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THE BRAZIL-CHINA SOY COMPLEX: A GLOBAL LINK IN THE FOOD-ENERGY-CLIMATE CHANGE TRILEMMA

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Abstract:

This paper traces the evolution, dynamics and implications of the Brazil-China soy complex, a trade link of global social-ecological significance. Recent scholarship, particularly in the environmental sciences, has critically analysed the social-ecological implications of Chinese imports of Brazilian soy. This paper contributes a socio-economic analysis of the soy complex as a manifestation of global linkages in the food-energy-climate change trilemma. The concept of the trilemma captures interconnections between food security, energy security and GHG emissions resulting from food and energy production – particularly as a result of the conversion of non-agricultural land to cultivate food and energy crops. Recent scholarship has highlighted the need to bring socio-economic perspectives to bear on trilemma challenges (Harvey 2014), arguing that these develop differently in different contexts as a result of distinctive combinations of political-economies operating within particular resource environments. This paper builds on this work by exploring how global trade links in important food and energy commodities (soy in this case) influence trilemma development and resulting land-use change. The paper begins with an overview of the concept of the trilemma and a summary of recent scholarship arguing for the need to bring socio-economic perspectives to bear on trilemma issues. I then turn to the empirical case of the Brazil-China soy complex, where I develop a socio-economic account of its evolution, dynamics and implications for land-use and land-use change. The paper ends with a short discussion on implications and directions for further work.

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1 Introduction

This paper traces the evolution, dynamics and impacts of Brazilian soy exports to China. I explore the Brazil-China soy complex as a manifestation of global linkages in the food-energy-climate change trilemma ('the trilemma'). The trilemma refers to the multiple and interdependent challenges by increasing demand for food, energy and materials combined with escalating GHG emissions stemming from their production and from resulting land-use change.

The conversion of uncultivated land to agriculture is a globally significant driver of environmental change (Foley *et al.* 2005). Yet, regulating land-use for sustainability is complicated by the fact that it is enmeshed with several interlinked global challenges, notably those pertaining to food and energy security. At the heart of the problem is increased and changing demand for food, energy and materials on the one hand, and the need to limit further expansion of agricultural area on the other.

Soy cultivation and trade is a globally significant driver of land-use change. Brazil and China constitute the two key focal points in the supply and demand for soy globally, and trade in soy between these two countries is a key determinant of their ability to maintain sustainable land-use, mitigate GHG emissions and meet changing demands for food. For China, imports of soy are fundamental to a burgeoning livestock industry, which is at the heart of the Chinese nutrition transition brought about by rising industrialisation and increased affluence. China's livestock industry in turn, is at the forefront of global debates about the ability of the planet to sustain dietary patterns converging on levels of (animal) protein consumption typical of the Global North. In Brazil, soy cultivation has long been at the forefront of passionate debate around a range of social-ecological issues, most notably Amazonian deforestation, peasant rights and sustainable agriculture. The Brazil-China soy complex represents the convergence of these two currents, and is a rich empirical field within which to unpack the social, economic and political drivers of current global challenges around sustainable land-use.

Scholarship in the environmental sciences has examined the social-ecological impacts of soy agronomies in Brazil (e.g. Fearnside 2001, 2005; Bickel and Dros 2003; Barona *et al*. 2010), and recent reviews collate evidence on the sustainability implications of increased demand of soy from China (e.g. Fearnside *et al*. 2013, Sharma 2014). This working paper builds on these studies to provide an analysis of the soy complex as a trilemma challenge whose dynamics stem from a unique combination of biophysical conditions, political-economies and development priorities in Brazil and China. The resulting form of the trilemma is thus an emergent property of distinctive, path-dependent and context-specific features. These determine the nature, scale and governability of land-use change. Illustrating the challenge as such allows us to begin unpacking the implications for sustainability regulation and social-ecological well-being.

Despite considerable progress towards sustainable intensification of agriculture in some countries and locations (Pretty *et al*. 2005; Pretty *et al*. 2010; Pretty and Bharucha *forthcoming*), current trajectories of demand for food, biomass energy and materials will entail continued agricultural *extensification* – i.e., the spread of cultivated area to uncultivated landscapes (Bajželj *et al.* 2014). Land conversion almost always results in elevated GHG emissions (amongst other social-ecological impacts, notably biodiversity loss) and entails difficult trade-offs between various human development and sustainability objectives. It is also well established that many forms of large-scale, 'business-as-usual' agriculture entail unacceptable social-ecological impacts, including elevated GHG emissions and reduced ecosystem services. Inappropriate management of agricultural land also reduces its productivity, potentially implying further extensification. Finally, climate change itself limits agricultural productivity, even as demand for agricultural goods continues to increase. At global level, these broad dynamics are captured by the concept of the food-energy-climate change trilemma, whose key conceptual contribution is to focus attention on the interconnections between these key global challenges. Each amplifies the others; successful management of one requires understanding and management of all. Past attempts at 'siloed' thinking in environmental management have suffered without the application of such a perspective.

The concept of the trilemma first appeared in the environmental sciences (Tilman *et al*. 2009), and has more recently become the focus of an effort in the social sciences to better understand the political-economic drivers of environmental change (Harvey and Pilgrim 2010; Harvey 2014). This work is bringing a socio-economic (specifically neo-Polanyian) perspective to bear on how trilemma dynamics have evolved in divergent ways within individual countries (e.g. Harvey 2014) or has taken a comparative approach, illustrating the particularities of different national contexts and the path-dependency of trilemma outcomes (e.g. Harvey and Pilgrim 2010; 2013). In this paper, the focus is on trilemma linkages *across* distinct contexts, through trade in soy, a major agricultural commodity of significance to global food and energy security and with particularly important implications for land-use and associated GHG emissions in Brazilian agriculture. The significance of this analysis is two-fold. First, it reveals how international trade adds a new layer of complexity to the task of unpacking trilemma dynamics within any particular national context. While sustainability science is increasingly grappling with the challenges posed by 'distant interactions' set up by global resource flows (e.g. Liu *et al*. 2013), scholarship has not yet sufficiently interrogated the origins and dynamics of these interactions from a trilemma perspective. This paper makes a beginning towards such an effort, though it cannot claim to have reached a definitive or comprehensive account. Second, it highlights how resource governance within any particular context must increasingly contend with global drivers emerging out of long historical trajectories and 'locked in' (Unruh 2000) by the architecture of international trade.

In what follows, I first introduce the contours of the food-energy-climate change trilemma in generic terms, and then outline the need to develop more context-specific accounts of trilemma dynamics. I then draw on Harvey (2014) to summarize the challenge this poses to the social sciences, and set out the case for engaging with a neo-Polanyian perspective. I then turn to the empirical case of the Brazil-China soy complex, where I provide a history of the development of the trade link now supplying Chinese livestock producers with Brazilian soybeans. This history proceeds in three parts. First, I examine how Brazil came to be a globally dominant producer of soybeans as a result of particularly well-suited biophysical conditions and the particular strategic intervention by the Brazilian state, which used soy (among other commodities) to develop an export-oriented agricultural economy. I then briefly turn to the historical developments on the other end of the supply-chain, in China, tracing how it came to be that the historic Chinese stance of self-sufficiency in food production came to be reversed so dramatically in the case of soy. Finally, I explore the current status and impacts of the Brazil-China soy complex and its implications for land-use. The paper ends with a short discussion on implications and avenues for further work.

2 The food-energy-climate change trilemma

Global social-ecological challenges are interlinked, stemming from interactions between their environmental, social, economic and political components. In 2009, the UK's then Chief Scientific Advisor, Sir John Beddington, spoke of a 'perfect storm' of global social and ecological change (Foresight, 2011a). Research on resilience in linked social-ecological systems (cf Holling 1973; Walker and Salt 2006) is at the forefront of the new fields of sustainability and Earth System sciences. Both research and policy increasingly emphasize the 'nexus' between food, energy and water-related challenges (Hoff 2011, Allouche *et al.* 2014). Located within a similar tradition, the concept of a 'food-energy-climate-change' trilemma focuses on the tight, multi-directional links between three social-ecological challenges: food security, energy security and climate change, and the implications of these, singly and in combination, for land-use and land-cover change, which lies at the heart of the trilemma.

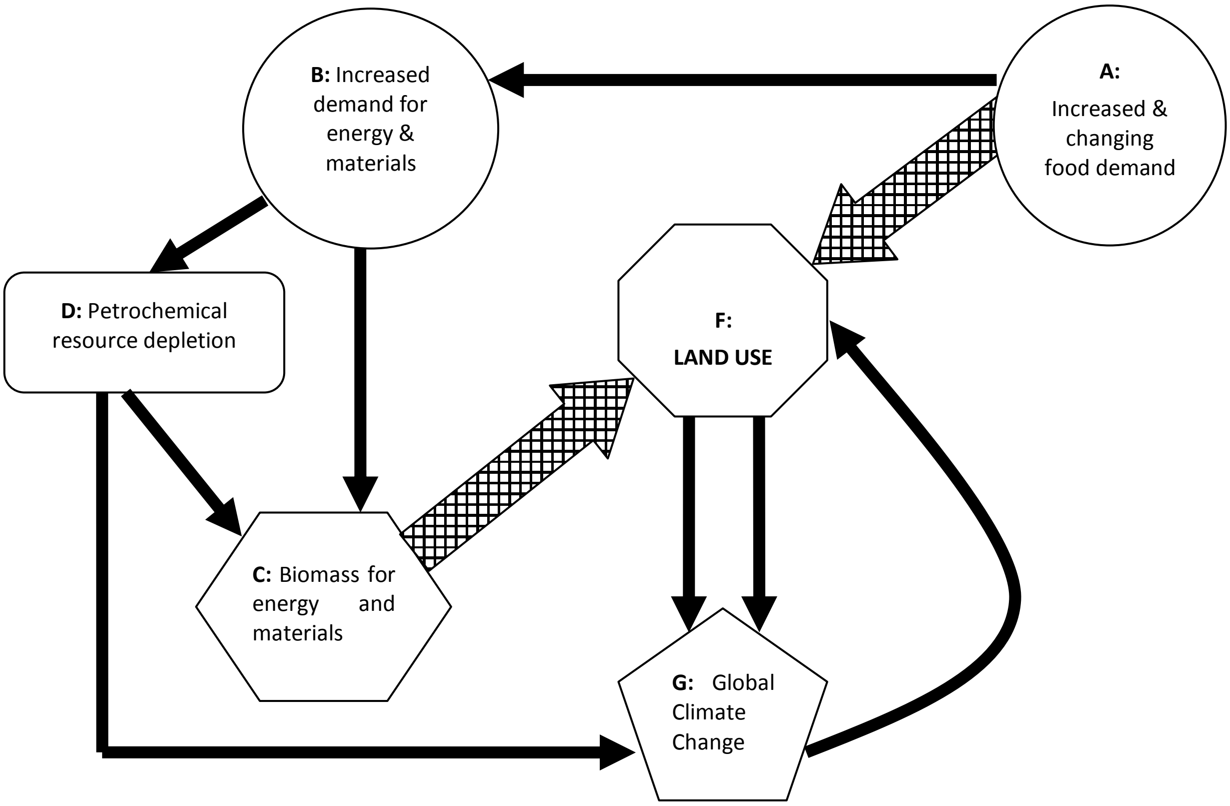
Increasing demand for food and bioenergy is likely to entail greater demand for agricultural land. Conversion of non-agricultural land to meet this need entails unsustainable GHG emissions. Conventional agricultural intensification also entails unsustainable social-ecological impacts, including higher GHG emissions, pollution from nutrient flows, land degradation and biodiversity loss. Thus, both extensification and conventional intensification operate in a positive feedback with climate change (Bajželj *et al*. 2014). Deepening climate change, in turn, implies reduced productivity of existing agricultural land – though the precise impacts vary by place. Food and energy are also interlinked. There is a strong correlation between food and energy (oil) prices, and the substitution of fossil fuels with renewables from biomass may generate further land-use change or land conversion (indirect land-use change, ILUC). In short, there exists a triple imperative to ensure sufficient food for a growing and increasingly affluent population, adequate low-carbon energy, and the management of global agriculture so as to reduce its environmental footprint (reduced extensification and increased sustainable intensification). Meeting these challenges will require careful attention by policy makers to the interconnections, feedbacks and trade-offs as they evolve in particular contexts. This context specificity of trilemma dynamics is important. The central operating insight of this paper is that countries experience and navigate these imperatives differently as a result of distinctive combinations of geography, resource environments, political economies, demography and development policies. Together, these determine how policy makers understand and prioritize different trilemma challenges and what they can do about them.

2.1 Land use and land cover change

The challenges posed by land-cover change have received critical attention since at least the 1970s. The science of land-use/cover change has "demonstrated the pivotal role of land change in the Earth System" (Lambin *et al.* 2007, p. 1).

Recent scholarship has highlighted the contribution of land-use and land-cover change (particularly driven by agriculture) in pushing key 'planetary boundaries' (cf. Rockström *et al*. 2009) for global climate change, biodiversity loss and altered nitrogen and phosphorus cycles. Agriculture contributes some 10-12% of global GHG emissions, and in recent years emissions from livestock have contributed a far greater share than emissions related to direct human consumption of crops (Tubiello *et al*. 2013). Agriculture also contributes between 52-84% of global emissions of nitrous oxide and methane (Smith *et al.* 2008). One estimate of future emissions suggests that by 2055, methane and nitrous oxide emissions from agriculture could increase by 57% and 71% respectively (Popp *et al*. 2010). Land-cover change contributes a significant component of total emissions from agriculture. Globally, an astonishing 80% of deforestation and forest degradation is estimated to be agriculture-related (Kissinger *et al*. 2012). Emissions from agriculture-related land-use change contributed 2.2–6.6 $GtCO_2e$ in 2008 (Vermeulen *et al*. 2012). Given the strong interconnections between agriculture and land-use related GHG emissions, it is clear that all countries face the challenge of somehow governing land-use so as to ensure food security and developing biofuel and biomass industries while also constraining agriculture-related GHG emissions. This is the challenge of the food-energy-climate change trilemma, illustrated graphically below (Figure 1).

Figure 1: The food-energy-climate change trilemma. Modified from Harvey and Pilgrim 2010.



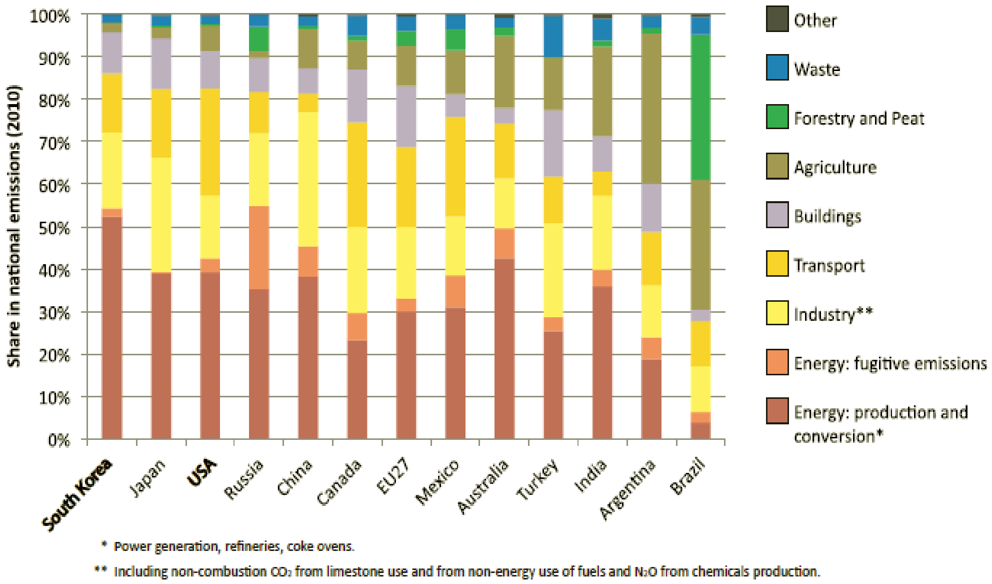
The background to changing land-cover and land-use (box f) is provided by assumed increases in global demands for agricultural products. These increases will stem from rising and changing demands for food (box a), increased demand for energy and materials (b), intensified by the increased use of biomass for energy and materials (box c), against the context of petrochemical resource depletion (box d). Together, these increased demands directly influence land-use and land-cover change by driving the conversion of non-agricultural land to cultivation, or intensifying the use of existing agricultural land, both of which imply increased GHG emissions, and thus intensify global climate change (box g). This in turn amplifies the pressure on agricultural land, because climate change implies reduced agricultural productivity.

This depiction of the interactions and feedbacks between significant global challenges, broadly accepted within the natural and environmental sciences, does not however adequately illuminate the ways in which land-use change actually unfolds in particular contexts as a result of specific and differing human decisions taken in response to each of the distinct challenges constituting the trilemma (boxes a, b, c and g.).

Countries and regions experience these challenges – singly and in combination – differently. The role of differing political economies, operating within distinct resource environments, and developing policy in response to different drivers and pressures, leads to an uneven development of different 'horns' of the trilemma. For example, Harvey and Pilgrim (2010) compare trajectories of biofuel innovation and spread in three distinct contexts – Brazil, the USA and Europe. They show how, as a result of differing priorities, combined with distinct political-economic configurations and biophysical capacities, each developed distinct trajectories of biofuel development and use. Motivated largely by concerns over energy security, both Brazil and the US initiated biofuel development in response to the oil price shocks of the 1970s. Brazil became a global pioneer in sugarcane bioethanol as a result of strong strategic political direction, coupled with a conducive agri-industrial environment. The United States, by contrast, demonstrates much stronger lock-in to a trajectory of continued dependence on fossil fuels. In the European Union, biofuels strategy has been guided by a different set of priorities – specifically EU commitments under the Kyoto Protocol. The EU has emerged as a global leader in rapeseed biodiesel production, but targets and investment in innovation are relatively less ambitious than in Brazil or the USA (Harvey and Pilgrim 2013).

In a similar vein, the role of different political-economies and resource environments are apparent in the quite distinct GHG emissions profiles of different countries (Figure 2).

Figure 2: Share of GHG emissions by source across 12 countries and the EU 27 in 2010. Source: UNDP Emissions Gap Report 2012 (UNEP 2012).



As Figure 2 illustrates, different countries contribute quite differently to global GHG emissions. Of particular relevance for this paper are the differential contributions made to total emissions by agriculture, forestry and transport. Brazil's GHG footprint is overwhelmingly dominated by emissions from agriculture and forestry. By contrast, as a result of its position as a biofuels pioneer, emissions from transport and energy production are comparatively negligible. Strong policy support, combined with the ability rapidly to set in place sugarcane ethanol production continue to constrain Brazilian transport-related emissions. The significance of this combination is further illuminated by the strong contrast with the emissions profile of the USA. Here, emissions from agriculture and forestry are negligible in the overall profile, while emissions from transport and energy production are sizeable by contrast. In part, this can be viewed as the result of a policy decision to maintain fossil-fuel based transport systems through international trade.

The implications for these differences for the global GHG 'footprint' of agriculture and land-use are, thus, that rather than a single undifferentiated *anthropogen* driving global land-use change and related GHG emissions, quite distinct regional trajectories exist across different contexts as a result of interactions between different political-economies and environmental capabilities. In other words, what is needed is a deeper understanding of the *sociogenesis* (cf Harvey 2014) of climate change - an exploration of the ways in which different political economies contribute differently to the global challenges of climate change, food production and energy security. Work exploring the differential evolution of responses to the trilemma across different contexts (Harvey and Pilgrim 2010) and within a single context (Brazil; Harvey 2014) now needs to be supplemented with an account of how trilemma challenges interact *across* contexts. International trade in agricultural commodities has, arguably, long constituted a strategic response to meeting demands for food and biomass-based materials. With continued growth in the world economy, and particularly accelerated growth in the developing world, the trilemma dynamics and linkages take on new significance in any consideration of global environmental change.

Accordingly, an emerging body of scholarship in sustainability science examines the environmental impact of 'distant interactions' between different parts of the world. Liu *et al.* (2013), for example, propose a framework to systematically explore the dynamics and impacts of so-called 'telecouplings' – environmental interactions between distant regions as a result of international trade, the spread of invasive species, transnational land deals and technology transfer. From the perspective of this paper, it is clear that these 'distant interactions' strongly influence the dynamics of trilemma unfolding along both sides of any resource chain. Importing countries in a position to engage in favourable terms of trade have long been able to circumvent resource scarcities and contribute to food and energy security by structuring particular trade linkages with exporting countries who are able to supply resources (but who may nevertheless find themselves navigating trade-offs with their own food and energy security or between export earnings and land-use change). Needless to say, the establishment of any such resource flows and the precise form they takes (and thus their implications for land-use change) are structured and regulated by the actions of importing and exporting countries pursuing their own particular strategic interests and priorities with varying degrees of success. This implies that trilemma dynamics at either end of a resource flow are continually evolving, with shifting implications for land-use and resulting climate change.

This sociogenic perspective on trilemma dynamics represents a novel effort in scholarship on environmental change. While the language of resilience in linked social-ecological systems is ubiquitous in the research, policy and practice of environmental governance, 'the social' is as yet deeply under-theorized and poorly illuminated in sustainability science compared to the ecological and environmental dynamics of climate change, biodiversity loss and global nutrient cycles. For example, though drawing on the language of the 'anthropocene', and thus placing human activity at the forefront of global environmental change, analyses of global planetary boundaries operate speak relatively generically of 'anthropogenic' change (Harvey 2014). To take another example, analyses of agricultural emissions invoke "population growth and rising affluence" as key drivers of increasing emissions from agriculture (e.g. Neufeldt *et al*. 2013, p. 23). At the same time, it is recognized that while technologies for a transition to low-carbon lifestyles exist, "there are important market- or tenure-related barriers that need to be overcome" (Neufeldt *et al*. 2013, p. 24). Absent from these analyses are accounts of how social, political and economic contexts drive distinct trajectories of environmental change and resource availability. This is not to say that such analyses totally eclipse the 'human' element as a driver of land-use change. Early scholarship on land-use and land-cover change (LUCC) argues for "an integrated social and natural science study of the impact feedback of land-use change on the global environment" (Ojima *et al*. 1994, p. 300). Yet, 'the social' is treated as a relatively undifferentiated contextual variable (e.g. see Figure 1, Ojima *et al*. 1994). More recent scholarship on LUCC recognises that "at the level of underlying causation, the most prominent causal clusters are made up of economic factors, institutions, and national policies…" (Geist *et al.* 2008, p. 44). Analyses of causation remain limited to descriptive accounts of the influence of economic and technological factors, demographic factors, institutional factors and cultural factors (e.g. Geist *et al*. 2008) as though these constitute meaningful units each distinct from the others. Scholars highlight the importance of multifactor causation: "the strongest finding emerging from the meta-analysis… is a resounding rejection of single-cause explanations of land-use change. No factor ever works in isolation" (Geist *et al*. 2008, p. 62). This points to the need for social scientific contribution that can bring theories of social and political and economic change to bear on issues of land-use change.

Conclusions and 'lessons learnt' broadly underscore the importance of 'policy support' for wider adoption, call for greater investment and underscore the importance of context-specific innovation.

Yet, policy processes are themselves complex, path-dependent and emergent phenomena balancing (or differentially prioritizing) a range of social and ecological contingencies. And so, while existing environmental science scholarship is rich in estimations of the GHG-savings potential of techniques such as no-till, agroforestry and improved nutrient and water management, and the scale of their adoption, what remains missing is a parallel consideration of the historic and current socioeconomic drivers pushing increased and changing demand for food, the tensions between different policy imperatives (e.g. food v. fuel) and the ways in which countries balance these demands differently. Harvey (2014) argues that social science accounts of environmental change have a role to play here, but have so far failed to adequately engage with the theoretical and empirical complexities involved.

2.2 The challenge to the social sciences

Scholarship across classical political economy, economic geography, political ecology and transition theory, while broadly engaging with the dynamics of interaction between socio-political and natural environments, do not yet provide a comprehensive account of how global challenges evolve over time as a result of the interaction between particular histories, political economies and distinctive geographies.

Harvey (2014) particularly highlights two conceptual gaps in existing social science accounts of linked environmental change. The first pertains to the use of a relatively generic and undifferentiated account of resource finitude. Beginning with classical political economy, which has long been preoccupied with the concept of 'scarcity' and its implications for socioeconomic development, to more contemporary rhetoric highlighting the demands of the '9 billion', there has been a relative failure to distinguish between different types and degrees of resource finitude (but see emerging work in political ecology, e.g. Mehta *et al*. 2010; Bharucha *et al*. 2014, where concepts of finitude and scarcity are being unpacked theoretically and empirically, with a view to nuancing how 'scarcity' is created, by what political-economic arrangements and with what implications for sustainable resource management.) Second, existing approaches have failed to adequately theorize the role of the state. Harvey (*op cit.*) contends that classical political economy has so far failed to account for the ability of states to overcome national finitudes through trade or other arrangements. Similarly, contemporary economic geography and political ecology accounts, while emphasizing spatially differentiated pathways and diverse outcomes, have tended to universalize processes or change, treating neoliberalisation, marketization and commodification as general, universal processes.

In short, neither prevailing natural nor social science accounts adequately conceptualize the differentiated, heterogenous, path-dependent and context-specific processes by which different regions contribute to, and experience, interlinked social-ecological challenges such as those exemplified by land-use change. Relying on global aggregates, undifferentiated concepts of finitude and paying inadequate attention to the role of the state, they cannot yet adequately capture the dynamics of emerging and intertwined global challenges.

Given the centrality of economic processes in driving global land-use and land-use change, and taking into account the above-described gaps in existing scholarship, this paper and the wider project within which it is embedded, draw on a neo-Polanyian perspective to illuminate processes of trilemma linkages between Brazil and China through the soy complex. This implies the need for paying adequate attention to how resource management and economic processes are instituted by specific political economies. Context – historical, political-economic and environmental – matters.

Land-use challenges provide a rich empirical field through which to develop such a neo-Polanyian perspective on the sociogenesis of environmental change. In turn, the application of such a theoretical framework illuminates the sociogenesis of these issues in much greater detail than is evident in existing accounts.

In what follows I attempt to trace the evolution and workings of the Brazil-China soy complex as a trilemma challenge generated sociogenically – that is, through particular social, political and economic trajectories in Brazil and China, interacting with their unique resource endowments and features.

3 THE RISE OF SOY CULTIVATION IN BRAZIL

The soybean (*Glycine max*) has been at the heart of a number of globally significant transitions in world agriculture and food systems throughout the 20th century. It is difficult to overstate its impacts on how we eat and live, which is all the more astonishing considering that for the first 3000 years of its use, soy remained a relatively humble food and forage crop limited to the regions of its first domestication. Asia, and particularly China, Indonesia, Japan and Korea, retained global dominance in soy production for millennia. The crop became known in Europe only in the 17th century, but it was innovations in the United States that opened up soy into a material with some 150 applications in food and industry. In the early 20th century, soy was largely a forage crop in the USA. By the 1940s, the balance of soy production had shifted decisively from East to West, where it remains. By 1956, the USA was producing more soy than all of Asia combined and was the leading global supplier of whole soybeans, soy oil and meal. By the end of the 1960s, farmers in the USA had grown 76% of the world's production compared with just 17% by China, the site of soy's original domestication (Hymowitz 1970).

The USA's global dominance of soy was soon to be challenged however, by the accelerating growth of soy cultivation in Brazil. Soy was introduced in Brazil in 1800, and began to take off after the government of São Paulo distributed seeds to farmers in 1900. Just 75 years later, Brazil overtook Chinese production, a remarkable outcome reflecting strong strategic political backing aimed at building an industrial, export-oriented agricultural economy. Specifically, the rise of soy production owed much to a series of rural credit, subsidy and price support programmes which were established to boost the production of key commodities (mainly soy and wheat), in order to boost declining agricultural exports. In addition, the potential to stimulate foreign exchange earnings also prompted the government to encourage a domestic crushing industry. Initially, both soy cultivation and crushing were concentrated in the southern states of Santa Catarina, Parana and Rio Grande do Sol. In addition to Brazil's strong commitment to drive its agricultural exports, a number of international factors drove the expansion of Brazilian soy. In 1973, the USA soy export embargo raised the price of soybeans, making their cultivation highly profitable. Crucially, it also encouraged the Japanese, so far primarily dependent on USA soy, to turn their attention to Brazil. Japanese financial support was instrumental to the further development of Brazilian soy and, of particular relevance for this paper, its northward spread away from Parana and Rio Grande do Sul. From the mid-1980s onward, European outbreaks of bovine spongiform encephalopathy (also known as mad cow disease) led to a search for alternative sources of protein for animal feed, providing a large and growing market for Brazilian soy.

In 1970, some three million hectares were planted to soy in Brazil; continuous spread meant that by 2003, some 18.5 million hectares were planted to soy (Bickel and Dros 2003). Crucially, this period saw the northward expansion of soy cultivation, as Brazilian industry strove to capitalize on the fortuitous combination of effective agricultural research, growing international demand, the attractiveness of soy in international investment and the availability of abundant land. A particular catalyst for soy's northward march was provided by the 'Japanese-Brazilian Programme for Cerrado Development' (PRODECER), which was launched in 1974 as a concerted effort to expand and modernize Brazilian soy. What was needed was varietal development, which would allow soy to be cultivated in soils of central and northern Brazil. The development of these new varieties and agronomies by the Brazilian Agricultural Research Corporation (EMBRAPA) allowed the profitable cultivation of soy without the application of nitrogen fertilizer, on soils with low phosphorus and high aluminium content. This "triumph of Brazilian research" (Fearnside 2001, p. 25) removed the only barrier to capitalizing on the lands of central Brazil, considered "the area of the globe most conducive to the expansion of soy agriculture" (de Sousa and Viera 2008, p. 238). Generous subsidies were provided by the Program for the Development of the Cerrados (POLOCENTRO), which distributed subsidized loans to facilitate the conversion of 2.4 million ha of cerrado land to agriculture between 1975-1982 (Mueller 1992). Here, a combination of relatively low prices, flat landscapes (a requirement for mechanized monoculture) and the on-going development of transport infrastructure facilitated the spread of soy cultivation on lands previously cleared for pasture and cattle.

For the purposes of a trilemma-focussed account, it is important to emphasize the complex and relatively indirect links between soy cultivation in Brazil and land-use change. The northward expansion of soy into the cerrado and Amazon have in no small part been enabled by the pre-existing trajectory of land-use change in these biomes. Land clearing for extractive industry and cattle came first, in other words. Also crucial were infrastructure projects (e.g. road construction). Explicit state intervention and backing for these forms of land-use change were premised on the need to 'develop' central and northern Brazil and harness their riches for the national cause. These trajectories of land-use, preceding soy cultivation, 'opened up' land, thus enabling the northward expansion of this profitable and increasingly important agricultural commodity. Thus, the spread of soy in Brazil can be seen as just the most recent push forward in an on-going and widespread transformation in land-use stemming not solely from demand for food commodities but instead embedded within a wider context of national socioeconomic development. Having said this, soy is *now* actively driving the industrialization of land-use (if not direct land-use change), providing a powerful rationale for agricultural intensification. As the foremost commodity amongst Brazil's agricultural exports, the soybean, as de Sousa and Viera (2008, p. 234-5) highlight, "is not merely a cash crop". Instead, it is "a powerful force for the dissemination of inputs, machines, silos and processing units [and] the use of a research-generated technologies and agricultural expansion…"

Soy thus sets in motion ripple-effects with their own implications for land-use. For example, transport networks are vital to support soy's function as an export commodity. Fearnside (2001) has particularly highlighted how these ripple-effects themselves drive further forest fragmentation, forest loss and catalyse further resource extraction and land-use change. The construction of a port in Santarém (Para state) by Cargill in 2003, has amplified the production of both soy and rice (the latter supported by local social and political factors) (Weinhold *et al*. 2011). In the cerrado, monocultures of cotton, sugarcane, maize and Eucalyptus and extensive cattle rearing operations co-exist with soy; together these crops contribute to Brazils' global dominance in global trade in primary commodities.

For state governments, soy provides an attractive avenue by which to "convert their sparsely populated subtropical and tropical plains to soy production areas to boost their economies" (Bickel and Dros 2003, p. 4). By the 1990s, the Mato Grosso had become the centre of Brazilian soy cultivation on large land-holdings with the aid of "some of the most modern agricultural technology in the world" (Brown and Koeppe 2012, p. 118). As with Brazil more generally, the expansion of soy cultivation in the Mato Grosso was at once instrument for and outcome of an explicit state project to civilize and harness the resources of what had previously been considered a 'backwater'. The interests of commercial growers and the state were tightly interwoven, as illustrated for example by the fact that Blairo Maggi, then governor of the Mato Grosso, was also the largest soy producer in the world (Brown and Koeppe 2012). His support in turn was instrumental in delivering the support of the agri-business community to Lula's presidential bid in 2006.

In sum, the rise of Brazilian soy evinces the creation of a politically instituted economic process for a major agricultural commodity that has come to play a central role in Brazilian development and foreign relations. International demand, first from Europe and more recently from China (both demanding soy meal for livestock) has been instrumental in helping soy to flourish, and in this sense the strategic importance of soy to Brazil has always been about international trilemma linkages – increased and changing demand for food in Europe and Asia coupled with abundant land and other resources in Brazil *effectively structured and mobilized* by the Brazilian state in order to fully capitalize on international demand.

3.2 Land-use and social-ecological impacts of soy cultivation in Brazil

Attributing land-cover change to soy is complicated by the fact that soy usually replaces other agricultural uses (notably cattle ranching) in a complex and multi-stage process. The displacement by soy of these other land-uses then leads to indirect land-use change (ILUC), whereby cattle ranching and cultivation are pushed further into uncultivated forest or savannah. In both the forest and savannah biomes, land conversion for pasture and cattle largely precede soy cultivation and land conversion for infrastructure to 'open up' the biomes has been proceeding from the 1960s. Loss of native vegetation to drive exports of agricultural commodities only began in the 1990s, in response to structural reforms to the agricultural sector and the impetus provided by the devaluation of the Brazilian Real. Soy cultivation reached the cerrado only in the 2000s, and is thus only the most recent development in a long, complex and continually evolving process of land conversion.

The social and environmental impacts of soy have been a source of concern even when soy initially replaced coffee cultivation in the southern states during the 1970s. These included soil degradation, displacement of small farmers, their loss of income and resulting net migration away to either urban areas or northward into the Amazon where they proceeded to clear forest (Diegues 1992; Kaimowitz and Smith 2001). Concern has been further amplified by the northward shift of large soy monocultures into rainforest and savannah biomes (e.g. Fearnside 2001).

Of particular concern is land-use change in the Brazilian savannah, or *cerrado* biome, which receives far less protection than the neighbouring rainforest biome and has, by virtue of strong concentration of land ownership and favourable topography and climate, become a key site of soy's expansion and intensification. The savannah has been recognized as amongst the most biodiverse in the world, hosting over 160000 species of plants, fungi, mammals, bird and reptile species. It is also a crucial source of water for Brazil as a whole, as the rivers the Amazon, Paraná-Paraguai and São Francisco all have their source within the savannah. Yet, deforestation rates here exceed those of the Amazon and Atlantic forest biomes (Ratter *et al.* 1997). Cattle ranching, pasture expansion, crop monocultures and charcoal production have together inundated the cerrado so that a mere 20% exists in an unfragmented state and under 3% is currently protected (WWF 2012).

Furthermore, the social-ecological impacts of land-use change in the cerrado transcend the biome itself. For example, Costa and Pires (2009) show that the impacts of cerrado deforestation can combine with those of Amazonian forest loss to increase the duration of the dry season; reduced precipitation, in turn, may push remaining forest over the climatic 'tipping point' beyond which savannah or seasonal forest vegetation may come to predominate (see also Costa and Foley 2000; Cox *et al*. 2000; Lenton *et al.* 2008 and Nobre and Borma 2009).[1]

Few studies comprehensively assess the full GHG implications of current and projected soy cultivation including the impacts of de-vegetation, land-use change and soy agronomies. Raucci *et al*. (2014) analyse GHG emissions from soy cultivation across 55 farms in Mato Grosso between 2007-2010 and estimate that the GHG intensity for soy cultivation in the state stood at 0.186 kg CO_2eq kg^{-1}. A Life Cycle Analysis up to the farm-gate indicates that the largest contributions to GHG footprint up to the farm gate come from decomposition of crop residues (38% of the total), fuel (19%) and fertilizer use (16%), liming (13%), pesticide use (7%), seeds (8%) and electricity consumed (<1%). In another study including assessments of the impact of direct land-use change under different scenarios across Latin America results in an estimate of 0.1 - 17.8 kg CO_2eq kg^{-1} soybean (Castanheira and Freire 2013). As might be expected, the highest GHG footprint was associated with the conversion of tropical rainforest to tilled soybean plantation. Discounting land-use change, soybean's GHG impacts were found to range from 0.3-0.6 kg CO_2eq kg^{-1} soybean (*Ibid*.)

Agricultural intensification – producing more crop yield per unit land – is one way to manage

[1] There is some debate about whether desiccation-driven conversion to savanna is a threat to the Amazon Basin. Walker *et al*. (2009) argue that it is not; Malhado *et al*. (2010) argue that their analysis "fails to consider the potential importance of the deforestation of the Cerrado in driving an increased water deficit".

trade-offs between food production and deforestation. Brazilian soy is the most productive in the world, but it has been argued (Fearnside, 2001; 2005; Sharma 2014) that intensification alone will be unable to equal projected demands, particularly those originating from the Chinese nutrition transition. There is some evidence for example that soybean yields in Brazil are "very close to the climatic potential yield" (Licker *et al*. 2010), thus making further deforestation very likely (Karstensen *et al*. 2013).

It is also clear that 'business as usual' intensification will produce additional trade-offs and interactions that ultimately limit the productivity of agricultural land. Expenditure on inorganic inputs, particularly to combat weeds and pests, already amount to up to a quarter of production costs for soy in the cerrado (WWF 2012) and it has been estimated that some 80% of Brazil's total agrichemical consumption is concentrated in the states of Sao Paulo, Mato Grosso, Parana, Rio Grande do Sul, Minas Gerais and Goias where soy is dominant.

3.3 Regulating land-use change up to the development of the Brazil-China soy complex

Concerns over Amazonian deforestation in Brazil predate the soy complex, and between the 1960s and 1990s, a distinct brand of Amazonian politics has consolidated a powerful critique of development trajectories in the Amazon and their social and cultural impacts on local populations and livelihoods (Hecht 2011). These struggles have long been intertwined with the emerging wider global environmental movement of the late 20th century, for example relying on the globalization of the environmental movement from the 1970s onwards, the actions of new transnational conservation and development agencies, the expansion of ecological and Earth System sciences internationally and within Latin America and new multidisciplinary projects linking social, cultural and ecological well-being (Hecht 2011). Together, these have formed the focus of a powerful social movement for forest conservation and social justice in the Amazon. It could be argued that the presence and strength of such a movement has given particular shape to subsequent efforts to regulate land-use and land-cover change associated with the soy complex.

Regulating deforestation in response to soy and associated land-uses has been seen as difficult in light of the progressive weakening of state institutions and the progression of a 'neoliberal' ideology of extractive development (e.g. Brown and Koeppe 2012). Domestic concern over the deforestation in the Amazon was reflected in the 2001 revisions to the Forest Code, which mandated stronger conservation measures, though increased market demand for beef and soy made it difficult to enforce the Code effectively (Brown and Koeppe 2012). Reflecting increased international concern over the influence of soy cultivation and livestock production in the Amazon, in 2006 the influential Greenpeace report *Eating the Amazon* made the case that land-use change associated with soy and livestock production was driving Amazonian deforestation, primarily in order to feed Europe's hunger for cheap feed and meat substitutes. The report focused specifically on the operations of US-based Cargill, "most culpable of the soya giants" (p. 37) whose silos and port were feeding many of Europe's largest poultry companies, implicating "the whole food industry" as a "partner in this forest crime" (Greenpeace 2006b, p. 41).

International attention, exemplified by the Greenpeace report, along with direct action protests in soy-exporting ports succeeded in motivating major soy producers and processors to declare the Soy Moratorium, which attempted to delink continued deforestation with soy cultivation. The Moratorium prohibited signatories from financing or purchasing soy grown on Amazonian land deforested after 24th July 2006. The Moratorium, in place until December 2014, is supported by strong mapping and monitoring that have notably weakened the links between fresh deforestation and soy cultivation, "show(ing) convincingly that only miniscule percentages of lands deforested after 2006 contain soy operations" (Brown and Koeppe 2012, p. 119).

Thus, while there has been some success in weakening the links between soy production and deforestation, it is important that soy has *not* historically been planted on recently deforested land, and given that the moratorium doesn't control deforestation for cattle ranching and pasture expansion, important concerns remain. These are only likely to deepen given that as a result of international demand, soy now has a fundamental role in further land-use change across Amazonia, and it has been estimated that growing demand for beef and soy will result in the additional deforestation of some 400,000 – 500,000 km^2 of Amazonian forest by 2020 (Walker *et al.* 2009 *in* Walker 2014). Foremost amongst drivers of projected demand is growing Chinese appetite for Brazilian soy. In 2013, Chinese imports of Brazilian agricultural commodities overtook the EU. Soy constituted 31% of Brazil's exports to China that year (Macau Hub, 14th January 2014).

4 CHINA AS THE WORLD'S FOREMOST IMPORTER OF SOY

I now turn to the evolution of Chinese demand for soy and the formation of a consequent commodity complex between Brazil and China.

Imports of soy to China represent the beginning of a new era in Chinese agricultural, land-use and development policy. While soy imports have marked a major a shift away from China's historic stance of food self-sufficiency, this development has exemplified the particularly 'Chinese characteristics' of China's new engagement with global markets (cf Harvey 2007) –

namely strong and sustained state intervention aimed at protecting China's interests and protecting the stability of supply for strategic crops.

In the following sections, I first outline the broad contours of the food-energy-climate change trilemma in China, before turning to the trilemma dynamics particularly contributing to China's decision to open itself to imports of strategically important food grains. I present this as the outcome of, on the one hand, changing demand for food and relative limits on the ability of Chinese farmers to cater to these. I then outline the ways in which Chinese state intervention has shaped the unique trilemma linkage manifested by the Brazil-China soy chain.

4.1 The food-energy-climate change trilemma in China

Briefly, the general contours of China's trilemma are as follows. Manufacturing-led economic growth, coupled with increasing material prosperity has led to substantial increases in energy demand from fossil fuels. Between 1990 and the mid-2000s, China's CO_2 emissions doubled and per capita emissions increased by 86% (Langeveld *et al*. 2014). Demand for transport fuels is rising: China has the second-largest car market globally and is the second-largest consumption of petroleum. Between 2000 and 2010, sales of passenger vehicles grew by some 20-fold (EIA 2014). As was the case for Brazil and the United States in the 1970s, China has been motivated to develop alternatives to fossil fuel energy in response to recent energy price instability, fuel shortages and the need to contain vehicular pollution (Koizumi 2014). The Chinese Five-Year Plan of 2001 emphasized the promotion of alternative, biomass-based energy. Effective strategic foresight and strong, targeted policy backing has led to a remarkable growth in biofuel production capacity. By 2006, a government mandate for the use of 10% bioethanol blend (E10) was in operation across 27 cities (Koizumi 2014) and by 2010, China ranked third in the world for ethanol production. The key feedstocks for Chinese bioethanol are maize from Heilongjiang, Jilin and Anhui provinces, wheat from Hernan and cassava from Guangxi. Production of biodiesel largely from used cooking oil has been relatively constrained by the availability of feedstock (Koizumi 2014). Over time it has become clear that further development of alternative fuels will be shaped by the long-standing commitment to national self-sufficiency in food grains. Chinese strategic direction for biofuels production has increasingly been shaped by the imperative to avoid any potential trade-off between food-v-fuel, thus orienting biofuels policy towards non-food crop alternatives and emphasizing the protection of land used for food production (Langeveld *et al*. 2014). In the mid-2000s, for example, when it was observed that corn consumption for bioethanol might have been competing with corn for food and feed (Koizumi 2014), the NDRC sought to limit further expansion of corn- and wheat-based bioethanol and has turned attention towards alternative feedstocks such as cassava and sweet sorghum. Further development of biofuels crops is also likely to focus on so-called marginal lands, to avoid the potential loss of prime croplands, which are already being lost for a number of reasons. Of particular relevance for this paper is the tension between, on the one hand, relatively limited agricultural land (itself a function of historical land-use decisions as much as biophysical endowments) and sharp escalations in demand for food as a result of a growing and urbanising population.

China feeds some 20% of the world population using only 9% of the world's arable land; this land is divided such that Chinese farmers cultivate only 0.08 ha of arable land per capita (World Bank 2013). This unique structure of agricultural land-use, set against China's growing population and an on-going nutrition transition, has put immense pressure on Chinese agriculture especially in light of an on-going crisis of water and land-degradation. Further, loss of agricultural land and declining quality of existing agricultural land has long been a key challenge in China[2] and continuing loss of cultivable area, combined with extensive degradation driven by misuse of existing agricultural area, have long fuelled concerns about the availability of food in China and the implications for food security globally (e.g. Brown 1995; GRAIN 2012).

In part, this squeeze on agricultural land has been an outcome of China's unique trajectory of land reform in the post-Mao era. Chronic food insecurity, poverty and rural discontent gave rise to grassroots experimentation with private control over agricultural plots in regions worst affected by Mao's Great Leap Forward. Initially quashed as a threat to socialist principles, these movements nevertheless received some measure of quiet support from provincial governments. In regions where local provisional governments acquiesced, productivity quickly increased (Lin 1992). However over time, the Chinese central government undertook a strategy of 'selective withdrawal', lifting restrictions on private (household) control over land, first in the most impoverished regions. By 1984, decollectivization was officially complete and the new Household Responsibility System (HRS) was adopted. Under this new system, land-use (but not ownership) rights were transferred to farm families, who for the first time were also permitted to engage in off-farm labour in neighbouring factories. Farm productivity rapidly increased[3], and a new labour force was unleashed for work in the new township and village enterprises (TVEs). Thus, these reforms could be said to have created a new, smallholder-focused production system, which, while temporarily and partially alleviating rural poverty,

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[2] Beyond the scope of this paper, but relevant for a wider study of agricultural land-use in China is the presence of long-standing contentions around precise estimates of China's agricultural area. See, for example, Smil (1999), who contends, "the official total of China's farmland is about 50% lower than the real figure… (an) underestimate (which) has been known to informed Chinese experts, as well as to some Western scholars, for nearly two decades" (p. 414).

[3] Lin (1989), Wen (1989), McMillan *et al.* (1989) identify the introduction of the HRS as a key driver of agricultural output growth. In a later study, Lin (1992) employs province-level data to assess the impacts of specific components of Chinese agricultural reform (the HRS being one of these), and finds that decollectivisation accounted for around half the productivity growth between 1978 and 1984. Adjusted state procurement policies also contributed positively to output growth, but the impact of other agricultural reforms was relatively small.

nevertheless had particular implications for the availability of food grain in an industrializing country beginning to experience a nutrition-transition. Freeing agricultural labour implied a concomitant increase in rural industrialization and the freeing up of a massive new labour force.

A deeper and more fundamental impact of these land-reforms was the gradual loss of agricultural land. Since the late 1970s, land loss due to infrastructure development housing and plant construction has been a significant driver of loss of agricultural land (Smil, 1999). In addition, with the gradual removal of Mao's policies, large areas have been converted to forest and pasture. Thus, - probably uniquely to the Chinese case – there has been a transition from cultivated land to non-cultivated, though vegetated area (the opposite of the transition underway in Brazil with the conversion of forest land to fields). Between the mid-1980s and mid-1990s, such conversion has driven up to a third of the total loss of cultivated area. In a similar vein, land cultivated to annual crops has been converted to perennial orchards, reflecting the increased demand for fruit for both domestic consumption and for export.

Finally, the quality of existing agricultural land has also declined precipitously, causing "as much loss every year as combined urban and rural construction" (Smil 1999 p. 426; see also; Song and Pijanowski 2014). Water scarcity is a growing concern following the depletion of groundwater for irrigation, particularly in the North; it is expected that this will intensify vulnerability to climate impacts (Wang *et al.* 2010).

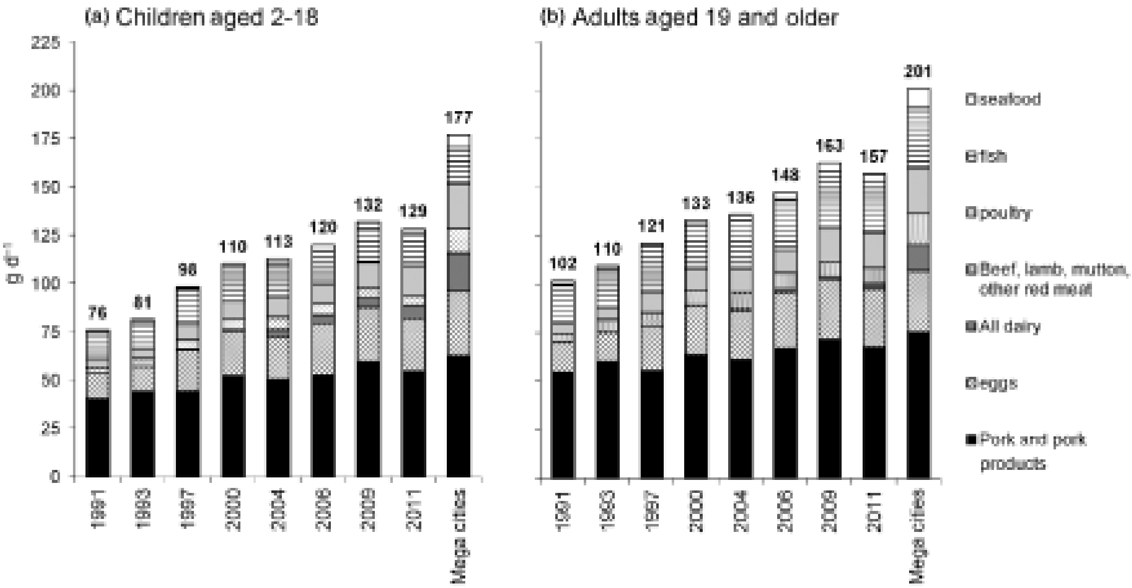
At the same time, as early as the mid-1980s, grain production began to stagnate again following the initial gains made after decollectivisation. Tension began to develop between the State's commitment to ensure the stability of the newly established HRS and increasing discontent with stagnating grain output, against a background of commitment to national grain self-sufficiency (Lin 1992). Deepening this tension was the long-standing "doctrine of equating advanced technology with big tractors and efficiency with large farm size", which was "still deeply rooted in the minds of many scholars and prominent leaders in China" (Ash 1988).

Against this context, new and increased demands for food had made a continued commitment to food self-sufficiency untenable for China. Specifically, China has been experiencing a significant and sustained nutrition transition since at least the 1980s (Smil 1999; Popkin 2014)[4]. From the mid-1990s to the mid-2000s, Chinese household's expenditure on food has

[4] The Chinese nutrition transition shows several unique features: occurring at a lower level of GNP than it did in the USA and Western Europe, and manifesting even amongst the poor, who have access to fats and animal products. Comparing shifts in meat consumption achieved in the United States, for example, Larsen points out that "It took China just 25 years to make the consumption leap achieved by the United States over a half-century" (2013, *not paginated*).

increased continuously, doubling at the end of the period (Chinese Statistical Association 2011). With these increases have come a fundamental change in food habits, "leaving behind a diet limited to rice and pork to include dairy products, wheat, cereals, and meat (both white and red)… converging with the food consumption patterns of developing countries… (including) the tendency to greater food consumption outside the home that has increased from 9 per cent to 21 per cent of total food expenditure between 1993 and 2005" (Wilkinson and Wsez Junior 2013 p. 249-250). There has been a notable diversification in the sources of dietary energy and protein, whereby from the early 1990s to 2011, there has been a sharp decline in the percentage of energy consumed from carbohydrates (particularly in the three megacities of Beijing, Shanghai and Chongqing), an increase in the percentage of energy consumed from fats, and an increase in the percentage consumed from protein. Consumption of animal-based foods has increased (Figure 3) – particularly in the megacities, and particularly for pork (Zhai *et al.* 2014)[5].

Figure 3: Daily intake of animal source foods in China 1991-2009. Source: Zhai *et al.* 2013.



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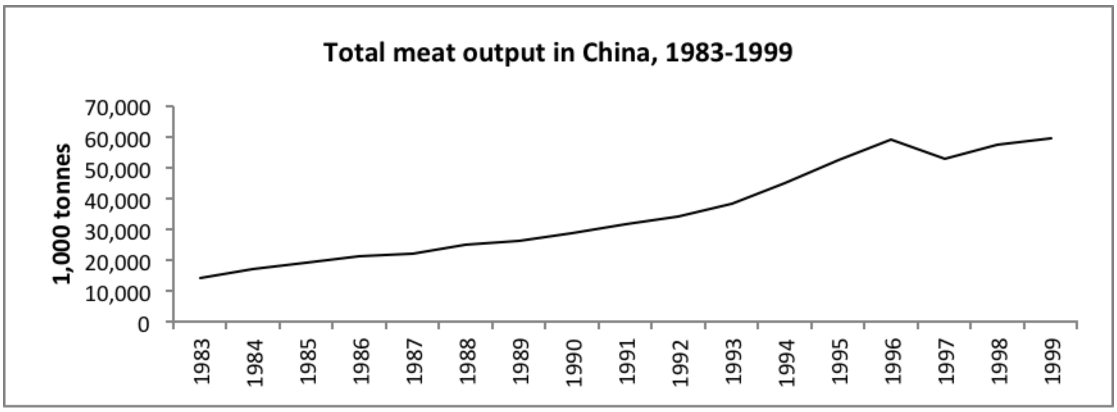
[5] But see Foresight 2011(b) who contend that it is unlikely that China as a whole will adopt North American levels of meat and dairy consumption. Instead, "most recent modeling suggests that the Chinese people will adopt a modified Japanese diet" (p. 22). Nevertheless, the authors report, there is clear evidence of rising incidence of overweight and obesity amongst young people. It is beyond the scope of the present paper to settle the question of future Chinese diets definitively, but it is clear that empirical data exists to show increased meat consumption at least for the present and foreseeable future.

At present, there are no definitive figures for meat demand in China (Sharma 2014). Official estimates count only consumption within the household and may thus underestimate total per capita intake. By these estimates, per capita meat consumption in China at present stands at 59 kg/person/year (Weis 2013). The total size of the Chinese population nevertheless means that it produces and consumes half of global pork, 20% of poultry and 10% of beef (Sharma 2014). These developments echo wider trends through Asia, where the 'meatification' of diets, in part the result of rising incomes, is a key source of pressure on global grain reserves.

Intertwined with increased consumption of animal products, and driving the push for more imports, is a state-led restructuring of livestock production. Traditionally, meat production was largely a small-scale affair, designed for local subsistence. Livestock was raised on household waste and in close integration with cropping systems: "local people raised local pigs and ate them in local (geographic, cultural and social, dietary) contexts" (IATP and Schneider 2011, p. 6). The food system was predominantly subsistence-oriented, provision was managed largely through traditional wet markets and food rationing was in operation. However, as initial confidence in the process of decollectivisation has waned, the Chinese agri-food system is undergoing another seismic shift. State policy has explicitly focused on increasing meat production by supporting the development of a domestic milling industry that would provide compound livestock feeds. This marked an important shift away from the historic structure of smallscale, subsistence-oriented livestock production to the creation of surpluses for trade. Prior to the intensification of livestock production, animal feed was composed of "low-quality grains, tubers, grain byproducts, table scraps, brewery residues, green silage, melons, water plants and other vegetation" (Tuan and Tingjun 2001, p. 2). A feed industry grew rapidly, "from nearly nothing before 1975 to … the world's largest feed producer by 1995" (IATP and Schneider 2011, p. 10). Concomitantly, total meat output increased steadily over the 1980s-1990s (Figure 4).

Figure 4: Total meat output in China, 1983-1999. Source: Data compiled by Tuan and Tingjun (2001) from China's Statistical Yearbook, various editions.



Pork has long been "the core of China's livestock industry" (Tuan and Tingiun 2001). Changes in the agrifood system and restructuring of the livestock sector are particularly exemplified by changes in pork production. In the 1980s, some 95% of hogs were raised in backyard enterprises. With the reforms initiated in the early 1980s, households were first permitted independent, household-scale livestock rearing and to sell animal products at rural markets. By the mid-1980s, the livestock sector was liberalized, with the abolishment of the procurement quotas and fixed procurement prices for government purchases. This change incentivized further (household-scale) production and the formation of specialized household-scale livestock rearing. The Household Responsibility System notwithstanding, collective livestock operations were developed and state-run breeding programmes supplied specialized household units with better pig varieties. Government targets for feed production (100-200 Mt by the year 2000 according to the programme implemented by the State Economic Commission in 1984) catalyzed in a great increase in the number of (state-owned) feed mills. Over the years, with an increase in the number of mills has also come a shift towards higher milling capacities (over 1 t/hr, 5t/hr and 10t/hr). Having thus put in place the infrastructure for a feed industry and set the livestock industry on the path to intensification, these developments paved the way for rapidly escalating demand for soy meal, and thence to the import of soy.

The 1989 'Vegetable Basket' programme encouraged peri-urban farmers to produce more and better meat, milk, eggs, fruit and vegetables for urban residents; as a result, the supply of meat to urban areas increased, as did the overall output of animal products. Finally, the state-led restructuring of the feed industry – including its liberalization (joint foreign ventures were allowed at this time) resulted in the production of compound, mixed and concentrate feeds and feed additives, and the wide availability across both rural and suburban areas. With the establishment of feed mills and the intensification of livestock production on the one hand, and stagnating soy production on the other, it became impossible to maintain the historic stance of self-sufficiency in soy.

Overall, accounts of the evolution of the soy complex tends to emphasize the influence of rising demand against limited production capacity (see, e.g. Brown-Lima *et al. n.d*.) The precise influence of different factors is as yet difficult to distinguish, but broadly, it is clear that there was increased demand for animal products, strong government intervention in setting up feed mills and intensifying livestock production, against the background of limits to the ability of China's smallholders to cater to the resulting increase in demand for soy (itself a function of government reforms creating a class of smallholders as well as a developing legacy of farmland loss as a result of both mismanagement and land use policy). Soy imports are expected to continue to grow, as it has been argued that China's nutrition transition is still in its early stages and thus the need for agricultural commodity imports will likely rise for some time yet (Valor Econômico 2012).

In any event, by the mid-1990s, China had switched from being a net exporter of soy to a net importer. By the early 2000s, China's soy imports had overtaken even those of the EU-27. And by 2005, China was importing half the world's soy. A historic shift was thus completed, from a strong policy of national self-sufficiency to interaction (albeit strongly structured and overseen by the Chinese state) with the world market for a key agricultural commodity; and from a commitment to preserving an agrarian economy built around smallholder production to larger, more commercial, industrial production and distribution systems.

China's decision to liberalize soy provided a huge market for Brazil and the US, who compete for the position of top suppliers to China (followed by Argentina in third place). While supplies from the USA to China are significant, it is in Brazil – and the Mato Grosso in particular – that soy production for the world market is accelerating fastest. Between 2000-2008, Brazil's soy exports to China increased nine-fold and by 2011-12, over 80% of Brazilian soy was imported by China (Sharma 2014).

4.2 The emerging structure of the Brazil-China soy complex

Unsurprisingly, given China's longstanding commitment to food self-sufficiency, the decision to liberalise soy has been accompanied by strong strategic action designed to ensure the stability of supply. In this sense, the search for international sources can be seen as merely an extension of longstanding Chinese policy, rather than a reversal – in other words, as "another kind of self-sufficiency" (Peine 2012, p. 205). To this end, the National Development and Reform Commission (NDRC) has taken a number of steps to, first, protect China's domestic crushing and livestock industries[6] and second, to encourage Chinese firms to extend themselves directly into the foreign soy supply chain, structuring it to their advantage. In 2007, the NDRCs *Catalog for the Guidance of Foreign Investment* protected the domestic soy processing industry by mandating that Chinese-owned enterprises must own the majority of shares in any venture with foreign partners. In 2008, the *Directive on Promoting the Healthy Development of the Soybean Processing Industry* again emphasized the need to protect the domestic soy processing industry, encouraged the consolidation of soy processing and animal feed firms, and specifically highlighted China's reliance on imported soy as a source of concern. It is this concern that lies at the heart of China's efforts to structure the Brazil-China soy trade

[6] State incentives to protect the domestic crushing industry were particularly spurred after the takeover of Chinese soy crushing by international agribusiness firms in the mid-2000s. Chinese soy crushers defaulted on payments to U.S suppliers, and arbitration by the Grain and Feed Association in London forced many Chinese crushing firms out of business. This paved the way for a takeover of the sector by international agribusiness firms, which "caused an outcry within the country" (Sharma 2014, p. 17). In response, the government put in place a range of policies and economic incentives to encourage domestic firms and limit the influence of transnational corporations.

Following these developments, the bulk of Chinese imports constitute whole soybeans, to be crushed and processed within China. This has a number of implications for the structure of the Chinese agrifood sector, potentially facilitating greater consolidation and 'upscaling'. The implications, if any, for land-use in Brazil and other centers of soy cultivation are as yet unclear and need further review.

so as to first, protect its domestic processing and animal feed operations and second, to ensure the stability of supply from Brazil. To this end, the Directive specifically encourages Chinese firms to 'go out' to develop international (in this case, Brazilian) sources of supply: "*target soybean-export countries to purchase soybean locally, and then rent port terminal, establish warehouse and transportation system, or purchase stakes of local agricultural enterprises and rent land to grow crops. Encourage domestic enterprises to build soybean processing plants in foreign countries"* (Petry and O'Rear 2008, p. 11).

In response, Chinese firms have been manifesting the 'going out' strategy by directly investing in Brazilian farmland and in Brazilian soy production more generally. For instance, the Chongqing Grain Group (a Chinese agribusiness firm) and Pengxin Group (a Chinese real estate firm) have between them invested in some 400,000 ha of Brazilian farmland to produce soybeans (Schaffnit-Chatterjee 2012, p. 6).

The resulting land-use change implications in Brazil are difficult to predict specifically, but there is little doubt that demand for Brazilian soy will continue to grow, and land conversion across the cerrado (to some degree) is inevitable. The structure of the Chinese 'end' of the trilemma linkage also has particular implications for land-use, GHG emissions and other sustainability indicators in China. The backyard and small-scale farmers who have historically produced all of China's pork are at a severe disadvantage in the new market economy (IATP and Schneider 2011) and "the broad trend is clear: larger-scale operations are increasing at the expense of household production" (Schneider and Sharma 2014, p. 19). In part due to their inability to compete with imports (including but not limited to those from Brazil), Chinese smallholders are leaving the land. Government policy too explicitly calls for an urban-led model of economic development whereby "central policies will effectively move hundreds of millions more people to China's cities, leaving only 400 million in rural areas" (IATP and Scheider 2011, p. 22).

Viewed in terms of trilemma dynamics, the structure of the Brazil-China soy complex presents tight and seemingly intractable tensions between increased soy production and GHG emissions (from land-use change but also across the agrifood chain), in addition to a range of other sustainability concerns (notably water quality and biodiversity loss). Whereas regulation has so far been somewhat successful in curtailing some of the impacts of soy agronomies in Brazil, the emerging structure of the Brazil-China soy complex means that regulation of land-use change will enter a new regime whose precise implications for climate change and sustainability in general are as yet still unfolding.

5 IMPLICATIONS AND FURTHER WORK

The new commodity chain of the Brazil-China soy complex implies a step-change in Brazilian soy agronomies and a turn-around in Chinese agricultural and development policy. This section lists the unique implications for land-use and land-use policy and discusses research avenues for the further development of a social science account of trilemma dynamics. These points will receive empirical attention in a wider project comparing trilemma dynamics across three BRIC countries, the USA and the EU.

First, any trilemma-focussed account of the soy complex and its implications will need to unpick the evolving regulatory environment conjured by Brazil in order to protect its soy sector from Chinese influence. While Brazil has much to gain from its trade in soy, and from deepened trade relationships with China more generally, "their interests in the case of soy may not exactly align even if they would both like the power of the ABCDs curtailed" (Sharma 2014, p. 26). Brazil's participation in the emerging 'Sino-centric' order has caused significant concern as a result of a decline in Brazil's manufacturing exports to China, the flooding of the Brazilian market with Chinese goods, a sharp escalation in Chinese investments in Brazil (Wilkinson and Wesz Junior 2012). These concerns, set against China's increasing 'land hunger' "makes Brazil uneasy" (NY Times 2011), and in response Brazil has initiated a number of curbs on the sale of land (FT 2011; Sharma 2014, Box 5). This implies that China's strategy of increasing direct control over its supply chain will necessarily be diluted, needing to work *via* partnerships with Brazilian firms and through investment in soy processing and distribution (rather than seeking its ultimate expression via direct control over soy-growing land itself). Chinese firms have expressed disappointment in Brazil's 'protectionist' policies: "public opinion sometimes seems to be against foreign investment… there are some antiquated ideas" (Reuters 2013, not paginated). Nevertheless, there are still a number of avenues through which China can continue to exert direct control over Brazilian soy production, such as through entering long-term leases, purchasing minority stakes in farming projects, investing in local companies and disbursing 'loans for grain' (Collins and Erickson 2012). These forms of control, already evident in Chinese dealings across Latin America, ensure continued trilemma linkages between Chinese demands for food, Brazilian land-use (and resulting GHG emissions). Legal and political negotiation between these two ends of the trilemma linkage will continue into the foreseeable future.

Second, China's Going Out strategy also places Chinese firms in competition with the US-based ABCDs. These control the majority of Brazil's exports and have extensive investments and control over grain elevators, crushing facilities, port terminals and distribution and "this means that China – and increasingly its own TNCs – are completing with the oligopolistic might of foreign TNCs through direct access to soy and by mimicking their methods of vertical and horizontal integration of the commodity chain…" (Sharma (2014, p. 26). Yet, Chinese firms are not finding 'Going Out' an entirely smooth venture. In April 2014, it was reported that Chinese buyers could default on payments for soy imported from the US and Latin America in order to avoid losses due to a depressed local market against increases in the futures prices and a tightening credit regime (Reuters 2014). The implications for the structure of the soy commodity chain will form a further strand of analysis in the on-going project to which this working paper contributes.

Third, further work will also be required to unpack the implications for land-use of China's seemingly infinite demand for Brazilian soy. For example, it has become evident that "in comparison with Europe, China showed itself to be somewhat indifferent to the social and environmental issues involving [soy] (Wilkinson and Wesz Junior 2013, p 254). Two key differences illustrate the significant contrast between the EU and China. First, China has 'opened its doors' to transgenic soy, "largely sealing the fate of the resistance to transgenics in Brazil" (Wilkinson and Wesz Junior p. 254). Second, Chinese firms have not shown themselves willing to be regulated through the Soy Moratorium and the Roundtable on Sustainable Soy, both so far central mechanisms for mitigating (to some limited extent) the influence of increased demand for soy on land-conversion in Brazil. To a significant degree, the soy moratorium has been the result of civil society movements for sustainable consumption – "European customers were getting uncomfortable having their products associated with the deforestation of the world's largest rainforest and threatened to boycott Brazilian soy" (Stewart 2014, *not paginated*). In part due to the resulting regulation, its efficacy and due to the intensification of soy production more generally, deforestation-driven GHG footprints of soy in Brazil have decreased. In a recent assessment of the environmental footprint of soy production in Mato Grosso over the 2000s, Lathuillière *et al*. (2014) find distinct differences in the GHG footprints (among other variables) of soy over the period. Deforestation associated with soy declined between the 2001-05 and 2006-10 periods. Specifically, deforestation per tonne of harvested soy was found to be 455 m^2 $tonne^{-1}$ for 2001–05 and 97 m^2 tonne−1 for 2006–10. This reduced deforestation in the second period (when China also overtook the EU as the top global importer) has resulted in lower GHG footprints attributable to trade in soy with both China and the EU. Yet, with the Moratorium coming to an end in December 2014, land conversion will be regulated by Brazil's new Forest Code, whose efficacy in light of continued escalations in Chinese demand would doubtless be a source of concern for observers. There is some evidence that soybean yields are "very close to the climatic potential yield" (Licker *et al.* 2010), thus making further land conversion likely (Karstensen 2013). At the same time, Chinese buyers are not going anywhere despite intermittent food safety scares (which temporarily depress demand for animal feed). It is clear that certain sections of Chinese consumers prefer industrially-produced meat, mirroring policy movements towards consolidation and industrialisation. Both seem to "equate industrial farming as the symbol of modernization and development (Schneider and Sharma 2014, p.22).

Finally, a critical social scientific account of the evolving trilemma will need to integrate how social and cultural change interacts with resource finitude to shape new trade links (and resulting land-use change). The Brazil-China soy complex may, for example, be assessed on two levels: first, as a manifestation of (relative) scarcity of agricultural land in China set against (relative) abundance of land in Brazil. Yet it is not simply scarcity of agricultural land (or even of food calories) that are driving change. Trilemma dynamics have so far been framed as interactions between resource demands (for food, energy and materials) and resource finitude / environmental degradation (e.g. finitude of land or GHG emissions from unsustainable land-use). It is argued that policymakers face complex decisions and trade-offs between these different push / pull factors. Yet, the soy complex is composed of multiple actors with both competing and overlapping interests, and with different endowments of social and political capital[7]. Trilemma framings of 'demand' for food (in China in this case) will need to engage critically with the question of who is demanding what, and with what implications for rural communities in both Brazil and China.

To conclude, the China-Brazil soy complex represents a distinctive trade link of global significance for the interlinked challenges of food, climate change and land-use. The complex is shaped by, first, the particular suitability of the Brazilian Mato Grosso for soy cultivation, and second, by China's emergence from grain self-sufficiency via land-reform and industrialization. At this historical juncture, the Chinese nutrition transition, combined with state support for corporations 'Going Out' to ensure 'a new kind of self-sufficiency' has created the conditions for a globally significant transition in land-use whereby Brazilian soy will increasingly supply Chinese markets. The resulting land-use changes, given Chinese priorities, will possibly entail greater conversion of non-agricultural area, possibly higher GHG emissions and significant local social-ecological impacts particularly in the Cerrado. A social scientific account of the trilemma, such as has been attempted in this paper, shows how policy processes, combined with distinct biophysical conditions and socioeconomic trajectories, shape social-ecological outcomes. Sustainability regulation will need to evolve to take these complex, path-dependent and evolving interactions into account.

[7] For a discussion of the roles and movements of multiple actors in Brazilian deforestation (not necessarily connected to soy), see Fearnside 2008 and for an overview of the evolving context of Brazilian environmental regulation, Fearnside 2013. Given this multiplicity of actors, priorities, hierarchies and values, it is unsurprising that approaches to scholarship and activism have been diverse and multi-layered. Goldsmith and Hirsch (2006) explore the soybean complex using three analytical lens: as an *agro-industrial complex*, as a *driver of change in agroecosystems* and finally as a *driver of infrastructure development.* Hecht (2011) explores the "multiple environmentalisms" (p. 4) at work against the industrialization of the Amazon basin, each with distinct discourses and strategies.

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