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Abstract

This paper explores the theoretical and conceptual nexus between climate change, workers' health, decent work, human rights, and the UN Sustainable Development Goals (SDGs) using the case of agricultural workers in Brazil. It posits the overall relationships between climate change risks and working conditions, relevant international legal standards and norms on worker rights, and the features of worker conditions in Brazilian agriculture. It offers a compelling research agenda with five operational pillars: (1) research, (2) surveillance and monitoring, (3) risk assessment, (4) risk management, and (5) policies and regulations. The holistic framework it develops avoids monocausal explanations, incomplete solutions, fragmented interventions, and unintended consequences, which impact the livelihoods and health of Brazilian agricultural workers. The paper concludes by highlighting that through research using a human rights perspective, Brazil can protect workers' health in the face of climate change.

Keywords: Sustainable Development, Climate Change, Workers' Health, Decent Work, Human Rights

Mudanças climáticas, trabalho decente e saúde dos trabalhadores no Brasil: considerações teóricas

Resumo

Este artigo explora o nexo teórico e conceitual entre mudanças climáticas, saúde dos trabalhadores, trabalho decente, direitos humanos e os Objetivos de Desenvolvimento Sustentável (ODS), usando o caso dos trabalhadores agrícolas no Brasil. Ele estabelece a relação geral entre os riscos de mudanças climáticas e as condições de trabalho, padrões e normas legais internacionais relevantes sobre os direitos dos trabalhadores e as características das condições dos trabalhadores na agricultura brasileira. Ele postula uma agenda de pesquisa convincente com cinco pilares operacionais: (1) pesquisa, (2) vigilância e monitoramento, (3) avaliação de risco, (4) gerenciamento de risco e (5) políticas e regulamentos. A estrutura holística ele se desenvolve aqui evita explicações e soluções monocausais, intervenções incompletas e fragmentadas, e múltiplas consequências não intencionais de maneira que podem trazer impacto real aos meios de subsistência e à saúde dos trabalhadores agrícolas brasileiros. Por fim, na conclusão ressalta-se que a pesquisa através da perspectiva dos Direitos Humanos o Brasil pode ampliar a proteção da saúde dos trabalhadores diante das mudanças climáticas.

Palavras-chave: Desenvolvimento sustentável, mudanças climáticas, saúde dos trabalhadores, direitos humanos

1. Introduction

The nexus between workers' health, decent work, and climate change exemplifies a complex and multifaceted challenge. Workers' health and decent work are elements embedded in fundamental human rights recognised by international bodies such as the United Nations, the International Labour Organization (ILO) and the World Health Organization (WHO). Recently, the ILO (2024) (1), established six main impacts of climate change on workers' health: heat waves, UV radiation, extreme events, workplace air pollution, vector-borne diseases, and pesticides, all of which tend to increase the global burden of diseases, enlarging the exposure to workers and related illnesses and deaths. For example, changes in temperature and precipitation patterns can alter the distribution and prevalence of vector-borne diseases and pest populations, increasing the risk of dengue fever, zika, chikungunya and malaria to outdoor workers (like in agriculture) who tend to be disproportionately exposed. Deforestation and land use change the activity of insects, fungi, mites, mice, and unwanted plants and can lead to significant exposure to chemicals relate to the increase in insects and pathogens (2).

Moreover, severe weather (droughts, floods, storms) causes substantial crop loss, affecting food security and result in income instability for agricultural workers who are primarily dependent on crop yields. In addition, climate hazards can lead to permanent impacts on health and labour productivity (3), indirectly increasing the risk of other social issues, such as land conflicts and mass rural-urban migration (4). Climate change risks disproportionately affect marginalised communities and segments of the working class, exacerbating pre-existing disparities and conditions and introducing greater volatility in income and livelihood shocks related to environmental degradation, which further push people towards the possibility of modern slavery by compelling migration for work or improved living conditions, and to enter precarious below-standard working conditions (5–8). It is a vicious cycle involving climate change, socioeconomic and environmental vulnerabilities, sharpening exclusion and marginalisation, exploitation, debt servitude and slave-like conditions, and environmental devastation (9).

For Brazil, a country with diverse climatic regions and a large workforce dependent on climate-sensitive sectors, the implications of climate change on workers' health and decent work are especially prevalent. For example, Brazil is currently facing a historic megadrought and the worst wildfire season in at least a decade, with 47,000 fire alerts by mid-September 2024 (10). These wildfires, together with intensified heatwaves and droughts, also worsen air pollution, releasing toxic emissions and harming human health, especially for outdoor workers. Agricultural workers in Brazil are particularly vulnerable to many of the negative consequences of climate change due to the country's large agricultural sector and persistent socioeconomic challenges (11). Increasingly poor working conditions due to climate change are contributing to degrading circumstances at work and overwhelming workloads (e.g., heat exhaustion)—two indicators of the Brazilian legal concept of 'conditions analogous to slavery' (Brazilian Penal Code). A drawback in Brazilian plans and policies for mitigating and adapting to climate change is that they have not correctly addressed work-related impacts and risks. Current plans and policies only cite the necessity for a "just transition for workers" and address the "commitment of labour forces" and the "loss of work productivity", but there remains a lack of concrete measures, such as reducing workload and the working during periods of high temperatures or heat waves (12).

This paper provides a comprehensive theoretical framework that clarifies the connections between climate change, workers' health, and decent work in Brazil's agricultural context grounded in a human rights perspective. Our approach recognises empirical gaps by conducting a narrative literature review (13) among concepts such as climate change, decent work, occupational health, and human rights. We then review methods related to how these concepts interlink, followed by proposing strategies to tackle these challenges. By analysing these intersections, the methods aim to uncover the complex interactions caused by historical vulnerabilities within the agricultural sector.

2. The Brazilian context

Since the second half of the 20th century, Brazil's agriculture adopted a production model based on a Green Revolution (increased use of advanced technologies, machinery, pesticides, water, land, human energy, and expansion of monocultures). Brazil is a large global producer and exporter of many primary goods and commodities, including soybean, coffee, cotton, corn, sugar, rice, manioc, and beans. In 2016, the sector employed over 18 million people and contributed over one-fifth of the country's GDP (approx. USD 166 billion), transforming Brazil into the largest net exporter of agricultural commodities in the world (14). However, this expansion has produced multifaceted exposure to human and environmental risks, putting traditional populations under pressure and threatening their lands, habits, culture, and ways of life (e.g., Indigenous people, small farmers, *quilombolas*, etc.). The aforementioned factors have caused significant transformation and impact on the health of the population health, particularly workers' health, due to the abusive use of pesticides, which affects children, elders, and the general population (even in the cities nearby monocultures) since they are spread and diffused in the air (by workers, by tractors, or by aircraft), leading to an increase in acute diseases (15).

In addition, Brazil is highly vulnerable to climate risk, ranking 27 out of 180 countries in the Global Climate Risk Index 2021, where the main climate risks include droughts, floods and epidemics (16). Brazil's population is suffering from a high incidence of climate-sensitive diseases. Rising temperatures are creating even more favourable conditions for vector-borne, water-borne, and other infectious diseases. Additionally, increased flooding due to heavy rainfall or extreme weather events exacerbates sanitation challenges and water-borne diseases like dengue, chikungunya, malaria, etc. A clear example occurred in 2024, when Brazil exceeded its worst-case projection for dengue cases in June 2024, with a record 5.5 million infections reported, representing a 240 per cent increase from the 1.6 million cases recorded in 2023, which was already among the highest on record (17). These risks are expected to impact Brazilian agriculture heterogeneously. For example, soybean and cotton crops are expected to be moderately affected by climatic change, while maize and wheat yields will decline significantly (14). Other key speciality crops, such as coffee and cocoa, face significant yield reductions due to changing rainfall patterns and increasing temperatures, exacerbating already difficult working conditions and decreasing labour productivity (18,19).

In addition to these climate-related risks, agricultural workers in Brazil are also a vulnerable group of people suffering from historical exclusion and processes of oppression linked to colonialism, slavery, patriarchy, racism, and sexism in capitalist development, shaping forms of structural violence and exploitation that expose them to discrimination, inequalities, and significant health repercussions (20). For instance, from 2020 to 2023, two of every three

people in conditions analogous to slavery (in Portuguese: Pessoas Em Condição Análoga À De Escravo – Resgates) were located in productive sectors associated with agriculture or forestry production (21).

3. Human Rights scope

Workers' health is a matter of human rights. Health is not simply a state of being free from illness, as defined by the World Health Organization (WHO). According to the principles of social medicine in Latin America, health is also determined by the living conditions that allow individuals and social groups to thrive, such as adequate food, housing, income, employment, and healthcare services. Human rights, including the right to health and safe working conditions, are intrinsically linked to decent work and workers' health. Violations of these rights often result from and contribute to poor occupational health and hazardous working conditions (7). The International Labour Organization (ILO) includes in its Fundamental Principles and Rights at Work access to "a safe and healthy working environment" (22), making explicit the connection between human rights and working conditions. The 1948 Universal Declaration of Human Rights (UDHR) and other international human rights instruments, such as the 1966 International Covenant on Economic, Social, and Cultural Rights (ICESCR) treat occupational health as fundamental to safeguarding the highest attainable standard of physical and mental well-being and a baseline for protecting workers' welfare and preventing harm.

The Constitution of the Federative Republic of Brazil (1988) also grounds health as a universal right: "Health is a right of all and a duty of the State and shall be guaranteed through social and economic policies aimed at reducing the risk of illness and other hazards" (Art. 196), and express the workers' health, as well as a universal right and under the State responsibility'to carry out actions of sanitary and epidemiologic vigilance *as well as those relating to the health of workers* (…) and to cooperate in the preservation of the environment, *including that of the workplace*" (Art. 200).

Since climate change poses a significant risk to workers, it should be integrated into occupational safety and health (OSH) and decent work (23) and in Brazilian Strategies and Initiatives according to the National Workers' Health Policy. The intersection of human rights, decent work and workers' health highlights the need for comprehensive measures to ensure safe workplaces and labour processes under exacerbating risks due to climate change and socio-economic pressures. Recognising these various definitions acknowledges that agricultural workers have the right to health, safe working conditions, and decent work; it also incorporates international human rights standards into national policies and practices (24).

[insert figure 1 near here]

Figure 1. Multilevel connection and interrelation between human rights, decent work and workers' health

4. Linkages with Sustainable Development Goals (SDGs)

In addition to the intersections within human rights, there is also a direct connection between climate and health-focused SDGs and the decent work SDG (8), which asks states to: "promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all." (Figure 2). In the context of occupational health, risk management is limited but can help to mitigate health risks associated with agricultural activities. For instance,

it is relevant to introduce a broader approach to deal with exposure to pesticides, heat stress, and physical injuries, thereby improving the overall health and well-being of agricultural workers (SDG 3), achieving decent work (SDG 8) and achieving responsible production (SDG 12).

On the other hand, estimating climate impacts on health, raising awareness and capacity for mitigation and adaptation, and working to reduce climate change-related risks in the workplace are critical elements of SDG 13 (climate action). Action to improve working conditions is also connected to SDG 1 (poverty) and SDG 10 (inequalities). The achievement of decent agricultural work practices through increasing resilience to climate change and enhancing income security and livelihood opportunities will help to reduce poverty and inequality. In addition, sustainable resource management and prevention programmes can positively impact the resilience of food systems to climate change in support of SDG 2 (hunger/sustainable agriculture). Finally, as women and children are among the highest-risk groups for forced labour and indecent work, gender inequalities in the workplace and occupational health and safety vulnerabilities are related to SDG 5 (gender equality).

[insert figure 2 near here]

Figure 2. Links between the Sustainable Development Goals, decent work, and occupational health

5. Knowledge gaps and limitations

Despite the inherent synergies and overlapping objectives among concepts and the increasing effort to tackle this issue through multiple lenses and disciplines (23,25), many challenges, limitations, and knowledge gaps remain. We classify challenges and knowledge gaps into the four priorities for action specified by Schulte et al. (2016) (26) for addressing climate-related occupational safety and health hazards. Framing these gaps within these priority areas will enable us to create a path of opportunities towards better-informed policy and regulations and how to integrate them in ways that enhance decision-making processes (Figure 3) more critically. These priority areas are discussed in turn.

[insert figure 3 near here]

Figure 3. Limitations and knowledge gaps that will support a better decision-making process.

5.1. Research in occupational hazards, invisible subpopulations and systemic thinking

One significant gap is the limited focus on specific occupational hazards like heat stress and air pollution. There are fewer studies on other occupational hazards, such as vector-borne diseases, increased pesticide exposure, UV radiation, and mental health (27). For example, more effort is needed to explore how climate-induced stress and anxiety are related to the disruption of farmer livelihoods and worker productivity and well-being (27).

Moreover, Parry et al. (2019) (28) highlight six forms of invisibility (social marginalisation, forced invisibility by migrants, spatial marginalisation, neglected diseases, mental health, uneven climatic monitoring and forecasting) that relate to unbalanced intervention plans, increasing the risk of vulnerable populations. Studies on informal workers in Brazil (29,30) have identified numerous occupational hazards, including poor hygiene, inadequate protective equipment, and exposure to hazardous materials. However, further research is needed to understand how climate change disproportionately affects vulnerable and marginalised populations and how to tailor interventions for these groups.

A systemic approach is required when analysing the effects of climate change on workers' health and decent work; considering how various elements interact within a larger context helps identify influence points for more effective interventions and sustainable solutions. In addition, addressing only one dimension can lead to incomplete solutions that fail to tackle the root causes or interconnected effects, and can lead to perverse or unintended consequences (8). For example, adaptation strategies focused solely on economic factors might overlook health impacts, while health-focused interventions might neglect economic or social dimensions (31). Additionally, some studies highlight the economic impacts of climate change, such as financial losses resulting from decreased productivity and cascading effects on social and economic stability. However, there is insufficient evidence regarding this long-term economic impact. For example, piecework systems (i.e., pay per unit produced) under heat-stress conditions may compel workers to exceed their physical limits to meet production targets and earn enough income to cover their basic living expenses. This can result in chronic illnesses that jeopardise their long-term earning potential due to health decrements, absenteeism and medical expenses (32), creating a poverty trap for the most vulnerable workers (3). Sustainable solutions require balancing immediate needs with long-term impacts, ensuring that interventions do not create new problems or aggravate existing ones, and promoting equity and justice across different sectors and communities (7).

5.2. Improve surveillance and monitoring systems

Improved surveillance and monitoring systems to track climate-related occupational hazards and health outcomes would enable better data collection and inform policy decisions to protect workers effectively (33). Significant gaps remain in implementing robust monitoring and enforcement processes to ensure compliance with human rights standards in the labour process and workplace. Monitoring social determinants in labour processes and work-related disability and illness statistics remains challenging, particularly for informal and more vulnerable workers and those without health services, resulting in underreporting and inadequate investigation.

Currently, Brazil is among the few countries that publish open state labour inspection data on workers identified and removed from conditions of modern slavery, and it has taken a leading role in addressing this issue. These working conditions are defined under Brazilian law as being analogous to slavery, including forced labour and violations of human dignity (e.g., lack of water and unsanitary housing accommodations) (34). These efforts provide an opportunity for researchers to integrate instances of these violations into comprehensive surveillance and monitoring systems. The data collected can feed into integrated risk assessments, assisting in identifying hidden and high-vulnerability populations, and highlighting new opportunities to strengthen procedures such as inspections and prevention programs.

5.3. Risk assessment: Integrated assessment modelling

Risk assessments help identify and evaluate the potential impacts of climate change on worker safety and health, enabling the development of targeted adaptation strategies to mitigate the identified risks. Vulnerability assessments have been used in Brazil to guide policy and adaptation measures in the agricultural sector (35) and can combine diverse scientific, economic, and social science expertise to provide comprehensive analyses and advice on climate change impacts and solutions. This approach supports establishing ongoing communication within the research community and between researchers and policymakers, facilitating agreement on complex issues (36).

Above all, by providing and analysing more granular data and addressing research challenges (section 5.1), risk assessments could support and increase labour inspection coverage in Brazil, detecting productive sectors or localities that require an increased inspection capacity. Likewise, a robust risk assessment can assist NGOs and unions in identifying high-vulnerability areas or communities to focus their interventions. Finally, risk assessments with surveillance data can enhance and support education and training programs, such as those promoting sustainable agriculture practices, which are crucial for improving workers' adaptive capacity and reducing their vulnerability to climate-related hazards.

5.4. Risk management: Workers' voices, interdisciplinarity, and uncertainties

Developing effective policies, regulations, and strategies —such as reducing workload and working hours, minimising the use of pesticides, eliminating aerial spraying of chemicals, empowering workers, and protecting biodiversity and social diversity— requires implementing adaptable practices tailored to the community level and incorporating workers' voices throughout all stages of the research and intervention processes to engage communities and empower workers. Moreover, integrating traditional knowledge and community voices with modern scientific insights in different agricultural management approaches (such as agroecological practices) can emphasise sustainable farming techniques that help to improve working conditions by reducing exposure to harmful chemicals and fostering biodiversity, enhancing the chances of creating effective and sustainable solutions.

Future research should assess the effectiveness of Community-Based Participatory Research (CBPR) (37) and different agricultural practices in safeguarding workers from various climate hazards and socio-economic vulnerabilities, thus fostering more resilient and just agricultural systems. Interdisciplinary approaches enable us to recognise synergies among goals – enhancing multidimensional aspects of well-being– and minimise the risk of negative impact and unnoticed trade-offs. Integrated models can evaluate the effectiveness of various adaptation strategies in agricultural sectors, guiding policy decisions that protect workers' health and livelihoods.

Risk management approaches necessitate the integration of multiple theoretical and methodological frameworks to encourage a more extensive network of collaborators capable of intervening holistically for the benefit of communities, generating a common ground for the participation of various disciplines, fostering mutual understanding, and enhancing dialogue. Moreover, interdisciplinary approaches support the interconnection of robust and flexible strategies at different scales of governance. For example, local-level strategies may focus on community-based adaptation and prevention activities, while national policies could involve

regulations or incentives and labour protection measures under the auspices of international agreements.

On the other hand, risk management must include a proper understanding of uncertainties in risk assessments and the entire system. Uncertainties arise in various aspects, including quantifying climate-related health risks, a crucial element in the unequal allocation of states' responsibilities, and concerns about extraterritoriality obstructing efforts to connect climate change with the right to health through legal action (39). Furthermore, since the level of impact and coping strategies depend heavily on socioeconomic status, sociocultural norms, and access to resources (3), reliable and granular information is crucial to understanding how vulnerability may vary depending on specific social, environmental, infrastructural, and public policy factors.

6. Discussion

The consequences of climate-related hazards are already visible in Brazil. Environmental stressors such as severe droughts in the São Francisco River Basin (40) impacting agriculture and water supply, rising temperatures exacerbating heat stress in sugarcane plantations in the Northeast (41), and extreme flooding in states like Bahia and Amazonas displacing thousands of residents (42), as well as an increasing exposure to pesticides in rural areas (43).

Droughts drastically reduce production, destabilising the livelihoods of agricultural workers who rely on predictable growing seasons. This situation has pushed many workers into informal labour arrangements, where practices often leave them without health insurance or legal protections, a pattern also seen among seasonal workers. Implementing support initiatives like crop insurance and financial assistance are beneficial for farmers and workers. Policies should require the formalisation of seasonal and temporary jobs for workers, especially those driven into informal employment, to secure access to health insurance, minimum wage protections, and legal rights. In addition, collaborations among local governments, NGOs, and agricultural cooperatives are vital in raising awareness about workers' rights and offering alternative income opportunities, including skills development programs.

Moreover, extreme temperatures contribute to heat-related illnesses such as heat stress, dehydration, chronic kidney diseases (CKD), and cardiovascular problems, which are particularly severe for those engaged in physically intensive labour, such as sugarcane workers who have faced extreme heat strokes during manual harvesting. These chronic illnesses threaten future earning potential, creating long-term poverty reinforcement loops for the already high-vulnerable workers. Government and industry should enforce heat safety regulations, including mandatory breaks, access to shaded areas, and provision of clean water to prevent dehydration and heat-related illnesses. Programs promoted by NGOs like La-Isla-Network[1] have demonstrated effectiveness in reducing the risk of heat-related illnesses through the combined application of basic worker protection measures while also generating economic benefits for the industry. Furthermore, the proliferation of pests under shifting and extreme climatic conditions has compelled farmers to increase their use of higher-toxicity pesticides and fertilisers to protect their crops and optimise yields to support their families. Technical training in good agricultural practices could enhance health and safety literacy. However, for

[1] https://laislanetwork.org

it to be effective, it must be co-designed with local entities to adapt the training to the context, considering cultural and language barriers and economic and social circumstances (44).

7. Conclusion

Workers' health and decent work are essential for promoting worker well-being. A comprehensive theoretical framework encompassing these concepts draws on an interdisciplinary paradigm, including public health, sociology, economics, environmental science and labour studies.

The effects of climate-related hazards have profound impacts on agriculture and disproportionately affect people who are already disadvantaged due to factors such as poverty, discrimination, gender and income inequalities, and lack of access to resources (28). Under climate change scenarios, working conditions appear to be getting worse, leading to new instances of excessive workloads and exacerbating vulnerabilities, which in our view constitute 'conditions analogous to slavery' found in Brazilian law. Integrating workers' health considerations and a decent work perspective into climate change's impact on agricultural systems is crucial due to associated vulnerabilities amplifying socio-economic disparities and increasing susceptibility to climate risks. Without support for adaptation measures, this vulnerability can spiral and worsen.

Addressing decent work and workers' health under pressures of climate change and a global 'poly-crisis' requires new, equitable, and intersectional (multi-SDG) public policies—ones developed by increasing the capacity of diverse social actors to identify problems and propose solutions through dialogue and participatory approaches. Economic development must be linked to the promotion of rights to health, a safe environment, and overall well-being for workers and vulnerable populations. In Brazil, initiatives and plans for economic growth have generally prioritised certain sectors, such as agriculture. Consequently, economic growth is accompanied by human rights violations, environmental degradation, and poor working conditions for the working class (including deforestation, pesticide use, and a declining capacity of the health sector to manage the increasing demand for healthcare due to diseases) (45).

Policies and regulations must include interdisciplinary perspectives to support marginalised groups, from financial support to improved labour processes to greater space for dialogue to include voices –that have historically and systematically been marginalised– in decision-making processes that directly affect them. Likewise, workers and communities possess unique knowledge from their direct experience and involvement in the labour environment. Incorporating workers' voices across all stages of research and intervention processes engages communities and empowers workers, increasing the success of developing effective and sustainable solutions. CBPR and citizen science ensure that the workers' voices are central to research and design interventions to create tangible improvements in their working conditions by focusing on observational studies and incorporating qualitative methods.

Through a human rights perspective, Brazil can create a strong agricultural sector that protects workers' well-being in the face of climate change. Simultaneously, an increased awareness of the interaction among multiple SDGs will promote decent work practices, health, and environmental resilience and ensure that interventions consider the broader context of social justice. This approach emphasises protecting agricultural workers' fundamental rights to health,

safe working conditions, and decent work, aligns with international labour standards and promotes sustainable and equitable development. In addition, integrating workers' health aspects and a decent work perspective on climate change affecting agriculture systems is vital since vulnerabilities associated with indecent work, such as limited mobility, debt bondage, and lack of legal protection, amplify the socio-economic disparities that increase the susceptibility to climate risks. By safeguarding these rights, we address vulnerabilities exacerbated by climate change, ensuring that marginalised populations are not left behind.

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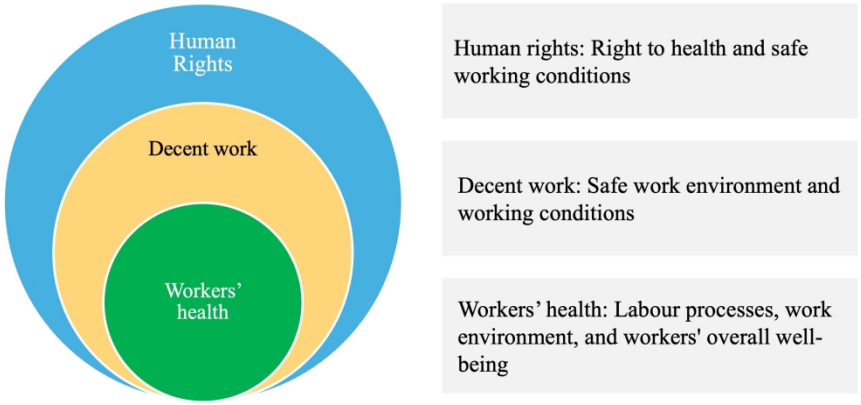
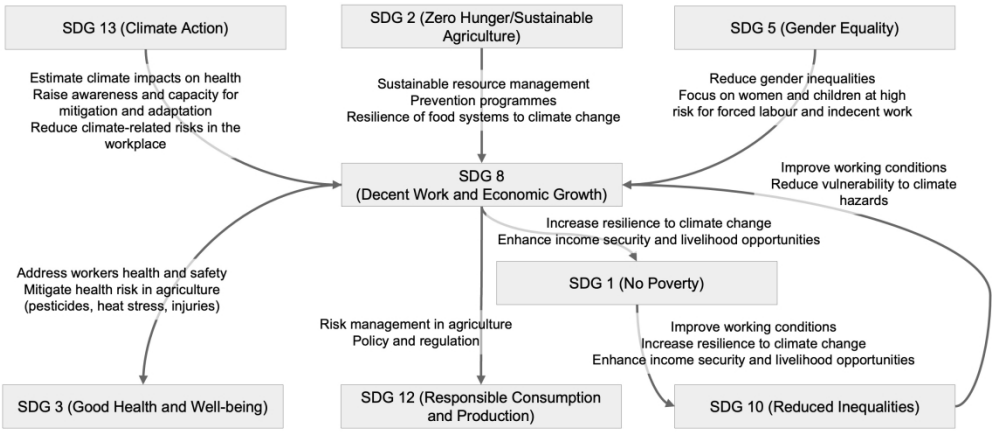


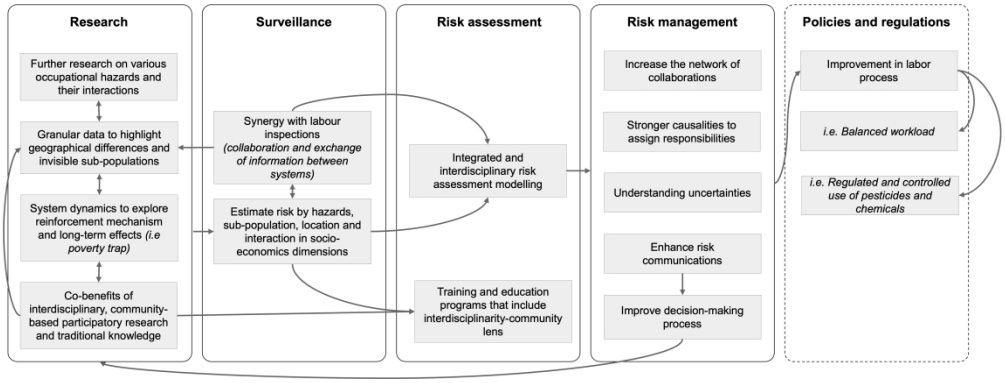
Multilevel connection and interrelation between human rights, decent work and workers' health

216x87mm (330 x 330 DPI)



Links between the Sustainable Development Goals, decent work, and occupational health

231x100mm (330 x 330 DPI)



Limitations and knowledge gaps that will support a better decision-making process

382x143mm (330 x 330 DPI)