agroforestry or agropastoral systems, enable improving productivity while restoring degraded lands and biodiversity, and mitigating climate change through a GHGs emissions' reduction and promoting soil carbon sequestration (Chiriacò *et al.*, 2021; Gocht *et al.*, 2016).

Agrobiodiversity production systems, also known as agricultural biodiversity, is believed to be key for agriculture by contributing positively to biodiversity conservation and preservation (UN FSS, 2021h). Agrobiodiversity refers to the variety and variability of ecosystems, animals, plants and microorganisms, at the genetic, species and ecosystem levels, which are necessary to sustain human life as well as the key functions of ecosystems (FAO, 2021b). The UN FSS set five cluster solution to foster agrobiodiversity (UN FSS, 2021h): (i) knowledge generation about crop and animal species, incentives for farmers and policy development, (ii) broaden the genetic base of crop and livestock species, (iii) restore degraded soils through food trees harvesting to provide healthier diets and landscapes, and contribute to climate change mitigation (iv) diversification of staple foods (wheat, rice, maize, potatoes, and soy) and bring to the market other major staples such as millet, and (v) conservation of food diversity in gene banks and in the field.

A move of agricultural practises towards agroecology and regenerative agriculture is seen as a key step to increase agrobiodiversity and the overall sustainability and climate-resilience of agri-food systems (European Committee of the Regions, 2021; UN FSS, 2021k; UNFCCC, 2021b; YOUNGO, 2021). Agroecology is a holistic and integrated approach that seeks to optimise interactions between humans and the environment (FAO, 2021c). Agroecological and regenerative agricultural approaches work with nature instead of against it and have the potential to simultaneously deliver both social and environmental benefits, including higher incomes and decent work, more diverse and healthy diets, increased agrobiodiversity, and carbon sink (UN FSS, 2021k). Configuring a new agri-food system in line with agroecology pillars is one of the best measures acknowledged as this approach entails adaptation, resilience, and mitigation in an integrated manner. (UNFCCC, 2021b, 2021d).

These approaches do not entail a series of defined silver bullet solutions, but they rather provide a framework of principles that can be translated into a range of practises in a context-specific manner (UN FSS, 2021k). Despite their demonstrated potential in supporting a transformation towards sustainability and resilience, these practises have received very little investment so far (UN FSS, 2021k).

In the way towards a new agri-food system, it is important to increase the awareness and knowledge of farmers, agricultural workers, Indigenous Peoples as well as of other actors involved in the agri-food system about the complex links between livestock management, climate change, deforestation, biodiversity loss, pandemics, and climate change. New practises should be adopted on the ground, taking into account what is exposed in this document and combined with high initial economic investment to have access and adopt new climate-smart technologies and practices

(FAO, 2021k; YOUNGO, 2021). Measurement, reporting, and verification tools are required to monitor the progress of the implementation of best practises and technologies, as well as their contribution in reducing GHG emissions (UNFCCC, 2021d). Those tools will allow acquiring science-based data to support decision-making and improve management capacity.

3.3 Socio-economic and food security dimensions

Considering how the COVID-19 pandemic has highlighted the vulnerabilities of the social and economic dimensions of current agriculture and agri-food systems (Moseley and Battersby, 2020b), future policies should be targeting these dimensions with a particular focus on groups most affected by the current crisis, such as rural and urban populations, rural workers, internal displaced people, refugees and migrants, Indigenous Peoples and youth and women.

In this context, direct support to marginalised populations' livelihoods is required both as part of recovery strategies and as a step to "build back better". In particular, economic inclusion programs may improve the conditions of the peoples in the most vulnerable situations, marginalised and extreme poor groups (ILO, 2021). These should be followed by social protection programmes more resilient to shocks and nutrition-sensitive to reach both short- and long-term goals (WFP, 2021). This kind of social and economic assistance should also have the aim to mitigate the population budget and liquidity constraints and can be directed into productive investments accelerating economies of the most impacted areas by the crisis. In building the resilience of agri-food systems to future disruptive events, the COVID-19 pandemic has proven the value of two key and cost-efficient short-term strategies to secure access to food to the people in the most vulnerable situations (UN FSS, 2021f). These include school meals, and cash, voucher or food-based safety nets to secure vital income to those whose income or expenditures are affected by the shock (UN FSS, 2021f). Rebuilding and scaling up these two strategies to become universal would help progress in guaranteeing the right to food for all. This solution needs to be accompanied by a new school curriculum related to nutrition and agriculture, particularly in rural areas.

A critical vulnerability of our agri-food systems highlighted during the pandemic is the length and connectedness of our food chains. Countries with higher globalisation levels have been more affected by the pandemic (Farzanegan, Feizi and Gholipour, 2020). Fostering horizontal and vertical cooperation among all actors involved in the different stages of the food chain (primary producers, manufacturers, or traders) through cooperative arrangements can shorten the supply chain, decrease transaction costs and enhance agile and faster food provision (UN FSS, 2021i). Furthermore, the supply chain can be shortened through fostering local food production for local use and distribution. Then, those hurdles related to food transportation experienced during the COVID-19 scenario are minimised (UN FSS, 2021j). Indigenous Peoples have also been further marginalised by the COVID-19 pandemic which impacted their strengths, networks and practises consequently reducing their access to traditional sources of food, diminishing their control over their diet and in general denying their food sovereignty (FAO, 2020e). Considering this background, it seems relevant to create new inclusive mechanisms for greater participation of Indigenous Peoples in the decision-making process in order to recognize and promote their existing capacity and knowledge, secure land tenure and foster their right to food (UN FSS, 2021l). As well, beyond improving the Indigenous living environments, governments, civil society, and international organizations are recommended to establish trust funds and other financial mechanisms to strengthen the community capacities, improving their livelihoods conditions and securing their food sovereignty (FAO, 2021m).

Moreover, the COVID-19 recovery policies should take into account gender inequalities in agri-food systems. Even though women cover fundamental roles and responsibilities in ensuring food security and nutrition at all levels, they are usually discriminated against in controlling resources and services and more in general influencing decision making process, also facilitating exploitation and violence (FAO, 2020f). This background is also followed by a general institutional/legislative discrimination against women in access to resources and political and social economic freedoms. Due to this dual problem, women in agri-food systems may face multiple forms of discriminations. Beyond recognising the different vulnerabilities between men and women, policies adopted should not ignore social norms, roles and socio-political dynamics which underpin gender inequality. Governments and international policy-makers should use approaches that recognise how women and men suffer different levels of vulnerability (FAO, 2020f). For this purpose, it is required to engage policies and programmes in agri-food systems that may facilitate behaviour change within populations to mitigate or eliminate cultural norms which limit women's involvement in food generation, production, and consumption. Beyond ensuring women's access to land and other natural resources such as water it may be useful to facilitate access to financial services, technologies, markets and to ensure access and availability of quality food for women.

The COVID pandemics brings attention to another relevant topic concerning the sustainability and healthiness of diets. For example, according to FAO, imbalanced diets, such as diets low in fruits and vegetables, high in red and processed meat, and excessive energy intake, represent one of the greatest health burdens globally and in most regions (Springmann, 2020). As well, the chronic diseases related to unhealthy diets require costly treatment (Muka *et al.*, 2015). Unbalanced diets are not just unhealthy for humans but also for the environment. The agri-food system is one of the major drivers of environmental impacts (Poore and Nemecek, 2018) and without dietary changes towards more plant-based diets, key environmental limits risk being reached, these are related to climate change, land use, freshwater extraction, and biogeochemical flows associated with fertilizer application(Willett *et al.*, 2019). Taking into account this challenge, additional policy measures are requested. In particular, policy-makers should incentivise a higher uptake of healthy and more sustainable diets including through media and education campaigns, fiscal measures (such as subsidies and taxation) and school and workplace approaches (Mozaffarian *et al.*, 2012). In this context, an important first step may be to align national food-based dietary guidelines stressing the relation between unhealthy eating and the environmental impact of diets (Springmann *et al.*, 2020).

4 Call to action

Parties to the Convention, governmental and non-governmental agencies, international finance institutions, as well as all actors involved in the agri-food system, need to urgently take into account how agri-food systems are interlinked with the (re-)emergence of zoonosis with pandemic risk, how pandemics impact agri-food systems, and how climate change is altering and affecting both pandemics and agri-food systems.

Several disease outbreaks have been traced-back to animal-borne pathogens, such as the Ebola virus or coronaviruses, which have caused multiple outbreaks in the last three decades. Furthermore, since 2005, the WHO has declared six public health emergencies of international concern linked to zoonotic agents. The most recent SARS-CoV-2-induced pandemic, has, by the time of writing this report, infected more than 267 million people (WHO, 2021b), and caused devastating impacts on socio-economic and food security dimensions of societies across the world. Although its origin is still unclear, it is believed to have jumped from animals to humans (Frutos, Gavotte and Devaux, 2021).

Now more than ever, it is urgently required to strengthen agri-food systems with a view to preventing, tackling and mitigating forthcoming adverse events coming from both climate change and zoonotic outbreaks. Since agri-food systems are clearly interconnected with environmental, animal and human health, they have the potential to minimize their influence on climate change and pandemics, which in turn will result in more sustainable and climate-resilient agri-food systems.

General recommendations:

- Address z**oonotic pandemics under the future topics of KJWA** to complete Parties' current analysis of the issues related to agriculture and climate change.

- Reinforce the **cooperation at national levels and internationally** to address issues related to zoonotic pandemics and climate change in the agri-food sector.

Animals are natural hosts of infectious agents that can be further transmitted along the food chain to susceptible and healthy animals and humans. This transmission, if not controlled, can result in disease outbreaks with serious public health consequences. In view of how climate change is catalysing the occurrence of infectious agents spill-over between animals and humans, changes in livestock management towards sustainability and resilience are key to attenuate zoonotic outbreaks. In this regard, it could be relevant to:

- **Introduce new protein sources for animal feed** retrieved from synthetic amino acids, algal, fungal, microbial or insects different to the conventional feed protein such as soy in view to reduce deforestation linked to crop production for animal feed.
- **Implement livestock-crop integrated systems** as a relative mitigation measure of GHGs emissions and land degradation linked to livestock production.
- **Enhance greater consumer awareness on food production and the effects of agriculture's mismanagement over the environment** together with **promoting plant-based sources of protein** as a complement to animal-based ones.

Unmanaged agri-food systems are negatively impacting ecosystems, leading to habitat and biodiversity loss. Due to deforestation and replacement of vegetation by crops, the interface between animals, humans and the environment is being expanded and opportunities for interaction between animals and humans increases together with risks for zoonotic outbreaks. Furthermore, agriculture's expansion along climate-driven shifts is altering migration patterns of wild animals forcing them to find alternative paths to new habitats Furthermore, agriculture has been reported as a major driver of biodiversity loss, which increases the risk of zoonotic outbreaks via a number of mechanisms. Therefore, we recommend to:

- **Integrate an agroecological approach to agri-food systems** to simultaneously foster the recovery and resilience of ecosystems and agri-food systems while having socio-economic and environmental benefits.
- **Increase agrobiodiversity and resilience to climate change impacts in agri-food systems** in terms of variety and variability of animals, plants and ecosystems to preserve the ecosystem's key functions and the livelihoods of peoples in the agri-food system.
- **Increase awareness, and promote knowledge exchange among peoples involved in the agri-food systems, Indigenous Peoples and farmers** about the interaction between animals, humans and the environment and how they impact climate change and the risk for pandemics.
- **Implement formal systems of incentives and funding mechanisms inclusively addressing all peoples involved in the agri-food systems, Indigenous Peoples and**

farmers to adopt best practices and technologies to strengthen agri-food systems towards sustainability and resilience.

- **Implement systems of incentives (on price tags or labels) for all kinds of consumers** to go for locally and more sustainably produced food and introduce systems through which consumers can track the salary of the workers involved in the value chain, origin and production methods of products.

Animal and human health are contingent on the environment's changes. Thus, climate change directly affects animal and human health through directly catalysing the (re-)emergence and distribution of infectious disease. For this reason, we urge to:

- **Better reflect and take into consideration human and animal health and the environment** in the design, implementation and evaluation of agricultural practises.

To achieve resilient agri-food systems against pandemic and climate change, policy-makers must also directly address issues related to socio-economic justice, socio-economic stability and other factors affecting food security from a socio-economic perspective. This should be done following participatory and inclusive processes to facilitate and support the design and implementation of just and effective context-specific policies that do not leave behind groups in vulnerable situations. At the same time, policies and action must follow a long-term perspective and integrative approaches that recognize the interaction between animal, human, and environmental health.

- Create **social protection mechanisms to ensure continued livelihoods in situations of climatological or pandemic emergencies** for migrant workers, informal workers, small-scale food producers and Indigenous Peoples.
- Ensure **formal and practical access to land and natural resources** for groups in vulnerable situations, such as youth, women, Indigenous Peoples and small-scale food producers.
- Address how **our consumption patterns and diets affect the health of humans, animals and the environment in school curricula**.
- Facilitate **financial support for civil society and community** led crisis response mechanisms.

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