Seeds, agricultural systems and socio-natures: Towards an actor-network theory informed political ecology of agriculture

Authors: Watts, N. and Scales, I.R.

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Abstract

Agriculture has recently been the subject of considerable research and policy attention. Events such as the 2008 'world food price crisis' and concerns over the future of global food security have led to calls for a 'New Green Revolution', with an emphasis on boosting yields through new transgenic crop varieties. However, critics have raised concerns over the growing role of global agribusiness and transnational capital in agriculture, as well as the potential social and ecological impacts of new technologies. An analysis of emerging agricultural trends thus demands a framework that is able to negotiate the complex multi-scalar interplay between environmental, technological, scientific, political, and economic factors. In this paper we focus on the potential contribution of a synthesis between political ecology (PE) and Actor-Network Theory (ANT) to our understanding of agricultural networks. We review the literature with a view to teasing out key insights and sketching out future research priorities. We focus on questions surrounding power and agency; the political ecology of scale; and the role of situated knowledges and practices.

Introduction

Agriculture has been the subject of considerable research and policy attention over the last ten years. Events such as the 2008 'world food price crisis' have raised questions about the ability of global food production to meet growing demand (e.g. FAO 2008, World Bank 2008, Foresight 2011). There have been calls for a 'New Green Revolution' to develop new crop varieties to increase global food productivity, improve nutrition, and help farmers cope with climate change (Godfray et al. 2009, Rockefeller 2006). Such developments follow more than a century of agricultural innovation and intensification, culminating in the agro-industrial model of production. At the same time, critics have raised concerns about the growing role of global agribusiness; the social and ecological impacts of new technologies (including genetically modified organisms - GMOs); the implications of trade liberalisation for farmers; and the role of the financialisation of agricultural commodities in food price instability (McMichael 2009, Bernstein 2014).

These trends point to the complex socio-environmental interactions that shape agriculture. An analysis of agricultural trends thus demands a framework that is able to negotiate the multi-scalar interplay between environmental, technological, scientific, political, and economic factors. In this paper we look at the potential contribution to our understanding of agricultural networks of a synthesis between political ecology (PE) and ideas from Science and Technology Studies (STS), more specifically Actor-Network Theory (ANT).

From its emergence in the 1980s, PE has concerned itself with providing place-based understandings of the factors that shape human-environment interactions, with agriculture

being one of its most important areas of enquiry (Peet & Watts 1996, Robbins 2012). However, PE has also recently been destabilised by a diverse range of critiques. Perhaps the most challenging are 'post-humanist' ideas that move away from a narrow focus in social theory on 'pure' human society and culture, and emphasise the complex ways that humans and non-humans are entangled.

While some areas of geography have seen fruitful engagement with post-humanist frameworks (e.g. Haraway 1991, Whatmore 2002, Castree 2003, Demerritt 2005, Muller 2015), research in PE has mostly kept its distance. However, there is now a growing literature that attempts to blend post-humanist concepts with the traditional concerns of PE (e.g Natter & Zierhofer 2002, Sneddon 2002, Gareau 2005, Rudy & Gareau 2005, Perkins 2007, Rocheleau & Roth 2007, Robbins 2012, Gabriel 2014). ANT scholars have also begun to deepen their engagement with the politics of nature (e.g. Latour 2004, McGee 2014, Muller 2015). However, questions have been raised about the limitations of ANT hybrids (e.g. Caster 2002, Fine 2005, Holifield 2009, Chagrin 2014).

We begin by providing a brief introduction to PE and ANT, in order to highlight recent debates. Having set the scene, we draw attention to important recent agricultural trends and consider the contribution that a merged ANT-PE approach might make to our understanding of such developments. We sketch out key research questions, focusing on: i) power and agency; ii) the PE of scale; and iii) the role of situated knowledges and practices in emerging agricultural networks. We argue that while such an exercise raises fundamental ontological, epistemological, and ethico-political issues, an ANT informed PE of agriculture has the potential to offer new insights into recent developments in agriculture.

The political ecology of agriculture past and present

PE is an approach to investigating human-environment relations that focuses on questions of access to and control over natural resources (Peet & Watts 1996, Robbins 2012). It is cross-disciplinary, drawing on a wide range of methods to examine how nature is perceived, managed, and contested (Goldman et al. 2011). PE is also marked by its commitment to environmental justice, seeking not just to analyse struggles over resources but also to influence them (Peet & Watts 1996, Forsyth 2008).

Ever since its emergence in the 1980s PE has had a strong engagement with agricultural issues, particularly in the Global South (Peet & Watts 1996, Robbins 2004). Early PE was heavily influenced by political economy, focusing on the role of class in contests over natural resources and the role of global capitalism as a driver of environmental degradation. An early example can be seen in Blaikie and Brookfield's (1987) work on soil erosion, in which the authors used the concept of a 'chain of explanation' to link local processes of soil degradation to broader political and economic changes.

As with most conceptual frameworks in Geography, PE has morphed through time in response to dominant issues and theoretical paradigm shifts. From the early 1990s PE became increasingly influenced by poststructuralist thought, feminist geography, and postcolonial studies, and began to ask deeper questions about issues of power and representation (Peet & Watts 1996, Fairhead & Leach 1996, Muldavin 2008, Rocheleau 2008, Robbins 2012). Moving away from broadly materialist analyses of natural resource use, researchers have become

increasingly engaged with the different ways that nature is perceived, understood, and presented by different social groups (Goldman & Turner 2011).

Recently there has been a proliferation of conceptual and theoretical approaches vying for dominance within PE. There have been calls for more sophisticated analyses of power that focus on the roles of gender, ethnicity, knowledge, and identity in contests over natural resources (Rocheleau 2008). While PE has become more diverse, some have argued that its explanatory power has been diminished through disassociation from its Marxian heritage (Moore 1993, Peet & Watts 1995, Mann 2009). PE has also been criticised for its geographical bias, with most research carried out in rural areas of the Global South (Walker 2003, Schroeder et al. 2006, Robbins 2012). Such tensions have led political ecologists to become increasingly eclectic in the theories and analytical tools that they draw on, with a growing number of researchers now experimenting with insights from STS and ANT.

Science and Technology Studies and Actor-Network Theory

STS is a burgeoning cross-disciplinary field that looks at how scientific knowledge is produced, circulated, and used in different social contexts (Law 2004). Although built on a diverse set of ideas, approaches, methodologies, theories, and analytical tools, STS is unified by the idea that the production, dissemination, and adoption of scientific knowledge is a deeply social process. According to Law (2004, p.12 emphasis in original) 'scientific knowledge and technologies do not evolve in a vacuum. Rather they participate in the social world, being shaped *by* it, and simultaneously *shaping* it'.

ANT is one of the most vibrant but also one of the most theoretically challenging branches of science studies. Its most noteworthy characteristic is its radical 'post-human' or 'more-than-human' ontological stance. While Geography contains a broad range of ontologies, the majority are unified by the fact that they are *binary* and *asymmetrical*. Binary ontologies divide the world into opposing categories (e.g. nature/culture, rural/urban, local/global, organic/synthetic, subject/object) and usually see one side of the dichotomy as dominant and thus shaping the other (Castree 2002). The things that make up the world are thus 'social *or* natural, active *or* passive, agent *or* acted upon… nature is separate from humanity and humans have the monopoly on knowledge, agency and morality' (Dyer 2008, p. 209 emphasis added). This leaves no room for 'hybrids', 'quasi-objects' and 'socio-natures' (Latour 1990, Haraway 1991, Murdoch 1997, 1998, 2001, Whatmore 2002, Forsyth 2003, Robbins 2012) - in other words, things that are not quite natural, not quite social (Castree 2002). It also privileges certain (usually human) actors and sees power as being held by particular individuals or institutions and projected outwards (Gabriel 2014). Nature is thus treated as 'the backdrop behind the stage on which human drama is conducted' (Busch & Juska 1997, p. 691).

In contrast, ANT's ontology is one of 'symmetry' (Law 2004, Latour 2005), where all objects and organisms are potential *actants* with the ability to influence the world. Having identified actants, ANT then seeks to trace the associations between them, linking them together into a network (Law 1992, Dankert 2010, Nimmo 2011).

As well as encouraging researchers to pay attention to non-human actants, ANT also encourages researchers to think relationally. In other words, rather than thinking about actants

in isolation, ANT argues that any human and non-human actant can only be defined in relation to other things: 'each of the separate pieces [in a network] is… made to be the way it is by virtue of its relationship to all the other parts… each [actant] becomes what it is through its specific relation to the other' (Robbins 2007, p.14). The process by which an actant takes on an identity in a network is referred to as 'translation'. This means that an actant's identity is dependent on the particular network(s) it is part of and is thus fluid and dynamic rather than concrete and timeless.

ANT's 'horizontal' ontology not only rejects binarism, it also rejects hierarchical views of the world. This means that spatial levels (e.g. 'local', 'regional', and 'global') are not used as *a priori* organising principles, and no hierarchical causality (e.g. 'top-down' or 'bottom-up') is assumed. Instead, networks are traced across space, allowing researchers to 'scale jump' (Marston et al. 2005). This can transform the way we understand politics, allowing for varying nodes of power and influence which traditional scalar analyses may not be able to capture (Zimmerer 2006, Rangan & Kull 2008, Farias & Bender 2010, Goldman et al. 2011).

Given its radically different ontology and epistemology it is not surprising that ANT has proved highly controversial. In particular, ANT's emphasis on non-human actants has lead to critiques that it promotes paralysing relativism and ignores human inequalities. If all actants and positions are treated equally, how can it be argued that any given network is more or less ethically desirable (Chagani 2014, Waelbers & Dorstewitz 2014, Ghose & Pettygrove 2014)? Accounts of different networks often miss out who benefits or loses (Ingram 2011).

According to Swyngedouw (1999, p.447), 'following the maze of socionature's networks…is not good enough if stripped from the process of their historical-geographical production'.

As well as these ethico-political concerns, doubts have also been raised about the extent of ANT's power as an explanatory tool (Knox et al. 2005, Heeks 2013). By emphasising that all networks are unique and important in their own right the identification of general processes or parallels between networks may be stifled. So although 'accounts of actants can animate discussion of nonhuman contributions, they can also reduce everything to the lower common denominator and dull analysis' (Taylor 2011, p. 82).

In his more recent writings, Latour (2013) has amplified ANT's depth by going beyond simply defining and tracing associations and networks to identifying 'modes of existence'. These modes are not domains separated by distinct borders, but instead are analogous with paths leading divergent routes through a variable topography. 'Science', for example, is not confined to what is traditionally known as the scientific discipline. Instead, scientific associations can be traced through various processes and institutions, so that the domain traditionally delineated as 'Science' includes many circulating elements that cannot be classed as scientific (for example faith in progress). This provides an opportunity for comparative anthropology, for example by understanding how and why varying collectives respond differently to the same set of events, or investigating what happens at the 'crossings' when modes of existence collide.

Power and agency in emerging agricultural networks

The last decade has seen significant change in global agricultural systems, with both new crops and new political and economic actors. For example, the expansion of biofuels has seen crops such as *Jatropha curcas* rapidly spreading around the world, with projects involving multinational agri-businesses, sovereign wealth funds, transnational capital, government ministries and international donors (White & Dasgupta 2010, Cotula et al. 2009). We are seeing unfamiliar global networks that differ substantially from previous eras of donor and state led agricultural development (McMichael 2009).

From a PE perspective, the most fundamental questions regarding these emerging networks relate to their power relations: who does what, who gets what, and what do they do with it (Bernstein 2010)? Research on agrarian change has tended to emphasise the power of capital in global food production and consumption. For example, Marxian analyses have revealed the role of labour, class and capital in shaping agricultural systems (Friedman 1993, Bernstein 2010, McMichael 2009). While such insights are useful, recent events raise important questions that are unlikely to be addressed by a narrow focus on global capital or PE's traditional focus on labour and the land use decisions of rural households.

Agricultural systems are the product of interactions between land managers and a wide range of non-human actants (e.g. seeds, soils, tools and animals). Since the 1960s, the spread of the agro-industrial model has hugely increased the number and diversity of agricultural actants and hybrid socio-natures, where relationships cut across economics, politics, biology, and chemistry (Busch & Juska, 1997, Noe & Alroe, 2012). Agricultural networks enrol

scientists, agri-business, financial capital, novel organisms and ever more complex technologies. While there is no doubting the major role humans have played in shaping agricultural systems, for example by selecting, breeding and genetically modifying plants and animals to suit their needs, it is important to recognise that these relationships are not just one way.

Paul Robbins' (2007) work on the PE of lawns in the USA shows how a focus on the agency of non-humans can transform understandings of human-environment interactions. Grass lawns are one of the largest and fastest growing landscapes in the USA. Maintaining lawns requires a considerable amount of time, labour, and money (Robbins & Sharp 2003). As with the agro-industrial model of crop production, lawns require irrigation, pesticides, herbicides, and fertilisers. Such efforts have significant environmental implications (Robbins et al. 2001, Robbins & Birkenholtz 2003, Robbins & Sharp 2003).

In explaining why Americans expend so many resources maintaining lawns, traditional social science approaches provide some insights. To a certain extent, lawns are socio-cultural phenomena, reflecting human aesthetic values (Robbins & Sharp 2003, Steinberg 2006, Robbins 2007). The political economy of lawn care also plays a role. In a highly competitive and increasingly consolidated market, fertiliser companies have pushed the idea of a perfect lawn (and the chemical tools to achieve it) in order to increase consumption of lawn care products (Robbins & Sharp 2003).

While useful, such interpretations are limited in that they tend to see lawns purely as cultural, economic, or political products. Robbins (2007) argues that lawns are not just passive products and that lawn cultivation is better understood as a network that enrols grasses,

weeds, home owners, gardeners, lawn treatment chemical, agri-chemical companies, and garden product retailers (amongst others). A lawn is the result of interactions between turf grasses, worms, weeds, pests and humans (Robbins 2007). Grasses 'push back', for example by making demands for nutrients, water, and certain mowing regimes. Other animals and plants (weeds and pests) 'misbehave'. Lawns require constant vigilance and action from 'lawn people', who tend to the lawn's needs even though it takes up time they would rather spend doing something else and requires agri-chemical inputs they know have serious potential environmental and health impacts (Robins & Sharp 2006, Robbins 2007).

Emerging agricultural networks raise questions about the role of non-human actants in the unfolding of political and economic processes. For example, how do novel seeds and technologies shape and constrain farmers practices and decisions? Historically, the ability of crops to reproduce has enabled farmers to experiment, hybridise and share seeds and thus disrupt attempts by global agribusiness to completely dominate seed markets (Kloppenburg 2004, Herring 2007). However, the proposed development of 'Terminator Seeds' (genetic use restriction technology that would cause the second generation of seeds to be sterile), together with efforts to patent genes, raises the possibility of greater corporate power in emerging agricultural networks (Kloppenburg 2004). Seeds will continue to be a site of tension and conflict, and the biology of agricultural plants and animals will play a key role in the politics of agrarian change.

The political ecology of scale in emerging agricultural networks

Recent research has revealed the complex scalar dynamics of emerging agricultural networks. On the one hand, the current global 'food regime' is dominated by global flows of capital and global commodity chains (Friedman 1993, McMichael 2009). This is most strikingly apparent in the wave of transnational 'land grabs', where diverse actors (from states to investment funds and conglomerates) have acquired land - much of it in the Global South - for a range of purposes ranging from food security to energy security and financial speculation (Cotula et al. 2009). At the same time, broadly neoliberal policies are unfolding differently according to national, regional and local socio-ecological contexts (Castree 2010).

From the beginning, PE has placed multi-scalar analysis at the heart of its approach to understanding human-environment interactions. However, while frameworks such as Blaikie and Brookfield's (1987) 'chain of explanation' have played a central role in encouraging researchers to link local land use practices to broader national and international political and economic processes, the early treatment of scale in PE has been critiqued for being overly prescriptive, hierarchical and arbitrary (Zimmerer & Bassett 2003, Neumann 2009, Robbins 2012).

As well as its tendency to resort to overly simplistic spatial hierarchical notions of scale, PE has been critiqued for its tendency to rely on 'pre-given sociospatial containers' (Zimmerer & Bassett 2003, p. 3) and to treat certain actors as 'black boxes': objects or systems that are viewed only in terms of inputs and outputs, without any knowledge of their internal workings (Taylor 2011). For example, research on the politics of agriculture often analyses land use in terms of 'household' choices or the influence of 'state' and 'corpo-

rate' power (Busch & Juska 1997). Households tend to be seen as stable and cohesive units of organisation with their own coherent internal motives and presumed shared interests (Noe & Alroe 2012, Rocheleau 2008). Work carried out under the banner of feminist PE is noteworthy in its attempts to extend PE's spatial reach to consider gendered relations both within and beyond the household and to complicate common units and levels of analysis (Rocheleau 2008).

In addition to challenging pre-given social containers, political ecologists have worked to conceptually refine scale in various ways (Neumann 2009, Zimmerer & Bassett 2003, Zimmerer 2006). For example, Zimmerer's (2000) work on irrigation in Latin America rejects the idea of a single pre-given spatio-ecological scale at which natural resource use is carried out and governed. In particular, he rejects crude *a priori* distinctions between purely 'local' canal-based irrigation and 'global' basin-style irrigation. Instead, he argues that the scale of resource use is a product of the changing politics of resource governance. In the case of Bolivia, the Spanish colonial state rescaled and reworked village-based Inca irrigation systems to the valley-scale. 'Local' irrigation must therefore be recognised in relation to processes that operate at other spatial levels. The scale of resource use is thus not simply predetermined by the physical and ecological scale of the natural resource but emerges from, and is produced by, political processes (Zimmerer & Bassett, 2003).

While PE has made important contributions to the theorisation of scale, problems remain (Zimmerer & Bassett 2003, Neumann 2009). Researchers remain prone to seeking causal connections between broad global processes and local resource use decisions, and thus to seeing the local as nested in the global (Neuman 2009, Goldman & Turner 2011). Field-

based investigations in PE are also often highly geographically bounded. This is most obvious in the fact that research is often self-identified as either 'rural' or 'urban'; or located in the 'Global North' or the 'Global South'. Furthermore, while research in PE has increasingly paid attention to the politics of the state (e.g. Sneddon, 2002, Molle, 2007; Tan-Mullins 2007), as well as transnational actors (e.g. Duffy 2006, Corson 2010), there is still a tendency to privilege certain spatial levels, especially 'local' case studies.

A merged ANT-PE approach has the potential to address these limitations. For example, Ghose and Pettygrove (2014) found that activists trying to protect urban community gardens in the USA often 'jumped' to central government in order to mobilise resources to enhance local interests. Struggles are thus simultaneously local and regional. Recognising and investigating blurred scales is particularly pertinent in today's globalised and highly interconnected world where processes are 'never captured by notions of levels, layers, territories, spheres, categories, structures, and systems' (Latour 1990, p. 3). Agricultural phenomena that tend to be considered 'global', such as multinational agri-businesses or transnational land acquisitions, are in fact composed of interwoven, embedded, and situated people, places, and things (Whatmore & Thorne 1997).

With regards to the emerging political ecologies of agriculture, there are questions about how novel actants are leading to a rescaling of the politics of agrarian change. To what extent are emerging networks and novel actants reconfiguring and destabilising previously stable units? It might be tempting to assume that transnational land acquisitions and the removal of trade barriers, as well as the development of GMOs and the patenting of genes by global agri-business, are leading to a simple 'scaling up' of power. However, this is likely to

be an over-simplification that ignores other political processes, particularly *within* states, corporations, communities and households.

The role of situated knowledges and practices in emerging agricultural networks

In response to events such as the 2008 world food price crisis, global agricultural policy has focused heavily on the potential for agricultural science to boost crop yields. In this model, scientists work in laboratories and field-stations to develop new technologies (for example plant varieties and agro-chemicals). These are then passed on to farmers who adopt them. However, while techno-centric approaches such as the Green Revolution have delivered large productivity gains, research has shown how such schemes have had uneven spatial and socio-economic benefits and often worked to exclude poor farmers and undermine 'local' knowledge and practices (Ellis & Bahiigwa, G. 2001, Dorward et al. 2004, Lipton 2007, Bernstein 2010).

In response to such criticisms, donors and policymakers have increasingly noted the importance of farmer experience and knowledge in tailoring crops to local conditions (Briggs 2005, Scoones & Thompson 2011). However, there is a danger that such efforts reinforce a false dichotomy whereby 'traditional' or 'local' knowledge is essentialised, reified and treated as something inherently different to 'western' scientific knowledge (Agrawal 1995, Bezner Kerr 2014). There are key questions about how different knowledges interact 'in the field'.

ANT has much to contribute to a more nuanced view of the interplay between agricultural knowledges. According to Latour (1996), science and technology have traditionally

been treated in three distinct ways: i) as real and grounded in objective 'nature'; ii) as (political and economic) products of social systems (e.g. 'capitalism'); and iii) as social constructions. In contrast, ANT provides the opportunity to study science as real, social and discursive at the same time (Latour 1996). This avoids three equally problematic views of agriculture: i) the mainstream technocentric view, which privileges western scientific knowledge and treats farmers as passive recipients of innovation; ii) the view that agricultural science and development are simply neo-colonial capitalist projects (eg. Shiva 1992, 1997, Daniel & Mittal 2009); and iii) a narrow post-structuralist focus on knowledge as socially constructed.

Recent research on the uptake of new seeds and technologies has started to break down unhelpful conceptual binaries surrounding 'scientific' and 'local' knowledge and reveal the hybrid knowledges produced by emerging agricultural networks. Ramisch's (2011) work on the Folk Ecology Initiative (FEI) in Kenya found that efforts to train farmers in new techniques unfolded in unexpected ways that did not conform to the usual trainer-trainee dichotomy. FEI was based on a 'mother-baby' trial of new crops and techniques. In this model researchers manage a central 'mother' trial, with farmers managing 'baby' trials on satellite plots that are supposed to replicate the experiment. FEI trialled a crop rotation model with maize as the standard cereal staple crop and various legumes used to replenish soil nutrients. During the experiments, the 'mother' trial managed by scientists showed that the most successful arrangement for boosting maize yields was crop rotation with the inedible legume mucuna (*Mucuna pruriens*). However, researchers found that farmers did not copy the model exactly, but improvised in ways that researchers had not anticipated. Instead of adopting the 'optimum' cereal-legume crop rotation, which involved planting mucuna every other year and

using fertilisers, farmers intercropped with edible soya beans and did not use fertilisers. The reason given was that it was deemed socially unacceptable to grow a crop that could not be eaten. Farmers considered the lower maize overall yield (compared to the 'ideal' model) to be an acceptable price to pay for the ability to produce a staple maize crop every year. They also found new uses for mucuna, for example using it as a blanket crop to smother problematic and persistent weeds on otherwise unusable land.

This example shows how 'scientific' and 'traditional' knowledge often hybridise 'in the field', and how farmers can disrupt 'ideal' models developed in laboratories and field stations. Looking at current efforts by scientists, states, and donors to start a 'New Green Revolution', we should expect farmers to appropriate new agricultural technologies such as GM seeds and use them in innovative ways (Herring 2007, Glover 2014). This might involve farmers using different practices to those prescribed, or cross-breeding GM seeds with local varieties to enhance their productivity in local agro-ecological conditions and make varieties more amenable to local taste preferences (Cleveland & Soleri 2002, Dowd-Uribe 2014, Glover 2014, Herring 2007).

Emerging agricultural networks are introducing a large range of novel seeds and technologies that have been developed primarily in the research laboratories of global agri-business. However, agricultural networks are rooted (physically and metaphorically) not only in the research laboratories, but also in field stations and farms. There is an urgent need to link the knowledge politics of universities, laboratories, field stations, and donors in the Global North with field sites in the Global South (Goldman & Turner 2011). How does knowledge travel between these sites? How are new seeds and technologies incorporated and hybridised?

Why do some innovations diffuse rapidly while others do not? What factors in agricultural networks help to explain differences *between* and *within* communities and households in the adoption of technologies and practices?

Conclusions

Recent trends have led to renewed interest in agricultural systems and relationships. A global food crisis along with a recent spate of transnational land acquisitions and the spread of novel seeds and technologies reveal some of the intricacies and controversies of contemporary agriculture. An analysis of emerging agricultural networks thus demands a framework that is able to negotiate the interplay between environmental, technological, scientific, political, and economic factors operating at multiple spatial levels.

Political economy and PE, with their focus on land, labour and capital, have made important contributions to our understanding of agrarian change. However, PE has undergone considerable criticism and has been destabilised from various perspectives. In an attempt to move beyond some of PE's limitations and to better understand the role of novel actants in emerging agricultural trends, a small but growing number of political ecologists have started to draw on insights from STS. ANT's radically different post-humanist ontology offers a particularly challenging set of ideas. In comparison to PE's more normative stance, ANT's approach and vocabulary might seem a little esoteric and apolitical. Nonetheless, thinking in terms of actor-networks has the potential to transform understandings of agrarian change. ANT encourages researchers to resist the temptation to assume the dominance of 'master

processes' such as capitalism; recognise the role of non-human actants; break out of their place-based silos; overturn simplistic ontological binaries (e.g. nature/culture, organic/synthetic, subject/object); open 'black boxes' such as 'households', 'states', and 'corporations'; and reconsider often arbitrary treatments of scale in order to trace connections across space and through time.

Looking in the other direction, PE also has much to offer ANT and STS. Most STS research has been carried out in controlled and ordered spaces such as research laboratories, and there has been limited engagement with field-based environmental sciences including conservation biology, ecology, and agricultural sciences (Goldman & Turner 2011). More generally, STS has been criticised for having an undeveloped sense of place and territory (Castree 2002, Rocheleau 2011). Although there are a small number of ANT studies of agri-food networks, the majority of these are undertaken in the context of the global industrialised North, for example in laboratories and corporate headquarters (Busch & Juska 1997, van Dooren 2008, Noe & Alroe 2012). PE can thus bring ANT's models 'back down to Earth' by tying agricultural networks to land, locating them in space, and putting them in their place (Rocheleau & Roth 2007, Rocheleau 2011). PE also presents ANT with a way forward to rectifying some of its ethico-political limitations. The task for researchers is not simply to track connections, but to evaluate the ethical and political implications of different networks (Ingram 2011). A network approach allows researchers to identify the areas of strong and dense linkages that are likely to be most resistant to change and yet afford opportunity for maximum intervention (Ghose & Pettygrove 2014).

In this paper we have set out the case for a merged PE-ANT approach to understanding emerging agricultural networks, on the basis that these two frameworks enrich each other, so that the resulting theoretical structure is more than the sum of its parts. However, the 'productive tension' (Chagani 2014) between ANT and PE has its limits, raising fundamental and possibly irreconcilable ontological, epistemological and ethico-political issues. These factors are not reasons to shy away from attempting this form of research. Rather, they act as a reminder of the liveliness of research on agriculture and human-environment interactions more generally.

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