Spatial Fix and Metabolic Rift as Conceptual Tools in Land-change Science

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Introduction

The cumulative and systemic implications of land change have prompted the inclusion of land-change science (LCS) in global change and sustainability discourse (Foley et al. 2005; Turner et al. 2007). The Board of the Millennium Ecosystem Assessment devoted significant portions of its report to land change and estimated that humans have "transformed" more than half of 6 of the Biosphere's terrestrial biomes and converted 25% of the Earth's terrestrial surface to cultivation (MEA 2005). Most projections indicate increased land scarcity in the near future, primarily due to expanding cultivation and urban expansion (UNEP 2012; Foley et al. 2011; Lambin and Meyfroidt 2011). This widespread and accelerating transformation of terrestrial biomes is one of the factors that prompted researchers to caution that forces within human society may be pushing the Biosphere towards a critical threshold and into a functional state with which humanity is unacquainted (Barnosky et al. 2012).

As an issue of global change, LCS also occurs within the discourse of Earth-system science (Kump et al. 1999; Mackenzie 1998), although land change—which is inherently local in scale and immediate in effect, but has become widespread globally—differs from issues such as anthropogenic changes to the global climate system and ozone composition, where the effects are distributed globally, at a remove from their causes (Smil 2002). Given the potential of cumulative local changes to trigger regional or global threshold crossings, Rockström et al. (2009) included a suggested upper limit of 15% of ice-free land devoted to agriculture[2] as one of their nine proposed planetary "boundaries." Land change has also been implicated as a major factor in climate change (IPCC 2008), anthropogenic biodiversity depletion (Lévêque and Mounolou 2003), and the approximate doubling of the quantity of reactive nitrogen cycling through the Biosphere (Smil 2011).

LCS and Sustainability

Earth-system science and LCS both fall within the broader discourse of sustainability (Turner et al. 2007). Although Earth-system science includes geologic, atmospheric, and marine processes not necessarily tied directly to land change (Schlesinger 1997; Berner and Berner 1996), human land-use is considered one of the most prominent and crucial linkages between human systems and the rest of the Biosphere (Liverman and Cuesta 2008). LCS approaches this relationship as a "coupled human-environment system," consisting of

2 The MEA's (2005) estimate differs from Rockström et al.'s (2009) due to different estimation methods and definitions of what is cultivated land.

bidirectional interactions that are primarily examined through computational modeling and scenario development (Robinson et al. 2007; Turner et al. 2007; Parker et al. 2003), or synthesis and meta-analysis of collections of case studies (Geist and Lambin 2002). The research agenda is largely determined by formal international institutions that use models, scenarios, and meta-analysis to identify policy and stakeholder decisions optimally consistent with pre-defined criteria of sustainability (Turner and Robbins 2008; Turner et al. 2007; GLP 2005; Turner et al. 2004).

A fundamental challenge in sustainability science, including LCS, has been the integration of numerous disciplines in a manner that provides adequate insight into interactions within and between both the "human" and "environment" aspects of the coupled human-environment systems (Carpenter et al. 2009; Liverman and Cuesta 2008). Integrating disciplines traditionally associated with the social sciences and humanities alongside the "natural" sciences in an adequately balanced way has proven especially problematic, yet it remains an urgent need (Lave et al. 2014; Palsson et al. 2013).

With its coupled-system approach, LCS has been in a position to facilitate this integration, despite the reluctance of some social scientists to engage in ecological issues and the logistical difficulties posed by the integration of biophysical and sociological data into models and scenarios (Robbins 2012; Turner et al. 2004). LCS has facilitated the identification and analysis of many proximate factors linked to land change, and has challenged several prevailing "environmental orthodoxies" with empirical evidence of complex causal pathways that fall between the extremes of single-factor causality and irreducible complexity (Turner and Robbins 2008; Forsyth 2003; Geist and Lambin 2002).

Weaknesses of LCS

Despite these advances, LCS has not been as successful in developing the theoretical framework needed to connect local land change with the global territoriality of the capitalist world-system. While empirical observation has confirmed that "globalization" tends to trigger rapid land change by increasing the complexity of factors that determine land-system configurations and severing local linkages between production and consumption (Lambin et al. 2001), LCS has not considered the underlying impetus of globalization processes or sufficiently accounted for land change in the evolution of the capitalist world-economy.

Two ideological commitments of LCS are largely responsible for this explanatory shortcoming: (1) a post-positivist ideology of science; and (2) a neoclassical ideology of economics (Robbins 2012; Turner and

Robbins 2008). The post-positivist ideology in which LCS frequently operates reinforces the tendency to treat nature as something apart from society, and therefore to fail to recognize nature as a product of society (Smith and O'Keefe 1980). The formal orientation of LCS towards policy input reinforces these ideological constraints, as the legitimacy of such input is based on an "ethical neutrality assumption" that proscribes more critical perspectives and privileges the status quo (Harvey 1974).

By deviating from these two ideological commitments to include insights from Marxist theory, we may gain clearer insight into the power dynamics and structural features of the global system underlying land change. Specifically, the concept of spatial fix (Harvey 2001a) can be used to place the notion of metabolic rift (Foster 1999a) in a geographic context that can be used in LCS to link the proximate drivers of land change to the geography of capitalism.

The Metabolic Rift

The concept of metabolic rift, originally proposed by Foster (1999a), is based on Marx's (1990, 1991) observations regarding the effects of land changes associated with the early growth of capitalism on agricultural nutrient cycles and the division into rural and urban populations. Foster et al. (2010a) and others (e.g., Clark and Foster 2009; Clark and York 2008) have generalized this observation to assert that capitalism poses a structural barrier to the reconciliation of social metabolism with biophysical processes, or to any human attempt to rationally control this metabolism.

The central theme of metabolic rift is that the organization, relationships, and institutions of production under capitalism disrupt the cycling of materials and energy, and force societal metabolism into a rate that exceeds the Biosphere's capacity to sustain essential resources and processes. This is primarily because capitalist production entails (1) subjugation and exploitation of human labor and other resources; and (2) the transformation of ecological limits into barriers to be overcome, all to the end of capital accumulation. This precludes the possibility of rational control over society's metabolism and its reconciliation with biophysical processes, as the process of production and accumulation is not controlled by social consensus, but by capital accumulation (Clark and York 2008; Foster et al. 2010a).

The treadmill of accumulation, central to this account of the metabolic rift, acts as a constant pressure to increase the rate and scale of social metabolism, as the driving force—as characterized by Marx—is accumulation for the sake of further accumulation and production for exchange-value instead of use-value. While this concept of a perpetually accelerating treadmill can serve as a direct metaphor for material flows

and hydrocarbon use, it does not address the geography of capitalism, or the capitalist production of space. This gap between Marxist critical theory and geography has limited the ability of critical scholarship to describe contemporary contradictions in the geography of capitalism as determinate features of the capitalist mode of production (Smith 2001).

The Geographic Expression of the Metabolic Rift

We refer to the geographic expression of the metabolic rift simply as the geographic rift, not as a new concept but as a shorthand. We also concur with McClintock's (2010) observation that "rift" actually refers to a spatio-temporal rescaling of social metabolism, but maintain the terminology for consistency with existing literature on the topic.

Historically, the agrarian question has been a prominent point where Marxist theory and geography intersected to consider the capitalist production of territory (de Janvry 1981). Thus, several scholars have pursued a geographic context for the metabolic rift based on agrarian issues. Dobrovolski (2012) used Marx's (1991) critique of differential land rent to describe how the capitalist world-market drives a metabolic increase in the exploitation of fertile land beyond its ability to generate sufficient exchange-value, at which point existing plots are abandoned and standing forests converted into agriculture. This application of land rent and metabolic rift to LCS functions particularly well in "frontier" regions of deforestation, such as the Amazon.

McClintock (2010) applied the concept of metabolic rift in an urban geographical context by examining urban agriculture comparatively in the Global North and South. In the process, he proposed that the metabolic rift has three connected dimensions: ecological, social, and individual, and contended that much of the work on the metabolic rift has focused on the first dimension at the expense of the other two. Urban agriculture, in this context, is an attempt to lessen the rift by re-localizing the scale of production, re-allocating territories to the production of use-values, and lessening the urban-rural divide.

Schneider and McMichael (2010) made this critique more explicit by arguing that the articulation of the metabolic rift as between ecological and social systems contributes to an "epistemic rift" in social and critical theory by maintaining the conceptual treatment of the two systems as separate. This goes back to the institutional and disciplinary separation of natural and social sciences that fields such as LCS are attempting to overcome. The authors pointed to the manner in which the food-sovereignty movement treats the two

systems as one as an example of a more unified approach. Wittman (2009) similarly described the actions of this movement, and La Vía Campesina in particular, as a "reworking" of the metabolic rift.

Moore (2000) took this critique further and placed it in a geographical context by considering the metabolic rift in the context of the evolution of the capitalist world-system (Wallerstein 1979). In this context, the capitalist exploitation of agricultural land continually depletes soil fertility, giving rise to "systemic cycles of agro-ecological transformation." In a later essay, Moore (2008) contended that his previous examination did not adequately transcend the habitual division of social and ecological, and incorporated Marx's value-theory to examine agrarian crises as crises of capitalism's production of nature and part of the formation and evolution of capitalism as a global ecological regime (Moore 2011).

Uneven Development and the Spatial Fix

Uneven spatial distribution of development constitutes the second theme in which Marxist theory has historically engaged with geography. Historically, geography, like many other social sciences, has been dominated by modernization theory (Wallerstein 1979), which posits uneven development as an artifact of pre-capitalist societies, and states that "underdeveloped" nations can improve the well-being of their peoples by following contemporary "advanced capitalist" models (Peet 1991). Although Wallerstein (1979) declared the theory dead, it persists in public policy, development agencies, and the international financial institutions, although based on neoclassical economic concepts rather than sociological ones (Peet 1991).

Critical geography, drawing on Marxist theory, posits that capitalism actively produces spatially heterogeneous development patterns (Smith 2008). Through the concept of a "spatial fix," Harvey (2001b, 2006a) has situated this heterogeneity in the context of crises of capital overaccumulation arising from the system's internal contradictions. As with other "fixes," the spatial fix postpones the inevitable crisis at the cost of exacerbating its underlying contradictions. The spatial component primarily refers to the attempt to displace the crisis and subsequent capital devaluation physically and temporally through the destruction and investment in reconstruction of fixed capital geographically. While increasing investment in fixed capital facilitates the accumulation process by minimizing the turnover time of commodity and financial capital (Marx 1992), it does so at the cost of eliminating capitalism's dynamism and adaptability, and constraining accumulation to a limited number of spatial and temporal (including technological) pathways. Moreover, as existing pathways become further entrenched, they develop a "geographical inertia" around local power structures, institutions, and routines that intensify this rigidity and the severity of the ultimate crises. As the rapid growth of finance capital in the USA has illustrated, the ability to rapidly switch capital between circuits

is vital to sustaining accumulation at regional and global scales, but is increasingly constrained by the rigidity of fixed capital (Harvey 2011). Capitalism's ability to exploit Smith's (1979) "rent gap" between the ground realized and potential ground rent is also highly contingent upon the extent to which necessary forms of fixed capital (i.e., transportation, communication, and other necessary infrastructure) can be restructured according to patterns of gentrification in built environments (Davis 2007).

At the global scale, Schoenberger (2004) points to the perpetuation of asymmetrical trade between the Global North and South as an illustration of the forcible displacement of devaluation frequently associated with the spatial fix.

Although the concept of spatial fix has primarily been applied to (human-)built environments, it is also evident in efforts to subjugate domestic agriculture to the global governance of neoliberal institutions such as the World Trade Organization and the International Monetary Fund. On the one hand, the undermining of domestic protections and supports for peasant or "smallholder" agriculture has allowed the agrifood industries of the USA and EU to forcibly displace the devaluation of their surplus (and highly subsidized) produce directly onto the more exploited classes, while on the other the ensuing depeasantization has created more opportunities for investment in infrastructure and other forms of fixed capital as the peasant mode of production is supplanted by "commercial" agriculture[3] (Bello 2009; Reinert 2007; Harvey 2004). In the case of the US African Growth and Opportunity Act (AGOA 2000), which promotes the intensification of peasant agriculture and integration into global trade markets as a poverty alleviation measure, the Brookings Institution (2011) observed that African markets—particularly if secured against competing industrial powers in Europe and China—could help to alleviate overproduction in the USA and create new opportunities for investment in infrastructure development.

Material and Geographic Perspectives on the Metabolic Rift

As developed by Foster et al. (2010), the concept of metabolic rift primarily describes capitalism's systemic tendency to shift social metabolism towards increased material throughput, as increases in the scale of production and the turnaround time can help sustain the accumulation rate. The concept of a rift reinforces the Marxist contention that this perpetually increasing throughput is a necessary precondition to the capitalist mode of production, taking the critique beyond the rhetoric of overconsumption (e.g., Ehrlich and Ehrlich

[3] Commercial agriculture here refers to the industrial, input-intensive, large-scale forms of agriculture such as those promoted by, e.g., Collier (2008).

2004). This rift concept also carries its critique further than Schnaiberg and Gould's (1994) "Treadmill of Production" critique, which—though it rejects the simplistic assertion that production is merely a function of consumption—posits increasing throughput as a product of monopoly capitalism rather than an inherent tendency (see also Gould et al. 2004).

Harvey's (2006a) spatial fix similarly, but in more detail, invokes capitalism's need to accelerate the circulation process to support accumulation (see also Smith and O'Keefe 1980), but incorporates a geographic context in which the infrastructure of fixed capital acts as an internal constraint on the ability to increase the rate of material throughput, thereby triggering periodic crises of overaccumulation of capital (often in money form) without productive outlets. Once fixed capital is devalued or destroyed, however, investment in new infrastructure acts as an outlet for surplus capital.

Taken together, these two concepts suggest that superimposed on the geography of capitalism's cycles of territorial destruction and reconstruction is a systemic tendency to reconfigure space in a way that facilitates the perpetual expansion of the volume, rate, and distance of material flows, or what could be called "geographic rift(s)" (with the stipulation that "rift" here is better understood as a rescaling rather than a chasm). This spatial reconfiguration, however, is constantly contested and itself transformed by both the internal constraints of fixed capital and by external constraints imposed by the human and non-human actors with which capitalism is articulated in the process of destroying and reconstituting space. This has important implications for LCS, as the biophysical and economic variables typically modeled in land-system studies stem from inherently complex causal chains with a high degree of geographic contingency. It also implies that the underlying power dynamics of different "stakeholders" will play a key role in structuring a territory, but that these dynamics interact in ways that produce unexpected outcomes. On the other hand, these complex underlying dynamics suggest ways in which LCS could more productively interact with other disciplines within the social sciences to identify common causal pathways and form empirical generalizations (e.g., developing a stronger theoretical foundation to complement Geist and Lambin's (2001) meta-analysis of tropical deforestation).

Historical "Moments" of Geographic Rift

The geographic rift is physically evident in three moments of geographic expansion and reconfiguration: (1) land appropriation, (2) forced migration, and (3) commodification. These moments frequently overlap in time and space, and their trajectories are multi-directional (Figure 1). As a systematic account of the evolution

of capitalism's geography is beyond the purview of this paper, this section contains a brief overview of these historical processes.

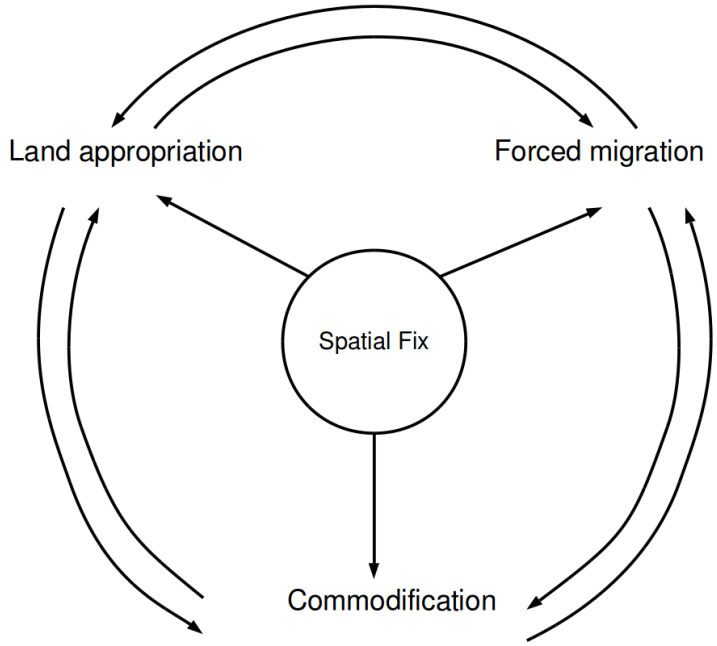

Figure 1. A conceptual diagram of the three moments of the geographic rift and their relationship to the spatial fix. The moments interact bidirectionally, and the spatial fix acts as an immediate driving force at each moment.

Land Appropriation

Historically, the primary mechanism of land appropriation has been its conversion into private property, through commodification and entrance into a market dominated by exchange-value rather than use-value (Courville and Patel 2006). In England, for example, this privatization was accomplished through the enclosure of common land and the expropriation of the peasantry (Marx 1990). In Latin America, the original inhabitants of the land being appropriated were frequently coerced into working for, or outright enslaved by, colonial authorities to provide resources for the colonizing country (Galeano 1997). Meanwhile in the colonial USA the original inhabitants were largely massacred or relegated to reservations on unwanted lands (Zinn 2003), and labor was supplied by a slave trade that simultaneously appropriated African labor-power, facilitated the development of plantation agriculture, and encouraged the development of capitalism in

Europe (Williams 1994). Colonialism and imperialism have been important components of the spatial fix, and help illustrate the causal linkages between capitalist crises and the geographic rift (Moore 2008; Harvey 2006).

Contemporary land privatization, as part of what Harvey (2004) calls "accumulation by dispossession" rather than "primitive accumulation," continues to force inhabitants to either migrate or participate in the capitalist market to pay taxes levied by the state (Harvey 2011). This contributes to metabolic rescaling primarily by changing the relations of production and the relations of affected people to the land. In cases where inhabitants are forced into the capitalist market, they may lose autonomy in the production process and be forced to accelerate the metabolism of resources to a rate faster than the local ecosystem can maintain.

Forced Migration

Although land appropriation is frequently a driver of forced migration; violence and disasters such as hurricanes, tsunamis, and earthquakes; human trafficking; socio-economic marginalization, exclusion, and unemployment; and over-qualification and unavailability of viable economic opportunities can also act as such drivers (Delgado Wise 2013). The spatial displacement of the devaluation of fixed capital frequently underlies the geographic restructuring responsible for creating such conditions (Harvey 2006). Forced migration was a key element of Marx's (1990) initial observation of the metabolic rift, as the aforementioned example of the enclosure of the English commons also involved the expropriation of the peasantry, which in turn led to widespread rural-urban migration, swelling the ranks of the industrial reserve army and triggering the urban accumulation of wastes that could have been used to mitigate the loss of fertility in agricultural soils (Marx 1991). In Central America in the late 19th century, the expropriation of the original inhabitants from optimal agricultural land often forced them to colonize high-altitude mountain slopes unsuitable for coffee production, thereby contributing to deforestation, erosion, and landslides (Faber 2003), a process that has been reproduced similarly in many other countries (e.g., Delang 2005).

Both land appropriation and forced migration have made significant contributions to tropical deforestation, which has been singled out as a land-change issue of particular concern due to the high concentration of biocultural diversity in the tropics and the climatic and hydrological ramifications of tropical forest loss (Cramer et al. 2004; Kump et al. 1999; Gorenflo et al. 2012). Case studies indicate that agricultural intensification, typically in conjunction with wood extraction and infrastructure development, are the primary

proximate drivers of tropical deforestation (Geist and Lambin 2002, 2004). Agriculture's contribution to deforestation has been exacerbated recently by agrofuel policies that encourage increases in soy, sugarcane, and palm oil production in the tropics, and growing instances of international land-grabbing (UNEP 2012; Gao et al. 2011). In the absence of evidence of socio-ecological benefits, these policies appear to be driven more by the pursuit of new avenues of capital accumulation and geopolitical interests than social or ecological concerns (McMichael 2010; Giampetro and Mayumi 2009; Koplow 2007). At a more general level, the Structural Adjustment Programs imposed by the international financial institutions, coupled with the minimization or elimination of trade protections through multilateral and bilateral trade agreements and the World Trade Organization (WTO), has accelerated the rate of depeasantization and internal migration, and undermined the possibility of food sovereignty in much of the Global South (Bello 2009). This, in turn, has encouraged further consolidation of landholdings and increased high-input export production.

Forced migration to informal urban settlements surrounding the periphery of or penetrating the world's largest cities is particularly problematic. This converts valuable agricultural, forested, and other landscapes at the urban margins into informal urban dwellings, and has become a significant global phenomenon (Vieyra and Escamilla 2011; Davis 2007), particularly in the Global South, where 50% of urban inhabitants live in poverty (UN-HABITAT 2003). Rural-urban migration also appears to be a significant driver of deforestation (DeFries et al. 2010) and can further exacerbate biodiversity loss when cultural landscapes are abandoned (Farina 2000).

States also frequently initiate forcible relocations of informal urban settlements, which involves both land appropriation and forced migration (Davis 2007). Appropriation of the land upon which a settlement resided opens new avenues for investment in infrastructure and other aspects of urban development, while transforming the city's geography by increasing the spatial segregation of the poor and the distance that those with formal employment must commute (Aguilar and Vieyra 2008).

For LCS, looking at migration in terms of land appropriation and other drivers identified by Delgado Wise (2013) provides an alternative to neoclassical economic assumptions that treat migration as a voluntary and non-problematic process driven by population growth and rational economic optimization. Instead, the conceptualization of migration as a moment of geographic rift suggests that the process is often forced, violent, and has deleterious socio-ecological consequences.

Commodification

Commodification is frequently linked to land appropriation and forced migration, and can follow, precede, or occur simultaneously with the other moments. A common instance of the commodification→land appropriation→forced migration pathway is the titling of informal settlements in the absence of state support for the poor, at which point poverty or debt forces inhabitants to relinquish their title and abandon the land (Davis 2007). This process has a rural equivalent in development initiatives to boost peasant productivity and integrate subsistence farmers into the capitalist market (Lambin et al. 2001). This intensification frequently involves large volumes of synthetic inputs, transforming agricultural landscapes into sources of nutrient, pesticide, and other forms of aquatic pollution, and can lead to land appropriation and forced migration when the volatility in the global market prevents smallholders from repaying loans (CHRGJ 2001).

Commodification illustrates the dialectical relationship between the material and geographic expressions of the metabolic rift, as geographic expansion and restructuring involve subjecting a larger proportion of the human population to the treadmill of accumulation. It also reflects spatial fix logic, as the process involves the construction of transport and communication networks as opportunities for capital investment and the effort to minimize turnover time by accelerating transport and communication (Harvey 2011). Under the neoliberal form of capitalism, gentrification and transformation of urban spaces have been particularly important avenues of surplus absorption (Hackworth 2006).

The rapid expansion of peri-urban housing around many cities in the USA between the 1950s and 2007 offers an important example of the linkages between spatial fix, commodification, and geographic rift. In addition to absorbing surplus capital, the development of peri-urban housing provoked significant increases in the metabolism of fossil-fuels and production of automobiles, as transportation between urban centers and peripheries became dependent on individual automobiles (Freund 2012). This development has converted valuable agricultural, forest, wetlands, and other land-covers into low-density urban settlements (Hansen et al. 2005) and transformed the concept of community and its relationship to place and landscape by encouraging more extreme forms of individualism rather than community solidarity (Frumkin 2002).

The process of commodification is important to consider as part of LCS, as it challenges the assumption that population growth has been the motive force behind the global expansion of agriculture, urban poverty, and other land changes—or the equally flawed neoclassical assumption that supply is a function of demand (e.g., Ehrlich and Ehrlich 2004; Lévêque and Mounolou 2003)—and that land-change pressures will subside with population stabilization (e.g., Wilson 2002). Instead, as Marx repeatedly emphasized in his critique of capitalism (Marx 1990, 1991, 1992), the logic of capital accumulation drives

capitalists to continuously expand the scale of production, regardless of demand. Therefore, LCS needs to consider capital accumulation to examine the ways in which the geographic rift reflects land change at different spatio-temporal scales.

Geographic Rift in the Capitalist World-economy

Another important issue that LCS must address is that capitalism is a global regime, and the geopolitical layer of state interactions introduces an additional "level of determination" into local interactions with the landscape (Smith 2009). This global regime attempts to actively produce space and "nature," often to facilitate the subjugation of resource-rich regions—in labor power, minerals, or other natural resources—to capital accumulation and perpetually increasing material throughputs, but the territorial arrangements that result depend on how these efforts are articulated with the human and non-human actors involved (Smith 2009, 2005; Bello 2000; Wallerstein 1979).

Although some land-change scientists have recognized a recent tendency towards tighter integration of local territories into global regimes, and that such integration often plays a significant role in territorial restructuring (e.g., Meyfroidt and Lambin 2009), the history of capitalism as a global regime is often neglected in LCS. The narrow confines of neoclassical economics in which LCS operates (Robbins 2012; Turner and Robbins 2008) limit insight into the political economy underlying global capitalism, and the emphasis on policy input neglects the importance of social mobilization in favor of policy changes and voluntary initiatives to manipulate global markets (e.g., Maniates 2010; Meyfroidt and Lambin 2011). LCS needs to address the underlying political economy of global capitalism, and the concepts of metabolic rift and spatial fix offer a framework which could help LCS develop a more critical perspective on the underlying drivers of land change (Lave et al. 2014; Robbins 2012).

Operationalizing Geographic Rift in LCS

If LCS is to make a genuine contribution to sustainability, then it needs to go beyond the proximate issues and address the underlying, systemic factors contributing to land change. The use of the spatial fix as a basis for considering the geographic expression of the metabolic rift can serve as a conceptual tool to facilitate such examination and create space for critical scholarship to engage constructively with LCS. This may also encourage LCS to move beyond policy recommendations to consider local people and movements for environmental justice, just sustainability, and degrowth as potential actors, and to become more critical of the role of the state (Agyeman 2005; Martinez-Alier 2012).

Although the divergent ideologies of LCS and political ecology and geography will continue to limit integration of the two fields, examination of the geographic rift suggests a number of points for immediate collaboration. The three moments of geographic rift described above can in several cases be directly or indirectly examined with quantifiable variables that are measured even in neoclassical economics, including land titling, concentration, and historical ownership; internal and external and rural and urban migration; commodity flows; and penetration by foreign capital. These variables could readily be incorporated into Geographic Information Systems and used in model development. Such innovative analyses could open new avenues for LCS to apply the tools of its discipline to the complex political ecology underlying land change (Turner and Robbins 2008). More importantly, the tradition of examining the influences of both human and non-human nature in LCS could help us better understand the general principles that govern how biophysical responses and geographic variations at the local level condition the manifestation of the geographic rift in the landscape, thereby enhancing our understanding of capitalism as world-ecology and transcending the classical Cartesian binary of human vs. natural systems (Moore 2011). Thus, examination of the geographic rift in LCS may promote more productive collaboration with other disciplines and enhance the explanatory, and ultimately transformative, potential of the field.

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