The Journal of Peasant Studies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/fjps20

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To cite this article: Jevgeniy Bluwstein & Connor Cavanagh (2023) Rescaling the land rush? Global political ecologies of land use and cover change in key scenario archetypes for achieving the 1.5 °C Paris agreement target, The Journal of Peasant Studies, 50:1, 262-294, DOI: 10.1080/03066150.2022.2125386

To link to this article: https://doi.org/10.1080/03066150.2022.2125386

Published online: 27 Oct 2022.

THE JOURNAL OF PEASANT STUDIES
2023, VOL. 50, NO. 1, 262–294
https://doi.org/10.1080/03066150.2022.2125386

Routledge
Taylor & Francis Group

FORUM ON CLIMATE CHANGE AND CRITICAL AGRARIAN STUDIES

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Rescaling the land rush? Global political ecologies of land use and cover change in key scenario archetypes for achieving the 1.5 °C Paris agreement target

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ABSTRACT
Advancing future-oriented perspectives in political ecology and critical agrarian studies, this paper examines projected land use and land cover change (LULCC) dynamics in four 'archetypal' scenarios foregrounded by the IPCC for limiting global warming to 1.5°C by 2100. Focusing on the Global South, we explore how these archetypes project a radical reversal of historical LULCC and rural population trends, potentially implying a considerable rescaling of contemporary land rush dynamics. Taken together, land-based climate mitigation futures highlight risks related to the (re)production of relative surplus populations through processes of rural enclosure and accumulation by dispossession in the Global South.

KEYWORDS
Political ecology; critical agrarian studies; land rush; land use and cover change; climate change

1. Introduction

Readers of this journal will be familiar with the land rush that swept through many parts of the globe, and particularly the Global South, throughout the first two decades of this century. During the apex of the global land rush (2007–2014), an annual mean of around 8 million hectares (Mha) of land deals was recorded by the Land Matrix database, with nearly 80 percent of these transactions occurring in the Global South. In short, these and similar land rush dynamics have been the subject of a generative, and still-growing, literature at the intersection of political ecology and critical agrarian studies (Borras et al. 2011; Fairhead, Leach, and Scoones 2012; White et al. 2012; Dell'Angelo et al. 2017). Important questions remain, however, about how both historical and contemporary land rush processes will articulate with the drivers and impacts of global climate change in the future (Franco and Borras 2021; Liao et al. 2021), as well as with attempts to mitigate climate change in the agriculture, forestry, and land use (AFOLU) sector (Davis, Rulli, and D'Odorico 2015).

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In this respect, it is notable that key scenario archetypes in the IPCC's (2018) influential *Special Report on Global Warming of 1.5 Degrees* (hereafter SR1.5) project land use and land cover change (LULCC) for cropland and pasture contraction – as well as forest cover and bioenergy cropland expansion – at rates of implementation similar to those observed within the aforementioned 'peak period' of the global land rush (2007–2014), albeit sustained throughout the remainder of the twenty-first century.[1] The sheer scale and rapidity of these projected changes in pasture, cropland, and forest land cover may thus provide us with a useful lens or prism through which to explore potential interrelations between climate change mitigation, land rush dynamics, and the risk of associated socio-environmental injustices across a range of future scenarios. Indeed, a growing body of literature demonstrates how land-based climate mitigation initiatives can entail adverse side effects or significant trade-offs between different 'sustainable development' objectives (Hasegawa et al. 2018; Doelman et al. 2019), and particularly so in low(er)-income countries with a high agricultural share of GDP or total employment (Hurlbert et al. 2019, 675). Especially severe trade-offs can occur, for instance, if land area requirements for afforestation or bioenergy carbon capture and storage (BECCS) initiatives are dramatically increased in lieu of aggressive near-term reductions in fossil fuel-related emissions, amounting to several million km^2 above 2020 reference levels in some scenarios (Doelman et al. 2020).

Exploring the implications of these 1.5 °C scenario archetypes – and in response to the *Journal of Peasant Studies'* call for critical research examining interrelations between climate and agrarian change – this paper seeks to deepen our understanding, in particular, of 'how climate change and the rural world intersect' (Borras et al. 2022a, 5) in the context of emergent land-based mitigation responses. Departing somewhat from the laudably incisive focus on contemporary and *historical* dynamics in both political ecology and critical agrarian studies, we explore how differential *future* intersections between 'climate change and the rural world' may vary across a range of archetypal mitigation scenarios. Although there is a significant knowledge base in sustainability science, Earth system science, and related fields appraising trade-offs between climate change mitigation and livelihood or development objectives across a range of future scenarios (e.g. Doelman et al. 2019, 2020; Henry et al. 2022), studies of the interface between climate and agrarian change have in some ways only just begun to emerge in earnest across the wider critical literature (see, for instance, Franco and Borras 2019; Borras, Franco, and Nam 2020; Franco and Borras 2021). Whilst there has now been more than a decade of empirical and historical studies of the asymmetrical impacts of land and resource acquisitions or 'green grabbing' for conservation, climate change mitigation, and other ecological restoration schemes (e.g. Kelly 2011; Fairhead, Leach, and Scoones 2012; Leach and Scoones 2015), only rarely have political ecologists and critical agrarian studies scholars examined the empirical substance of *future* climate change mitigation scenarios or projections in detail (for emerging exceptions, see *inter alia* Buck 2019;

[1]Land-based climate mitigation includes a mix of different mitigation strategies or 'integrated response options' (IPCC 2020) across the agriculture, forestry, and land use (AFOLU) sector. Climate change mitigation in this sector can be realized both by reducing or avoiding emissions from agriculture, as well as from catalysing forms of land use or cover change that are deemed to be 'desirable' from a mitigation perspective. Accordingly, relevant 'integrated response options' in the AFOLU sector often entail vast scales of projected reforestation or afforestation, as well as the widespread establishment of bioenergy carbon capture and storage (BECCS) plantations (see also Carton 2019; Carton et al. 2020).

Carton 2019). In other words, we suggest that there is significant potential for political ecologists and other critical scholars to generate more granular theorizations of how Blaikie and Brookfield's (1987, 17) famously 'shifting dialectic between society and land-based resources' may resolve differentially across a range of possible mitigation futures, and with what implications.

Empirically, this paper seeks to encourage further discussion and debate on these issues by drawing upon four scenario archetypes recently foregrounded by the IPCC for limiting global warming to 1.5 °C above pre-industrial averages (see IPCC 2018). Specifically, these archetypes include: i) the Low Energy Demand (LED) scenario (Grubler et al. 2018), ii) Shared Socioeconomic Pathway 1 (SSP1-19), iii) Shared Socioeconomic Pathway 2 (SSP2-19), and iv) Shared Socioeconomic Pathway 5 (SSP5-19).[2] Particularly the latter three pathways are 'archetypal' in the sense that they are distilled from a broader suite of approximately 90 scenarios for meeting the 1.5 °C target with limited or no overshoot, thus illustrating the 'variety of underlying assumptions and characteristics' that underpin the full range of mitigation trajectories in the IPCC's SR1.5 assessment (Rogelj et al. 2018b, 110). Importantly, each archetype envisions differential future pathways for urbanization, economic growth, socioeconomic inequality, international cooperation, and institutional or technological innovation. For instance, the LED scenario projects a 40 percent reduction of final global energy demand below 2020 levels by 2050, including a downscaling of industrial activity in the Global North by 42 percent (Grubler et al. 2018, 520). At the other end of the spectrum, SSP5-19 entails 'accelerated globalization' (O'Neill et al. 2017, 174), an increase in final global energy demand that exceeds 2010 reference levels by a factor of at least 1.4 (Rogelj et al. 2018a, 328), and the maintenance of significant rates of global compounding economic growth (Kriegler et al. 2017).

Methodologically, we assess the political-ecological implications of the four scenario archetypes by contextualizing projected land use and cover change (LULCC) vis-à-vis the observed history of LULCC in the second half of the twentieth century (1960–2000) (Lay et al. 2021; Winkler et al. 2021), as well as the scale and rate of transactions documented throughout the 2007–2014 'peak period' of the global land rush (Rulli, Saviori, and D'Odorico 2013; Liao et al. 2021). To meaningfully assess changes in available pasture, cropland, and forest land cover in the past and in the future, however, we also account for parallel 'megatrends' in population, economic development, and human settlement dynamics. In doing so, we extract related conceptual implications from our analysis for the present *Journal of Peasant Studies* forum, highlighting how these future projections threaten to articulate with concerns related to rural enclosures (White et al. 2012), primitive accumulation or 'accumulation by dispossession' (Kelly 2011; Fairhead, Leach, and Scoones 2012), and the production of relative surplus populations (Benanav 2014; Li 2017) across the four scenario archetypes.

The contributions of this approach are several. As Borras et al. (2022a, 16) emphasize in their introduction to this forum, the 'processes of enclosure and extraction that neoliberalism accelerated' throughout the last several decades 'have changed agrarian class dynamics […] Today, there is a staggering rise in the number of people who originated from rural areas but are now partly or fully separated from their means of production

[2]For an overview of the Shared Socioeconomic Pathways (SSPs) and their corresponding 'narratives', see the associated special issue of *Global Environmental Change* (e.g. O'Neill et al. 2017).

and social reproduction'. Indeed, analyses of enclosure and subsequent partial or total dispossession in the land rush literature have deepened our understanding of the often formally-unstated or disavowed social, political, and economic consequences of large-scale land and resource acquisitions (see, especially, Wily 2012; Cotula 2013; Dell'Angelo et al. 2017). Crucially, our analysis furthers the existing scholarship on these themes by highlighting how 1.5 °C scenario archetypes project future LULCC to unfold in a radically different demographic context relative to the recent historical record, and particularly so in the Global South. Whereas cropland and pasture expansion unfolded over the last 60 years against a demographic background of a growing rural population in the Global South, the conversion of cropland and pastures to forests and bioenergy plantations in 1.5 °C scenario archetypes is projected to occur in the context of a rapidly shrinking rural population. Not least, then, we illuminate how this anticipated reversal of historical trends raises critical questions for political ecology and critical agrarian studies about, *inter alia*: 1) the conditions under which rural areas depopulate in diverse future scenarios; 2) the agrarian political economy of transforming rural smallholdings to both 'sustainably intensified' sites of agricultural production and forests or other plantation-based carbon sinks; and 3) the implications of transitioning rural areas from their historically latent function of 'warehousing' relative surplus populations (Li 2010; Benanav 2014) to a context in which cities and other urban areas are presumed to fulfil this role (see also Davis 2006; Harvey 2012).

In unpacking these contributions, the article proceeds as follows. First, we revisit seminal works in political ecology and critical agrarian studies on global land rush dynamics, highlighting how a new generation of empirical inquiries into emergent land use and cover change trajectories may both extend and enrich the significance of these contributions. Secondly, we present empirical findings from our analysis of the above four scenario archetypes, disaggregating the spatial extent and rate of projected LULCC across several world regions, and highlighting related socio-environmental justice considerations. Thirdly, we situate findings on the magnitude of future LULCC and rural population change projected within each archetype with two key 'analogues': i) observed LULCC trends throughout the mid-to-late twentieth century (1960–2000), as well as ii) Land Matrix data on the scale and rate of acquisitions over the first two decades of the twenty-first century (2000–2020). We conclude with an overture to this JPS forum – as well as to broader communities of practice in political ecology and critical agrarian studies – inviting further inquiries into the potential for emergent climate change mitigation trajectories to entail a 'rescaling of the land rush', as it were.

2. Political ecology, sustainability transformations, and emergent trajectories of global climate change mitigation

In political ecology, critical agrarian studies, and related fields, recent scholarship has productively examined the multi-scalar politics of various 'transformations to sustainability' on a planetary scale (Scoones et al. 2020). Importantly, this literature highlights contestations over which pathways to sustainability are most suitable, feasible, or desirable – and for whom (Leach, Raworth, and Rockström 2013; Cavanagh and Benjaminsen 2017; Newell, Paterson, and Craig 2021). Scholars have recently highlighted, for instance, the emerging 'decarbonization divide' between Global North and South, implicating Northern transport and energytransitions in the production of 'toxic ecologies' or 'sacrifice zones' with deleterious implications for human health, environmental pollution, and rural displacement in the Global South (Sovacool et al. 2019, 2020; see also Dunlap and Laratte 2022). As critical agrarian studies scholars have been at pains to highlight, in particular, the emerging impacts of these sustainability transformations will inevitably articulate with a baseline context already characterized by large and growing inequalities within and across world regions, potentially thus accelerating ongoing processes of socioeconomic differentiation or class formation in both rural and urban areas (Edelman and Wolford 2017; see also Akram-Lodhi et al. 2021).

Indeed, recent studies of sustainability transformation across multiple socio-ecological domains build upon decades of critical scholarship examining interventions to foster climate change mitigation in the agriculture, forestry, and land use (AFOLU) sector. Here, numerous scholars have illuminated how these interventions are often predicated on a false equivalence between 'luxury emissions' from industry or transportation in the Global North and 'survival emissions' from agriculture or biomass-related energy production in the Global South (e.g. Agarwal and Narain 1991; see also Bumpus 2011; Carton, Lund, and Dooley 2021). Particularly when related interventions incentivize, or depend upon, the displacement of rural land users, such initiatives raise well-documented concerns about multifaceted social and environmental injustices. Amongst others, these risks include the 'moral hazard' that offsetting or cross-sectoral mitigation schemes may result in emissions reduction deterrence (Anderson and Peters 2016; Carton 2019), as well as human rights concerns regarding displacement, dispossession, or restricted access to lands and resources (see, *inter alia,* Beymer-Farris and Bassett 2012; Cavanagh and Benjaminsen 2014; Fisher et al. 2018; Cavanagh et al. 2021). Indeed, both political ecologists and critical agrarian studies scholars have repeatedly highlighted important trade-offs and associated environmental (in)justice risks associated with the implementation of climate mitigation policies across different regions, scales, and sectors (Akram-Lodhi et al. 2021; Newell 2022).

To date, however, much of the recent literature has focused on the implications of contemporary or *historical* interventions for conservation or climate change mitigation, rather than on the scale and potential consequences of projected *future* interventions. Laudably, a small number of recent studies have begun to redress this knowledge gap, for instance by producing critical analyses of fossil fuel-intensive mitigation pathways and their reliance on bioenergy carbon capture and storage (BECCS) or other speculative carbon capture and storage technologies (Dooley and Kartha 2018; Buck 2019; Carton 2019; Carton et al. 2020). In addition, a small cluster of studies has generated more focused analyses of shifting relations between climate change impacts, climate change mitigation initiatives, and their implications for agrarian politics (Borras and Franco 2018, 2019; Borras, Franco, and Nam 2020, 2011; Franco and Borras 2021). However, engagement between political ecology, critical agrarian studies, and the wider spectrum of projected mitigation pathways that have arisen from a range of different integrated assessment and other modelling frameworks remains quantitatively limited. Indeed, as Figure 1 illustrates, relatively few analyses in the critical literature overtly engage integral aspects of the mitigation scenario scholarship, as reflected by a paucity of studies exploring – for instance – both political ecology and the Shared Socioeconomic Pathways (SSPs) or Representative Concentration Pathways (RCPs).

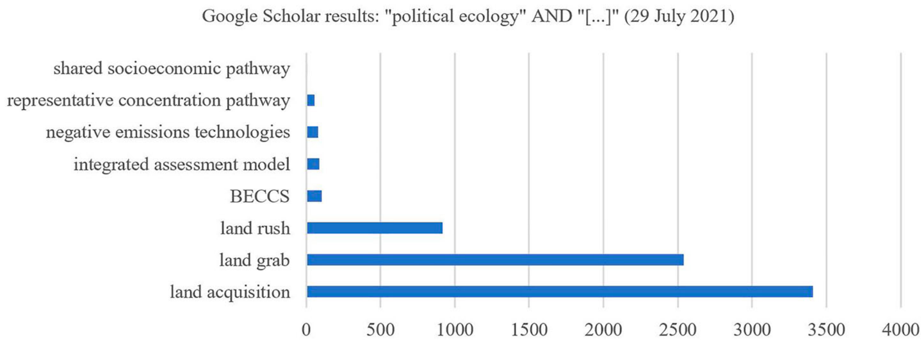

Figure 1. Google scholar results ('political ecology' AND ' … '). Data: Google scholar (29 July 2021).

These and related lacunae point to a growing need for studies situating emergent trajectories of climate change mitigation vis-à-vis diverse critical engagements with a perceived 'global land rush' emerging in the aftermath of the 2007–8 financial crisis. As will be well-known to readers of this journal, historically significant spikes in global food and energy prices followed the financial crisis, prompting a range of investors and other actors to 'rediscover' investment opportunities in agriculture and other key natural resource sectors (Borras et al. 2011; Dell'Angelo et al. 2017). Rulli, Saviori, and D'Odorico (2013), for instance, suggest that these price dynamics catalysed a measurable uptick in large-scale land acquisitions involving transnational investors, many – but not all – of which targeted lands and resources in the rural Global South. Importantly, such investments were often underpinned or legitimized by narratives of unused or idle land (Geisler 2012), as well as by arguments concerning the potential for efficiency gains to be realized via agricultural intensification and the associated closure of 'yield gaps' in ostensibly undercapitalized forms of smallholder agriculture (Li 2014).

In turn, this land rush sparked a 'literature rush' of academic publications in political ecology, critical agrarian studies, and related fields (Scoones et al. 2013). Here, key foci include the role of corporate actors (White et al. 2012); the involvement of states and state agencies (Wolford et al. 2013); and the various ways in which land or resource acquisitions elicit diverse 'responses from below' from both individuals and communities (Hall et al. 2015). Increasingly, critical scholars have also addressed the implications of these processes for ecosystems and natural resource management beyond 'land' as such, including biodiversity conservation, landscape-based environmental change mitigation (including REDD+ and other forms of forest or ecosystem restoration), and the acquisition of water resources, fisheries, or other marine ecosystems (Benjaminsen and Bryceson 2012; Fairhead, Leach, and Scoones 2012; Dell'Angelo, Rulli, and D'Odorico 2018). Again, however, much of this literature engages land and resource acquisitions in historical perspective, illuminating how contemporary dynamics map onto the often-unresolved legacies and injustices of colonial, authoritarian, or other contested forms of land management and environmental governance (Fairhead, Leach, and Scoones 2012; Geisler 2012; Wily 2012). Whilst critical research on low-carbon pathways and the associated 'processes and structures of inequality, exclusion and injustice' is growing (Sovacool et al. 2019, 1), these tensions and contradictions have largely not yet been examined across the full range of projected land-based mitigation pathways in detail.

On one hand, such relatively limited engagement with the scenario analysis literature is understandable. Political ecologists and critical agrarian scholars are keenly aware of how LULCC processes are governed by political-economic dynamics that are often poorly represented – or even simply illegible – within integrated assessment and other modelling frameworks (e.g. Leach and Scoones 2015; Asiyanbi and Massarella 2020). Behind the abstract net LULCC figures that these modelling frameworks produce lies the complex ground-level reality of land and resource conflicts, as well as patterns of capital accumulation, commodification, and the concentration of land or resource ownership (Dell'Angelo et al. 2017; Borras, Franco, and Nam 2020). As critical scholars know all too well, in 'reality' the drivers of land use or cover change are anything but straightforward. Indeed, attempts to reconfigure the ownership of lands and resources via transnational investment often fail, as the case study literature illustrates in particular (Cavanagh and Benjaminsen 2014; Borras et al. 2022b; see also Li 2014). Considering the gravity of these and related assumptions embedded within the 'black box' of specific IAM methodologies, critical scholars might thus be tempted to dismiss these scenario archetypes altogether as being simply 'unrealistic' or irreparably blind to certain political-economic realities. Others might demur that – in light of observed GHG emissions trajectories and the potential activation of malign 'tipping points' or planetary feedback loops (e.g. Kemp et al. 2022) – the 1.5 °C mitigation target is simply increasingly unattainable, undermining the utility of a detailed critical analysis of associated mitigation scenarios.

Epistemologically, however, it is somewhat problematic to conclude that a projected *simulation* – or more specifically, an *optimization* or 'optimized simulation' – is '(un)realistic' in this sense. In other words, IAM frameworks have been 'optimized' or otherwise parameterized in such a way that they are effectively forced to produce scenarios that result in the achievement of the 1.5 °C Paris Agreement target or other specified objectives. In these scenarios, desired objectives are thus in fact 'achieved' via the specified mechanisms and pathways. Figuratively speaking, the metaphorical 'dominos' in these scenarios are compelled to fall in ways that are essentially necessitated by the achievement of the specified objectives or parameters – such as 1.5 °C of warming above pre-industrial averages, or radiative forcing of 1.9 watts/m^2 by 2100 – albeit via distinct pathways across the LED and SSPx archetypes. As Keppo et al. (2021: 5) note, the production of these scenarios unavoidably requires IAMs to deliberately simplify complex system dynamics, denoting that they are 'generally not meant to be normative, nor provide a blueprint for policy makers'. Differently put – as Rogelj et al. (2018a, 331) write – 'because models are stylized, imperfect representations of the world, feasible dynamics in a model might be infeasible in the real world, while vice versa infeasibility in a model might not mean that an outcome is infeasible in reality'.

Seen this way, one could suggest that the value of IAM outputs does not lie in their analytical precision or implied feasibility, but in their generation of a range of future 'archetypes' or illustrative scenarios in relation to which both historical and emergent empirical trajectories can be contextualized. In this article, we thus offer a critical analysis of four such scenario archetypes, seeking to broker an initial conversation and to encourage further research on these themes in political ecology and critical agrarian studies. To this end, in what follows we reconstruct LULCC implications within and across four mitigation archetypes: LED, SSP1-19, SSP2-19, and SSP5-19. Subsequently, we distil key insights or 'takeaways' from this analysis vis-à-vis the political ecology and critical agrarian studies literature on the global land rush, highlighting considerable potential for further engagement in these fields.

3. Context and methodological approach

Methodologically, we draw upon an analysis of quantitative output from IIASA's SSP and 1.5 °C scenario explorer database (see Huppmann et al. 2018), which facilitates access to the empirical substance of scenarios associated with the four archetypal mitigation pathways foregrounded by the IPCC (2018) *Special Report on Global Warming of 1.5 °C*. Utilizing IIASA's scenario explorer, we obtained output for projected LULCC by 2100 relative to 2010 reference levels. Specifically, this describes land cover changes in – *inter alia* – pasture, cropland with and without second generation bioenergy crops, and forests (both natural and managed) over time, measured in millions of hectares (Mha).

Output is available for three shared socioeconomic pathways (SSP1, SSP2, SSP5) which have been fed into six IAM frameworks to simulate future land cover changes for a mitigation target of 1.5 °C above pre-industrial averages.[3] This mitigation target (1.5 °C) broadly corresponds to Representative Concentration Pathway (RCP) 1.9, which entails radiative forcing of 1.9 watts/m^2 by 2100. Hence, our analysis is based on the following three SSPx-RCP1.9 archetypes: SSP1-RCP1.9, SSP2-RCP1.9, and SSP5-RCP1.9. In addition, we also examined the LED scenario, which is based in part upon SSP2-RCP1.9, albeit with adjustments specifically intended to model a divergent 'low energy demand' scenario that would avoid reliance on land-intensive negative emissions technologies, specifically BECCS (Grubler et al. 2018). Whereas multiple model 'runs' of every individual SSP were completed across different IAMs – each of which entails somewhat varying methodologies and assumptions, resulting in significant differences in output across modelling frameworks even for the same SSPx scenario (see also Skeie et al. 2021) – the LED scenario was quantified through the MESSAGEix-GLOBIOM 1.0 framework alone (Grubler et al. 2018). Although our approach relies on mean LULCC values distilled from multiple different 'runs' of the same broad SSPx archetype – rather than median values and ranges for LULCC output across individual scenarios within each archetype – this approach nonetheless reflects important general tendencies across the full range of the four illustrative mitigation pathways, and is thus practicable for encouraging an initial wave of critical discussion on these issues.

Indeed, in aggregate the four scenario archetypes present us with an indicatively broad range of mitigation futures. This is particularly so insofar as each archetype is infused with a distinct storyline or 'narrative' about future socio-ecological trajectories (O'Neill et al. 2017). These trajectories reflect divergent outcomes across key indicators including human population growth, international cooperation (or the lack thereof), urbanization, and economic development. Given our focus on LULCC from pastures and cropland to forests and biofuel cultivation, we are particularly interested in implications for shifting rural population and human settlement dynamics. To this end, Table 1 and Figure 2 highlight projected population and urbanization figures for both the three SSPx scenarios and

[3]These IAM frameworks include AIM, IMAGE, MESSAGE-GLOBIOM, REMIND, and GCAM. For the purposes of our analysis, WITCH was excluded due to incomplete datasets on land use.

Table 1. Future population and urbanization dynamics and underlying assumptions. (Based on Jiang and O'Neill 2017; Riahi et al. 2017; Grubler et al. 2018). Data for urbanization rate: Jiang and O'Neill 2017. Population data: FAO-historical, IIASA-projected.

	SSP1 and SSP5	SSP2 and LED
Global population, first half of twenty-first century	Moderate population growth	High population growth
Global population, second half of twenty-first century	High overshoot (at 8.5 billion) and shrinking population (to 7 billion)	Low overshoot (9.5 billion) and stabilization at 9 billion
Global population, 2010 vs 2100	Almost identical (around 7 billion)	Growth from 7 to 9 billion
Urbanization rate (World)	High urbanization rate (from 60% in 2020 to 92% in 2100)	Moderate urbanization rate (from 56% in 2020 to 79% in 2100)
Urbanization rate (Global South)	High (from 49/84/53% in 2020 to 90/95/91% in 2100 –Africa/Latin America/Asia)	Moderate (from 46/82/48% in 2020–73/91/78% in 2100 –Africa/Latin America/Asia)
Modelled assumptions	Increased migration and fast urbanization due to medium to high economic growth, high income growth, relatively low income inequality, 'environmentally friendly living arrangements' (SSP1); high economic growth and technological change, increasing agricultural productivity, growing wealth (SSP5)	Moderate income and economic growth, and moderate socio-economic inequality lead to moderate urbanization rate, in line with historical development. LED scenario with much more aggressive assumptions concerning reductions in consumption, energy conservation or efficiency, industrial activity, and therefore final global energy demand

LED to illuminate how rural population is projected to change from 2020 until 2100 (see also Jiang and O'Neill 2017).[4]

Several key trends are notable. First, rural population has almost doubled in the last 60 years in the Global South, while it has stagnated in the North (Figure 2). Second, all four scenario archetypes project a significant and absolute depopulation of rural areas across the world (Table 1 and Figure 2). Here, SSP1 and SSP5 futures project that around 500 out of 600 million rural people will live in the Global South. By contrast, SSP2 and LED futures project that around 1.7 out of 1.8 billion rural people will live in the Global South. These reductions converge with unprecedented urbanization processes. Here, SSP1 and SSP5 reflect the highest rates of urbanization (92% globally), whereas SSP2 and LED evince a slightly more 'moderate' degree of urbanization, both simulating an 80% urban share of world population by 2100 (Riahi et al. 2017, 158). Importantly, this is relative to an approximately 57% urban share of world population as of 2021 (World Bank 2022).

Although most population and economic development assumptions in LED are based upon the 'middle of the road' SSP2 scenario, LED also includes a unique 'food security' constraint. This is intended to ensure that 'increased populations in the global South are not worse off in terms of animal and vegetal calorie intake as a result of climate mitigation efforts based on land use (for example, the expansion of bioenergy crops)' (Grubler et al. 2018, 525). Although this specific constraint is unique to LED, SSP1 also includes somewhat optimistic socioeconomic assumptions. van Vuuren et al. (2017: 241), for instance, highlight how assumptions of 'significant gains in access to food' underpin IMAGE-based SSP1 projections. This denotes that in SSP1 'policies to reduce poverty

[4]We follow the IIASA regional level definition, which includes 'countries from the reforming economies of Eastern Europe and the Former Soviet Union' as part of Global North. See IIASA (2021), https://tntcat.iiasa.ac.at/SspWorkDb/dsd?Action=htmlpage&page=about (accessed 15 April 2021).

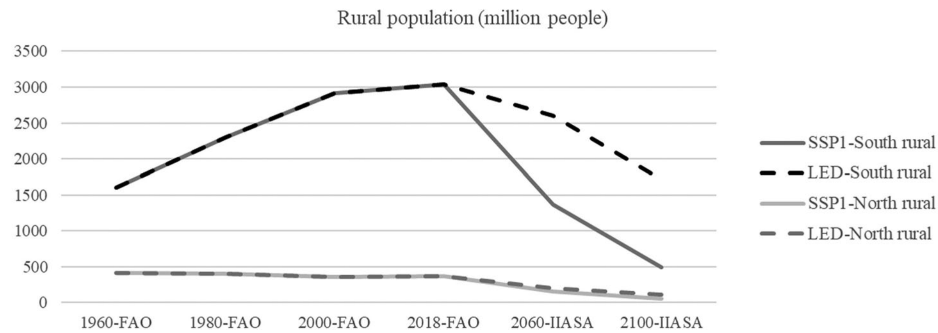

Figure 2. Rural population across global south and global north according to different population projections. 1960–2018 historical data (FAO). 2060–2100 projection (IIASA). SSP5 data not included, given a strong similarity with SSP1. SSP2 data not included, as it is identical with LED. SSP1 is based on IMAGE model, LED is based on MESSAGEix-GLOBIOM model.

and hunger in combination with increased welfare lead to an increase in per capita consumption of food' (van Vuuren et al. 2017: 243). Similarly, Popp et al. (2017, 340–341) emphasize that mitigation response options largely do not 'influence food prices [in SSP1] due to a general "food first" policy, which can restrict agricultural expansion to avoid deforestation, but further only allows bio-energy on areas not needed for food and feed production.' Moreover, Riahi et al. (2017, 158) show how the three SSPs compatible with a 1.5 °C climate future are underpinned by significant reductions in income inequality.

Given the above parameters and assumptions, we reiterate that these scenario archetypes are perhaps best conceptualized as *optimizations*, rather than as forecasts – much less as 'predictions' – in the conventional sense. That is to say, even the most sophisticated integrated assessment frameworks necessarily entail simplifications of the empirical dynamics that characterize all complex social, economic, and biophysical systems in practice (Gambhir et al. 2019; Peng et al. 2021). This underscores how SSP1, SSP2, and SSP5-based archetypes are inherently 'optimized' – and therefore, remain somewhat 'optimistic' – in the sense that all mitigation-relevant choices, decisions, and transactions take place in relatively well-governed, technologically advanced, and administratively expedient worlds. With respect to land use and cover change, the most prominent of these assumptions include: i) demand changes (e.g. dietary changes that shape agricultural and livestock demand and supply in desirable ways); ii) innovations that enable efficiency gains (e.g. sustainable intensification in agriculture, or energy conservation measures that reduce final global energy demand); iii) efficient markets and price discovery mechanisms that successfully 'internalize externalities' (e.g. by successfully pricing carbon emissions to improve the affordability or attractiveness of alternative energy sources and land uses); and iv) globally expedient governance and policy implementation (allowing for rapid and uniformly competent rollout of large-scale response options, such as afforestation or BECCS).

Crucially, these 'optimistic' assumptions are not prevalent to the same extent in all five SSPs. 'Resurgent nationalism' and regional conflicts dominate SSP3, for example, denoting that economic development is slow and inequalities persist or worsen, limiting the kind of mitigation effectiveness that is a necessary precondition for meeting the 1.5 °C target (O'Neill et al. 2017). Similarly, SSP4 is characterized by increasing inequality across and within countries, leading to a growing gap between cosmopolitan elites and 'a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy' (Riahi et al. 2017, 157). As Rogelj et al. (2018a, 325) note, '1.9 W/m^2 scenarios could not be achieved in several models under SSPs with strong inequalities'. In other words, 1.5 °C compatible scenarios are seemingly difficult – if not simply impossible – to model successfully in a world that is characterized by growing geopolitical tensions (SSP3) and/or inequalities (SSP4). This is significant, as it also suggests that 1.5 °C *can* be achieved if the world 'follows a path in which social, economic, and technological trends do not shift markedly from [recent] historical patterns' (Riahi et al. 2017, 157). Such is the definition of SSP2, upon which LED is based.

In the following section, we turn to an analysis of historical patterns to illustrate the significance of LULCC projected in these future scenario archetypes. Firstly, we examine projected LULCC across the four archetypes, disaggregating results to illuminate divergent implications across world regions. Secondly, we contextualize scenario projections in relation to broader patterns of historical land use and cover change across the twentieth and early twenty-first centuries. Thirdly, we situate the scale and rate of projected LULCC vis-a-vis the recent 'global land rush' – as documented by the Land Matrix database (2022) – highlighting the contribution of global land rush dynamics to global LULCC patterns in the early twenty-first century.

4. Emergent land use and cover change trajectories in historical perspective

4.1 Land use and land cover change in 1.5 °C futures: differential impacts across scenarios, world regions, and modelling frameworks

Across the four scenario archetypes, the magnitude of associated land use and cover change is quite striking both in absolute terms, as well as when considered relative to 'baseline' scenarios for each SSP (Figure 3). Here, baselines reflect future trajectories resembling business as usual trends, with no additional climate change mitigation policies beyond those in place at a given reference year. A comparable future baseline is not available for the LED scenario; however, its shared premises with SSP2 allow for a degree of useful contextualization vis-à-vis the SSP2 baseline.

Averaging quantitative output across available IAM modelling frameworks (Figure 4, left panel), all four scenario archetypes reflect a vast reduction in pasture land cover globally, ranging from 847 to 683 Mha between 2010 and 2100, and amounting to a mean annual pasture reduction of 7.6–9.4 Mha. This is accompanied by a significant absolute reduction in cropland, ranging from 480 Mha in the SSP1-19 'sustainability' archetype, to 69 Mha in the LED archetype (mean annual reduction of 0.8–5.3 Mha). In general, pasture land cover reductions are necessary to enable the implementation of land-based mitigation response options on a vast scale across the four archetypes. Land area requirements for bioenergy cropland and BECCS, for instance, range from 759 Mha in SSP5-19 to 158 Mha in LED, amounting to a mean annual growth of 1.8–8.4 Mha (Figure 4, left panel). This is accompanied by a similarly vast land area

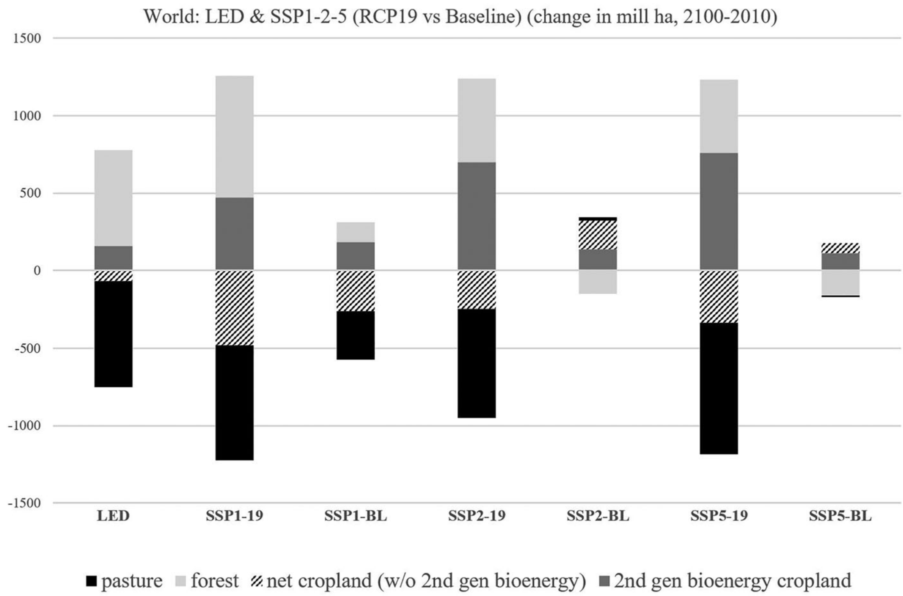

Figure 3. World land use/cover change (in millions of hectares in 2100, relative to 2010 reference levels) in key emissions reduction pathways under baseline (no additional mitigation policies) and mitigation policy conditions for limiting global warming to 1.5 °C above pre-industrial averages (RCP1.9). Data: © IAMC 1.5 °C scenario explorer hosted by IIASA https://data.ene.iiasa.ac.at/iamc-1.5c-explorer (see Huppmann et al. 2018).

requirement for afforestation, ranging from 786 Mha in SSP1-19 to 475 Mha in SSP5-19, or an annual mean growth of 5.2–8.7 Mha (Figure 4, left panel). Even the LED scenario, which is notable in its aversion to allocating bioenergy cropland for BECCS, compensates for this avoidance by projecting afforestation on a scale that exceeds expansions of forest land cover in both SSP2-19 and SSP5-19, amounting to approximately 620 Mha of afforestation by 2100, or roughly 7 Mha per year on average (Figure 4, left panel).

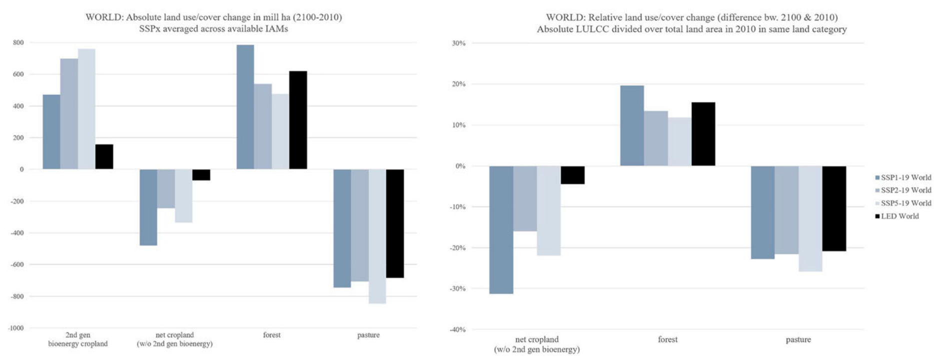

Figure 4. World land use/cover change in absolute (left panel) and relative terms (right panel), in key emissions reduction pathways for limiting global warming to 1.5 °C above pre-industrial averages. Each SSP archetype represents averaged outputs across all available IAMs. LED archetype is based on a single IAM model. Data: © IAMC 1.5 °C scenario explorer hosted by IIASA https://data.ene.iiasa.ac.at/iamc-1.5c-explorer (see Huppmann et al. 2018).

In absolute terms, comparing and contrasting these projections allows us to highlight average rates of annual change (intensity) of land-based climate mitigation initiatives, expressed in Mha per year (Figure 4, left panel). Another way to explore the magnitude of change is by plotting LULCC in relative terms, thus illustrating the amount of land affected by 2100 as a share of totally available land of the same category in 2010 (Figure 4, right panel). Across all four archetypes, we see a similar reduction in pasture (ca. 21–26%), a bigger spread in afforestation (ca. 12–20%), and an even bigger spread in cropland reduction (ca. 5–31%). Here, LED stands out from the other three scenarios by projecting 'merely' a 5% reduction in cropland cover. Unlike LED, the 'food first policy' scenario in SSP1 (Popp et al. 2017, 340) leads to a 31% contraction of cropland in 2100 compared to 2010 levels. Likewise, LED projects by far the least amount of additional land for bioenergy cultivation (Figure 4, left panel) – although we cannot illustrate it in relative terms given the lack of bioenergy cropland in 2010.

In short, both the intensity and the scale of projected land cover change raise serious questions regarding how rural populations will be impacted, particularly in the case of wholly or partially subsistence-oriented pastoralists, smallholder farmers, and other populations whose livelihoods are closely tied to the natural resource base (see also Doelman et al. 2019, 2020). To further examine these dynamics, we disaggregate the magnitude of projected LULCC across world regions to highlight divergent consequences across the Global North and South (Figure 5). Comparing projected LULCC (2100-2010) relative to the available land in 2010 in the same category and region, we see significant differences between Global North and South,[5] and between different scenario archetypes (see Figure 5, right panel). Here, SSPx reductions in cropland (without bioenergy) amount to around 23–36% of available cropland in the North, and 9–28% in the South. By contrast, LED offers a less interventionist scenario, projecting 4% reductions in cropland in the North, and 8% in the South. With regard to changes for pasture, similar projections apply for LED, but somewhat reversed for non-LED outputs. SSPx reductions in pastures amount to around 19–23% of available pasture in the North and 23–27% in the South, whereas LED projects reductions amounting to 16% in the North and 24% in the South. Finally, looking at forest cover change, the Global North is projected to gain 6–13% of forest cover, while the South is to experience afforestation between 18 and 26% for SSPx projections. Again, LED follows the trend by projecting 9% growth in forest cover in the North and 24% in the South.

Overall, relative to 2010 land area size, the comparison between North and South highlights a higher loss of cropland in the North (although not for LED, where it is reversed), more afforestation in the South and more losses of pasture in the South (Figure 5, right panel). As above, LED projects the least losses in cropland and the least increases in bioenergy cultivation (Figure 5). However, in absolute terms (Figure 5, left panel), all four scenarios project a disproportionally affected Global South compared to the North, across all four land cover change categories (with one exception of cropland in the SSP2 archetype, where the Global North is losing more cropland than the South, in absolute terms).

[5]In this context, the term 'Global South' refers to an aggregation of the R5MAF, R5LAM, and R5ASIA regions. For country-level definitions, see IIASA's SSPs database: https://tntcat.iiasa.ac.at/SspWorkDb/dsd?Action=htmlpage&page=about (accessed 26.07.2021)

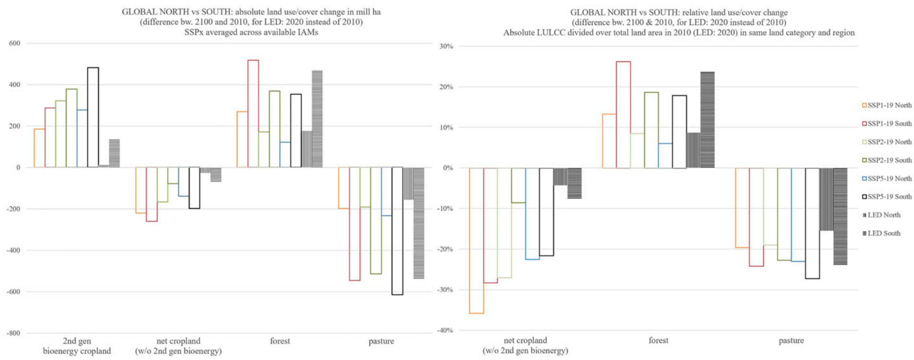

Figure 5. Global north vs Global south - absolute (left panel) and relative (right panel) land use/cover change, in key emissions reduction pathways for limiting global warming to 1.5 °C above pre-industrial averages. Data: © IAMC 1.5 °C scenario explorer hosted by IIASA https://data.ene.iiasa.ac.at/iamc-1.5c-explorer (see Huppmann et al. 2018).

Disaggregating land cover change in spatial terms even further, Figure 6 illustrates differences within the three regions that make up the Global South according to IIASA's regional definitions: Middle East and Africa (MAF), Latin America (LAM), and Asia (ASIA).[6] In the MAF region, for instance, land cover for pasture declines dramatically across the SSPx archetypes, ranging from 304 Mha in SSP-19 to 208 Mha in SSP2-19, or a mean annual reduction between 2.3 and 3.4 Mha. Mirroring global dynamics, this is accompanied by the vast implementation of response options entailing expanded land cover for bioenergy crops and forests. Bioenergy cropland requirements range from 166 Mha in SSP5-19 to 73 Mha in SSP1-19, for example, whereas forest expansion ranges from 140 Mha in SSP1-19 to 93 Mha in SSP2-19. Annually, this amounts to a mean growth of cropland for bioenergy at the scale of 0.8–1.8 Mha, and of forest land at the scale of 1–1.6 Mha. One positive aspect is the moderate cropland reduction in the MAF region, with SSP2 even projecting growth in cropland (Figure 6).

A comparison between the three regional blocks within the Global South suggests that in absolute terms ASIA is projected to lose the least amount of pasture, while losing the most cropland and experiencing the highest growth in bioenergy cropland (Figure 6, left panel). Relative to 2010 reference levels (Figure 6, right panel), ASIA is still projected to lose the most cropland, while LAM is projected to lose the most pasture land cover. All three regions are projected to experience comparable levels of afforestation, most of which takes place in the SSP1 archetype.

Taken together, the compounding losses in cropland and pasture – particularly in the Global South – suggest an overarching scramble for land to satisfy mitigation demands via either afforestation or BECCS. Further unpacking the significance of these land area requirements, in what follows we contextualize the scale and intensity of projected future LULCC for climate mitigation vis-à-vis historical analogues from the second half of the twentieth century (section 4.2) and the recent land rush from the early twenty-first century (section 4.3).

[6]We do not include LED projections at this scale, due to lack of disaggregated regional output (LED output only includes figures at the World and Global North-Global South scales).

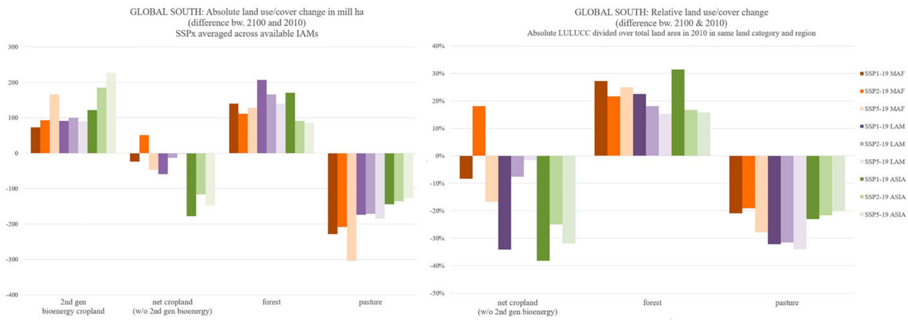

Figure 6. Global south - regional land use/cover change in absolute (left panel) and relative terms (right panel) in key emissions reduction pathways for limiting global warming to 1.5 °C above pre-industrial averages. MAF: Middle East & Africa; LAM: Latin America; ASIA: most Asian countries with exception of Middle East, Japan and former Soviet Union states. Data: © IAMC 1.5 °C scenario explorer hosted by IIASA https://data.ene.iiasa.ac.at/iamc-1.5c-explorer (see Huppmann et al. 2018).

4.2 Land use and land cover change dynamics throughout the second half of the twentieth century

To unpack the significance of 1.5 °C land use and cover change trajectories, we situate projected LULCC in the four scenario archetypes vis-à-vis the historical record compiled by the FAO. This allows us to contextualize projected scenarios in relation to historical LULCC data, which reflects how a land class (such as cropland) expands or shrinks over time (e.g. annually) at a given scale. Figure 7 illustrates how – unlike in the Global North (grey) – net cropland and pasture land cover have steadily increased between 1961–2000 across the Global South (black), while forest land cover has decreased between 1990–2000 (FAO data). To assess the significance of these historical data, we situate these trends vis-à-vis projected (2010–2100) global LULCC trajectories (for clarity, plotting SSP1 and LED data only).[7] In short, Figure 7 indicates a radical reversal of historical LULCC dynamics in the Global South. Here, historical pasture and cropland expansion are to be transformed into an absolute reduction, while historical deforestation trends are to be reversed via large-scale afforestation (in varying combinations of both 'natural' and 'managed' plantation forests).

In Figure 8, we compare the intensity of historical and future LULCC for cropland, pasture, and forest, spanning the periods 1961–2000 (FAO),[8] and 2010/2020-2100 (IIASA). Several aspects are noteworthy. First, there is a significant difference between the *direction* and *intensity* of annual LULCC in the Global North and Global South throughout the second half of the twentieth century. With regard to the *direction* of change, pasture and cropland have increased in the Global South, unlike in the Global North. As to the *intensity*, the Global South has experienced significant rates of LULCC across the three land classes, again, unlike in the North.

[7]With the exception of LED, the IIASA database does not provide a North-vs-South breakdown of global LULCC trajectories.

[8]However, for lack of pre-1990 data for forest LUC in Global South and Global North we only include two datapoints for forest based on FAO: 1990 and 2000.

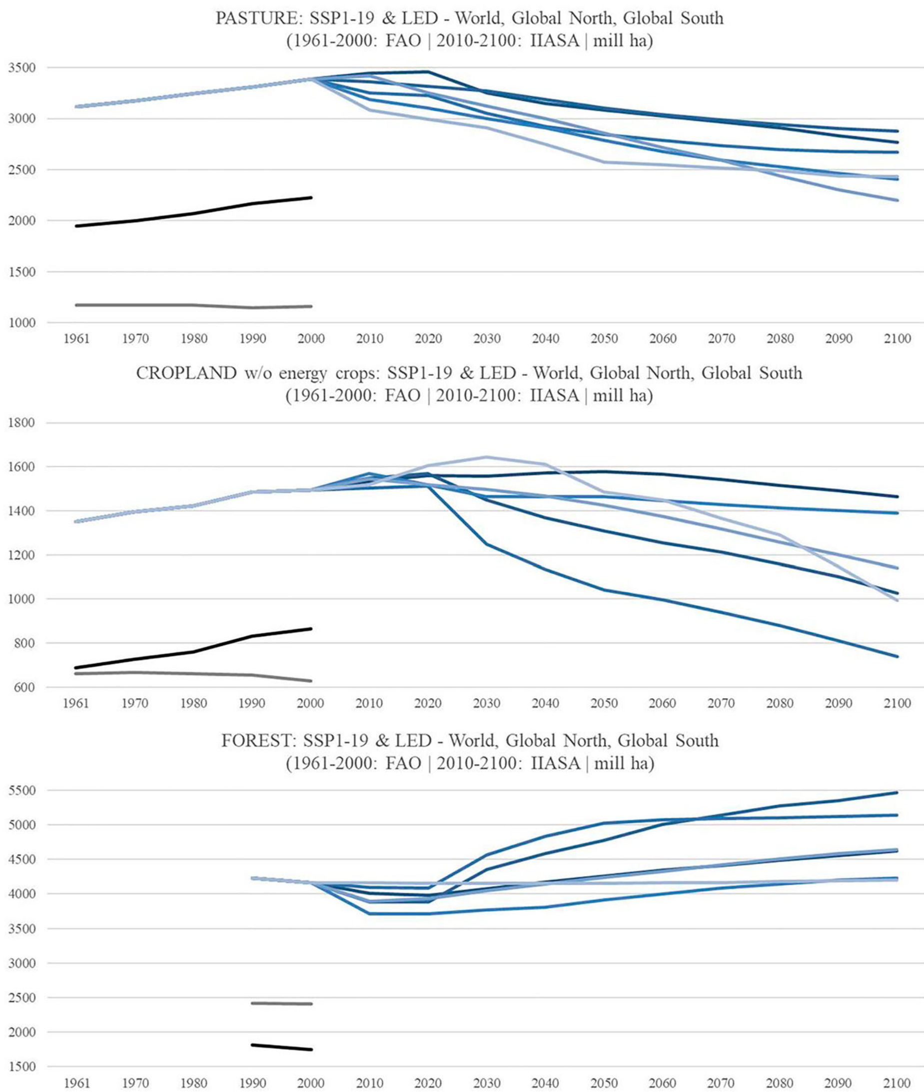

Figure 7. Historical and future land use/cover, *globally* (in different shades of blue). Historical land use/cover in Global South (black) and Global North (grey). Historical data (1961–2000) from FAO, future data (2010–2100) from IIASA.

Second, these differences in *intensity* between Global North and Global South are projected to continue in 1.5 °C climate futures, although this time LULCC assumes a similar *direction* across North and South. The annual rate of projected change in the Global North is situated between −2.3 and +2.2 Mha, hence somewhat higher than in the past (−0.2 to −1.1 mill ha p.a.). In the Global South, the annual rate of net LULCC evinces a much higher rate than in the North, amounting to –6.8 to +5.9 mill ha p.a. in the future and –6.2 to +6.9 mill ha p.a. in the past. In other words, the Global South is not only expected to halt its historically intense rates of cropland and pasture *expansion* (4.4–6.9 mill ha), but to undergo similarly intense rates of cropland and pasture *reduction*

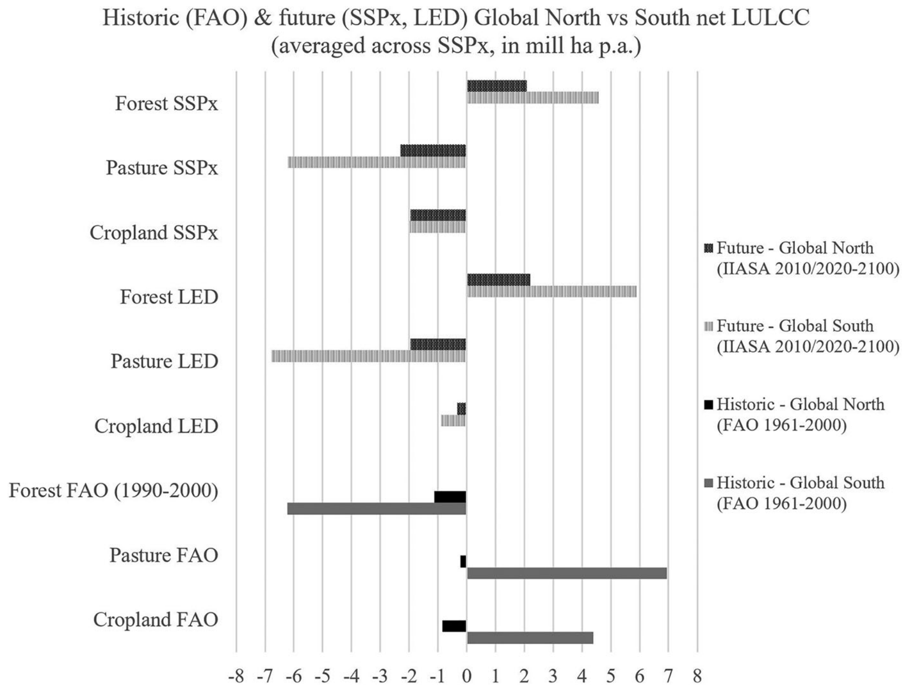

Figure 8. Rate of mean annual net LULCC: Future (LED and SSPx archetypes) and historic (FAO 1961-2000). SSPx = averaged across SSP1, 2, and 5. Data: IIASA/Huppmann et al. (2018), FAO.

*(*6.2–6.8 mill ha), therefore dwarfing both historical and projected LULCC dynamics in the Global North.

Importantly, the twentieth-century history of pasture expansion took place in the context of a growing rural population in the Global South. By contrast, future projections of pasture contraction are underpinned by rural depopulation. As discussed in relation to Figure 2 above (see Section 3), the Global South is projected to lose almost half of its current rural population by 2100 in SSP2 and LED futures, amounting to around 1.7 billion rural people in 2100. SSP1 and SSP5 futures are characterized by even more depopulation in the rural South, amounting to roughly half a billion people living in rural areas by 2100. The reconfiguration of LULCC dynamics in predominantly rural areas to mitigate climate change is thus projected to take place in spaces that are much less densely populated in the future.

Taking into account future population projections, in Figure 9 we compare the rate of cropland and pasture availability per rural person in 1960 (FAO), 2020, and 2100 (IIASA). Here, we draw attention to the Global South in particular, given that rural population is already at low levels in the Global North today. As Figure 9 illustrates, the rate of cropland and pasture availability per rural person is less pronounced in LED and SSP2 futures compared to SSP1 and SSP5, given that the former are projected to experience more modest urbanization rates than the latter. Taken together, Figures 7–9 hint at significant transformations of LULCC dynamics and rural demographics in the Global South. In the following Section 4.3, we draw upon an additional analogue in the form of the recent global

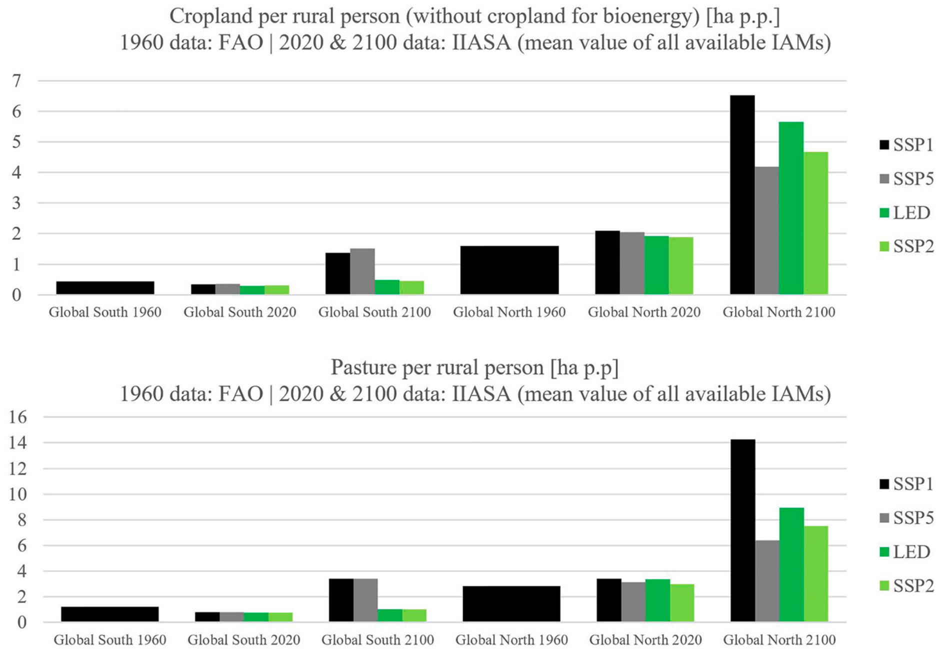

Figure 9. Global North vs Global South - historic and future land availability per rural person (top panel: Cropland, bottom panel: Pasture).

land rush to further contextualize the significance of both the scale and rate of projected LULCC in the above four scenario archetypes.

4.3 The land rush as spatial analogue for projected 1.5 °C land use and cover change futures

Important concerns have been raised in recent literature regarding the theme of figuratively ‘messy hectares’ (Edelman 2013) in the global land rush debate, or the challenge of reliably quantifying land acquisition dynamics since the turn of the twenty-first century (see also Scoones et al. 2013; Borras et al. 2022b). In this context, some scholars have suggested that quantitative analyses risk unduly asserting ‘false precision’ (Oya 2013) regarding the spatial extent of such acquisitions. Conversely, others have noted that all quantitative datasets typically evince limitations with respect to their reliability, and that – if these limitations are accounted for – the kinds of ‘imperfect data’ (Rulli and D’Odorico 2013, 907) generated by initiatives like the Land Matrix database still potentially facilitate useful insights into relevant empirical dynamics.

Simply put, we share many of the methodological concerns raised by critical scholars regarding the reliability of quantitative land rush data. Indeed, we do not seek to detract from critiques that have rightfully highlighted the implicit ‘politics of evidence’ (Scoones et al. 2013) within differing calculations of the spatial extent of global land and resource acquisitions (see, especially, Edelman 2013; Oya 2013). Such concerns are perhaps especially acute in relation to the possible ‘double-counting’ of overlapping or sequential transactions involving the same lands or properties (e.g. Scoones et al. 2013, 475). On the other hand, we note that the Land Matrix database only includes transactions that have been actively submitted by activists, researchers, or other scholars. As a result, the database may exclude an unknown number of land deals implemented, for instance, in the wake of the 2007–8 crisis, but which have eluded identification for a variety of reasons (Edelman 2013). In some cases, such uncertainties may thus result in an *under*estimation of the true extent of the global land rush in aggregate (Borras et al. 2022b), even while small-scale instances of 'double counting' may result in the over-estimation of the spatial extent of discrete land transactions at the local scale.

In light of these and related challenges, our intention here is not to imply that the Land Matrix database somehow 'perfectly' describes the full nature or spatial extent of land rush dynamics since 2000. Rather, we seek to illuminate how these data may nonetheless provide us with a useful qualitative *analogue* or reference point in relation to which the significance of future LULCC trajectories may be contextualized, rather than 'compared' in the formal sense. In doing so, we follow the Land Matrix (2022) database in defining a land acquisition as a transaction that involves: i) a 'transfer of rights to use, control, or ownership of land through sale, lease, or concession'; which ii) has been 'initiated since the year 2000'; iii) covers 'an area of 200 hectares or more'; and iv) implies 'the potential conversion of land from smallholder production, local community use, or important ecosystem service provision to commercial use'. Overall, the database tracks a total of approximately 93.2 Mha of land deals (2000–2020) globally (around 4.4 Mha annually) and 73 Mha in the Global South (around 3.5 Mha annually), across all acquisition types and implementation statuses.

Importantly, acquisitions logged in the Land Matrix database are not distributed evenly across the first two decades of the twenty-first century. Rather, available data reflect a clear spike of acquisitions between 2007 and 2014, and particularly so in the Global South (Figure 10, top panel). This 'peak' period of acquisitions correlates with two parallel spikes in food and energy prices that followed the global financial crisis of 2007–2008 (Figure 10, bottom panel). Considering these food and energy price dynamics, it is notable that land acquisitions in the Global South in the year 2011 alone (12.4 Mha) account for nearly 17% of all Global South acquisitions logged in the Land Matrix database from 2000 to 2020. Moreover, such correlations are perhaps especially ominous in light of recent macroeconomic developments. Whilst energy prices have fallen somewhat in recent years (2015–2020), both food and energy prices are once again rising sharply in the tumultuous context of the global COVID-19 pandemic, associated supply chain disruptions, and the geopolitical fallout from Russia's war of aggression in Ukraine. An important, empirically-open question thus remains concerning whether – or to what extent – an observable spike in land acquisitions will once again accompany resurgent food and energy prices.

More immediately than in the past, however, contemporary responses to the food and energy crisis must also navigate emissions reductions pledges associated with (*inter alia*) the 1.5 °C Paris Agreement target, which according to the IPCC (2018) would entail a decline in global net anthropogenic CO_2 emissions of approximately 45% below 2010 levels by 2030. Incentives for both mitigation and non-mitigation-associated land acquisitions are in some ways thus even more pressing than in the aftermath of the 2007–8 financial crisis. Methodologically, however, one cannot directly 'compare' the magnitude or spatial extent of historical land acquisitions (for instance, as documented within the

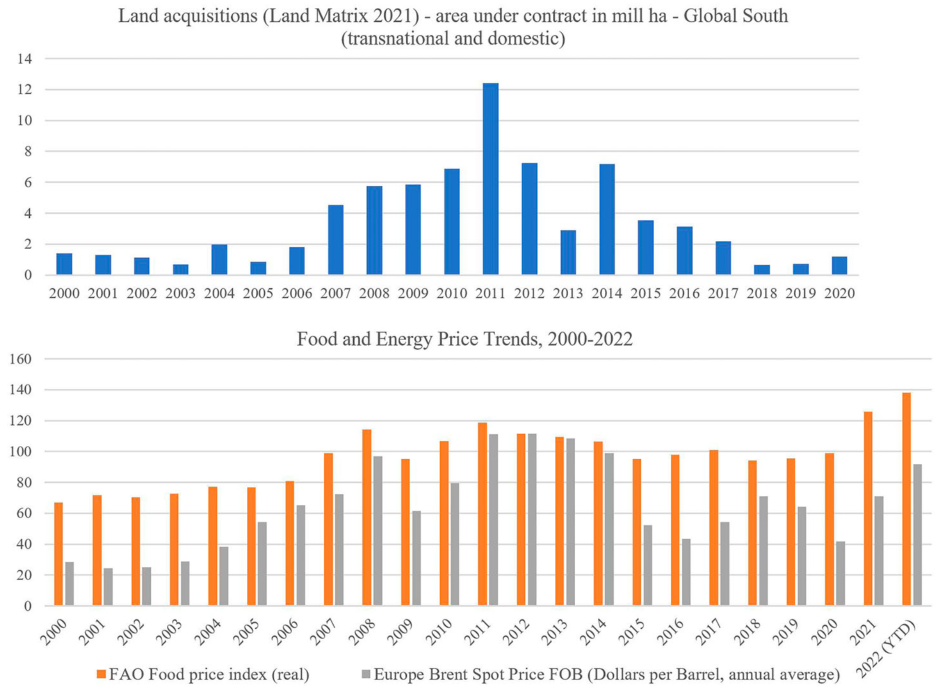

Figure 10. Land acquisitions per year, Global South, 2000–2020 (top panel) and FAO food price index and europe brent spot price (annual average, 2000–2022) (bottom panel). Data: Land Matrix Database, FAO and US EIA (2022).

Land Matrix database) with future LULCC projections for meeting the 1.5 °C target across the above four scenario archetypes. Amongst other constraints, individual Land Matrix transactions may or may not entail either land use or land cover *changes* per se (e.g. from forest cover to cropland or vice versa). Moreover, even if such changes are purportedly desired by investors, the speculative nature of many land deals implies that corresponding alterations of land use or land cover may not actually materialize on the ground (Borras et al. 2022b).

Assuming that a significant proportion of projected LULCC for climate change mitigation will materialize through single change events in the future, however, it is nonetheless salient that average rates of projected LULCC (in Mha per annum) resemble rates of acquisition throughout the ‘peak period’ documented in the Land Matrix database. Indeed, across the three SSPx and LED archetypes, mean future LULCC in the Global South is projected at approximately 6 Mha p.a. of pasture reductions and 4.5–6 Mha p.a. of forest cover expansion (Figure 7). Temporally, this is reminiscent of the rate of land acquisitions during the ‘peak period’ (2007–14) of the global land rush – during which the Land Matrix database tracked approximately 6.6 Mha p.a. of land deals in the Global South – albeit, importantly, sustained throughout the remainder of the twenty-first century. This is significant given that – whilst the critical literature increasingly takes issue with the reliance on afforestation and BECCS in scenarios that envision the slowest rates of transition away from fossil fuels (e.g. SSP5-19; see Carton 2019; Hickel 2019) – rates of projected LULCC even in the Low Energy Demand (LED) archetype still remain considerable relative to both the historical record and the 'peak period' of the global land rush (Cavanagh 2021). Indeed, although it laudably eschews reliance on BECCS, the LED scenario nonetheless entails a global expansion of forest cover alone amounting to 646 Mha between 2020-2100, or an average of approximately 8 Mha per annum, sustained throughout the rest of the century.

Drawing upon the empirical precedent of twentieth-century LULCC (as highlighted in Section 4.2), it is not implausible that projected LULCC would unfold through single mitigation-related events, and particularly in the Global South. Winkler et al. (2021), for instance, estimate that 38% of global LULCC (pasture, cropland and forestry) in the period 1960–2019 involved single change events, the majority of which occurred in the Global South. Potapov et al. (2022) echo this observation, highlighting how in the last two decades, 79, 61, and 39% of cropland expansion in Africa, South-East Asia, and South America, respectively, took place through the conversion of natural vegetation: in other words, through single LULCC events. Moreover, achieving the 1.5 °C Paris Agreement target implies that mitigation-related interventions at the landscape scale will largely necessitate both direct and sustained transition from – for example – pasture to forests, cropland to forests, or pasture to bioenergy cropland. That said, even if projected LULCC is achieved as the *net* outcome of multiple change events -- and on top of a significant volume of other, more conventional land acquisitions -- our reference to the historical analogue of the global land rush simply becomes more conservative. In the latter case, projected net LULCC futures (4.5–6 Mha p.a.) will amount to gross LULCC above 6 Mha p.a., likely exceeding what the Land Matrix database has tracked for the 'peak period' of the global land rush, albeit sustained throughout the remainder of the century. Given these considerations, we suggest that the Land Matrix offers a reasonable – potentially even a somewhat conservative – qualitative analogue that allows us to make sense of the projected scale and rate of mitigation-related transformations at the landscape scale.

Differently put, discrete instances of land use or cover change for climate change mitigation can often entail similar socio-economic consequences as conventional land or resource acquisitions. This is particularly so insofar as these changes imply conversion to non-agricultural or non-productive land uses, as well as corresponding opportunity costs or restrictions of access to natural resources for rural populations. Already, a substantial case study literature engaging dynamics of 'green grabbing' (Fairhead, Leach, and Scoones 2012) illustrates how such restrictions may catalyse outright dispossession (e.g. Beymer-Farris and Bassett 2012; Cavanagh and Benjaminsen 2014), as well as more subtle forms of 'control grabbing' (Hall et al. 2015) with negative implications for rural livelihoods (see also Fisher et al. 2018; Cavanagh et al. 2021). Given both the magnitude and rate of projected LULCC across the four scenario archetypes, we thus infer that considerable potential exists for the latter dynamics to entail a significant 'rescaling of the land rush'. This is particularly so in light of the role of the global land rush as a significant contributor to both GHG emissions (Liao et al. 2021) and broader LULCC dynamics in recent history (Winkler et al. 2021), as well as the significant reconfiguration of prevailing historical patterns implied within future LULCC projections (Figures 7–9). Yet the question remains: what lessons, exactly, should critical scholars extract from historical dynamics of land and resource acquisition to guide the analysis of emergent trajectories of land-based climate change mitigation? Seeking to encourage further discussion and debate surrounding these concerns, the ensuing section sketches out an initial series of analytical 'contours' or emerging conceptual foci that may warrant further attention in political ecology, critical agrarian studies, and related fields.

5. Global political ecologies of 1.5 °C land use and cover change futures

To situate key insights from our analysis, we begin by highlighting the likely enduring significance of six key trends that White et al. (2012) argue have underpinned the global land rush in the first two decades of the twenty-first century. These include: 1) 'the global anticipation of food insecurity', which led to a new wave of corporate investment in the agricultural sector; 2) 'new forms of resource extraction for fuel security', incentivizing biofuel production and the acquisition of land for alternative energy projects; 3) 'new environmental imperatives and tools', precipitating resource acquisitions in the name of conservation or environmental change mitigation; 4) 'extensive infrastructure corridors and Special Economic Zones' that link extractive frontiers to metropolitan areas and foreign markets; 5) the 'creation of new financial instruments', which led to speculative and risk hedging investments; and finally, 6) a new 'set of rules, regulations and incentives provided by the international community' that promote land or resource acquisitions institutionally, legislatively, and financially. Taken together, these trends highlight the 'dispossession of land, water, forests and other common property resources; their concentration, privatization and transaction as corporate (owned or leased) property; and […] the transformation of agrarian labour regimes' within the recent land rush (White et al. 2012). In other words, through the shifting politics and political ecologies of land and resource control, some individuals, communities and/or land users have become gainfully incorporated into land deals. Simultaneously, others have either been excluded outright, or incorporated in accordance with terms and conditionalities that they perceive to be detrimental (Hall et al. 2015).

As Borras et al. (2022a) highlight in their introduction to the present *Journal of Peasant Studies* forum, these dynamics of dispossession, (adverse) inclusion, and outright exclusion increasingly already play out vis-à-vis the uneven impacts of both climate change and attempts at its mitigation. Importantly, these malign outcomes can manifest via processes of 'accumulation [or dispossession] from above' as well as through dynamics of 'accumulation [or dispossession] from below' (Cousins 2013; see also Amanor 2012). That is to say, simultaneous accumulation (by some) and dispossession (of others) may result from large-scale land or resource acquisitions for climate change mitigation, ecosystem restoration, or agribusiness enterprises that are imposed 'from above', for instance via transnational investment flows or donor-driven schemes facilitated at the national and regional scales by state agencies or other intermediaries (Wolford et al. 2013). Yet these intertwined phenomena of simultaneous accumulation and dispossession can also occur at much 'smaller' scales, for instance when the imposition of ostensibly 'climate smart' or 'sustainably intensified' agricultural practices result in the expansion of already well-capitalized small or medium scale enterprises at the expense of less well-capitalized 'competitors' (Franco and Borras 2021; see also Cavanagh et al. 2021). As Borras, Franco, and Nam (2020) remind us, ostensibly 'non-corporate' or smaller-scale land transactions can contribute to land rush dynamics in ways that either *exacerbate* climate change (by heightening emissions from intensified agricultural production – see Liao et al. 2021) or contribute to its mitigation (i.e. when medium-scale enterprises respond to new economic incentives for emissions reductions, land use change, or land cover change, displacing already marginal households or agricultural producers in the process).

Ultimately, these emerging concerns once again underscore White et al.'s (2012, 620) observation that recent rush dynamics have threatened to precipitate 'a truly wide-ranging "land reform"', albeit a largely regressive one in which 'governments take land from the poor and give (or sell or lease) it to the rich'. Reflecting on the recent turn toward mainstreaming climate change adaptation and mitigation concerns in land governance frameworks, Borras and Franco (2018, 1314) thus rightfully highlight how tendencies to favour 'the landed classes and elite actors engaged in capital accumulation, while marginalising social justice land policies of redistribution, recognition and restitution' threaten to become entrenched in prevailing climate change responses as well. As Section 4 has illustrated above, projected LULCC for climate change mitigation can certainly be conceptualized as a wide-ranging land reform at the global scale. What remains less clear, however, is the extent to which land-based climate mitigation initiatives will further amplify these *regressive* patterns of land reform, in practice amounting to a 'rescaling of the land rush', as it were.

Three key insights from the above analysis of our four scenario archetypes suggest that projected LULCC futures may indeed indicate an incipient rescaling of the land rush in this regard, amounting to what Borras, Franco, and Nam (2020, 2) term 'regressive climate change politics' (also see Franco and Borras 2021). Firstly, it is notable that none of the above four scenario archetypes overtly explore post-capitalist or post-growth pathways. The SSP2 ('middle of the road') scenario, for instance, assumes that future development trajectories will 'not shift markedly from historical patterns' (Riahi et al. 2017). Likewise, SSP5 ('fossil fuelled development') echoes a return to the spirit of the post-World War II era, assuming the continuation of 'resource and energy intensive lifestyles' through rapid economic growth, albeit in ways that are offset through the deployment of large-scale 'techno-fixes', such as afforestation or BECCS (Riahi et al. 2017). By contrast, the SSP1 ('sustainability') archetype anticipates decreasing inequality between and within countries, underpinned by wider transitions to a broadly-defined 'green economy' (O'Neill et al. 2017). More radically, the LED ('low energy demand') scenario envisions the pursuit of sustainable development via considerable reduction in energy demand and material throughput, particularly in the Global North (Grubler et al. 2018) – albeit in ways that largely remain ambivalent about possibilities to maintain modest levels of compounding economic growth. Differently put, the four archetypes continue relying on economic growth – albeit in progressively more 'green' iterations over the coming decades – and in which processes of compounding GDP growth are absolutely decoupled from greenhouse gas emissions over time.

Such an aversion to explicitly post-growth scenarios is concerning, given that a rescaled land rush to mitigate climate change in a broadly 'green' capitalist scenario risks perpetuating most – if not all – of the six trends that White et al. (2012) have observed in the recent 'peak' land rush period, and particularly so in the Global South. Indeed, past correlations of heightened land acquisitions, food prices, and energy prices (see Figure 10, bottom panel) are perhaps especially concerning in light of emerging geopolitical developments, the implications of which will reverberate for years – if not the next decade and more – to come. Whilst energy prices declined somewhat in recent years (2015–2020), both food prices and energy prices are once again rising sharply in the tumultuous context of both the global COVID-19 pandemic and the ongoing war in Ukraine. In particular, the second-order implications of the latter are expected to significantly disrupt global markets for energy, agricultural commodities, and – importantly – fertilizers. Indeed, following the outbreak of the war in Ukraine, the food price index reached an all-time high of 159.7 in March 2022 – almost 21% above the 2011 peak, and nearly 16% higher than the previous historical maximum, recorded during the OPEC oil crisis in 1974. Similarly, Brent spot prices have rallied in early 2022 to an average of almost 108 USD over the year to date. This represents a 63% increase in the food price index and a 157% increase in average Brent spot prices from 2020 levels, respectively. In short, this confluence of trends raises concerns about the extent to which 'the global anticipation of food insecurity' (White et al. 2012) will once again precipitate a global rush for land and resources, albeit this time mapping onto the context of emergent mitigation-related LULCC via afforestation and biofuel plantations at the expense of cropland and pasture on a vast scale.

Secondly, projected LULCC in the four scenario archetypes is envisioned to take place under radically different demographic conditions relative to the recent historical record. Over the course of the late twentieth and early twenty-first centuries, land use and cover change dynamics in the Global South were underpinned by growing rural populations and an increasing – or at least not stagnant – land base for cropland and pasture (Figure 7). By contrast, all four scenario archetypes project a massive loss of pasture and cropland, dovetailing with a rapidly shrinking rural population. In other words, this radical reversal of historical LULCC trends in terms of land availability and rural demography implies an acceleration of historical patterns of de-agrarianization and de-peasantization (Bryceson, Kay, and Mooij 2000), realized through ostensibly 'sustainable' forms of agricultural intensification and associated practices of 'land sparing' to facilitate growth in forest land cover or other mitigation-related land uses.

In this respect, contemporary land rush dynamics may once again provide us with a glimpse into the implications of anticipated LULCC trajectories to meet the 1.5 °C Paris agreement target. As Peters (2013, 538) cautions with respect to the future 'upscaling' of large-scale agriculture on the African continent, in particular:

> If the currently influential view that large-scale agriculture is the only and proper way to produce foods and other agricultural products maintains its dominance, the fate of people who live on and from that land is to be rendered 'surplus' to perceived development needs. At best, the agro-industrial vision of the future marginalizes small-medium scale farming into enclaves or as appendages to large-scale, industrial agriculture; at worst, it is erased.

Differently put, if land-based climate mitigation futures unfold as projected through the combination of a rescaled land rush, exponentially increasing carbon prices, and rural depopulation (see Figure 8), rural spaces across the Global South will become increasingly economically valuable as carbon sinks and 'sustainably intensified' agricultural zones through a new wave of enclosures. Conversely, large segments of (formerly) rural populations will at least initially be rendered surplus to capital's requirements, pending their ability to transition to non-agricultural livelihoods in cities or other urban areas. In short, there is a significant risk that dispossession from rural landscapes through yet another wave of new enclosures will underpin land-based climate mitigation responses across the four scenario archetypes.

Thirdly – and perhaps most importantly – the above dynamics of simultaneous rural depopulation and enclosure once again highlight the need for a corresponding analysis of shifting human settlement patterns vis-à-vis the production of what Marx (1990 [1867], 782–802) once termed 'relative surplus populations', or populations that are 'superfluous to capital's average requirements for its own valorization'. Such dynamics are important to our analysis of projected LULCC futures, given that – in the past – cropland and pastures have expanded in the Global South in lockstep with growing rural and urban populations (see Figures 2 and 7). Broadly, this denotes that rural landscapes have often acted as a 'temporary sink for excess urban workers' (Benanav 2014, 110). At times, this has facilitated practices of 'managing dispossession' (Li 2010) that allow 'latent' surplus populations to assume agrarian livelihoods as peasants or smallholders. In stark contrast, the future mitigation scenarios we have examined in this article largely do not offer such an option across broad swathes of the rural sphere in the Global South, implying that latent surplus populations are expected to become 'manifest' via processes of urbanization and rural depopulation (Benanav 2014, 110, 178).

Global urbanization and rural depopulation of this kind risk prefiguring futures characterized by insecure, informal, and precarious urban labour, with little or no possibility to return to either subsistence-oriented or modestly market-oriented production in rural areas. Yet integrated assessment model scenarios largely cannot directly capture or represent such informal phenomena, given their inevitable simplifications of complex system dynamics (Peng et al. 2021). In this sense, IAMs may not be strictly 'wrong' to claim that certain 1.5 °C-compatible scenarios are underpinned by reduced inequality, continued economic growth, and relatively more 'sustainable' forms of development (e.g. Riahi et al. 2017). That is to say, a reduction of *formal* inequalities and an increase in precarious, *informal* surplus populations are not necessarily mutually exclusive outcomes within the context of these scenario projections.

In sum, the above three insights present us with a series of pressing questions that may warrant further exploration and debate in political ecology, critical agrarian studies, and related fields. For instance – even in futures characterized by the effective limitation of global warming to 1.5 °C above pre-industrial averages by 2100 – how 'successful' will these simultaneous processes of expansive LULCC and widespread urbanization be in unleashing a new phase of capital accumulation through ostensibly 'green' growth? To what extent will such growth in fact gainfully integrate newly landless populations of former smallholders into formal wage relations within the context of rapidly urbanizing human settlements? In other words: how confident should we be that land-based climate mitigation responses will in fact *achieve* the simultaneous ambitions of securing both a spatial and a socio-ecological fix for capital in the 'age of stagnation' (Copley 2022)?

In Jason Moore's (2010, 395) terms, such a 'success' would effectively mark the end of the long economic downturn since the 1970s, which has all-too-often been understood as a 'developmental crisis' of capitalism to be overcome 'through new forms of productivity and plunder' (see also Harvey 2003). On one hand, liberal analysts might contend that there is perhaps nothing *inherently* undesirable about such an outcome, particularly if it is compatible with SSP1-esque ambitions to reduce formal inequalities both between and within nations. Indeed, if Moore (2010) is correct that our present conjuncture has led to the unravelling of the 'cheap' global food regime – as evidenced by the 2007–8 crisis and its aftermath in the form of the global land rush (see also Figure 10) – then a 'rescaled' land rush driven by the implementation of climate mitigation initiatives could conceivably result in such a combined spatial and socio-ecological fix. Conversely, the following observation from Davis (2006, 16) provides two key reasons for concern in this regard:

> Rather than the classical stereotype of the labor-intensive countryside and the capital-intensive industrial metropolis, the Third World now contains many examples of capital-intensive countrysides and labor-intensive deindustrialized cities. 'Overurbanization,' in other words, is driven by the reproduction of poverty, not by the supply of jobs. This is one of the unexpected tracks down which a neoliberal world order is shunting the future.

Differently put, a critical analysis of scenario projections for a 1.5 °C future resonates with Davis' anticipation of incipient 'capital-intensive countrysides' and 'labor-intensive deindustrialized cities'. In the context of Global South, the former eerily resembles newly 'green' projections regarding the rapid decline of croplands and pastures in hitherto undercapitalized rural areas. Indeed, across the projected LULCC futures examined above, these areas are envisioned to rapidly transform into capital-intensive carbon sinks and 'sustainably intensified' agricultural enterprises. By contrast, the latter will increasingly manifest as growing urban spaces to absorb the future landless poor, that 'floating' part of relative surplus population that is slated for displacement from rural areas (Marx 1990 [1867]).

In this respect, we emphasize that our analysis offers a complementary take on the question of 'green labour' in the unevenly emergent green economy. Neimark et al. (2020), for instance, have recently highlighted the rise of what they call the 'eco-precariat' in the context of environmental interventions in rural areas of the Global South. Whilst these authors focus on people labouring precariously *for* environmental interventions, however, here we highlight the simultaneous production of populations who are rendered surplus *through* or as a result of environmental interventions, such that their labor is often not 'needed' except perhaps in a variety of emergent informal or precarious settings (see also Kelly 2011; Fairhead, Leach, and Scoones 2012). Here, Neimark et al. (2020, 8) suggest that – through accumulation by dispossession – land-based rural livelihoods are transformed into a 'working class of proletariat or wage workers' that can be subsequently enrolled in environmental interventions and projects as labourers, leading to the production of what they call the 'eco-precariat' and the 'hyper-eco-precariat'. Whereas this seems to imply a largely 'complete' process of primitive accumulation or accumulation by dispossession, we note that – in practice – the actual extent of proletarianization often remains highly uneven or 'incomplete' (Bluwstein et al. 2018). Differently put, a portion of the rural population previously engaged in land-based rural livelihoods will often not be absorbed into the waged working class – however precarious its status – but rather risks being rendered as an expandable 'surplus' altogether. Simply put, such a predicament constitutes a highly fraught foundation for agrarian politics in future scenarios characterized by both the ostensibly 'successful' and 'sustainable' limitation of global warming to 1.5 °C above pre-industrial levels.

6. Conclusion

Engaging recent debates on multi-sector sustainability transformations in political ecology and related fields, this article has explored the land use and land cover change (LULCC) implications of four scenario archetypes recently foregrounded by the IPCC for limiting global warming to 1.5 °C above pre-industrial averages. Empirically, we have disaggregated LULCC projections across the four scenario archetypes, examining their divergent impacts across several world regions and highlighting a suite of associated socio-environmental justice implications. Overall, we underscore how all four mitigation archetypes may imply a considerable 'rescaling of the land rush' with respect to the spatial extent of projected LULCC, as well as simulated rates of implementation, which evince few empirical analogues in the twentieth and early twenty-first centuries. Differently put, prevailing 1.5 °C scenario archetypes imply unprecedented both rural and urban transformations, and particularly so insofar as they entail a radical reversal of historical LULCC dynamics in the Global South. We note, for instance, that the observed history of twentieth-century pasture and cropland expansion is broadly simulated to rapidly transform into an absolute reduction across the four archetypes, while historical deforestation trends are projected to be reversed via large-scale reforestation and afforestation (involving varying combinations of both 'natural' and 'managed' plantation forests). In other words, the Global South is not only projected to rapidly halt its historically intense rates of cropland and pasture *expansion* (4.4–6.9 Mha p.a.), but to undergo similarly intense rates of cropland and pasture *reduction* (6.2–6.8 Mha p.a.) throughout the remainder of the twenty-first century, thereby dwarfing both historically observed trends and simultaneously projected LULCC dynamics in the Global North.

To contextualize the significance of this reversal of historical LULCC trends, we have drawn upon the recent land rush as an additional spatial 'analogue' or reference point that will be familiar to many political ecologists and critical agrarian studies scholars. Methodologically, we have not sought to formally 'compare' the spatial magnitude of historical land acquisitions with future LULCC projections across the above four scenario archetypes. Indeed, as emphasized above, individual transactions logged in the Land Matrix database may or may not entail either land use or land cover *changes* per se (e.g. from forest cover to cropland or vice versa). Nonetheless, it remains notable that average rates of projected LULCC in the four scenario archetypes resemble rates of acquisition throughout the 'peak period' (2007–2014) of the global land rush, albeit sustained throughout the remainder of the century. Importantly, the database tracks a total of approximately 73 Mha of land deals in the Global South (2000-2020), amounting to an average of roughly 3.5 Mha of acquisitions per year, or 6.6 Mha per year throughout the 'peak period' of the global land rush. This is notable, given that – across the SSPx and LED archetypes – mean future LULCC in the Global South is projected at approximately 6 Mha p.a. of pasture contraction and 4.5–6 Mha p.a. of forest cover expansion. Even the Low Energy Demand (LED) scenario – promoted by critical scholars for its avoidance of certain land-intensive mitigation initiatives, such as BECCS (e.g. Hickel 2019) – projects an increase in forest land cover alone amounting to approximately 646 Mha globally and 470 Mha in the Global South between 2020 and 2100, or around 8 Mha per year on average (5.9 Mha p.a. in the Global South). Simply put, the sheer scale and rate of these LULCC projections even in low(er) energy demand scenarios raise important questions about their articulation with both contemporary and historical land rush dynamics, as well as their corresponding potential to be accompanied by related socio-environmental injustices.

As a result of these and similar risks, our analysis has sought to illuminate associated conceptual implications for the present *Journal of Peasant Studies* forum, highlighting concerns related to rural enclosures, primitive accumulation or 'accumulation by dispossession', and the implied production of relative surplus populations in future scenario archetypes. Here, we conclude by emphasizing that – despite these risks – none of the 1.5 °C scenario archetypes examined above would be likely to amount 'in practice' to what one might term a 'conclusively' stable political-ecological formation (see Wainwright and Mann 2013). Indeed, each of the four archetypes are potentially characterized by their own implicit contradictions or latent political-ecological tensions, some of which may precipitate the emergence of what Franco and Borras (2019) call 'agrarian climate justice' movements. That is to say, mitigation futures characterized by 'green' growth, large-scale land sparing dynamics through LULCC, and widespread urbanization may only temporarily yield spatial or socio-ecological 'fixes' for capital. Conversely, these dynamics will inevitably also foment contradictory political-ecological tendencies of their own, which will almost certainly precipitate further contestation, mobilization, and conflict. Many rural people in the Global South, for instance, will simply not volunteer to be dispossessed and urbanized into informal and precarious wage relations without the prospect of a suitable and/or viable alternative livelihood. Similarly, both the urban poor and middle classes will undoubtedly oppose the erosion of their standard of living via food or energy price inflation, and particularly so if 'demand reduction' initiatives are haphazardly implemented, resulting in demand *destruction* via sustained price increases instead. Already, a growing segment of the urban – or 'newly urbanizing' – poor is increasingly engaging in struggles demanding basic rights and respect for human dignity, at times escalating into strikes, riots, and other forms of organized or semi-organized resistance (Davis 2006; Harvey 2012; Clover 2019). Ultimately, this predicament echoes Tania Li's (2011, 281) observation that 'any program that robs rural people of their foothold on the land must be firmly rejected […] unless vast numbers of jobs are created, or a global basic income grant is devised'. Land-based climate mitigation under predominantly capitalist political-ecological conditions (perhaps approximating the 'climate leviathan' scenario described by Wainwright and Mann 2013) may represent such a programme, with a rescaled land rush and the production of an unprecedented eco-surplus population as its outcome.

Acknowledgments

Both authors contributed equally to this article. Order of authorship is alphabetical. We would like to thank the editors of the *Journal of Peasant Studies* Forum on Climate Change and Critical Agrarian Studies, as well as the three anonymous reviewers, for helpful comments on past versions of the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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