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Current Opinion in Environmental Sustainability

Security risks from climate change and environmental degradation: implications for sustainable land use transformation in the Global South

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Climate change and environmental degradation remain the most complex challenges that present and future generations of humankind face and raise several security risks that have received relatively little attention in the literature. This paper aims to review the evidence of security risks arising from these challenges in the Global South and to provide forward-looking perspectives on how to increase the resilience of affected individuals and communities. We see diverse land use strategies as a key element to drive a transformation towards greater sustainability and resilience. We propose that rural land use in the Global South should be geared towards the promotion of resource and biodiversity conservation, the development of agroforestry, tree-based farming systems, the diversification of crops, and the utilization of climate-resilient cultivars, and neglected and under-utilized plants. These actions would contribute to addressing the security risks stemming from the interconnected challenges of climate change and environmental degradation.

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Current Opinion in Environmental Sustainability 2023, **63**:101322

This review comes from a themed issue on **Resilience and Peace**

Edited by **Albert Norström, Cedric de Coning, Cibele Queiroz, Jeeyon Kim, Rika Preiser** and **Florian Krampe**

For complete overview of the section, please refer to the article collection, "Resilience and Peace"

Available online 4 July 2023

Received: 22 November 2022; Revised: 12 June 2023; Accepted: 15 June 2023

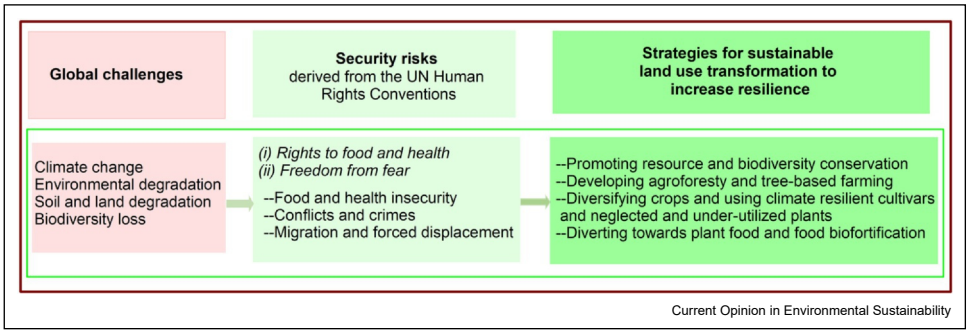
https://doi.org/10.1016/j.cosust.2023.101322

Introduction

Climate change and environmental degradation, including biodiversity loss, remain the biggest challenges that present and future generations face. The latest report of the Intergovernmental Panel on Climate Change (IPCC) documents the widespread and pervasive impacts of climate change on humans and social-ecological systems and indicates that we are set to surpass the 1.5°C threshold by 2040 [1]. At the same time, in many regions of the world, natural resources such as land, forests, and water have been reported to be increasingly degraded or depleted [2], and more species are threatened with global extinction than ever before [3]. To mitigate climate change, more land needs to function as a carbon sink by extracting CO_2 from the atmosphere, while the conservation of biodiversity requires more land to be protected and restored. This dilemma of climate change and environmental degradation raises several security concerns as it significantly increases the likelihood of food insecurity [4], conflicts, and crimes [5] in the absence of trust and cooperation [6], and migration and forced displacement [7–9]. This jeopardizes individual, communal, national, and international security [10–12].

In addition, these two challenges are interconnected, making them exponentially more difficult to address [13] and undermining the adaptive capacities of affected individuals and societies [14]. Climate change is eroding agricultural production and disrupting food supplies [15], thereby increasing food insecurity and health risks. The 2021 State of Food Security and Nutrition Report documents that between 720 million and 811 million people worldwide faced hunger in 2020, which is approximately 1 in 10 people, and the number of hungry people worldwide has been rising since 2014, mainly due to the growing number of conflicts, climate-related shocks, or economic slowdowns [16]. Climate change and food insecurity intensify the competition and extraction of limited natural resources, which have been increasingly degraded [7]. Increases in land degradation and water scarcity, in turn, exacerbate climate change and food insecurity [17] and limit efforts to adapt to and mitigate climate change [18].

Figure 1



Conceptual linkages between climate change and environmental degradation with security risks and the land use pathways to address the risks and increase resilience.

Individuals and communities in rural areas of the Global South are harmed first and worst [19]. This can be attributed to several reasons. First, their livelihoods heavily rely on weather-sensitive sectors such as agriculture and the extraction of increasingly degraded natural resources. Second, their welfare levels are low, and their adaptive capacity to cope with these challenges is very limited. Third, there are insufficient institutional arrangements in place to support them [20]. Fourth, these areas often exhibit high levels of fragility, socioeconomic instability, and political unrest [19]. These characteristics amplify security risks and deteriorate their resilience to change [21], leading to vicious circles of violence, vulnerability, and climate change [22]. Thus, it is crucial to comprehend the security risks posed by these interconnected challenges and enhance the resilience of vulnerable individuals and communities to address these issues, including food security.

This review article aims (i) to explicitly explore the interconnectedness of security risks arising from climate change and environmental degradation, (ii) to synthesize published evidence on the interconnectedness from the past couple of years, and (iii) to suggest evidence-based transformative pathways of land use for increasing the resilience of poor individuals and communities in the Global South to address these interconnected crises. Our focus is on the security issues at individual and communal levels rather than national or international levels, and on land transformative pathways based on the diversification of farming and food systems, ecosystem restoration, and expansion of protected areas. The focus is justified by the fact that land is the major source of livelihood for the majority of the poor peoples in the Global South and these above-mentioned security risks are directly linked to how their land is used. The focus on farmers and rural communities does by no means absolve the state of any responsibility. On the contrary, the political responsibility for creating human rights-compliant living conditions lies certainly with the governments and other stakeholders at national and international levels, and not least with the Global North which has significantly contributed to climate change and the degradation of environmental resources.

Interconnected security risks from climate change and environmental degradation

Climate change and environmental degradation, including soil and land degradation, and biodiversity loss, pose several security risks which we define as all risks that jeopardize (i) basic human rights as enshrined in the United Nations (UN) Human Rights Conventions as well as (ii) the freedom from fear. Basic human rights such as the rights to adequate food, health or personal liberty, and security are guaranteed in the International Covenant on Civil and Political Rights and the International Covenant on Economic, Social, and Cultural Rights, while the idea to 'enjoy freedom from fear' can be found in the Preamble of both Human Rights Conventions. The interconnectedness of such security risks makes it especially challenging for poor individuals and communities in rural areas of the Global South to deal with them. Figure 1 shows the line of argumentation from the global challenges around land use which result in security risks, including food and health insecurity, conflicts and crimes, and migration and forced displacement. To address the security risks, different land use pathways are suggested which are known to increase the resilience of farming households.

Food and health insecurity

Climate change increases food and health insecurity and risks the above-mentioned basic human rights to adequate food and health through both rapid- and slow-onset events. Rapid-onset events such as floods, droughts, and storms destroy crop and livestock production and increase the risks of food insecurity [23]. Fluctuations in temperature and precipitation reduce

the productivity of staple crops [24]. Evidence suggests that yields of many staple crops have already been compromised, leading to a drop in estimated caloric availability in nearly half of all food-insecure countries [25]. Other pillars of food security also turn out to be affected by climate change. Extreme weather events disrupt food supply chains and reduce the disposable income of individuals and households in affected regions, thereby reducing access to food [26]. Furthermore, food stability and utilization can be negatively impacted by climate change due to changes in food prices and links to other goods and services such as sanitation, when climate change puts a strain on the provision of safe drinking water and causes changes in the nutrient composition of food [27].

Climate change exacerbates environmental degradation through its impacts on livelihoods, loss of biodiversity, ecosystem services, and increased competition for natural resources. This is partly due to the rise in sea level and the reduction in arable land [28]. For example, the recent massive floods in Pakistan that occurred in mid-2022 cost over US$ 30 billion, affecting millions of people [29]. In addition, the increasing trends of land degradation and population growth have also led to a greater demand for food, water, and other natural resources, resulting in increased competition for their acquisition [30].

Moreover, prioritizing climate change mitigation strategies without considering other issues such as food insecurity could lead to policy failure. While food insecurity is affected by climate change, a recent study indicates that a comprehensive strategy to mitigate climate change and reduce greenhouse gases could also negatively impact food security through indirect effects on price increases and shortages of agricultural commodities [31]. This suggests that an action to minimize environmental degradation and the impact of climate change should not undermine the food insecurity of millions of poor around the world. For example, Fujimori [32] reports that land-based mitigation can affect food markets and food security and suggests that these be incorporated into climate change mitigation strategies.

Climate disasters disrupt food systems [33], thereby exacerbating food insecurity and making public health systems vulnerable. Food insecurity triggers health problems and is also one of the major reasons for malnutrition and the associated negative health outcomes. Several types of diseases are reported due to food insecurity such as dyslipidaemia, hypertension, overweight, underweight, diabetes mellitus, and cardiovascular diseases, and they are likely to increase in the future due to climate change [34]. Climate change also favors the emergence, recurrence, and spread of infectious diseases [35] making people health-insecure. It also undermines many of the social determinants of good health, such as livelihoods, equality and access to health care, and social support structures [36]. Extreme events such as heat waves, wildfires, and floods triggered by climate change have been reported to have direct psychological effects, such as increased depression, anxiety, and other mental health problems [37], commonly known as climate distress or climate anxiety, especially in young people [38]. The increase in the frequency and intensity of climate-related disasters has resulted in deaths and illnesses in recent years [39]. These climate-sensitive health risks are disproportionately perceived by the most vulnerable and disadvantaged, including women, children, ethnic minorities, poor communities, migrants or displaced persons, older populations and those with underlying health conditions [40].

Likewise, environmental degradation has several negative impacts on human health. It leads to respiratory and infectious diseases via air pollution or triggers the main health problems mentioned above via food insecurity and increasing water scarcity. Moreover, environmental degradation, especially via the exploitation of forests, is likely to amplify changes in the emergence of novel diseases, leading to precarious health situations in many parts of the world [40].

Conflicts and crimes

Perhaps the most visible security concerns related to climate change and environmental degradation are that these may increase the risk of conflicts through either direct or indirect impacts or both, where conflict is understood as a disagreement or dispute between at least two parties, regardless of whether they are countries, regions, human groups, or individuals (interpersonal insecurity). When conflicts arise, they can turn violent, or have devastating consequences, including politically motivated crime. Therefore, although some forms of conflict provide an opportunity for cooperation and lead to a positive outcome, it is important to prevent conflicts from occurring and to find peace-building solutions in a conflict-affected environment [41].

Climate change increases the risk of conflicts and crimes through direct and indirect pathways [42,43]. The direct pathways include behavioural effects and those related to resource scarcity. In addition to conflicts, security risks can also stem from very personal behavioural factors that are not directly related to a conflict with other parties. For example, food insecurity can incentivize individuals to engage in behaviours that threaten peace, as this reduces the opportunity cost of joining or supporting armed groups. At the same time, food insecurity and poverty are burdensome and can lead to grievances and generate frustration and anger, leading individuals to engage in anti-social behaviours [44]. The indirect pathways are due to diminished economic and livelihood capacity and migration and displacement [45]. Warmer temperatures

elevate discomfort, irritability, and aggressiveness, and increase hostility and violence [42]. Warmer temperatures also facilitate outdoor activities, exposing more people to offenders and leaving homes unprotected. Evidence demonstrates a positive association between a rise in daily mean temperature and an increase in sex offenses in several US cities [46], or between climate variability and crime rates in Beijing, China [47]. Climate-induced indirect pathways of loss of livelihoods, increased competition for limited natural resources, migration and forced displacement risk more conflicts [10] and their effects are associated with more crime, including disorganized crime such as theft or organized crime such as illegal logging [48], corporate pollution or even piracy and kidnapping [49]. In addition, human trafficking, money laundering, smuggling, wildlife trafficking and other criminal activities are likely to increase due to climate-induced resource scarcity [50] with a high degree of impact in developing countries where environmental degradation and poverty are greatest [50].

Food insecurity and environmental degradation have been found to be a cause and a consequence of conflict, crime, and violence. While food insecurity alone need not lead to violent conflict, it can become a key factor in increasing social ills, coupled with threats to livelihoods, socioeconomic inequalities, and political exclusion [51], as in Darfur since 2003 [52], South Sudan in 2013, Syria in 2011, and Yemen in 2018 [53]. Armed conflicts destroy agricultural land, irrigation systems, and other related infrastructure, displace people, disrupt food supply chains, and increase food prices, thereby increasing poverty and food insecurity not only for conflict-affected populations but also for people in other parts of the world [54]. Crimes related to food insecurity due to food shortages and food adulteration have been found to be linked as they reinforce Mafia-like actors in the food systems [55]. Such actors are likely to create crimes in society to increase their profits, making society unsafe and risky. Other crimes related to food insecurity include stealing food, crops, and animals from other farms and even destroying the farms. Anecdotal evidence suggests that there are numerous examples from sub-Saharan Africa and Asia, where conducting such farm destruction is common. Such crimes in food-insecure regions could provoke civil unrest, and as climate change progresses and negatively impacts agricultural production, such food-related crimes are likely to increase [55]. Conflict, crime, and food security are thus closely intertwined; if one of them escalates, the others follow, and it is the poorest and most vulnerable who suffer hardest.

Regarding environmental degradation, it is often assumed that an increase in resource scarcity is linked to an increased likelihood of conflicts and crimes [10]. Conflicts arise when there is unequal access to scarce resources, for example, when a powerful individual or group of individuals takes control of these scarce resources at the expense of weaker and poorer individuals or groups. It is also pointed out that there are always other social and economic factors that contribute to the emergence of conflicts. For example, it is often argued that conflicts are more likely to break out in poor countries of the Global South, where people's livelihood depends on sectors directly affected by climate change, such as agriculture [10].

Climate change and environmental degradation, often associated with increasingly scarce natural resources, weaken state institutions and provide opportunities for various types of crimes, including discrimination [53]. Conflicts even lead to the most serious crimes [56]. Darfur is such an example, demonstrating how a resource conflict, largely triggered by climate change, is strongly interrelated with severe social and ethnic conflicts [52]. Resource scarcity (water, food, soil) always harbors the potential for political conflict, because scarce resources trigger distribution struggles, that is, the various social and political groups formulate and try to assert their interests. These clashes of interests divide societies ('them and us'), promote radicalization and lead to intergroup conflicts. Sooner or later, these social conflicts turn into political conflicts which challenge the state [52]. In the worst case, the state takes sides with one group or another (i.e. ethnic or social group) and/or misuses the conflict for its own political interests, for example, by shifting the blame for the crisis onto 'scapegoats' or by reacting in an authoritarian or repressive manner [57].

Climate change can also provide opportunities for crime following disasters such as hurricanes, floods, or blackouts. In such situations, the abilities of the state to exercise direct control (through police and other security services) are — at least temporarily — severely reduced [43]. This demonstrates the importance of the state's role in maintaining security in the face of climate change and conflicts. This political dimension should thus not be ignored.

Migration and forced displacement

There is a strong link between climate change and migration and forced displacement [58]. Millions of people around the world are forced to leave their homes because of floods, desertification, prolonged droughts, cyclones, rising temperatures, or coastal erosion. Arguably, climate-driven disasters, both rapid- and slow-onset events, are the main drivers of migration and forced displacement. Climate-induced migration and displacement erode fragile livelihoods and ecosystems, aggravate existing vulnerabilities, and undermine the resilience of the poor in many developing countries [59]. Migration and forced displacement not only expose the affected communities and individuals to high-security risks, but

they also have serious long-term socio-economic consequences for society. The emerging issue of forced displacement is that migrants are likely to participate in protests in both the original and the new destinations, leading to societal and governance challenges [8,60].

There is mixed evidence, however, on climate-related attitudes of displaced migrants towards original and new destinations [9]. While some studies show that most home destinations of migrants suffer from labor shortages, shrinking agricultural labor capacities, and a reduction in the quantity and diversity of food crops [61], others point out that displaced migrants are likely to send remittances to their families from their new destinations that diversify their household income [9,62]. However, displaced migrants can also bring dire problems related to terrorism [63], crimes, and armed conflicts to destination countries [63]. After all, migration and forced displacement make the affected individuals and societies prone to high-security risks.

Towards more resilient land use and food production

In this section, we propose several resilient pathways of land use that are particularly relevant to poor people in rural areas of the Global South. Given that land serves as their primary source of livelihood, addressing the interconnected challenges of climate change and environmental degradation is directly tied to how their land is utilized. Our starting point is the overall goal of ensuring sustainable food production while mitigating climate change and minimizing environmental degradation. We argue that such a comprehensive approach is needed to ensure planetary health and to promote resilience, especially in the face of climate change [64,65]. We interpret resilience as the absorptive, adaptive, and transformative capability of the rural poor to deal with these two interconnected challenges.

Promoting resource and biodiversity conservation

Evidence suggests that promoting resource and biodiversity conservation can have major climate benefits and supports food production [3]. Efforts such as reforestation, coastal area rehabilitation, restoration of degraded arid- and semi-arid ecosystems, restoration of inland wetlands, and biodiversity compensation can help reverse biodiversity losses [66]. As natural resources such as forests are a major source of livelihood for the rural poor in the Global South, improving natural resource stock and conserving biodiversity are essential to them [67].

Developing agroforestry and tree-based farming systems

Agroforestry and tree-based farming systems should be promoted on marginal agricultural land where the scope for closing the crop yield gaps through agronomic interventions is limited. This can result in income security for many farmers who have less leeway to close the crop yield gaps. This will also reduce the conflicts caused by illegal deforestation and resource extraction and help improve income and reduce carbon footprint [66]. There is growing evidence that tree-based farming systems and agroforestry promote carbon storage and reduce environmental conflicts, particularly in Africa [68]. This includes various strategies such as adopting local soil management options by considering site-specific trade-offs. Agricultural programs such as improving soil health through the incorporation of legumes not only improve crop productivity but also provide natural nitrogen. This would lower the use rate of nitrogen fertilizer, which is the major contributor to greenhouse gases and a productivity-limiting factor [69]. When implementing such initiatives, it is imperative to understand the local site-specific soil degradation status, crop yield gaps, carbon sequestration potential, and incentives that can contribute to land-based mitigation strategies [70,71]. Such site-specific CO_2 reduction measures also not only minimize the risk of conflict but also contribute to food security.

Diversifying crops and using climate-resilient cultivars and neglected and underutilized plants

In recent decades, the intensification of cultivation aimed at enhancing productivity has had unintended consequences. Not only has it led to the loss of biodiversity, but it also has resulted in increased CO_2 emissions and environmental degradation [72]. Most of the global food production comes from regions with high levels of environmental degradation and associated human health costs [73]. For example, food production in Latin America, which is a major contributor to global food security, comes at a high environmental cost as agricultural land expands through deforestation. There is an empirical precedent showing that increasing biodiversity improves crop productivity and food security and contributes to climate-resilient agriculture [74]. Future efforts should continue to diversify crops that make land more multifunctional rather than monocultures.

Another issue is to provide smallholder farmers with climate-resilient cultivars. Breeding programs can incorporate abiotic (e.g. tolerance to drought, heat, and waterlogging) and biotic (e.g. disease, insect, and pest resistance) stress-tolerant genes into crop varieties that could resist the effects of climate change and result in higher productivity [75]. In addition, neglected and underutilized plants have a higher potential to mitigate the impacts of climate change and they have higher nutritional value [75]. Therefore, future efforts should also be directed towards integrating underutilized and neglected plants into the food systems. This will also increase local participation in food systems as local communities have better knowledge of the farming practices of these plants and these activities make them less dependent on external food systems.

Diverting towards plant food and food biofortification

Climate change affects the diet composition of various crops through decreases in soil fertility and crop yield, changed dietary nutrient composition and bioavailability, pest resistance and risk of malnutrition [76]. At the same time, red meat consumption is associated with a high ecological footprint and greenhouse gas emissions promoting climate change [77]. Future food and nutrition systems should therefore shift to plant-based foods or forage fish, bivalve, mollusks, and insects that result in less greenhouse gas emissions and lower environmental footprints [78]. However, where there is poor access to nutritious plant-based foods in the Global South, meat and livestock can still be a source of various nutrients as well as income and other social functions [77].

Food and nutrition security can also be achieved through food biofortification. There is growing evidence that the increasing levels of micronutrients content in crops can contribute to food and nutrient diversification [79,80]. Moreover, food biofortification can also help alleviate nutritional and health problems such as zinc and vitamin A deficiencies, which are more common in developing countries, particularly in sub-Saharan Africa. Food biofortification can also reduce the spread of infectious diseases, which is a major problem in developing countries, and can serve as a conflict and risk reduction strategy.

Conclusion

Our main goals were to understand the links between security risks, climate change, and environmental degradation to find sustainable transformative ways to increase the resilience of vulnerable individuals and communities in rural areas of the Global South. We identify health and food insecurity, conflicts, and crimes, as well as migration and forced displacement as security risks emerging from these two interconnected challenges. We propose that rural land use should be geared towards the promotion of resource and biodiversity conservation, development of agroforestry and tree-based farming systems, diversification of crops, and utilization of climate-resilient cultivars and neglected and under-utilized plants. We argue that engaging these pathways is vital for promoting planetary health and attaining the resilience of individuals and communities at risk of climate change, food insecurity, and environmental degradation in the Global South.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank the editor and an anonymous reviewer for their constructive and useful comments that improved the quality of the article. We thank the Asian Development Bank Institute (ADBI) for paying the open access fee for this article.

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- • of special interest
- •• of outstanding interest

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The authors use high resolution satellite data to assess the forest carbon losses and find that gross tropical forest carbon loss has doubled worldwide from 2001 to 2005 to 2015–2019, with most of the loss being associated with large-scale commodity or small-scale agriculture activities in Africa and Southeast Asia, highlighting the failure of existing strategies to reduce forest loss and emphasizing the importance of monitoring deforestation trends following the new pledges made in Glasgow.

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The authros summarize two hypotheses relating to the general support for the use of violence, which is the actual outcome authors investigated in their empirical analysis. First, the more resilient, the less likely an individual supports the use of violence following agricultural production shocks. Second, the higher the subjective perception of being resilient, the less likely an individual supports the use of violence following agricultural production shocks. The findings show that household resilience plays a key role in understanding the relationship between climate shocks and conflict risks, as less resilient individuals who report experiencing drought and associated losses are more likely to support the use of political violence. This study is based on the novel household survey data from two conflict-affected regions in the Eastern Democratic Republic of Congo.

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This research presents a systematic review of literature on climate-induced socio-environmental conflicts, arguing for the need to reframe such conflicts to better understand the complex interactions between the environment, society, and power. The review highlights the importance of considering multiple dimensions of conflicts, such as agency, identity, and justice, and suggests that a reframing of these conflicts can inform more effective policy responses.

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In this article, the authors show that global agricultural production could be severely impacted by warming temperatures, as rising temperatures are predicted to decrease both cropping frequency and yields. The authors also find that reduced cropping frequency is likely to be the most significant factor, and that even moderate warming scenarios could lead to substantial reductions in crop yields. The authors emphasize the urgent need for adaptation measures to minimize the impacts of climate change on global food security.

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This is a review article on relationship between climate chagne mitigation and the global carbon curve. The authors find that the global emissions have not significantly decreased. The authors identify several key factors that have impeded progress, including political barriers, technological and economic challenges, and individual and societal factors. The authors also suggest strategies for accelerating progress in climate mitigation, such as increasing public awareness and engagement, incentivizing technological innovation, and promoting international cooperation.

18. • Barnes ML, Wang P, Cinner JE, Graham NAJ, Guerrero AM, Jasny L, Lau J, Sutcliffe SR, Zamborain-Mason J: **Social determinants of adaptive and transformative responses to climate change**. *Nat Clim Change* 2020, **10**:823-828.
This article examines the social determinants of adaptive and transformative responses to climate change. The authors argue that social factors such as power relations, gender, culture, and historical legacies play a critical role in shaping climate responses, and that efforts to address climate change must be grounded in an understanding of these complex dynamics. The article suggests that climate action should prioritize empowering marginalized communities, promoting social justice, and incorporating diverse perspectives and knowledge systems.

19. •• Queiroz C, Norström AV, Downing A, Harmáčková ZV, De Coning C, Adams V, Bakarr M, Baedeker T, Chitate A, Gaffney O, *et al*.: **Investment in resilient food systems in the most vulnerable and fragile regions is critical**. *Nat Food* 2021, **2**:546-551.
This article argues that investing in resilient food systems is critical to address the impacts of climate change, particularly in vulnerable and fragile regions. The authors highlight the need for a comprehensive approach to building resilient food systems, which should include improving infrastructure, promoting sustainable agricultural practices, and enhancing social safety nets. The article emphasizes the urgent need for targeted investments in vulnerable regions to address the impacts of climate change and build a more sustainable food system for the future.

20. •• Nguyen TT, Nguyen TT, Do MH, Nguyen DL, Grote U: **Shocks, agricultural productivity, and natural resource extraction in rural Southeast Asia**. *World Dev* 2022, **159**:106043.
The article investigates the impact of external shocks on agricultural productivity and natural resource extraction in rural Southeast Asia using a panel dataset from Vietnam, Laos, and Cambodia. The authors find that external shocks such as natural disasters and commodity price fluctuations have a significant negative effect on agricultural productivity, and that this effect is amplified in areas where natural resource extraction is prevalent. The study suggests that policies aimed at promoting diversification and resilience in rural economies could mitigate the negative impacts of external shocks.

21. • de Coning C: **Adaptive peace operations: navigating the complexity of influencing societal change without causing harm**. *Int Peace* 2020, **27**:836-858.
The article argues that traditional peace operations have not been effective in addressing the complexity of conflicts in many parts of the world, and that a new approach called "adaptive peace operations" is needed. The author defines adaptive peace operations as a process of continuous learning and adaptation to the context and emphasizes the importance of avoiding unintended negative consequences of intervention. The article concludes that adaptive peace operations require a new mindset, new tools and methods, and a focus on building trust and partnerships with local actors.

22. •• Buhaug H, Von Uexkull N: **Vicious circles: violence, vulnerability, and climate change**. *Annu Rev Environ Resour* 2021, **46**:545-568.
The article examines the complex relationships between climate change, violence, and vulnerability, and how they create vicious cycles that reinforce each other. The authors argue that climate change exacerbates existing social and economic inequalities, leading to conflicts and violence, which in turn further undermines the ability of communities to cope with climate change impacts. The study suggests that addressing the underlying drivers of vulnerability and violence is crucial for building resilience to climate change and achieving sustainable development.

23. •• Hasegawa T, Sakurai G, Fujimori S, Takahashi K, Hijioka Y, Masui T: **Extreme climate events increase risk of global food insecurity and adaptation needs**. *Nat Food* 2021, **2**:587-595.
The article analyzes the impact of extreme climate events on global food security and the adaptation needs required to address them. The authors find that extreme weather conditions such as heatwaves,

droughts, and floods can significantly reduce crop yields, increasing the risk of food insecurity. The study suggests that climate change adaptation strategies should prioritize improving agricultural productivity and increasing the resilience of food systems, while also addressing the social and economic factors that contribute to vulnerability.

24. •• Grote U, Fasse A, Nguyen TT, Erenstein O: **Food security and the dynamics of wheat and maize value chains in Africa and Asia**. *Front Sustain Food Syst* 2021, **4**:1-17.

The article examines the dynamics of wheat and maize value chains in Africa and Asia and their contribution to food security in these regions. The authors find that the value chains for these crops are complex and involve multiple actors and activities, from production and processing to marketing and distribution. The study suggests that improving the efficiency and inclusiveness of these value chains can help to enhance food security by increasing the availability, accessibility, and affordability of wheat and maize products.

25. Ray DK, West PC, Clark M, Gerber JS, Prishchepov AV, Chatterjee S: **Climate change has likely already affected global food production**. *PLoS One* 2019, **14**:1-18.

26. •• Richards CE, Lupton RC, Allwood JM: **Re-framing the threat of global warming: an empirical causal loop diagram of climate change, food insecurity and societal collapse**. *Clim Change* 2021, **164**:49.

The article proposes an empirical causal loop diagram that illustrates the complex interactions between global warming, food insecurity, and societal collapse. The authors argue that the current framing of climate change as a technical problem that can be solved through technological solutions and market mechanisms overlooks the systemic nature of the problem. The study suggests that addressing climate change requires a more holistic approach that considers the social, economic, and political dimensions of the problem, and that engages stakeholders at all levels to build resilience and adapt to the changing climate.

27. •• Köberle AC: **Food security in climate mitigation scenarios**. *Nat Food* 2022, **3**:98-99.

The article explores the potential trade-offs between food security and climate mitigation efforts, and how they can be addressed. The author argues that climate mitigation strategies such as land-use changes and shifts to low-carbon diets can have significant impacts on food security, particularly in developing countries where agriculture is a major source of livelihoods. The author suggests that policies aimed at promoting sustainable agriculture, improving access to markets and finance, and reducing food waste can help to ensure that climate mitigation efforts do not compromise food security.

28. • Chen CC, McCarl B, Chang CC: **Climate change, sea level rise and rice: global market implications**. *Clim Change* 2012, **110**:543-560.

The article analyzes the potential market implications of climate change and sea level rise on global rice production and trade. The authors use a modeling approach to simulate the effects of climate change on rice yields and the resulting impacts on production, trade, and prices and finds that climate change could lead to significant reductions in global rice production and trade, with the most vulnerable regions being those with low-income populations that heavily rely on rice as a staple food. The article suggests that adaptation measures such as developing new rice varieties and improving irrigation systems can help to mitigate the negative impacts of climate change on rice production and trade.

29. •• Bhutta ZA, Bhutta SZ, Raza S, Sheikh AT: **Addressing the human costs and consequences of the Pakistan flood disaster**. *Lancet* 2022, **400**:1287-1289.

The article highlights the human costs and consequences of the 2010 Pakistan flood disaster, which was one of the largest and most devastating natural disasters in recent history. The authors describe the challenges faced in responding to the disaster, including the lack of preparedness, limited resources, and the complex social, economic, and political factors that contributed to the disaster. The study emphasizes the importance of addressing the root causes of vulnerability and strengthening disaster risk reduction efforts to prevent similar disasters in the future.

30. • Harvey M, Pilgrim S: **The new competition for land: food, energy, and climate change**. *Food Policy* 2011, **36**:S40-S51.

The article discusses the emerging competition for land use between food, energy, and climate change mitigation efforts. The authors argue that the growing demand for biofuels as a low-carbon alternative to fossil fuels is leading to the conversion of agricultural land to energy crops, which can negatively impact food security and contribute to deforestation and biodiversity loss. The study suggests that addressing this competition for land requires a more integrated approach that balances the social, economic, and environmental trade-offs between food, energy, and climate change mitigation efforts.

31. Hasegawa T, Fujimori S, Havlík P, Valin H, Bodirsky BL, Doelman JC, Fellmann T, Kyle P, Koopman JFL, Lotze-Campen H, *et al*.: **Risk of increased food insecurity under stringent global climate change mitigation policy**. *Nat Clim Chang* 2018, **8**:699-703.

32. •• Fujimori S, Wu W, Doelman J, Frank S, Hristov J, Kyle P, Sands R, van Zeist WJ, Havlik P, Domínguez IP, *et al*.: **Land-based climate change mitigation measures can affect agricultural markets and food security**. *Nat Food* 2022, **3**:110-121.

The article analyzes the potential impacts of land-based climate change mitigation measures on agricultural markets and food security. The authors use a modeling approach to simulate the effects of various mitigation measures, including afforestation, bioenergy production, and soil carbon sequestration, on land use, crop production, and food prices. The study finds that these mitigation measures can have significant impacts on agricultural markets and food security, with the potential to increase or decrease food prices depending on the specific measure and implementation scenario. The article suggests that a more integrated approach is needed to balance the trade-offs between climate change mitigation and food security objectives.

33. •• Davis KF, Downs S, Gephart JA: **Towards food supply chain resilience to environmental shocks**. *Nat Food* 2021, **2**:54-65.

The article discusses the need for food supply chain resilience in the face of environmental shocks, such as extreme weather events and climate change. The authors argue that current food supply chains are vulnerable to these shocks and require systemic changes to become more resilient, including diversification of production and supply chain pathways, investment in infrastructure and technology, and development of adaptive governance mechanisms. The study provides a framework for assessing the resilience of food supply chains and offers policy recommendations for promoting greater resilience in the face of environmental shocks.

34. •• Militao EMA, Salvador EM, Uthman OA, Vinberg S, Macassa G: **Food insecurity and health outcomes other than malnutrition in Southern Africa: a descriptive systematic review**. *Int J Environ Res Public Health* 2022, **19**:5082.

This systematic review article examines the relationship between food insecurity and non-malnutrition health outcomes in Southern Africa. The study finds that food insecurity is associated with a range of negative health outcomes, including increased risk of infectious diseases, mental health disorders, and chronic diseases such as diabetes and hypertension. The article highlights the need for greater attention to food security in health interventions and policymaking in Southern Africa.

35. • Hess J, Boodram LLG, Paz S, Stewart Ibarra AM, Wasserheit JN, Lowe R: **Strengthening the global response to climate change and infectious disease threats**. *BMJ* 2020, **371**:1-7.

This article highlights the connections between climate change and infectious disease threats, and the need for a strengthened global response to address these challenges. The authors discuss the potential impacts of climate change on infectious disease transmission, as well as the need for greater collaboration between public health and climate change experts. The article calls for increased investments in research, surveillance, and interventions to mitigate the health impacts of climate change and infectious disease threats.

36. •• Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Beagley J, Belesova K, Boykoff M, Byass P, Cai W, Campbell-Lendrum D, *et al*.: **The 2020 report of the lancet countdown on health and climate change: responding to converging crises**. *Lancet* 2021, **397**:129-170.

This article analyzes the impact of climate change on health and evaluates the response of governments and the global community. The report highlights the urgent need to reduce greenhouse gas emissions and transition to a sustainable and healthy future. It also underscores the importance of addressing social determinants of health and the need for global collaboration and political will to tackle the converging crises of climate change, COVID-19, and social inequalities.

37. Clayton S, Karazsia BT: **Development and validation of a measure of climate change anxiety**. *J Environ Psychol* 2020, **69**:101434.

38. • Wu J, Snell G, Samji H: **Climate anxiety in young people: a call to action**. *Lancet Planet Heal* 2020, **4**:e435-e436.

This article highlights the mental health impacts of climate change on young people, including anxiety, stress, and depression. It argues that

climate change-induced mental health issues must be recognized and addressed as a global public health concern. The authors call for the implementation of measures such as public awareness campaigns, mental health support services, and climate action plans to mitigate the negative impacts of climate change on mental health.

39. •• Vicedo-Cabrera AM, Scovronick N, Sera F, Royé D, Schneider R, Tobias A, Astrom C, Guo Y, Honda Y, Hondula DM, *et al.*: **The burden of heat-related mortality attributable to recent human-induced climate change**. *Nat Clim Change* 2021, **11**:492-500.
This study quantifies the number of excess heat-related deaths attributable to human-induced climate change over the past three decades. The researchers found that around a third of the global heat-related deaths observed from 1991 to 2018 can be attributed to human-induced climate change. The results suggest that immediate action is needed to reduce greenhouse gas emissions and prevent further heat-related deaths in the future.

40. WHO: **COP26 Special Report on Climate Change and Health. The Health Argument for Climate Action**. World Health Organization; 2021.

41. •• Krampe F, Smith ES, Hamidi MD: **Security implications of climate development in conflict-affected states implications of local-level effects of rural hydropower development on farmers in Herat**. *Polit Geogr* 2021, **90**:102454.
The article examines the security implications of rural hydropower development projects for conflict-affected communities in Afghanistan. It explores how such projects have impacted farmers' livelihoods, land-use practices, and access to water resources, which are significant factors in the rural economy and food security. The study finds that rural hydropower projects have resulted in social and environmental disruptions, with potential implications for security and stability in the region.

42. • Koubi V: **Climate change and conflict**. *Annu Rev Polit Sci* 2019, **22**:343-360.
This article provides an overview of the existing research on the relationship between climate change and conflict. It highlights the complex and multidimensional nature of this relationship, which can operate through multiple pathways, such as resource scarcity, economic shocks, and state fragility. The authors argue that while climate change is not the sole cause of conflict, it can exacerbate pre-existing vulnerabilities and increase the risk of violence.

43. • Agnew R: **Dire forecast: a theoretical model of the impact of climate change on crime**. *Theor Criminol* 2012, **16**:21-42.
This article proposes a theory about how climate change may lead to an increase in crime. The author suggests that environmental pressures caused by climate change, such as extreme weather events and resource depletion, may lead to increased stress and strain on individuals and communities, which in turn may lead to an increase in criminal behavior. The author also argues that climate change may lead to greater economic inequality, which can also be a contributing factor to crime.

44. Brück, Tilman; Habibi, Negar; Sneyers, Astrid; Stojetz, Wolfgang; Van Weezel S.: **The Relationship Between Food Security and National Security;** 2016. Available online at https://isdc.org/wp-content/uploads/2019/08/Food-Security-and-Conflict-2016-12-22.pdf. Accessed April, 2023.

45. •• Sharifi A, Simangan D, Lee CY, Reyes SR, Katramiz T, Josol JC, Dos Muchangos L, Virji H, Kaneko S, Tandog TK, *et al.*: **Climate-induced stressors to peace: a review of recent literature**. *Environ Res Lett* 2021, **16**:073006.
The article reviews recent literature on climate-induced stressors to peace. It analyzes the implications of climate change-related impacts, such as natural disasters, food and water insecurity, migration, and conflict over resources, for peace and stability in affected regions. The authors argue that climate-induced stressors should be considered in peacebuilding efforts and that a multi-dimensional approach is needed to address the complex and interrelated challenges posed by climate change.

46. Xu R, Xiong X, Abramson MJ, Li S, Guo Y: **Association between ambient temperature and sex offense: a case-crossover study in seven large US cities, 2007–2017**. *Sustain Cities Soc* 2021, **69**:102828.

47. • Shen B, Hu X, Wu H: **Impacts of climate variations on crime rates in Beijing, China**. *Sci Total Environ* 2020, **725**:138190.
This article investigated the relationship between climate variations and crime rates in Beijing, China. The authors used time-series data to explore the correlation between temperature, precipitation, and crime rates from 2005 to 2015. The results showed that higher temperatures and lower precipitation were significantly associated with increased crime rates in Beijing.

48. •• Souza LEV de, Fetz M, Zagatto BP, Pinho NS: **Violence and illegal deforestation: the crimes of "environmental militias" in the Amazon forest**. *Capital Nat Soc* 2022, **33**:5-25.
This article provides a detail analysis of the links between deforestation and violence in the Amazon region, highlighting how the presence of illegal armed groups, known as "environmental militias", exacerbates the environmental and social impacts of deforestation. The authors describe how these groups use violence to control land, intimidate local communities, and carry out illegal activities such as logging, mining, and farming. They argue that addressing the problem of environmental militias requires a multifaceted approach that involves strengthening law enforcement, promoting sustainable land-use practices, and supporting local communities.

49. Eklow K, Krampe F: Climate-related Security Risks and Peacebuilding in Somalia. Stockholm International Peace Research Institute; 2019.

50. Tiscornia L: **How climate change affects organized criminal group behavior**. *Stud Comp Int Dev* 2022, **58**:29-54, https://doi.org/10.1007/s12116-022-09360-1

51. •• Kemmerling B, Schetter C, Wirkus L: **The logics of war and food (in)security**. *Glob Food Secur* 2022, **33**:100634.
The article discusses the relationship between war and food security. The authors argue that war affects food security through various channels, such as displacement, destruction of infrastructure, and disruption of trade. Furthermore, they suggest that food insecurity can also be a driver of conflict, as it can create grievances and exacerbate existing tensions. Finally, the article highlights the need for integrated approaches that address both food security and conflict prevention to achieve sustainable peace.

52. Hagan J, Rymond-Richmond W: **The collective dynamics of racial dehumanization and genocidal victimization in Darfur**. *Am Sociol Rev* 2008, **73**:875-902.

53. Bjornlund V, Bjornlund H, van Rooyen A: **Why food insecurity persists in sub-Saharan Africa: a review of existing evidence**. *Food Secur* 2022, **14**:845-864.

54. •• Nguyen TT, Timilsina RR, Sonobe T, Rahut DB: **Interstate war and food security: implications from Russia's invasion of Ukraine**. *Front Sustain Food Syst* 2023, **7**:1080696.
The article discusses the impact of the recent invasion of Ukraine by Russia on food security, particularly in the regions affected by the conflict. The authors argue that the war has led to a significant decrease in food security due to disrupted trade, reduced agricultural production, and increased food prices. The authors also highlight the importance of effective governance and policies that can mitigate the negative impacts of conflict on food security.

55. •• Rizzuti A: **Organised food crime: an analysis of the involvements of organised crime groups in the food sector in England and Italy**. *Crime Law Soc Change* 2021, **78**:463-482.
This article examines the involvement of organized crime groups in the food sector in England and Italy. It discusses the characteristics and modus operandi of these criminal organizations, as well as the challenges in investigating and prosecuting such crimes. The study concludes by highlighting the importance of international cooperation and intelligence sharing to tackle organized food crime.

56. Hahn Rafter Nicole: **The crime of all crimes: toward a criminology of genocide**. New York University Press; 2016.

57. White R: **Climate Change Criminology**. Bristol University Press; 2020.

58. Hoffmann R, Šedová B, Vinke K: **Improving the evidence base: a methodological review of the quantitative climate migration literature**. *Glob Environ Change* 2021, **71**:102367.

59. • Kaczan DJ, Orgill-Meyer J: **The impact of climate change on migration: a synthesis of recent empirical insights**. *Clim Change* 2020, **158**:281-300.
Two authors of this paper from Australia and USA, conducted a meta-analysis of empirical studies to synthesize recent insights into the impact of climate change on migration. They found that climate-induced migration occurs primarily within national borders and is largely driven by short-term, non-permanent movements. The authors also noted that

the environmental factors that contribute to migration are complex and interact with political, economic, and social factors, making it difficult to attribute migration solely to climate change. Additionally, the authors highlighted the need for better data and methods to accurately measure climate-induced migration and inform policy decisions.

60. Petrova K: **Natural hazards, internal migration and protests in Bangladesh**. *J Peace Res* 2021, **58**:33-49.

61. Blackmore I, Rivera C, Waters WF, Iannotti L, Lesorogol C: **The impact of seasonality and climate variability on livelihood security in the Ecuadorian Andes**. *Clim Risk Manag* 2021, **32**:100279.

62. Cattaneo C, Bosetti V: **Climate-induced international migration and conflicts**. *CESifo Econ Stud* 2017, **63**:500-528.

63. Asaka JO: **Climate change — terrorism nexus? A preliminary review/ analysis of the literature**. *Perspect Terror* 2021, **15**:81-92.

64. •• Sampath V, Nadeau KC, Ebi KL, Narvaez D, Tessema MT, Pak-Gorstein S, Darmstadt GL: **Improving planetary health is integral to improving children's health — a call to action**. *Pediatr Res* 2022, https://doi.org/10.1038/s41390-022-02432-x.
The article emphasizes the importance of planetary health and how it affects children's health. It highlights the interconnections between human health, the environment, and the ecosystem. The authors call for a concerted effort from policymakers, healthcare providers, and individuals to improve planetary health to achieve better child health outcomes.

65. Myers SS, Pivor JI, Saraiva AM: **The São Paulo declaration on planetary health**. *Lancet* 2021, **398**:1299.

66. •• Shin YJ, Midgley GF, Archer ERM, Arneth A, Barnes DKA, Chan L, Hashimoto S, Hoegh-Guldberg O, Insarov G, Leadley P, *et al*.: **Actions to halt biodiversity loss generally benefit the climate**. *Glob Chang Biol* 2022, **28**:2846-2874.
The article highlights that the actions taken to protect biodiversity could help mitigate climate change. The article is based on a systematic review of various studies and reports from around the world that focus on the interconnection between biodiversity and climate change. The findings suggest that taking measures to preserve biodiversity could also reduce greenhouse gas emissions, conserve carbon storage, and enhance ecosystem services, thereby providing a range of co-benefits to society.

67. •• Ricciardi V, Mehrabi Z, Wittman H, James D, Ramankutty N: **Higher yields and more biodiversity on smaller farms**. *Nat Sustain* 2021, **4**:651-657.
The study examines the potential of small-scale agriculture to address the challenges of food security and biodiversity conservation. The authors found that smaller farms tend to have higher yields and greater biodiversity per unit of land compared to larger farms. The findings suggest that promoting small-scale agriculture could help to enhance both food security and biodiversity conservation.

68. •• Pokorny B, Robiglio V, Reyes M, Vargas R, Patiño Carrera CF: **The potential of agroforestry concessions to stabilize Amazonian forest frontiers: a case study on the economic and environmental robustness of informally settled small-scale cocoa farmers in Peru**. *Land Use Policy* 2021, **102**:105242.
The article describes a case study on the economic and environmental benefits of agroforestry concessions in the Amazonian Forest frontiers. The study focuses on informally settled small-scale cocoa farmers in Peru who are often vulnerable to deforestation and land degradation. The results of the study suggest that agroforestry concessions can provide a viable alternative for these farmers, promoting economic stability and environmental conservation.

69. •• Bonilla-Cedrez C, Chamberlin J, Hijmans RJ: **Fertilizer and grain prices constrain food production in sub-Saharan Africa**. *Nat Food* 2021, **2**:766-772.
The study finds that access to affordable fertilizers is one of the main constraints to increasing agricultural productivity and food security in sub-Saharan Africa. The researchers found that the current prices of fertilizers in the region are three to four times higher than in other parts of the world. Additionally, the study suggests that price volatility in grain markets further exacerbates food insecurity in the region.

70. • Rumpel C, Amiraslani F, Koutika LS, Smith P, Whitehead D, Wollenberg E: **Put more carbon in soils to meet paris climate pledges**. *Nature* 2018, **564**:32-34.
The article argues that increasing carbon sequestration in soils through sustainable land use practices can contribute significantly to mitigating climate change. The authors suggest that soil organic carbon (SOC) could be increased by 0.4 ± 0.2 gigatons (Gt) per year globally by 2030 through feasible land management practices. This could help to offset 2–3 billion tons of CO_2 emissions per year, making a significant contribution towards meeting the goals of the Paris Climate Agreement. The authors propose several strategies to increase SOC, including promoting conservation agriculture, agroforestry, and improving soil management practices in livestock production systems.

71. • Amelung W, Bossio D, de Vries W, Kögel-Knabner I, Lehmann J, Amundson R, Bol R, Collins C, Lal R, Leifeld J, *et al*.: **Towards a global-scale soil climate mitigation strategy**. *Nat Commun* 2020, **11**:1-10.
This article argues that an increase in the carbon content of soil is necessary to mitigate climate change. It presents a comprehensive review of the current knowledge on soil carbon sequestration and highlights the potential for soil carbon management to contribute to climate change mitigation. The article identifies several opportunities for increasing soil carbon, such as improving land use practices, promoting agroforestry, and applying organic amendments. The authors also call for coordinated international action and financing to support soil carbon management practices.

72. Menegat S, Ledo A, Tirado R: **Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture**. *Sci Rep* 2022, **12**:1-13.

73. Morris M, Sebastian AR, Perego VME: **Future Foodscapes: Re-imagining Agriculture in Latin America and the Caribbean**. World Bank Group; 2020.

74. • Tamburini G, Bommarco R, Wanger TC, Kremen C, van der Heijden MGA, Liebman M, Hallin S: **Agricultural diversification promotes multiple ecosystem services without compromising yield**. *Sci Adv* 2020, **6**:eaba1715.
This paper demonstrates that agricultural diversification leads to multiple benefits for both farmers and the environment by promoting ecosystem services such as pest control and pollination. The authors found that diversified farming practices such as intercropping and crop rotation not only increase yield stability but also promote soil fertility, which can mitigate the effects of climate change. Additionally, the authors argue that agricultural diversification can reduce reliance on external inputs like pesticides and fertilizers, which can have negative environmental impacts.

75. •• Kulkarni AP, Kuchanur PH, Satihal DG, Zaidi PH, Rahut DB: **Stress-resilient maize hybrid adoption factors and impact: Evidence from rain-fed agroecologies of Karnataka state, India**. *Front Sustain Food Syst* 2022, **6**:909588.
The study analyzes the adoption of stress-resilient maize hybrids in rain-fed agro-ecologies in Karnataka state, India. The results suggest that farmers who have access to irrigation and extension services have a higher likelihood of adopting stress-resilient maize hybrids. Furthermore, the adoption of these hybrids leads to increased yield, improved food security, and higher incomes for farmers.

76. •• Owino V, Kumwenda C, Ekesa B, Parker ME, Ewoldt L, Roos N, Lee WT, Tome D: **The impact of climate change on food systems, diet quality, nutrition, and health outcomes: a narrative review**. *Front Clim* 2022, **4**:941842.
This article provides a narrative review of the impact of climate change on food systems, nutrition, diet quality, and health outcomes. The authors discuss how climate change leads to reduced agricultural productivity, lower availability, and access to nutritious foods, and increases in food prices, which can negatively impact the diet quality and nutritional status of individuals, particularly those in low-income countries. Additionally, the article highlights the potential indirect effects of climate change, including the increased risk of infectious diseases and mental health problems, and the challenges in adapting to climate change and promoting sustainable food systems. The authors conclude by calling for a multifaceted approach to address the complex challenges of climate change and food systems, including policies that support sustainable agriculture, food waste reduction, and nutrition education programs.

77. •• Parlasca MC, Qaim M: **Meat consumption and sustainability**. *Annu Rev Resour Econ* 2022, **14**:17-41.
This article explores the impact of meat consumption on sustainability. The authors argue that meat consumption contributes to environmental problems such as greenhouse gas emissions, water pollution, and

deforestation, and that reducing meat consumption can contribute to a more sustainable food system. They discuss potential strategies for reducing meat consumption, including education and awareness campaigns, policy interventions, and technological innovations. The authors also highlight the need for a more comprehensive approach to sustainability that considers the economic, social, and environmental dimensions of food production and consumption.

78. • Kim BF, Santo RE, Scatterday AP, Fry JP, Synk CM, Cebron SR, Mekonnen MM, Hoekstra AY, de Pee S, Bloem MW, *et al*.: **Country-specific dietary shifts to mitigate climate and water crises**. *Glob Environ Chang* 2020, **62**:101926.

The article suggests that shifting dietary patterns can help mitigate climate change and water scarcity in specific countries. The authors provide country-specific recommendations for changes in dietary habits that can reduce the environmental impact of food production while ensuring food security and nutritional adequacy. The article highlights the importance of considering local contexts and cultural factors when promoting sustainable dietary shifts.

79. Tripathi S, Bahuguna RN, Shrivastava N, Singh S, Chatterjee A, Varma A, Jagadish SVK: **Microbial biofortification: a sustainable route to grow nutrient-rich crops under changing climate**. *F Crop Res* 2022, **287**:108662.

80. •• Praharaj S, Skalicky M, Maitra S, Bhadra P, Shankar T, Brestic M, Hejnak V, Vachova P, Hossain A: **Zinc biofortification in food crops could alleviate the zinc malnutrition in human health**. *Molecules* 2021, **26**:1-17.

The article reviews the significance of zinc as a vital micronutrient for human health and the challenges of zinc deficiency worldwide. Zinc biofortification, which is the process of enhancing the concentration of zinc in edible parts of crops, is proposed as a sustainable and cost-effective approach to combat zinc deficiency. The article discusses several zinc biofortification strategies, including agronomic practices, breeding techniques, and genetic engineering, and highlights the potential of this approach to improve the nutritional quality of crops and human health.