***The environmental polycrisis and Global Production Networks: Insights from agriculture in South Africa, Kenya and Nicaragua***

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# Abstract

The environmental polycrisis, including climate change, biodiversity loss and water scarcity, touches down in agricultural Global Production Networks (GPNs) through different environmental interactions. Drawing on environmental economic geography and critical systems thinking, we propose a novel conceptualisation to trace environmental interactions of influence, disruption, and synergy, and their implications for GPNs, GPN actors and the environmental risks they face. Through empirical material from horticulture in South Africa and Kenya and cocoa in Nicaragua, we demonstrate this conceptualisation’s relevance by showing how environmental interactions reshape GPNs, creating uneven environmental risks for smallholders accompanied by often adverse economic and social implications.

Keywords: Polycrisis, Global Production Networks, environment, agriculture, climate change, value chains

# Introduction

Covid-19, a steady stream of news on (trade) wars alongside catastrophic floods, droughts and wildfires – it is crisis upon crisis, which have recently been conceptualised as a polycrisis, the effects of which accelerate, amplify or reinforce each other (Helleiner, 2024; Lawrence et al., 2022; Tooze, 2022). As entangled economic, social, and environmental shocks have increased in frequency and magnitude, we argue that the environmental dimension is a critical component of the polycrisis because societies and economies all exist and operate within the environment. Much of the environmental dimension of the recent polycrisis has been relegated to a debate about climate change, which is often seen as a ‘single issue’ (Hoyer et al., 2023). We argue that climate change, while crucial, is only one aspect in understanding the environmental dimension of the intensely debated polycrisis, particularly when analysing agricultural production. Climate change may both cause and amplify the effects of global and local environmental crises, such as droughts, floods, soil degradation, and biodiversity loss, the impacts of which reverberate through Global Production Networks (GPNs; Henderson et al., 2002; Coe and Yeung, 2015) and Global Value Chains (GVCs; Gereffi *et al.*, 2005)[[1]](#footnote-2). However, there is a lack of research exploring (a) how specifically the intensifying environmental polycrisis interacts with and thereby (re)configures GPNs, and (b) the new forms of environmental risks that it creates, amplifies or accelerates within (and beyond) the GPN. Consequently, we explore the research question: How does the (environmental) polycrisis interact with GPNs, (re)shaping the environmental risks faced by GPN actors?

First, we make an important analytical contribution by tracing how the environmental polycrisis manifests within GPNs by developing the concept of environmental interactions. We draw on environmental economic geography (e.g. Bridge, 2008a; Bridge, 2009; Baglioni and Campling, 2017; Ponte, 2019), and (critical) systems thinking (e.g. Cabrera and Cabrera, 2019; Ortiz *et al.*, 2021; Jackson, 2024) to explain that environmental interactions not only consist of ecological stocks and flows as systems thinkers examine, but also are complex socio-ecological relations between GPN actors, their immediate environment and broader dynamics. Systems thinking focuses on pathways and outcomes of how crises materialise and manifest with what repercussions, while research in GPNs are relational analyses of how a good or service is produced and refined out of human and natural resources. Studies in agricultural GPN/GVC research predominantly focus on how actors within networks or chains re-organise their structures or strategically couple with different actors to cope with multiple crises, but this does not usually take a broader systems perspective (see e.g. Follmann *et al.*, 2024, for a review). Thus, this paper fills an important research gap by studying the pathways of how environmental polycrisis alters social and environmental dynamics both within and beyond the GPN. There has been little use of GPN’s relational analytical lens to highlight social and environmental dynamics in the context of an environmental polycrisis specifically, which we explore further below. We conceptualise three types of environmental interactions: (1) influence, where the environmental polycrisis changes the environmental conditions of production in ways that influence what GPNs can (not) produce; (2) disruptions, with the polycrisis disrupting how GPNs can function compared with GPN actors’ expectations; and (3) synergy, where the polycrisis or measures to address the polycrisis may enhance environmental functions affecting GPN actors (Ortiz et al., 2021).

Second, we explore the dynamics of how environmental interactions linked to the environmental polycrisis accelerate, amplify or mitigate environmental risks faced by GPN actors (Franz et al., 2018; Lanari & Bek, 2022). Environmental risk is a manifestation of the degradation (reversible or irreversible) of biophysical inputs available to GPN actors, intersecting with how GPN actors access and use these inputs. Floods, droughts, biodiversity loss, and other environmental degradation have been part of many societies over distant and recent histories, often independent of this current environmental polycrisis. Here we argue, however, that the confluence of undercurrents that form today’s polycrisis do intersect with and exacerbate existing as well as creating new dynamics of environmental risks which threaten agricultural production and livelihoods, particularly of smallholders. As we will highlight, the dynamic nature of a polycrisis can re-structure the conditions of production and create new socio-ecological conflicts within GPNs.

In terms of our empirical contribution, we show how the environmental polycrisis touches down in three agricultural GPNs through complex dynamics of interactions and environmental risk to demonstrate the value and different facets of our conceptualization: horticulture in Kenya (Mwangi Wangui et al., 2019), fruit in South Africa (Ijabadeniyi and Buys, 2012), and cocoa in Nicaragua (Aguilar and Guharay, 2013). We show the environmental polycrisis disrupts crop productivity by altering essential factors like genetic resources, disease, soil health, and water availability, which exacerbates socio-ecological conflicts. In Kenya, environmental risks are intensified by lead firms prioritising export crops, resulting in worsening relationships among GPN actors and increased livelihood vulnerabilities. In Nicaragua, climate change is amplifying risks to cocoa GPNs from fungal disease, though this can be mitigated if addressed through alliances of lead firms, farmers, experts and civil society. South African farmers have introduced efficient irrigation to counteract water scarcity, yet this has inadvertently increased water demand and caused tensions, though efforts like clearing invasive species have provided synergies that have balanced environmental and livelihood risks within the GPNs. Thus, we contribute local evidence from different agricultural GPNs to existing, often global-level understandings of the environmental polycrisis that solely focus on climate change, connecting the GPN-level and its biodiversity, soil and water realities to the systems-level thinking of the polycrisis. Furthermore, we contribute to unpacking the non-linear effects of multiple environmental crises on different actors and their environment within GPNs, as well as the mutually reinforcing processes of how such socio-ecological changes circulate in GPNs and broader systems. To emphasise the complexity of the polycrisis, we also account for contemporary GPN-driven power asymmetries (Coe et al., 2008) that intersect with the environmental polycrisis across these case studies. In sum, we argue that it is vital to engage with the environmental polycrisis in the analysis of (agricultural) GPNs.

The paper is structured as follows: in our conceptual framework, we first introduce the notion of the polycrisis and particularly our focus on its environmental dimensions, before linking it to environmental risks and our conceptualisation of environmental interactions. Next, we discuss our methodology that integrates critical systems with GPN mapping. We then delve into brief empirical vignettes illustrating influencing, disrupting and synergistic environmental interactions from Kenya, Nicaragua and South Africa. We conclude by discussing the non-linear paths through which the polycrisis unfolds through environmental interactions in agricultural GPNs, and implications for GPN analysis.

# Conceptual framework

In our conceptual framework, we first define the environmental polycrisis, and the importance of analysing its links to agricultural production through a critical systems thinking perspective. Following this, we conceptualise and problematise how environmental polycrisis manifests through environmental interactions in GPNs, including by drawing on environmental risks.

## 2.1 The environmental polycrisis

The polycrisis describes three or more distinct crises that are often sequential, but overlapping, and interact to accelerate, amplify or reinforce each other (Helleiner, 2024; Lawrence et al., 2022; Tooze, 2022). Polycrisis has emerged from systems thinking, linked to the concept of systematic risks, that is when a disruption affects (a part of) a system and spreads beyond system boundaries, creating or reinforcing a disequilibrium, harms and spillovers (Lawrence et al., 2022, 2024; Søgaard Jørgensen et al., 2023).

While the environment has been considered an integral part of the polycrisis, it is often assumed to be homogeneous without specifying what types of natural resources are affected in what ways, or by focusing on very specific forms of the ecological crisis, particularly climate change. However, environmental crises are heterogenous (Cooper et al., 2021; Redclift, 2010), with multiple causes simultaneously interacting to accelerate climate change, biodiversity loss, or degradation of water systems (Wenzel, 2019). Within the polycrisis literature, limited studies offer nuance on multiple environmental crises. For instance, Hoyer *et al.* (2023) suggest climate variability and disasters are a part of a polycrisis, while Søgaard Jørgensen *et al.* (2023) study the polycrisis through the lens of global evolutionary Anthropocene traps, which are increasingly hard to reverse and likely to affect human well-being. However, these studies are at global scale, and only unpack the ways societies collectively respond to a polycrisis.

While issues such as climate change or biodiversity loss are global and tend to affect marginalised groups disproportionately (IPCC, 2021), they materialise as a crisis at different rates and in diverse ways depending on contexts. For example, in agricultural production, a global environmental polycrisis may touch down as multiple local environmental crises, such as habitat and biodiversity loss, soil degradation, or droughts and floods occurring simultaneously or sequentially, with risks originating in one system entailing consequences for other sub-systems (Dixon et al., 2023). Therefore, focusing on specific networks or territories enables a deeper understanding of the ways the global environmental polycrisis manifests as local crises, and specifically how it intersects with and amplifies wider environmental issues. Drawing on critical systems thinking, economic geography, and environmental economic geography, this paper will focus on how the environmental polycrisis interacts with agricultural GPNs.

## 2.2 The environmental polycrisis and critical systems thinking

Systems thinking has been fundamental to understanding complex environmental problems such as climate change and biodiversity (Ballew et al., 2019; Ortiz et al., 2021). It is a loosely defined field (Cabrera et al., 2018) that accounts for systems theories, philosophies, perspectives, methodologies and models (Jackson, 2024) to disentangle organised and disorganised complexity across different elements (Jackson, 2024; G. Midgley, 2000). The first wave of systems thinking drew on systems dynamics and systems engineering (Bogdanov, 1984; Von Bertalanffy, 1972), offering functionalist perspectives of maintaining a state of balance and social equilibrium between interconnected components (i.e. physical units such as machines, people, resources or intangible units such as policies, information) within a system (Leleur, 2014; Mooney et al., 2007).

Predominantly environmental interactions were interpreted as non-linear causal relationships linking socio-technical system components that were defined functionally based on stocks or flows of natural resources and ecosystem services (Bosch et al., 2007), while interactions with human relations and institutions were modelled through agent-based simulations (Krakauer, 2018; G. Midgley, 2000). Relationships within functionalist systems thinking are modelled as feedback loops, i.e. interactions between different sub-components of a system. They are described as *balancing*, which are self-regulating, stabilising loops that maintain equilibrium, or as *reinforcing loops* which go in the same direction as existing dynamics, amplifying either growth or decline (Kim, 1999; Wolstenholme, 2003).

In response to questions about whether systems thinking may be too deterministic, Burton (2003) emphasised a more qualitative, participative and interpretive understanding of human systems. In this case, environmental interactions were seen to occur through the intersubjectivity of human relations with the environment, and through negotiated meanings (Ackoff, 1981; Checkland, 1980). However, some argued (Jackson, 2024; Midgley, 2000; Mingers, 2014) the need to account for power sensitivities, especially because of the different and competing levels of complexity within a system, which led to critical systems thinking.

Critical systems thinking calls for more pluralistic theoretical underpinnings and methodologies, to facilitate unpacking the hierarchy of interactions within and between different components of a system (Toulmin, 1992), including coercive and exploitative relationships with marginalised actors (Ulrich, 1983). Pluralism extended to looking at ‘multiple perspectives’ (Cabrera & Cabrera, 2019; Jackson, 2019) to better reflect how specific actors view themselves and the other system components. For instance, there has been increased focus on ethical considerations for non-human agency (Porter & Córdoba, 2009; Reynolds & Blackmore, 2013; Ulrich, 1983), offering ways to integrate literature around the social construction of nature. For instance, Hasyimi *et al.* (2024) use critical systems thinking to understand the complexity of food security by utilising plural methodologies that incorporate socio-economic and environmental factors. This ensures that food policies consider unintended consequences and stakeholder interdependencies, while utilising system dynamics modelling and scenario planning, to anticipate the impacts of climate change, land consolidation, and food safety programmes. Broadly, critical research on systems thinking suggests a plurality in perspectives and methodologies to elicit the complex relationships between different types of human and non-human actors within a system. Thus, critical systems thinking, by its very structure, suggests the ability to study polycentricity of uncertainties or shocks, especially related to the environment and actors involved (Jackson, 2024).

The globalisation of production, distribution and consumption (Kaplinsky, 2016) and rising levels of resource use matter for and drive much of today’s hyperconnected polycrisis. Through a systems lens, Ortiz *et al.* (2021) explored the connections between climate, biodiversity, trade and agriculture, who found that their interactions have been understudied, but could for instance create reinforcing feedback loops, such as farming for meat-intensive diets driving climate change, and in turn threatening agricultural productivity. However, their analysis did not account for GPN actors, nor explicitly engaged with the polycrisis and the plural lens it arguably requires. Overall, (critical) systems thinking has yet to problematise how the biodiversity and climate change polycrisis touches down in such interconnected agricultural GPNs. In combination with critical systems thinking, we use GPN literature and environmental economic geography to explore how the (environmental) polycrisis interacts with agricultural GPNs, compounding environmental risks faced by GPN actors, as explained below.

## 2.3 Conceptualising and problematising environmental interactions in GPNs

GPN research allows for unpacking power relations between lead and supplier firms (corporate power) and non-firm actors such as governments and civil society (institutional or collective power). As a relational lens rooted in economic geography and political economy, it also permits an analysis of the network, societal and territorial contexts in which lead firms are embedded and thus allows for studying the environmental underpinnings of these dynamics (Coe et al., 2008; Coe & Yeung, 2015; Henderson et al., 2002; Hess, 2004). Further developments under the banner of GPN 2.0 extend these understandings by factoring in competitive dynamics and the risk environment to investigate how firms and non-firm actors seek to enhance value creation and capture activities (Coe & Yeung, 2015). The related GVC analysis focuses on input-output structures of how goods and services flow between fragmented stages of production to consumption (Kaplinsky and Morris, 2001). GVCs primarily focus on the importance of global lead firms, and how they exert power on the other actors within the chain (Gereffi et al., 2005). Agricultural and food production have both been researched through a GPN lens (see for instance Hughes *et al.*, 2014; Irarrázaval and Bustos-Gallardo, 2019; Vicol *et al.*, 2019) and GVC lens (Challies & Murray, 2011; Havice & Campling, 2017; Lanari et al., 2024); however, only a limited number have explicitly focused on the environmental dynamics or utilised a system lens.

In agricultural GPNs, only few researchers have used critical systems thinking to understand the complexity of how ‘dynamic uncertainties’ arise beyond the scalar boundaries of GPNs and how they dynamically ‘interact’ with the GPN (Muflikh et al., 2021). Environmental uncertainties include floods, droughts, forest fires, changes in vegetation, biodiversity, and seasonality of production (Newlands et al., 2014). In systems studies that have included GPNs, there has been a greater plurality of methodologies and perspectives, drawing on interviews and different GPN actors’ views. For instance, Muflikh et al. (2021) attempted to unpack how endogenous price volatility affects Indonesian chili production networks. They found that the Indonesian government’s intervention by introducing import restrictions encouraged chili production and reduced price volatility by increasing local production, but did not mitigate unsustainable agricultural practices. This suggests a balancing loop, where external changes by the government did not significantly alter existing unsustainable practices. Another example by Kiloes et al. (2023) found that the production of low-quality mangoes in Indonesia was propelled by poor agricultural practices and high input costs. This led to lower yields and income, worsening land quality and creating a vicious reinforcing loop.

These studies suggest that environmental interactions in agricultural GPNs are worth investigating because exploitative growing practices undermine nature’s capacity to regenerate, accelerating environmental damage within GPNs. However, these studies do not offer conceptualisations to trace how the environmental polycrisis (re)shapes production in GPNs, nor how it restructures GPN actors’ relationships such as lead firms and farmers, whilst simultaneously amplifying environmental risks for GPN actors. Thus, integrating (critical) systems thinking and GPNs, we define environmental interactions as the ways in which the system-level environmental polycrisis touches down in GPNs. For the latter, we draw on environmental economic geography (EEG) to explain how crises translate and materialise within GPNs. Finally, we also discuss how environmental interactions manifest as environmental risks within GPNs (and beyond). Together, this definition provides scope for more plural theoretical and methodological approaches, connecting critical systems thinking with GPN analysis and EEG, and includes multi-actor perspectives and data. In the next section, we define what environmental risks are, before explaining our conceptualisation of environmental interactions.

### 2.3.1 Environmental risks in GPNs

The global-level environmental polycrisis is liable to accelerate and amplify environmental risks faced by GPN actors (Lanari & Bek, 2022). Recent efforts to increase the explanatory power of GPNs have introduced the concept of ‘environmental risk’ (Coe & Yeung, 2015). In this initial conceptualisation, the understanding of environmental risk is only superficially developed (see Franz, Schlitz and Schumacher, 2018 for a critique), describing only extreme events (e.g. tsunamis) and their impact on production, distribution, and consumption. Recent efforts have attempted to explore the notion of environmental risks in GPNs in more depth (Völlers et al., 2023), including an understanding of more continuous and underlying environmental risks beyond extreme events (Lanari & Bek, 2022).

Drawing on Lanari and Bek (2022), we understand environmental risks as the ecological manifestation of environmental interactions that are experienced by GPN actors*.* In that sense, environmental risks are seen as an outcome of environmental interactions. They originate from the degradation (reversible or irreversible) of biophysical inputs used by the GPN, intersecting with how GPN actors access and use these inputs amid the polycrisis. Lead firms, in particular, but also producers and suppliers, are increasingly aware of their businesses’ exposure to individual environmental risks and how they may be compounded by worsening social and ecological relations. Thus, environmental risks may lead to other risks for GPN actors, such as reputational risks (e.g. loss of social licence to operate or loss of customers/buyers), social risks (e.g. blacklisting of farmers from participation), or regulatory risks (e.g. increased regulation from government or through voluntary standards) (see Lanari and Bek, 2022). Finally, environmental risks also close the feedback loop by explaining how actions within GPNs can affect components beyond the GPN.

### 2.3.2 Environmental interactions: Environmental Polycrisis and GPNs

Drawing on EEG, we argue that the interaction between the environmental polycrisis and GPN actors is an interdependent relationship. Because agricultural GPNs are dependent on the environment for production, the dynamic nature of the environmental polycrisis can re-structure conditions of production and create new conflicts by rupturing the relations and exchanges between GPN actors and nature within GPNs (Bakker & Bridge, 2006; Banoub et al., 2021; Bridge, 2008b). Such conflicts include changing relations between powerful and marginal actors, reduced access to natural inputs for production, or reduced crop yields and quality (Angel, 2006; Baglioni, 2018). As the environmental conditions of production are dynamic and can affect the profitability of business, they can force GPN actors to adapt to constant changes in production (Bridge, 2008b). More powerful actors in GPNs such as lead firms through strategic alignment with institutions (e.g. governments) continue to enhance their profitability, while trying to adapt to or incrementally reduce, the effect of environmental risks (Havice & Campling, 2017). However, less powerful actors such as farmers in GPNs, face deeper struggles between the deterioration of natural resources that are intrinsically linked to their livelihood, and complying with lead firm requirements (Krauss & Krishnan, 2022).

Thus, the overexploitation or degradation of natural resources in GPNs can create or exacerbate environmental crises such as reduced sink effectiveness or deterioration in biophysical conditions affecting production, impacting farmers more asymmetrically than lead firms (Bridge, 2008b; Havice and Campling, 2017, Follmann et al., 2024). This suggests that environmental polycrisis reinforces accumulation and appropriation of natural resources within GPNs. Consequently, social and environmental crises are exacerbated as the natural environment’s ability to regenerate is undermined. This is both due to more intensive practices in existing production regions as well as due to the increased integration of new areas into GPNs (Baglioni & Campling, 2017; Campling, 2012). This thus enables lead firms especially with low environmental commitments to ‘leave’ particular territories of agricultural production (Krishnan et al., 2023). This equally creates balancing loops, when actors and the environment within GPNs are able to self-regulate themselves following the effects of a polycrisis (e.g. degradation being slowed by GPN actors being pushed towards better due diligence) or reinforcing feedback loops, when different components of the system affect the GPN in a way that accelerates or exacerbates existing dynamics within GPNs, creating new or deepening environmental risks (e.g. reinforcing lead firms’ corporate power leading to overexploitation) between actors in GPNs and the broader environment.

Integrating critical systems thinking and EEG, we conceptualise three environmental interactions to depict how the systems-level polycrisis, i.e. interlinked biodiversity, climate change and other global-level dynamics, touch down in agricultural GPNs.

The first interaction, *influence*, relates to how the environmental polycrisis changes the environmental conditions of production, highlighting its (re)shaping of what GPN actors can (not) produce given GPNs’ dependency on food, fuel, genetic resources, freshwater, provision of nutrient/water/waste cycling, and regulation of pollination. It also considers how socio-ecological relationships change for different actors, including how marginalisation shapes access to livelihoods, food or clean water as well as exposure to pollutants, as well as how GPN actors respond to the changes in environmental conditions (Bridge, 2008a) and the risks created or exacerbated. The second interaction, *disruption*, highlights how ongoing or one-off disruptions through the environmental polycrisis touch down in GPNs, i.e. how disruptions such as floods or droughts affect the environmental conditions of production. The disruption equally reconfigures economic interests while favouring some actors and interests over others, all of which manifest as risks for different GPN actors. The third interaction, *synergie*s, highlights how the environmental polycrisis, and responses to it, may also be beneficial to an agricultural GPN, its actors, and/or the environment in which it is embedded, and may mitigate environmental risks.

Each of these interactions will affect different GPN actors differently given existing power asymmetries, creating, exacerbating or mitigating environmental risks, which interact with wider balancing or reinforcing loops. A *balancing loop* occurs when actors and the environment within GPNs are able to self-regulate themselves following polycrisis effects to create a situation of equilibrium and ‘business as usual’, meaning socio-ecological relations will remain either good or contested. A *reinforcing loop* occurs when the different components of the system, affect the GPN in a way that accelerates or exacerbates existing (good or contested) dynamics within GPNs.For instance, in an ‘influence interaction’, reinforcing loops occur when climate change and biodiversity degradation further reduce freshwater and genetic resource material, which affects how crops are produced in GPNs. This impinges on farmers' socio-ecological relations and their access to natural resources, thus creating new environmental risks and deteriorating relations between farmers and lead firms or governments, which in turn may further exacerbate climate change and biodiversity or other environmental risks beyond the GPN.

We explain our three interactions, (1) influence, (2) disruptions and (3) synergies, in more detail in Table 1. We indicate illustrative questions on how these environmental interactions affect different GPN actors and socio-ecological relations also from a systems perspective, their links to example environmental risks (see section 2.3.1 for details) and related reinforcing or balancing loops. These three interactions should be viewed as a spectrum rather than as separate categories (Raynolds, 2009), as for instance some influence interactions can also disrupt or enhance other GPN or broader environmental functions.

***Table 1: Environmental interactions and risks in GPNs***

|  |  |  |
| --- | --- | --- |
| **Environmental interactions: how polycrisis touches down in GPNs** | **Illustrative questions related to environmental interactions and socio-ecological relations from a systems and GPN perspective** | **Environmental risks in GPNs: manifestation of environmental interactions in GPNs and related feedback loops** |
| **Influence:** Environmental polycrisis reshapes what GPN actors can (not) produce given GPNs’ dependency on food, fuel, genetic resources, freshwater, provision of nutrient/water/waste cycling, regulation of pollination etc. | As e.g. freshwater resources become scarcer, whose uses for production and livelihoods are upheld? How do lead firms, governments and farmers adjust or transform their GPN relations due to changing availabilities? | The polycrisis creates or exacerbates environmental risks faced by GPN actors e.g. around the use of or access to resources on which production depends (example of a reinforcing loop), though ‘influences’ are moderate enough that actors may be able to mitigate the risk by altering practices in response. |
| **Disruption:** Environmental polycrisis disrupts how GPNs can function compared with GPN actors’ expectations, either on a one-off or ongoing basis through e.g. rising temperatures or extreme events. | How do changes to ecological stocks and flows affect production, consumption and use of resources within GPNs? How do e.g. poor crop quality, lower yields or impossibility of standard compliance affect farmers’ relations with the environment, with government, civil-society organisations (CSOs) and lead firms? How do responses by lead firms further alter socio-ecological relations? | Disruptions resulting from the polycrisis are severe enough to create or exacerbate environmental risks affecting diverse GPN actors which are difficult or impossible to mitigate, in addition to spillovers beyond the GPN (example of a reinforcing loop). |
| **Synergy:** The polycrisis or measures to address the polycrisis such as alleviating water shortages, biodiversity loss or soil quality may enhance GPN production. | How does the polycrisis, or measures to address it, facilitate better or more efficient production? How is this shaping farmers’ workloads and livelihoods, and lead firms’, governments’ or CSOs’ expectations? | Measures to address the polycrisis may reduce environmental risks in the GPN and beyond, but may also exacerbate them by increasing resources being dedicated to GPN production and consumption (example of balancing loop). |

In sum, these environmental interactions of influence, disruption and synergy encompass different ecological stocks and flows and non-linear socio-ecological relations concerning different GPN actors, affecting environmental risks faced by them. Below, we use empirical data from horticulture and cocoa cultivation to illustrate how the systems-level polycrisis touches down in three specific GPNs through influence, disruption or synergy, while creating, amplifying or mitigating environmental risks for GPN actors. This allows us to test and demonstrate the value of our conceptualisation by illustrating the nuances of how the environmental polycrisis reshapes production conditions and relations between different GPN actors and intersects with existing economic and social dynamics, often to the detriment of more marginalised smallholders. First, however, we explain our methods in the next section.

# Methodology

## Research design

We draw on plural methodologies within critical systems thinking (Cabrera & Cabrera, 2019) as well as GPN mapping (Barrientos, 2002). This includes interview data collected through case studies to give space for plural understandings of environmental interactions. Drawing on the work of (critical) systems thinkers, we select the key components of the system, including climate change, biodiversity, agriculture and GPNs, and focus on multiple environmental crises to address what we see as a blindspot in current polycrisis discussions. The aim of this article is not to unpack what is fueling the environmental polycrisis, but investigating ways in which it is affecting agricultural GPNs and documenting these dynamics at the level of the GPN.

The case studies presented follow an in-depth approach (Yin, 2015) based on multi-year engagements with South African and Kenyan horticulture, and Nicaraguan cocoa GPN actors respectively. We used data from a range of sources, including semi-structured interviews, focus groups, document analysis (e.g. articles, grey literature on industry and NGO reports), and casual forms of observation (e.g. participation in relevant industry and NGO workshops or gatherings) to aid with the critical system and GPN mapping. A purposive snowballing sampling strategy (Flick, 2002) was utilised to conduct interviews. All interviewees were anonymised, and their confidentiality guaranteed in line with ethical approval processes of our respective Universities.

In Kenya, research was conducted between 2014 and 2019 through 65 semi-structured interviews. In South Africa, 76 semi-structured interviews were conducted in the drought-stricken Western Cape province over the course of 2017. The cocoa case study encompassed a total of 96 semi-structured interviews mostly in Nicaragua and Germany from 2014 to 2017. The actors interviewed included smallholder producers, farmer cooperatives, and large-scale producers; industry associations; national and international market actors; NGOs; academics; representatives from local, provincial, and national governments; and lead firms.

To analyse our material, we subjected all of the cleaned interview and secondary data to a thematic analysis, which is a method for identifying, analysing and reporting patterns or themes (Braun & Clarke, 2006). While the data was originally collected for other research purposes, this study reoriented the focus towards the environmental polycrisis, requiring collective and iterative development of new themes as we elaborated our conceptualisation (Srivastava & Hopwood, 2009). This involved a multi-year, multi-researcher collaboration involving dialogue, i.e. ongoing conversations between the authors that enabled the synthesis of diverse empirical contexts and perspectives (Berg, 2005; Sullivan, 2012) in conceptually driven analysis. This began with a collaborative process of recoding the data, in which each author revisited her case material with the shared purpose of exploring environmental interactions, socio-ecological dynamics, environmental risks and feedback loops. This meant recoding data as part of reanalysis, i.e. taking a second, third, and fourth look (Wästerfors et al., 2014). Iteratively, we brought together insights from our respective cases, identified convergences and tensions, and collectively refined emergent thematic codes, trialling and refining different conceptualisations together which draw on economic geography, political economy and GPNs, environmental economic geography, and critical systems thinking (see section 2.2). Given the themes emerging from our data, through collective reflection, we synthesised these recurring dynamics into the three conceptual categories: influence as a more ambiguous interaction, synergy as interactions with predominantly benefits or win-win feedbacks, disruption for interactions with mostly negative implications amplifying environmental risk.

To ensure consistency and rigour, we used the software tool NVivo 12 to organise and analyse both primary and secondary data in a systematic manner (Yin, 2013). We actively contrasted how similar dynamics (e.g. a synergy) played out differently in different cases, allowing us to sharpen the boundaries and meaning of each concept and understanding contextual conditions. Throughout the analysis, we shared emerging insights, disagreements, and interpretive questions. We verified the validity and reliability of the results through triangulation between primary data, observations, field notes, secondary data, follow-up interviews with some actors, and discussions among our research team (Maxwell, 2017; Yin, 2015).

## 3.2 Case studies

**South Africa-UK GPNs:** The agricultural sector in the Western Cape Province of South Africa contributes 23% to the national Agriculture, Forestry, and Fisheries sector, 3% of GDP, and 55% of all agricultural exports in 2022 (Morokong et al., 2024). It is dominated by horticultural production, which makes up 52% of the annual agricultural production value of the Province (S. Midgley et al., 2016). In 2022, roughly 216,000 people worked in the agricultural sector of the Western Cape, which amounts to 24% of the total national employment opportunities within that sector and 8.1% of the regional workforce (Morokong et al., 2024, p. 26). This is relevant as the creation of employment opportunities has been an important political priority for recurring South African governments post-apartheid. The irrigated horticulture industry is particularly labour-intensive and high-value and as a consequence has been singled out as an industry to grow and support further (NPC, 2012). This growth is facilitated by export markets, as much of the deciduous fruit produced in the Western Cape is exported. South Africa is one of the top four *pome fruit* (apples and pears) producers in the Southern Hemisphere alongside Chile, New Zealand, and Argentina and most of its summer fruit (apricots, nectarines, peaches, and plums) is also exported (S. Midgley et al., 2016).

**Kenya-UK GPNs:** Kenyan fruits and vegetables (e.g. green beans, snow peas, baby vegetables) represent one of the country's foremost foreign exchange-earners, contributing 26% of its agricultural GDP, employing 5.5 million farmers and workers, and accounting for 8% of the country’s total exports as of 2017 (Kangai & Gwademba, 2017). The UK imports over 80% of Kenyan green beans and snow peas (Barrientos, 2019). Corporate power is instrumented through CSO-driven standards GlobalGAP, Fairtrade, Organic, and supermarkets' own standards (e.g. Tesco Nature, M&S Farm to Fork). Compliance with such standards is defacto mandatory for farmer participation in GPNs (Barrientos et al., 2018). Global environmental crises manifest in Kenya through climate change and biodiversity loss intersecting with floods, droughts, high temperature, water scarcity, and loss of crop supporting species, leading to economic losses estimated at 3% of the country’s GDP (Ministry of Environment and Forestry, 2020; World Bank, 2024a). Both green beans and snow peas require well-drained loamy soil, sufficient ground water, and temperatures between 18-27C (Kenya Agriculture and Livestock Research Organization, 2016, 2019) and production is concentrated in the sub-counties Kirinyaga, Meru, Murang’a, and Nyandarua, which together produce over 90% of both crops (Agriculture and Food Authority, 2022). Both crops are considered ‘alien’ crops (Krishnan, 2018) because they were introduced to the country by European traders and supermarkets in the late 1970s (Dolan & Humphrey, 2004). Thus, they are not indigenous to the ecosystem, and introduced variants of new diseases (Okello et al., 2007).

**Nicaragua-Europe GPNs:** In rural Nicaragua, cocoa production constitutes a relevant source of income. In 2020, approximately 40% of the country’s 6 million inhabitants lived in rural spaces, with agriculture, forestry and fisheries accounting for 15% of the country’s GDP (World Bank, 2024b). The country with significant forest cover has seen a steady rise in cocoa exports, from 1,500 metric tonnes in 2009 to 6,000 metric tonnes in 2020, with Belgium and Germany as two key destinations (Revista Nicaragua Exporta, 2021). While cocoa exports are significant, there is also in-country consumption of cocoa in maize drinks such as Pinolillo, although domestic sales yield lower prices and require more labour in terms of post-processing for farmers (interviews #34, #51, civil society). As cocoa is native to Central and South America, it is traditionally grown in agroforestry systems, i.e. intercropping cocoa trees with shade trees, bananas, citrus or other plants with food security or cocoa-enhancing benefits (interview #58, research; Aguilar and Guharay, 2013). The advancing agricultural frontier, particularly cattle-rearing, as well as considerable mining operations in the country intersect with biodiversity and climate change dynamics to affect cocoa production GPNs in the polycrisis age.

# Empirical evidence on environmental interactions: influence, disruption, synergy

## 4.1 Influence

**In the Kenyan case,** climate change and biodiversity dynamics *influence* the biophysical conditions that enable production of green beans and snow peas within GPNs including soil and water cycling. Several GPN actors in lead firms, county governments, Kenyan export firms (KEF) and civil-society organisations such as the Fresh Producers’ Export Association of Kenya (FPEAK), in collusion, began advocating the higher remuneration potential of such crops. This forced farmers towards planting non-indigenous export varieties rather than growing crops for food security (Kenya Agriculture and Livestock Research Organization, 2016; Krishnan, 2018). Such crops have higher water and chemical needs than traditional crops, altering soil physiology and fertility (Mwangi Wangui et al., 2019). Delays in rainfall and higher temperatures due to climate change *influence* the functioning of GPNs by reducing crop growing time, increasing incidence of crop failure, and reducing crop quality (#4farmer, #2HCD).

This has introduced new environmental risks for farmers in GPNs, including changes to soil physiology and fertility. Firms and government entities, including Kenyan export firms (KEFs) and the Horticultural Crops Directorate (HCD), pressure farmers to buy high-yield export varieties of green beans and snow peas from approved sellers. These seeds, often from multinationals like Bayer and Monsanto, do not reproduce naturally and require extra irrigation and specific fertilisers, increasing soil chemical content. Additionally, farmers must burn or uproot old crops to replant, preventing indigenous seed banks and leaving them reliant on seed companies for access. The effects of climate change and expanding erosion created new tensions between farmers and their environment, some opting to leave land abandoned or fallow when deterioration was significant, as reversing degradation would be too expensive, affecting production and livelihoods. Others attempted to increase investment in restoration activities by increasing use of traditional farming (e.g., using natural manure and animal urine), which created new conflicts with KEFs and lead firms, who retaliated by rejecting farmer produce and blacklisting farmers from selling to them.

Overall, this created reinforcing loops, where environmental polycrisis induced climate change and biodiversity loss, creating a host of environmental risks within GPNs. This led to uneven power dynamics enabling lead firms to appropriate natural resources of farmers, while providing no support to farmers in return. Farmers also had to make important decisions on the extent to which they could exploit natural resources they owned. These processes reinforced environmental interactions, where environmental and livelihood risks were worsened.

Climate change is a key driver of how polycrisis *influences* cocoa GPN actors in **Nicaragua,** particularly how fungal diseases might evolve (Delgado-Ospina et al., 2021), which result in environmental risks to local smallholders and by extension to other GPN stakeholders. Fungal diseases such as *moniliasis* are a long-standing problem for cocoa smallholders and their plantations in Nicaragua and beyond, as wind-dispersed spores within a plantation or to adjacent ones can threaten harvests and limit usable cocoa pods (#57, civil society; #55, research, #59, development agency). These diseases are a management problem (#59, development agency) requiring training and labour inputs to resolve, and socially constructed: if a neighbour does not eliminate *moniliasis*-affected pods, it will put other cocoa plantations, and their livelihoods, at added risk. This equally poses an environmental as well as possible regulatory or reputational risk to global cocoa buyers.

Despite many anticipated adverse effects of climate change (#55, 58, research), mitigating this fungal risk (Delgado-Ospina et al., 2021) equitably could provide additional benefits by increasing harvestable cocoa pods, conveying other techniques such as pruning to diversify the genetic pool and boost productivity, and potentially lead to a balancing loop. Though it remains to be seen precisely how aggravating climate change and biodiversity loss will affect fungal diseases, expanding training and capacity-building for better management and added payments for labour could thus not only mitigate this environmental risk. It could also increase productivity if stakeholders, especially powerful global buyers, are forward-looking and willing to invest in capacity-building through existing alliances with cooperatives, CSOs or government-supported agricultural extension officers (#51, NGO, #54, private sector). This is an example of how the polycrisis *influences* the cocoa GPN: while climate change can exacerbate threats to the viability of cocoa production including disease, mitigative strategies by farmers, lead firms, governments or civil society, if implemented effectively, collaboratively and equitably, potentially offer positives to the GPN by shoring up cocoa supply to the benefit of local livelihoods as well as the global cocoa GPN.

## 4.2 Disruption

**In the Kenyan case,** the environmental polycrisis has prompted a rise in severity of droughts in Murang’a and Meru *disrupting* the circulation of freshwater. Farmers are required to pay for expensive testing of irrigation water forcing many farmers to rely solely on rainfall (#6FG, #1KARLO). In response, farmers have begun to invest in rainwater harvesting infrastructure, building furrows, and using rooftop tanks. However, these conservation efforts, due to limited resources, have not significantly eased water table pressure. Over time, falling water tables have increased soil salination impacting the soil structure and the ability of green beans and snow peas to take up water. Many farmers have sought support from lead firms, KEFs and the HCD to develop environmental initiatives and invest in soil and water restoration. However, many KEFs blacklisted farmers and ‘dropped’ areas that were suffering from environmental issues, quickly switching to new areas (#3,4 Farmer). Even when farmers were part of cooperatives, these forms of collective power have not increased bargaining ability. This created tensions between farmers and the KEFs, including violent ‘stone throwing’ and verbal abuse of KEF representatives, thus impacting farmer livelihoods.

Furthermore, to comply with international standards, farmers intensified production through monocropping, to grow green peas and snow peas in blocks. This *disrupts* soil nutrients, diminishes deep root systems, soil microorganisms and biodiversity, and overall productivity. However, monocropping is cheaper than other more sustainable multi-cropping, as it reduces the overall cost of certifications (e.g. GlobalGAP, Rainforest Alliance). Thus, such intensification by farmers often creates socio-ecological conflicts in GPNs between farmers, their environment and lead firms.

Droughts and floods increased pest and disease outbreaks, pushing farmers to use pesticides, fungicides, and herbicides. However, they had no say in the types or amounts used, as these were dictated by international standards, often disregarding Indigenous knowledge. Farmers often spent over 25% of their costs on chemicals, many of which proved ineffective. Excessive use risked exceeding maximum residue limits (MRL)[[2]](#footnote-3) for exports, increasing regulatory pressure in Kenya. The HCD added traceability checks, raising costs without effectively managing pests. Consequently, Indigenous practices like regenerative agriculture faced resistance, amplifying costs and labour due to corporate and institutional pressures.

In sum, deteriorating reinforcing loops are created, spurred by how issues caused by the environmental polycrisis are accelerated and amplified by GPN actors, especially lead firms, and in some case farmer choices. New environmental risks and conflicts created led to the circulation of worse outcomes.

In the **South African** case study, the environmental polycrisis manifests as *disruptions* around limited water resources. Deciduous fruit is a high-value, but capital-intensive crop. Trees are expensive to purchase and set up, requiring several years to establish before they bear fruit. Irrigation plays a crucial role, particularly over the hot and dry summer months. Many farmers use automated high-tech irrigation systems that are highly efficient. While this facilitates water management on the farm, highly efficient irrigation can have negative ecological impacts (Lanari et al., 2024). This is because with less efficient irrigation systems water ‘losses’, such as runoff, are recovered within the catchment, e.g. by contributing to aquifer recharge (Ward & Pulido-Velazquez, 2008). With efficient irrigation systems, any water savings made at the farm-scale tend to be reinvested within the production site, e.g. by expanding the production area. Because little to no water can be recovered, highly efficient irrigation systems can increase local water consumption (Perry & Steduto, 2017), resulting in a reinforcing loop.

An additional worrying effect of high-tech irrigation is that water becomes a more valuable input. This is due to the combined effects of farmers being able to irrigate larger areas, obtain higher yields, and making pumping more affordable. In the Western Cape, many interviewed farmers rely at least partly on boreholes to irrigate their orchards. Due to a combination of changing rainfall patterns, recurring droughts, and overabstraction often due to apartheid-era water policy legacies, groundwater aquifers are increasingly becoming depleted, exacerbating environmental risks. Many boreholes now do not last a whole irrigation season before they are depleted, or farmers might need to dig deeper to access water (e.g. 100 meters rather than 30 meters; #66, farmer). This literal “race to the bottom” (#66, farmer) puts further pressure on groundwater recharge, creating a vicious cycle, further limiting water for fruit production, which in turn leads to more farmers digging deeper and further for water. In some cases, this has led to rogue water use by producers, as farmers use more than their allocated share or dig new boreholes elsewhere on their farms without permits (#13, farmer). This puts again further pressure on already strained water resources and has led to real trepidation about how this unchecked use has affected the overall sustainability of water sources (#63, farmer), further strengthening the reinforcing loop.

## 4.3 Synergy

In the **South African case study**, water quality is a concern for many export-oriented fruit growers. The stringent phytosanitary standards of export markets mean that the highest water quality is a key requirement to produce for export (Lanari & Bek, 2022). Pollution in the study area often occurs because of complex social-political dynamics, such as a combination of failing Municipal Wastewater Treatment Plants (WWTP), and the proliferation of underserviced and unserviced settlements post-apartheid (Ijabadeniyi & Buys, 2012). The resulting pollution of water (often including E.coli contamination) is an example of how the polycrisis manifests ecologically. This results in an important environmental risk for export-oriented growers and they actively mitigate this by leveraging synergetic environmental interactions, creating a balancing loop.

The river environment is characterised by wetlands and wetland plants (the palmiet), which have filtration properties to clear the water of contaminants, such as E.coli (#67, policy). Farmers downstream of the wetland often worry less about water quality because of its cleansing properties (#4 and #15, farmers). Many farmers engage in the clearing of alien invasive plants which contributes to improved water flows through the wetlands. Alien invasive plants are non-indigenous plants introduced to South Africa in the 17th century by colonial settlers. Of the more than 8,750 species that have been introduced, 161 are highly invasive, e.g. Hakea, Eucalyptus, and Acacia. Alien invasive plants spread rapidly and outcompete native vegetation. This disrupts the local ecosystem, particularly because they are much more water-intensive than native vegetation (Bek et al., 2017). Many farmers engage in clearing activities of these alien invasive plants specifically to increase the availability and reliability of water (#14 and #15, farmers) to mitigate risk from reduced water flows and consequently the poor performance of the wetland. Clearing of alien invasive plants has resulted in tangible improvements in river water flows, wetland restoration, and groundwater recharge (#3 and #11, NGO/policy), also improving biodiversity, and thus balancing the loop. This exemplifies the synergy between fruit GPNs in the Western Cape and the environment, while also addressing environmental risks faced by GPN actors regarding water quality.

Another example of a synergy is **the cocoa case study in Nicaragua**. Following cattle-rearing, which will often have entailed deforestation, soils can be so compacted from cattle that the land will no longer be cultivable (Aguilar & Guharay, 2013). However, measures by smallholders such as removing remaining grassy vegetation, and planting special plants to ‘renovate’ compacted soils, can make them available for cocoa production in the medium term (#34, NGO; #51, NGO), and entail wider benefits for carbon sequestration or biodiversity and livelihoods. This involves biomass-generating and soil-improving plants such as green manure (e.g. velvet beans; Aguilar and Guharay, 2013). It can also involve combining these special plants with some cocoa and temporary shade shrubs, with more cocoa introduced over time and intercropped with leguminous plants (e.g. *Canavalia* or *Cajanus cajan*) to boost nutrient recycling, with plantains for food security and pollination, timber trees for carbon credits, and native trees for biodiversity (#54, private sector). The absence of cattle-rearing and reforestation can entail further biodiversity benefits by boosting available habitats (#51, NGO).

Cocoa agroforestry systems can thus offer synergies and address environmental risks. As a balancing counterweight to the polycrisis’s capitalist dynamics promoting cattle-rearing and deforestation, the cocoa GPN can encourage alliances of local stakeholders with global buyers and NGOs, tree nurseries, cooperatives or extension agents to reclaim compacted soils. In addition to boosting farmer livelihoods and food security, this can entail wider benefits for local biodiversity from reforested spaces and the intercropped plants and trees, or offer scope to engage with carbon credits (Somarriba et al., 2013), thereby reducing or mitigating environmental or even social and regulatory risks. With cocoa a ‘natural ally of nature and biodiversity’, these ‘renovated’ soils can boost biodiverse habitats and corridors and potentially slow down the agricultural frontier, though the precise benefits in terms of stopping deforestation are difficult to monitor (#51, NGO). Especially for environmentally conscious stakeholders, investing in this type of vision can constitute a significant synergy, while addressing or mitigating environmental risks facing cocoa GPN actors related to deforestation or biodiversity loss.

# Discussion and conclusion

This paper has explained how the environmental polycrisis touches down in GPNs and how it shapes the environmental risks faced by GPN actors in these increasingly turbulent times. The existing polycrisis literature usefully emphasises the urgency and diversity of how multiple crises compound (Lawrence et al., 2024). However, there is a real danger of the polycrisis literature essentialising the environment as a homogeneous entity and reducing it to climate change. By investigating the environmental polycrisis, we unpack the intersecting, interacting and mutually reinforcing environmental crises relating to climate change, biodiversity and species loss, and environmental degradation to understand how they will affect agricultural GPNs specifically, and intersect with environmental risks. The diversity of repercussions from the environmental polycrisis affect GPN actors in various ways.

We develop a novel conceptualization of environmental interactions to highlight the different ways the environmental polycrisis touches down in GPNs, by drawing on literature from critical systems thinking, environmental economic geography, and GVC-GPN analysis. Our three environmental interactions highlight the different ways in which the polycrisis can influence or disrupt, but also create synergies within GPNs. They are: (1) influence, namely how the environmental polycrisis alters conditions of productions affecting socio-ecological dynamics between powerful actors in GPNs and farmers, and therefore creates new or affects existing environmental risks for GPN actors; (2) disruption, how the polycrisis disrupts ecological stocks or flows creating or worsening socio-ecological conflicts, thereby accelerating environmental risks in GPNs, and (3) synergy, how the polycrisis or responses to the polycrisis enhance environmental functions affecting GPN actors, thereby reducing environmental risk within GPNs. Unpacking environmental interactions allows us to scrutinise the various ways the environmental polycrisis impacts on how GPNs can utilise the environment as a producer of food, fuel, fibre, as a regulator of water cycles or pollination, or as a sink. It further facilitates interrogating how these interactions then intersect with existing power asymmetries faced by different GPN actors, which the environmental polycrisis can intensify or accelerate. Importantly, it also highlights the dynamics of how environmental risks are manifest in and faced by GPNs and GPN actors, that is how environmental interactions create, amplify or sometimes mitigate environmental risks.

Empirically, through examples from three different agricultural GPNs, we have demonstrated that the environmental polycrisis both changes and limits the productive capacity of GPNs. This creates new or reshapes existing environmental risks that GPN actors have to cope with.

*Influence* environmental interactions have created varied outcomes in Kenya and Nicaragua. In both cases, the environmental polycrisis has impinged on crop productivity by limiting genetic, soil and water cycling necessary for crops, and increasing fungal infestations. This has created new environmental risks by deteriorating crop quality and quantity, which has negatively impacted the socio-ecological relations between farmers’ land, lead firms and non-lead firm actors. However, in the Nicaraguan case, if an alliance of lead firms, cooperatives, government and civil society could equitably facilitate training, capacity-building and additional labour for plantation management, this could address the risk and possibly boost productivity and facilitate a balancing loop. This is in contrast to the Kenyan case, where it has led to reinforcing and worsening of relations, livelihood loss and degradation of agricultural systems.

Environmental interactions *disrupted* both the Kenyan and South African GPN production through polycrisis-induced accelerated drought and shifting rainfall impinging on water availability in GPNs. In both GPNs, farmers responded through socio-technical solutions, such as new/efficient irrigation systems. However, such responses drove increased water use and led to skewed water allocation between farmers, which created new socio-ecological conflicts between lead firms and farmers, and engendered environmental risks around water availability and crop quality within GPNs and beyond, while suggesting reinforcing loops.

To mitigate polycrisis dynamics, South African farmers have been clearing invasive species to reduce the trees’ intensive water consumption, while Nicaraguan cocoa growers have resurrected compacted soils for cocoa production. This has created *synergies* for the GPN and mitigated environmental and livelihood risks. This exemplifies a balancing loop, where responses by farmers dampened possible socio-ecological conflicts with powerful GPN actors, as well as safeguarding natural resources. In sum, our empirical evidence validated the need to pay attention more systematically to the polycrisis, and particularly its environmental dimension, in GPN research. While our empirical examples illustrating our conceptualisation stemmed from three Global South/Majority World countries – Kenya, Nicaragua, South Africa -, we encourage testing the framework created in other agricultural GPN contexts.

Methodologically, we draw on plural methods within critical systems thinking (Burton, 2003; Cabrera et al., 2018; Jackson, 2019) and GPN research (Bek et al., 2017; Henderson et al., 2002; Hess, 2004; Irarrázaval & Bustos-Gallardo, 2019) to show that the environmental polycrisis and the environmental aspects of agricultural GPNs are complex and cannot be analysed in isolation. This is due to their knock-on effects on the socio-ecological and economic aspects of production. That said, it is important to recognise our methodological limitations which do not quantify causality nor measure environmental consequences through biological or ecological methods, but rather elicit the non-linear effects on GPNs as part of wider systems through qualitative data. This is particularly important as the environmental polycrisis can create disproportionately large or small changes given the unpredictability of the speed and strength with which crises overlap and interact (Lawrence et al., 2024). Our approach, developed iteratively, offers the potential for a rigorous study of non-linear effects and provides granularity, which can also be helpful to policy-makers, to understand unintended consequences of environmental crises in agricultural GPNs and the spaces within which they operate.

We showed that the environmental polycrisis, through its environmental interactions and intersections with existing power asymmetries, is undermining the capacity of farmers to cope with environmental risks by removing or endangering livelihoods. A key common theme has been the polycrisis exacerbating the increasingly complicated access to clean water due to strict phytosanitary standards of export markets, and the availability of high-quality soil and biodiversity to facilitate agricultural production. Given the accelerating polycrisis and particularly climate change, these issues are set to intensify and aggravate further. It is important not to naturalise environmental risks, especially when linking to their socially constructed nature. Rather, acknowledging and understanding environmental polycrisis dynamics may present an opportunity to reconfigure GPNs towards inclusive and more sustainable networks of production. Such analysis facilitates diving deeper into how socio-ecological tensions emerge in GPNs due to environmental interactions, manifest as environmental risks, are shaped and/or reproduced, and the pathways through which these create socio-environmental implications beyond the GPN.

In sum, we argue that it is vital to engage with the environmental polycrisis in the analysis of (agricultural) GPNs. We must link global-level discussions of the polycrisis with more granular, local evidence of dynamics which include, but go beyond climate change, connecting the GPN level and its biodiversity, soil and water realities to systems-level thinking. Taking seriously the diverse threats entailed by the environmental polycrisis through our conceptualisation may create space to reshape GPNs in more equitable and sustainable ways.

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1. In this research we use terminology of GPNs as an umbrella term, given the close relationship between the GPN and GVC literature, and refer to both approaches collectively; where required we refer specifically to the GPN or GVC strand (see e.g. Neilson, 2019; Barrientos, 2019; Follmann et al., 2024). [↑](#footnote-ref-2)
2. The MRL was a protocol set by the European Union on the use of only certain types and specific amounts of pesticides to be applied to exported produce in 2009. Kenya violated this protocol by exceeding the MRL on green beans and was banned from selling to European markets and given until September 2014 to adjust their practices (Interview: #2kgov, #1kKePhis). [↑](#footnote-ref-3)