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A. Haroon Akram-Lodhi

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The ties that bind? Agroecology and the agrarian question in the twenty-first century

A. Haroon Akram-Lodhi

International Development Studies, Trent University, Peterborough, Canada

ABSTRACT

This paper argues, firstly, that the notion that a resolution of the agrarian question requires the dissolution of small-scale farming is not what Marx thought. It argues, secondly, that extractivist capitalist agriculture is not developing the productive forces. It argues, thirdly, that contemporary agroecological farming is a knowledge-intensive form of production that can maximize the productivity of energy flows, which are central to the productive forces. Cumulatively, it is suggested, the terms and conditions by which the contemporary agrarian question can be resolved is through an agroecological agrarian transition.

KEYWORDS

Agrarian question; agroecology; rural development; agrarian change; peasants

1. Introduction

In an important intervention, Jun Borras has sought to understand how it might be possible to reconcile the views of those scholars that adhere to the socioeconomic class analysis of Marxist agrarian political economy and the advocates of 'left-wing agrarian movements and the broad food sovereignty movements … that are anti-capitalist in their ideological orientation' and which 'are often lumped together, pejoratively, as populists' (Borras 2020, 8). This paper is at once a contribution to that debate while at the same time being much narrower than Borras's intervention, in the sense that it focuses upon the 'agrarian question' of Marxist political economy and on agroecology, which is a 'core component' (Borras 2020, 20) of food sovereignty.

Agroecology is 'the science of applying ecological concepts and principles to the design and management of sustainable food systems' (Gliessman 2006) as well as a political practice (Rosset and Altieri 2017). The proponents of agroecology argue that it can form the basis of a more sustainable agriculture based principally but not exclusively upon small-scale farming that is embedded within a locally-oriented and democratized food system in which power is distributed equitably and intersectionally among the direct producers and eaters (Altieri 2009). To achieve this social transformation it is agency which is key: the agency of transformative resistance to the capitalist world food system and the agency witnessed in the farmer-to-farmer networks that propagate the science and practice of the agroecological alternative among small-scale farmers around the world.

CONTACT A. Haroon Akram-Lodhi haroonakramlodhi@trentu.ca International Development Studies, Trent University, 1600 West Bank Drive, Peterborough, K9J 7B8, Canada

For proponents of Marxist political economy, the capacity of this agency to transform is a populist chimera because it ignores underlying structural constraints. The foundation of Marxist agrarian political economy since the late nineteenth century has been the agrarian question, which is about understanding the terms and conditions by which capital and commodified labour-power do or do not emerge in the countryside and then, more generally, across a society, as capitalism develops (Akram-Lodhi and Kay 2016). Within this approach, one reading of the agrarian question holds that small-scale farming must be transformed so as to promote the emergence of the capital-labour relation in order for rural capitalism to develop (Warren 1980). According to an alternative reading of the agrarian question, contemporary capitalist development no longer requires capital to emerge in the countryside; alternative sources of accumulation can be located in the era of neoliberal globalization (Bernstein 1996/97) and as a consequence small-scale farming is now irrelevant to capitalist development. At the same time, in both of these readings of the agrarian question it is argued that a key reason why small-scale farming is doomed or is irrelevant is because it is a form of productive organization that is not capable of developing the forces of production, which is a necessary precondition of capitalist – and post-capitalist – development (Bernstein 2010).

As a consequence, while there may be extensive dialogue between scholars of the agrarian question and advocates of agroecology (Bernstein 2014; Holt-Giménez and Altieri 2013) around sources of power and forms of resistance in the capitalist world food system, such a dialogue fails to transcend what appears to be a mutually exclusive emphasis on the one hand on agency and on the other hand on structure. Thus, notwithstanding what appears to be a common objective, the analysis that underpins the two starts from such fundamentally different premises that it is often hard to envisage where the common ground lays between them.

This article is contrarian. Its purpose is to explicitly bridge the ground between scholars operating within a Marxist agrarian political economy perspective and advocates of agroecology. It seeks to do this by arguing that from a materialist perspective in the current conjuncture it is small-scale agroecological farming that offers the means by which to develop the productive forces necessary to lay the foundation of a post-capitalist future. In order to substantiate this argument, the paper suggests that the notion that a resolution of the agrarian question requires the dissolution of small-scale farming is not what Marx thought by the end of his life. It secondly proposes that contemporary extractivist capitalist agriculture is not developing the productive forces. On the contrary, the paper argues that contemporary agroecological farming is a knowledge-intensive form of production that maximizes the productivity of energy returns relative to energy investment and that this constitutes the development of the productive forces. This argument therefore seeks to align the analysis of both Marxist agrarian political economists and agroecologists. This is by no means an arcane dispute in the musty corners of academia. An alignment between agrarian political economy and agroecologists, or between scholars and activists, or between theoreticians and practitioners, is a precondition of building the political alliances and social movements capable of creating unity out of diversity. Cumulatively, it is suggested, the terms and conditions by which the contemporary agrarian question can be resolved is through an agroecological agrarian transition. The agrarian question and agroecology are bound together as two critical aspects of a post-capitalist future that, it must be emphasized, is being politically built by rural and food-based social movements in the present.

2. The agrarian question

It has now been 150 years since Karl Marx's (1976, orig. 1867) analysis of the origins of capitalism, which has come to be called the 'agrarian question', and which consists of three interrelated issues: the terms and conditions by which capitalism does or does not transform agricultural activities by subsuming them to the market imperatives of the capitalist mode of production; the contribution of agriculture in consolidating capital accumulation both within and beyond the sector; and the impact of these processes on the political agency of rural peoples (Akram-Lodhi and Kay 2010). Marx's analysis of the agrarian question was focused on the first element, being principally concerned with how agriculture did or did not facilitate the emergence of capital and hence capitalism. Thus, as Henry Bernstein (2006) emphasizes, his focus was on the agrarian question of capital. To do this, Marx carefully considered the relationship between small-scale pre-capitalist peasant farming, small-scale peasant production that is subsumed to capitalism, and how, through the transformation of the former into the latter, the emergence of agrarian capital took place. In this reading, historical and contemporary peasants can be analytically approached as female and male agricultural workers whose livelihoods are primarily but not exclusively based on having access to land that is either owned or rented, who have diminutive amounts of basic tools and equipment, and who use mostly their own labour and the labour of other family members to work that land. So, allocating small stocks of both capital and labour peasants are 'petty commodity producers', operating as both petty capitalists of little consequence and as workers with little power over the terms and conditions of their employment (Bernstein 1991; Gibbon and Neocosmos 1985).

Marx identified three 'paths' of transition from pre-capitalist peasant farming to small-scale petty commodity peasant farming subsumed to capitalism (Akram-Lodhi and Kay 2016). The first, and most fully developed, analysis of the development of capitalism in agriculture offered by Marx is that which was published in the first volume of *Capital* (Marx 1976, orig. 1867). There, the so-called 'primitive accumulation' that was witnessed in England used dispossessory enclosures by predatory feudal landlords, later supported by the state, to reconfigure the relations of production in order to physically expel relatively prosperous rich peasant tenants from the land and create a propertyless class of rural waged labour that faced a class of capitalist tenant-farmers, beneath the dominant landlord class (Tribe 1981). Byres (2009) calls this 'landlord-mediated capitalism from below'.

For decades this account was seen by many as the sole analysis offered by Marx of the development of capitalist agriculture, but it was not. Marx argued that 'the history of … expropriation assumes different aspects in different countries, and runs through its various phases in different orders of succession, and at different historical epochs' (Marx 1976, 876). He later wrote that the analysis of *Capital* is 'expressly restricted to the countries of Western Europe' (Marx 1983, 117, orig. 1925) and that it is wrong to place all rural transformations 'on the same plane' (Marx 1983, 107, fn c). In this light, it is important to recognize that Marx identified a second 'path' of agrarian transition, namely peasant class differentiation, which is witnessed when

> the custom necessarily develops, among the better-off rent paying peasants, of exploiting agricultural wage-labourers on their own account … In this way it gradually becomes

> possible for them to build up a certain degree of wealth and transform themselves into future capitalists. Among the old possessors of the land, working for themselves, there arises a seed-bed for the nurturing of capitalist farmers, whose development is conditioned by the development of capitalist production. (Marx 1981, 935)

Thus, peasant petty commodity producers can stratify into distinct classes based upon their position as buyers or sellers of labour-power, a process that is driven by the market imperatives of capitalism to exploit labour, improve productivity and cut the costs of production (Wood 2009).

Finally, late in his life Marx elaborated a third path of agrarian transition, which would witness the peasant community collectively slowly transforming itself into 'an element of collective production on a national scale' (Marx 1983, 106). For this to occur, land would have to be held in common and all community members would have access to the land necessary to produce their subsistence. Membership of the community would not be based solely on kinship, and collectivism would have to be capable of overriding private property. In such settings, peasant communities witnessed 'dualism', with common lands such as pasture and forest sitting beside individual peasant plots (Marx 1983, 104). This set of social relations unevenly combined the progressive features of capitalism with a set of features derived from historically-adaptable peasant social relations. In primitive accumulation, Marx had argued that the powerful would encroach upon common lands and render peasant livelihoods inadequate. As this makes clear, though, late in his life he saw an alternative: that the articulation of progressive and historically-adaptable social relations could cumulatively allow the community to 'reap the fruits with which capitalist production has enriched humanity without passing through the capitalist regime' (Marx 1983, 112), provided new technologies developed the forces of production in a way that sustained the position of small-scale petty commodity peasant farming and provided that state support for small-scale petty commodity peasant farming was forthcoming. In so doing, capital still subsumes peasant labour, although it does so through forms that result in the consolidation of the peasantry as subordinated petty commodity producers.

Marx therefore argued that processes of capitalist development could, in agriculture, create: 'peasant dispossession by displacement', or enclosure; 'peasant dispossession by differentiation'; or sustain a 'hybrid' form of peasant subsumption to capital that maintains and sustains peasant communities where collective tendencies dominate because 'smallholding and petty landownership … production … proceeds without being governed by the general rate of profit' (Marx 1981, 946; Arraghi 2009, 118). In so doing, Marx did not identify unilinear social processes but rather diverse, dynamic and recurrent manifestations of multifaceted and contradictorily changing patterns of social and economic relations that continually and complexly reconfigured rural labour regimes subject to multiple determinations and contingencies. As a consequence, petty commodity production does not have to be dissolved in order for capitalism to develop (Warren 1980); and contrary to the view that petty commodity production is now irrelevant to capitalism (Bernstein 2006), petty commodity production in the countryside – and elsewhere – might well be integral to varieties of capitalism (Harriss-White 2012a). Thus, Marx's agrarian political economy is not hostile to the place of small-scale petty commodity peasant farming; rather, it requires a critical interrogation of the structural constraints under which it operates and the political ramifications of those constraints for a post-capitalist alternative.

3. The productive forces and the corporate food regime

As just noted, Marx argued that the sustenance of small-scale petty commodity peasant farming required the introduction of new technologies that developed the productive forces. In capitalism the productive forces consist of commodified labour, that is to say labour-power, along with the means of production. Conventionally, the means of production are taken to include instruments of production, which consist of tools, machines, instrumental materials, premises, and spaces. The means of production also consists of raw materials that are capable of being transformed through the labour-process; such raw materials in capitalism are generally but not exclusively not the products of nature but are the outcome of previous production. Therefore, the productive forces consist of an object or objects bearing productive power that can materially contribute to production. Growth of the productive forces in capitalism is equated with needing less labour-power to produce more with the means of production and so increasing the production of surplus-value. Marxist economics thus understands capitalist efficiency to be equated with a maximization of the extraction of surplus-value, which requires growth in labour productivity, which in turn structures the level of income of those that are working. Hence, increases in labour productivity are central to capital accumulation.

Jason W. Moore takes this further, arguing that the extraction of surplus-value 'depends upon the fruits of appropriation derived from Cheap Natures, understood primarily as the "Four Cheaps" of labour-power, food, energy and raw materials' (Moore 2015, 17). These together constitute 'a productive force' (Moore 2015, 16) because the Four Cheaps bear productive power that can materially contribute to production. However, capitalism generates a 'growing throughput of matter and energy per labour hour' (Foster and Burkett 2016, 160) that results in increasingly profligate natural resource consumption even as the capacity to locate new sources of the Four Cheaps are diminished and diseconomies of scale are generated. Entropy is witnessed as capitalism exhausts 'the historical relation that enabled it to appropriate the work of nature with such extraordinary and unprecedented power' (Moore 2015, 295).

This exhaustion is writ large in global agriculture. The contemporary corporate food regime is dominated by global agro-food transnational capital, driven by world market prices and the financial imperatives of short-run profitability, and characterized by relentless food commodification underpinning 'supermarketization' (Akram-Lodhi 2012). This regime forges global animal protein commodity chains while spreading transgenic organisms, which together broaden and deepen the temperate 'industrial grain-oilseed-livestock' agro-food complex (Weis 2013). At the point of production, the dominant producer model of the corporate food regime is the fossil-fuel driven, large-scale, capital-intensive extractivist capitalist farm. This requires, through enclosures and market imperatives, deepening the simple reproduction squeeze facing small-scale petty commodity producers around the globe as world market prices for farm products fail to cover the actual costs of production (Akram-Lodhi and Kay 2010). A core market for agro-food transnational capital are relatively affluent global consumers in the North and South, whose food preferences in the last quarter century have been shifted toward 'healthier', 'organic' and 'green' products that have large profit margins. At the same time, for the global middle class the corporate food regime sustains the mass production of very durable highly processed food manufactures that are reliant on soy, high

fructose corn syrup and sodium, and whose lower profit margins mean that higher volumes of product must be shifted. Thus, the corporate food regime simultaneously fosters the ongoing diffusion of industrial 'Fordist' food alongside fresher 'post-Fordist' food (Akram-Lodhi 2012). The corporate food regime is sustained by capitalist states, the international financial and development organizations, and big philanthropy. Notably missing from the profit-driven logic of the corporate food regime are those that lack the money needed to access commodified food in markets and who are bypassed by the regime. This relative surplus population is denied entitlements to food as a result of the normal and routine working of the food markets of the corporate food regime; they face food-based social exclusion (Akram-Lodhi and Kay 2010). For the relative surplus population the only apparent answer to the agrarian question lies in waged labour, whether it be on the farms of others, or whether it be in off-farm rural or urban livelihoods; but for most, waged labour is at best irregular, low paid, and frequently unsafe.

Four trends are exhibited within the corporate food regime. First, the tendency to the concentration and centralization of capital is powerfully present within it. This is evidenced, for example, by the merger of Monsanto and Bayer, the takeover of Syngenta by ChemChina, and the continuing role of national supermarket chains in dominating food retailing in the United States, Europe and increasingly developing countries; in the late 2000s Joachim von Braun (2008) estimated that around one-quarter of all the value generated in the corporate food regime was captured by the ten largest global supermarkets. Moreover, centralization of capital goes further than this: Clapp and Isakson (2018) ably demonstrate the extent to which asset management companies hold significant stakes in agro-food transnational capital both within segments of the agro-food commodity chain and across segments of the agro-food commodity chain, generating financialized interlocking cross-holdings that confer monopoly power over the food system to finance capital. Secondly, the data that is available suggest that agro-food transnational capital was very profitable over the course of the decade following the onset of the 'global food crisis' in 2007 (for the first few years, see Akram-Lodhi 2012). Third, however, notwithstanding large cash reserves, low interest rates and a limited regulatory environment agro-food transnational capital undertakes far more investment in mergers and acquisitions than it does in research and development. Driven by financial markets' requirements regarding short-term profitability, increasingly, input suppliers, food traders and food processors are relying on mergers and acquisitions to boost margins, rather than allocating significant shares of retained earnings to invest to innovate and thus meet market imperatives. Indeed, all one has to do is walk around a local supermarket to get a sense of how profoundly there has been a lack of innovation by capital. Fourth, there is the issue of agricultural productivity.

Agricultural productivity can be measured in terms of yields per unit of labour, which as noted can be thought of as a measure of capitalist efficiency. If this is used, real agricultural value added per worker in global agriculture increased by an impressive 2.06 per cent per year compound between 1980 and 2015. Agricultural productivity can alternatively be measured in terms of yields per unit of land,[1] in which case, globally, cereal yields in kilograms per hectare increased by an equally impressive 1.73 per cent per

[1]Analogous to capitalist efficiency, this can be thought of as a measure of feudal efficiency.

year compound between 1967 and 2014.[2] Indeed, in the countries that make up the Organization for Economic Cooperation and Development, cereal yields in kilograms per hectare increased by 1.72 per cent per year compound between 1967 and 2014.

However, other measures of agricultural productivity are less favourable. If the products of agriculture are divided between food and non-food agricultural production, are displayed per person rather than per worker or per hectare, and are arrayed net of the use of agricultural products as farm inputs, productivity figures begin to be somewhat weaker. Net per capita food production grew by 0.97 per cent per year compound between 1961 and 2014, while net per capita non-food agricultural production grew by 0.81 per cent per year compound over the same period. While important, given the global asymmetrical distribution of food between the 'stuffed and starved' (Patel 2007), the ongoing 'meatification' of diets by capital (Weis 2013), and the fact that the global number of people who do not take in enough food for an active and healthy life has barely moved in 40 years (Akram-Lodhi 2021), it becomes easier to understand why hunger continues to be a significant issue in the corporate food regime.

Another measure of agricultural productivity is to examine changes over time; for example, the rate of growth of yields per unit of land. For the three cereals – maize, rice and wheat – and soybeans, which cumulatively account for almost two-thirds of global calorie intake (Zaraska 2017), the trend since 1964 is quite alarming. Deriving a linear trend from a five-year running median of the rate of growth of yields per unit of land, which is done to smooth out annual variability, for each of the four crops produces Figures 1–4.

Two important conclusions can be drawn from Figures 1–4. The first is that for the four most important crops grown in the world the rate of growth of crop yields in kilograms per hectare has been in trend decline for decades, and particularly since the early 1980s. The second is that for maize and for wheat the rate of growth of crop yields is now near zero per year. In this light, while absolute global crop production is growing, it is very important to stress that it is doing so at an ever slower rate.

As noted, capitalist efficiency should be evaluated in terms of productivity per worker. Therefore, Figure 5 applies a linear trend to the rate of growth of constant agricultural value added per agricultural worker between 1994 and 2018. Figure 5 is quite striking for demonstrating that while the rate of growth of constant agricultural value added per worker is volatile over the 24 year period, the trend over the period is for near-zero improvements in the rate of growth of constant agricultural value added per worker.[3] In this light, while agricultural value added is growing, it is doing so at an almost stagnant rate.

It is important to exercise caution when evaluating global data aggregates, as the opportunities for errors and omissions are substantive. Nonetheless, the trend is striking. I would suggest that notwithstanding remarkable increases in production it is difficult to come to the conclusion that the corporate food regime is developing the productive forces in global agriculture. Rather, a more appropriate hypothesis might be that the

[2]The data in the next two paragraphs and Figures 1 through 4 are drawn from the World Bank (n.d.) and Food and Agriculture Organization (n.d.).

[3]If the data in Figure 5 is smoothed using the running median method, in order to remove variability, the trend rate of growth of constant value added per worker in agriculture is also stagnant. The fundamental point does not therefore alter: the productive forces are not developing.

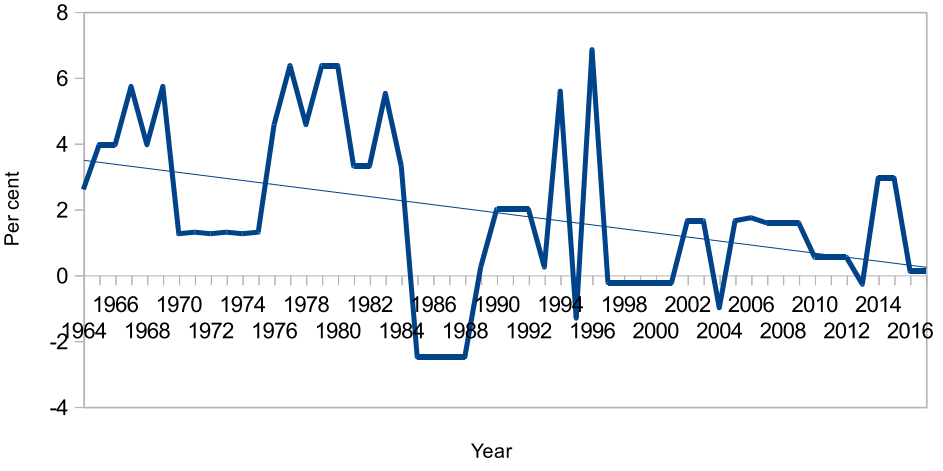

Figure 1. Rate of growth of maize yields, kg/ha, 1964–2017. Source: Food and Agriculture Organization (n.d.).

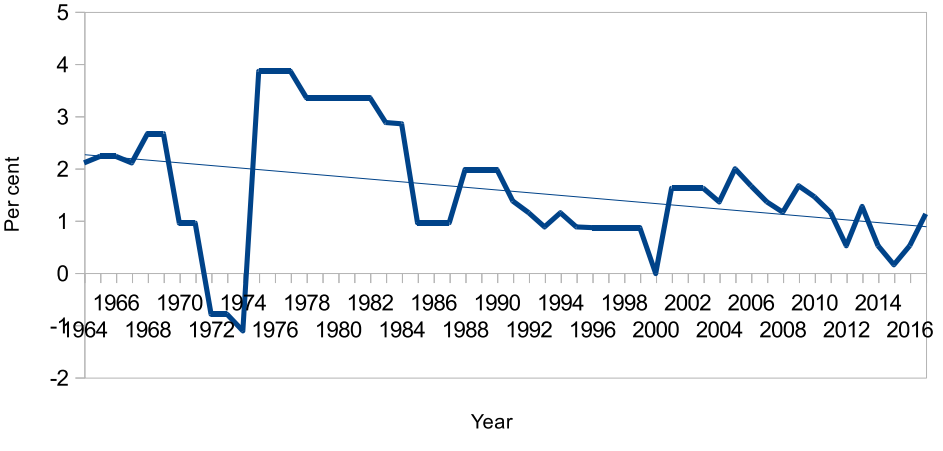

Figure 2. Rate of growth of paddy rice yields, kg/ha, 1964–2017. Source: Food and Agriculture Organization (n.d.).

corporate food regime is inhibiting the growth of the productive forces in global agriculture, given declining rates of growth of yields.

What drives the apparent inhibition in the growth of the productive forces? Tony Weis draws attention to the accelerating 'deterioration of the very biophysical foundations of agriculture' (Weis 2010, 316) as capital erodes the 'inherent brake' of 'environmental stochasticity' (Wallace and Wallace 2016, 11). Weis includes among these:

- soil erosion and salinization;
- the overdraft of water and threats to its long-term supply;
- the loss of biodiversity and crucial 'ecosystem services' such as pollination and soil formation;
- increased greenhouse gas emissions;
- and an overdependence on fossilized biomass.

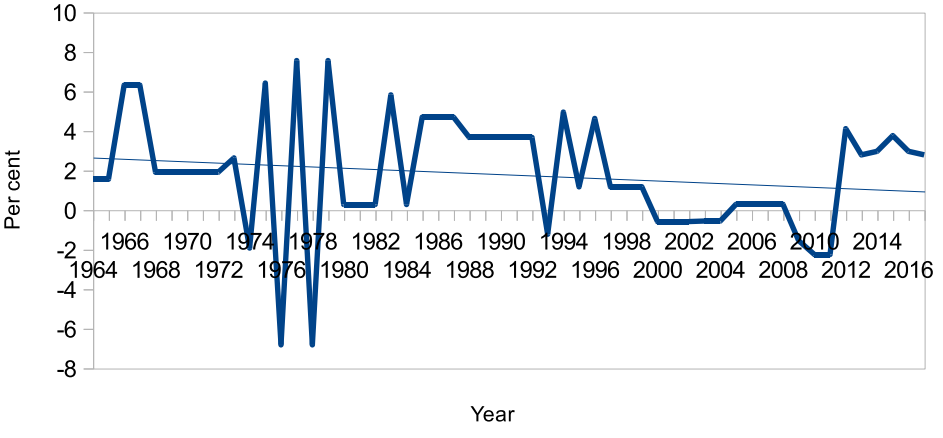

Figure 3. Rate of growth of soybeans yields, kg/ha, 1964–2017. Source: Food and Agriculture Organization (n.d.).

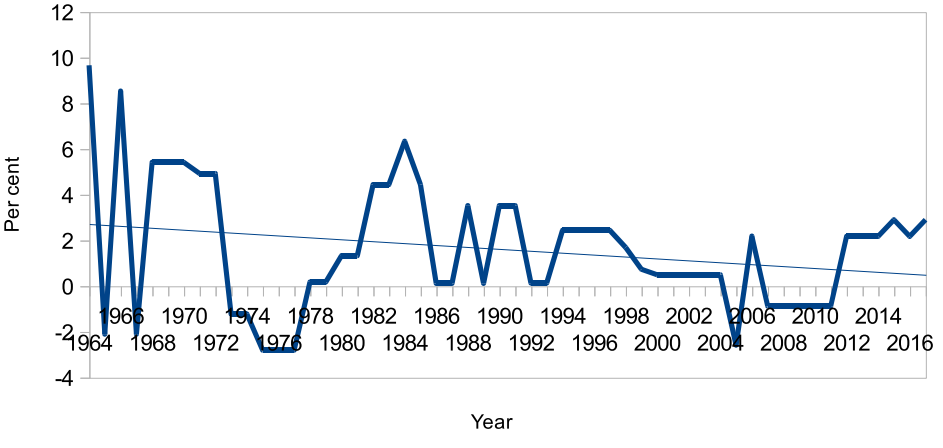

Figure 4. Rate of growth of wheat yields, kg/ha, 1964–2017. Source: Food and Agriculture Organization (n.d.).

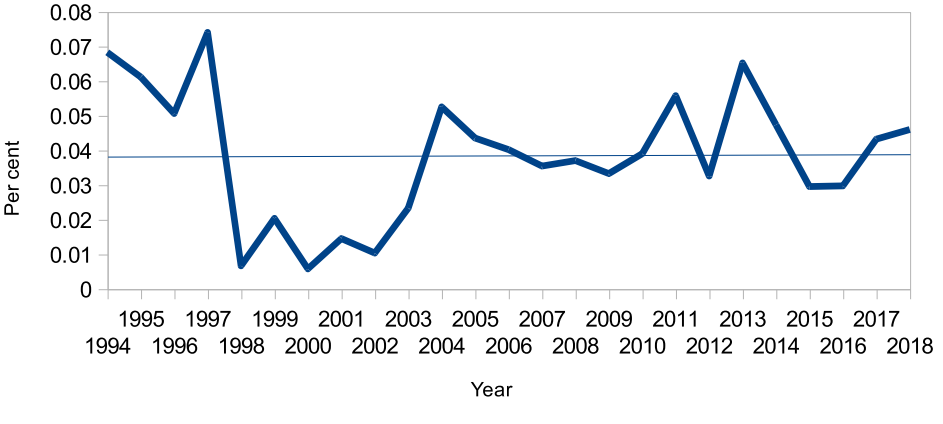

Figure 5. Rate of growth of constant agricultural value added per agricultural worker, 1994–2018. Source: World Bank (n.d.).

Chemical fertilizers destroy soil biota and significantly diminish nutrient recycling. Pests, weeds, viruses and bacteria are continually adapting to chemical pest management. Cumulatively, the erosion of agriculture's biophysical foundations is reflected in the sector's global contribution to climate change. It has recently been estimated that the food system is responsible for one-third of all anthropogenic greenhouse gas emissions (Crippa et al. 2021). Wallace and Wallace (2016, 2–3) add that 'intensive agriculture's … production cycles degrade the resilience of ecosystems to disease, and accelerate pathogen spread and evolution'. This has been quite explicitly demonstrated for the emergence of the SARS-CoV-2 virus responsible for the COVID-19 pandemic (Akram-Lodhi 2021; Wallace 2020). The capacity to appropriate the Four Cheaps, which was so central to the establishment of capitalism, is thus eroding.

It must be emphasized that declining rates of growth of yields is the central component of the argument that farming in the corporate food regime requires exceptional levels of innovation, through the interventions of institutions like the major agro-chemical companies, the Gates Foundation, and the Alliance for a Green Revolution in Africa.[4] While accepting the aforementioned drivers of declining rates of growth of yields noted by Weis, proponents of capitalist agricultural techniques also point to the inadequate use of chemical fertilizers and the need to produce highly-productive transgenic seed varieties that are resilient to the impact of climate change.[5] Proponents of the corporate food regime thus advocate the need to 'green' capitalist agriculture by introducing 'climate-smart' farming techniques and technologies. However, the fetishism of technological solutions fails to situate these technologies within the profit-seeking that is at the heart of the social relations of capitalism. As previously noted, in contemporary financialized capitalism retained earnings are being disproportionately used to fund mergers and acquisitions rather than research and development. Moreover, that research and development that is done is overwhelmingly done for private profit, and not public good, and thus capital must be able to privately regulate the use of those technologies that are developed. The need to privately regulate technologies is buttressed by the fact that in the 'technological treadmill' (Buckland 2004) of the corporate food regime 'increasing resistance leads to increasing pesticide use, generating mounting costs for farmers and further environmental degradation. This in turn requires additional doses of nutrient application to keep squeezing productivity out of the soils' (de Schutter and Frison 2017). What is bad for the ecology is however good for capital's bottom line as the cost of inputs sold by oligopolistic agro-chemical companies in the private markets that they regulate rise faster than farmgate prices, resulting in ever-higher shares of the final price accruing to agro-chemical capital as profit, placating financial markets (Qualman et al. 2018).

Notwithstanding the marked increase in agricultural production witnessed since World War II, systemically declining rates of growth of yields and stagnant growth in constant value added per worker makes it appear that some of the Four Cheaps of labour – power, food, energy and raw materials – are becoming exhausted. The appropriation of the work of nature upon which capitalism depends has become increasingly problematic

[4] I am grateful to an anonymous reviewer for making this point.

[5] 'False promises' is the title of a review of the evidence regarding the efficacy of the programming undertaken by the Alliance for a Green Revolution in Africa. The report argues that, on its own terms, it has failed to deliver. See Wise (2020) for further details.

because the capacity to enclose new sources of unpaid work are becoming constrained to an ever-greater degree as the productive forces in global agriculture have become fettered. The response of capital to these systemic challenges has not been to unleash a new wave of competitive innovation and creative destruction; rather, it has been to use oligopolistic strength as a means to appropriate rents.

4. Rethinking the productive forces

If Marx offers a sympathetic account of the possibilities of small-scale petty commodity farm production, and if the corporate food regime has fettered the productive forces of global agriculture, this begs a question: can small-scale petty commodity production develop the productive forces beyond that which capitalist agriculture has achieved? That this might be implied from Marx seems clear; if peasant production can continue beyond capitalism, Marx's political economy suggests that it would have to be because it develops the productive forces.

There are two aspects of the productive forces that are important to highlight in this regard, but which too rarely enter into discussion. The first is knowledge. According to Cohen (1978), scientific knowledge is a productive force because it bears productive power that can materially contribute to production. However, because scientific knowledge can be informal as well as formal, a more general formulation of Cohen's point should be made: knowledge bears productive power that can materially contribute to production and is therefore a productive force. Indeed, in small-scale petty commodity production this might be held as an axiom. The management of land and the application of labour does not occur in a vacuum but is applied on the basis of knowledge, of the farm, of soil fertility, of the agroecosystem, and of the landscape. This position echoes that of Toleubayev, Jansen, and van Huis (2010, 374), who argued that 'knowledge is not an epiphenomenal element of the agricultural labour process but has to be conceptualized theoretically as a structuring component'.[6]

Locate this within the corporate food regime. Across the advanced capitalist countries, and increasingly in developing countries, there is witnessed

> the incessant breakdown of labor processes into simplified operations taught to workers as tasks … (A)ll conceptual elements have been removed and along with them most of the skill, knowledge, and understanding of production processes. Thus the more complex the process becomes, the less the worker understands. The more science is incorporated into technology, the less science the worker possesses. (Braverman 1974, 319)

Braverman was writing about assembly lines. However, within much contemporary farming, of both the capitalist and petty commodity form, farm methods, techniques and technologies are predicated upon the de-skilling of both farmers and rural waged labour in production techniques, in part because in their relationship to both upstream and downstream capital farmers are required to disavow their knowledge of 'the art of farming' (van der Ploeg 2015). As a result, farmers, like workers, are increasingly alienated from the process and product of production; alienated labour, and hence commodity fetishism, are an outcome of the degradation of work. Toleubayev, Jansen, and van Huis (2010, 374) note that 'reconceptualising the role of knowledge in the labour process

[6]I am grateful to an anonymous reviewer for reminding me of this point.

… enables the possibilities for social transformation of agrarian structures to be viewed differently', in that social transformation requires the reassertion of the centrality of knowledge; one might also state that reconceptualizing the role of knowledge results in the constraints to social transformation being view differently. Be that as it may, the effect of the degradation of the knowledge around the art of farming is to reduce the productive powers that labour and labour-power can materially contribute to production. Thus, contemporary capitalist agricultural techniques effectively debase the productive forces.

The second aspect of the productive forces that must be highlighted is that of energy. Energy here is not used in the sense of power derived from resources, natural or otherwise; rather, it is used as it is in physics, as the ability to do work, with 'work' being understood as the ability to capture and expend energy. Energy is a universal constant, in that it can be neither created nor destroyed, but can only be changed from one form to another. On earth, more than 90 per cent of all energy is derived from the sun. Natural resources are stocks of accumulated energy from the sun; when natural resources are used, they generate flows of energy that originated in sunlight. Similarly, manufactured goods are ultimately a product of stocks and flows of energy, from natural resources, from intermediate goods, and from labour. Farming is a way of capturing the energy of the sun, as joules become converted into food calories, which is then returned to the 'fields in the form of food-fuelled work' (Qualman 2019, 7) by people, animals and natural resources or their by-products.

Energy is a productive force: when an object or objects bears productive power it represents a stock of energy that can materially contribute to production when converted into an energy flow from the object, as an input, to the product of production, as an output. Indeed, energy is not *a* productive force; it is the basis of all production and thus the foundation of the productive forces. Energy flows have an association with historical materialism that goes back to the work of Sergei Podolinsky in the early 1880s (Foster and Burkett 2016; Martinez-Alier 1987), which, while flawed, remains something that is far too little recognized.

In understanding energy flows as the foundation of the productive forces, the work of Pimentel and Pimentel (2008) is central, as they are the world's leading authorities on energy stock and flows in farming. They have put together comprehensive assessments of inflows and outflows of energy across a variety of farming systems; their results take into consideration on-farm labour that does not confront labour markets as well as common property resources that are usually not costed. In other words, they try and incorporate all forms of energy flows into farming. Some of their results are worth reviewing.

In Table 1, farming systems that are defined as 'human power' systems rely on energy stocks and flows from self-employed farm labour, self-provided inputs, and simple tools and equipment such as axes and hoes. No livestock or machinery is used to supplement human labour. They thus resemble petty commodity production from an earlier period. Farming systems that are defined as 'mechanized' rely on flows of energy from self-employed and waged farm labour, as well as the transformation of stocks of energy into flows of energy in the form of purchased seeds, herbicides and pesticides, irrigation, farm machinery and gasoline. The characteristics of farming systems that are not defined can be assumed on the basis of their location, the United States, as being mechanized. Mechanized farms thus resemble more capitalist forms of farming.

Table 1. Energy ratios by crop, farming system and location.

Type of farming system	Location	Energy ratio (output/input)
Maize (human power)	Mexico	10.7
Maize (mechanized)	United States	2.5
Rice (human power)	Borneo	7
Rice	California	2
Sorghum (human power)	Sudan	14
Sorghum	United States	2

Source: Geo-Mexico, the geography of Mexico 2010.

Consider US and Mexican farm production. In terms of output of maize per hour of labour and in terms of output of maize per unit of land US farms are always more efficient than Mexican farms. For example, US agricultural value added per worker in 2013 was $69457; for Mexico, $4221. Cereal yields per hectare in the United States in 2013 was 7340 kilograms; for Mexico, 3387 kilograms.[7] By conventional measures American farms are far more productive than Mexican farms. Now consider maize in Table 1. In terms of energy flows the small-scale Mexican maize farm that relies on human labour is four times more efficient than the capitalist American farm that relies on mechanization because it feeds 'back energy into securing more energy, … generat(ing) large energy surpluses' (Qualman 2019, 107). Thus, Mexican maize farms have far higher energy returns on energy expenditures than do American maize farms. As Jason Moore might put it, the productivity of capitalist farms in terms of labour is predicated upon the extractive appropriation by capital of stocks of energy in natural resources such as hydrocarbons, soils and water, which capital in turn transforms into flows of energy-carrying materials, in the form of material farm inputs. When the materiality of the full spectrum of energy stocks and flows are fully incorporated through the use of energy accounting the superiority of the capitalist farm becomes something of a chimera. Such a finding is consistent with a conclusion reached by Tim Bayliss-Smith (1982) almost 40 years ago: 'only in fully industrialized societies does the use of energy become so profligate that very little more energy is gained from agriculture than is expended in its production.'

This begs a question: does it matter? It does, because this differentiates capitalist from pre-capitalist modes of production. As Qualman (2019, 14) argues,

> in traditional agricultural systems, humans made food by utilizing cycles: circular flows of fertility; circular exchanges of metabolic energy and labour-power; and self-supplied seeds and livestock … All of these circular flows … were solar powered.

Agriculture's cyclical loops of energy and energy-carrying materials were historically simplifications of nature but were nonetheless interwoven into 'diverse, diffuse, multinodal webs that constitute and support circular flows' (Qualman 2019, 33). Through these webs agriculture was closely interwoven with the necessities of human survival: food, fibre, fuel and forests. Energy surpluses from farming were used to increase the energy density of the landscape; thus, farm labour was used more intensively, irrigation systems were built, and terraces constructed. It was the increase in the energy density of the landscape that established the preconditions for non-agricultural occupations to

[7] http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators, accessed on 26 March 2016.

become possible, for agrarian civilizations to emerge, and for food empires to be built. At the same time, however, this was governed, to a large degree, by negative feedbacks: processes that dampened excessive variation in order to maintain systemic stability, in part by reducing unnecessary energy and material use and any resulting waste (Qualman 2019, 197). As a result, pre-capitalist modes of production witnessed energy and energy-carrying materials being largely an outcome of contemporaneous processes.

Capitalism is different. Capitalism is predicated upon a world-historic appropriation of the Four Cheaps, but in particular energy and energy-carrying material inflows from prehistory, in the form of hydrocarbons, that geometrically increase the amount of work that can be done. It is the mobilization of massive increases in the amount of work through the appropriation of the unpaid work of nature on a world scale under the social-property relations of capitalism that creates the socioecological preconditions of surplus-value generation and capital accumulation. Indeed, to paraphrase Ostwald (1907), the history of capitalism is the history of increased control over energy. This increased control comes about as a consequence of capital breaking down webs in order to appropriate energy; indeed, this might be seen as an underlying driver of primitive accumulation. Thus, capitalist agriculture is predicated upon 'the labour-energy and traction-energy loops … (being) split open and made increasingly linear and increasingly far-flung in space and time' (Qualman 2019, 20) in order to access larger stocks and flows of energy. As a result, 'a historical oddity – cheap, abundant energy – has become a civilizational necessity' (Qualman 2019, 161) in the complex societies of late capitalism, and access to cheap energy has become predicated upon the creation of positive feedbacks where 'more begets more, seemingly without limit' (Qualman 2019, 194). Yet the sustained reliance on positive feedback brings with it the probability of 'overshoot, peak-and-crash, and perhaps a violent flying apart' (Qualman 2019, 197), particularly as capitalism's appropriation of energy impacts upon forms of energy available in the future, in the form of climate change.

This is not a story of energy determinism. Rather, it is a materialist analysis in which capitalism is 'a set of relations through which the "capacity to do work" – by human and extra-human natures – is transformed into value' (Moore 2015, 14). In this, it is consistent with Marx, who recognized the importance of energy stocks and flows, and their association with crisis. In volume 3 of *Capital* Marx writes that 'freedom … can only consist in this, that socialized man, the associated producers, govern the human metabolism with nature in a rational way … with the least expenditure of energy and in conditions most worthy and appropriate for their human nature' (Marx 1981, 959). Recalling that Marx associated freedom with socialism, and that socialism was predicated on the development of the productive forces, it might be suggested that Marx at least thought about how the development of the productive forces might be equated with a minimization of energy expenditure relative to energy returns. Indeed, to put it somewhat crudely, it might be suggested that for Marx just as labour productivity reflects capitalist efficiency energy productivity might be reflective of socialist efficiency. In this light, and given the deep-seated and well-established economic and ecological contradictions of the corporate food regime, it might be suggested that the structure of social-property relations under capitalism have come to fetter the development of the productive forces in farming and agriculture precisely because they do not serve to minimize energy flows.

Marx writes at the beginning of *Capital* that 'labour is … not the only source of material wealth … labour is the father of material wealth, the earth is its mother' (Marx 1976, 134). As Frederick Soddy later commented, 'Marx's disciples … forgot all about the mother' (quoted in Harriss-White 2012b, 102). Thus, as Akram-Lodhi and Kay (2010) argued, the agrarian question shapes and is shaped by the ecology of farm production. The 'ecological agrarian question' requires paying close attention to the ways in which the capital-labour relation shapes and is shaped by the prevailing ecology and as such is about how rural labour processes and ecological processes are intertwined. As such, it cannot focus in isolation on the agrarian question of labour, and the terms and conditions by which classes of labour reproduce (Bernstein 2006), because this suggests that they do so autonomously of socioecological, and hence social-property, relations. Yet socioecological relations are both a cause of and caused by the ecological impacts of prevailing social-property relations, which contemporarily witness soil erosion, groundwater overdraw, and the negative consequences of agro-chemical ecosystem engineering, among other impacts, all of which place fetters on the capacity to increase the unpaid work of nature as returns on energy expenditures diminish, with implications for the production of surplus-value. In a time of food, financial, fuel and climate crisis, and in the aftermath of a pandemic, the contradictions of the ecological agrarian question may have created the preconditions for a set of social and political struggles that promote farming systems that unleash the productive forces by using knowledge to increase energy returns on energy expenditures. Such a farming system, I now argue, may well be agroecology.

5. Agroecology

Agroecology has become a highly contested concept, as demonstrated by FAO's searchable definitional database (FAO n.d.). In part, this is because specific agroecological farm practices are diverse and potentially could be distributed over a range of production types and scales, from pre-capitalist peasant farmers to petty commodity producers operating in capitalist economies to waged labour-based capitalist farms.[8] One way of approaching this contestation is to avoid narrow technical definitions and instead embrace the complexity of mutually-compatible alternative emphases. Here, Wezel et al. (2009), as explored by McCune and Rosset (forthcoming), can be especially helpful. Following Wezel, McCune and Rosset argue that agroecology is a science that examines and explains 'the functioning of agroecosystems, primarily concerned with biological, biophysical, ecological, social, cultural, economic and political mechanisms, functions, relationships and design.' It is also however 'a set of practices that permit farming in a more sustainable way' (McCune and Rosset forthcoming), particularly by minimizing the use of external inputs. Finally, agroecology is a movement aspiring to both ecologically sustainable and socially-just farming. Agroecology is thus derived from principles and focuses on processes, rather than emphasizing techniques and inputs (Rosset and Altieri 2017, 9).

As a science and as a practice, agroecology leverages agglomerations and assemblages of local and Indigenous knowledge about nature, food and farming systems, combining 'modern science and ethnoscience' (Rosset and Altieri 2017, 9) in ways that are 'relevant to the needs of small farmers' (Rosset and Altieri 2017, 9) in order to sustain agroecosystems

[8] I am grateful to an anonymous referee for pointing out the need to stress diversity.

'that cycle nutrients through closed systems, maintain soil fertility and need very few external inputs' (McCune and Rosset forthcoming; Gliessman 2006), in part by increasing the recycling of biomass waste and minimizing nutrient losses. Agroecological farm systems should be diversified at the plot, farm and landscape level, and this diversification is both time-bound, in the form of crop rotation, and space-bound, in the form of intercropping. Agroecological farming practices seek to optimize the use of diverse, locally-developed and variable varieties and breeds that have a lower impact on the farm and the landscape. Production is meant to be integrated across crops, livestock and other local resources and outputs so as to produce complementaries that should, it is suggested, maximize beneficial biological interactions and feedback loops within the agroecoystem. Production processes in agroecological systems are meant to be labour-intensive and, for the most part, small-scale, although some mechanization might occur.

By eliciting positive biophysical processes between plants and species, microclimates can be better managed, biodiversity can be maximized, and long-run soil activity – and hence fertility – sustained by the management of organic matter. This not only maintains the integrity of the soil but sustains and indeed improves its productive potential while sequestering carbon. This is, for advocates of agroecology, of critical importance, because agroecology has, by increasing energy returns on energy expenditures, the potential to generate energy surpluses, increase crop yields, and enhance agricultural surpluses. Agricultural surpluses are derived from polycultures and thus the simultaneous productivity of multiple products (Altieri and Nichols 2005) because these pay far closer attention to the agroecological needs of landscapes, input requirements that are consistent with those landscapes, output choices that are appropriate for that landscape, and climate change. Thus, farm input and output choices are heterogeneous and are based, as they were for all but the last century or so, on local preferences and markets, including cultural and social norms, and not on the needs of distant external markets. This, it is argued by proponents of agroecology, should result in a stronger agroecosystem in which classes of rural labour can try to secure a sustainable livelihood.

An alternative way of framing agroecological science and practice, in terms used in Section 4, is that agroecology is in part a farm management system predicated upon closing the linearities of capitalist agricultural techniques and reconstituting closed loop cycles within diverse multi-nodal webs of life as a means of sustaining and indeed enhancing soil fertility. As such, it reduces reliance on energy and energy-carrying material inflows across time and space while maintaining contemporary energy density and high returns on contemporary energy expenditures.

Although this description of agroecology stresses varieties of science and practice, for its proponents agroecology is far more than just a technical means of increasing the efficient use of resources. Agroecology advocates see it as the basis by which the capitalist food system can be challenged and transformed in ways that foster the emergence of more sustainable and socially-just forms of agriculture embedded within locally-oriented food systems in which power has been intersectionally decentralized and democratized. As part of the strategy to build this social movement, specific knowledge about localized agroecosystems is spread through participatory or farmer-to-farmer led learning and research (Rosset and Altieri 2017). However, in order to challenge and transform the food system, the politics of the social movements striving for systemic change must be

capable of challenging the power of capital in the food system and beyond. This is discussed below in Section 8.

As a rural development strategy, agroecology has two key benefits, in both advanced capitalist and developing countries. First, agroecological practices are far more labour-intensive than extractivist capitalist agricultural practices, and as such meet a challenge of the twenty-first century: creating jobs (McKay 2012). Soil maintenance and nutrient recycling all tend to be labour intensive, for example. For the woefully underemployed women and men that constitute the relative surplus population such jobs are a vital part of improving their livelihoods. Moreover, even in the advanced capitalist countries there are many women and men who, if farming provided a decent and sustainable livelihood, would opt to farm out of choice. This is particularly so amongst younger people, seeking the autonomy of a sustainable lifestyle that farming has the potential to provide.

Second, as the East Asian case demonstrates, labour-intensive agriculture squeezes production and productivity as structural transformation occurs, and this would be an important part of any resolution of the agrarian question (Studwell 2014). Some might argue that this reifies the inverse relationship between farm size and productivity per unit of land, which meta-studies indicate is negative (Ricciardi et al. 2021). However, Marx's understanding of petty commodity production is not based upon identifying the technical coefficients of production. Rather, the intensity of factor utilization is a function of the social relations of production in which the emergence of differentiated access to the productive forces is both a result of and an influence upon stratified access to the means of production and thus peasant class differentiation amongst farm households (Dyer 1997). With peasant class differentiation, exploitative relationships can develop between and within rural classes in formation. Exploitative relationships force factor intensification upon poor peasants, and this in turn results in higher cropping intensities, higher labour inputs per hectare, and higher yields. As Dyer writes, 'the poor peasant maximizes output because … survival … depends on it … [T]he factors driving a poor peasant to intensify labour effort are more important than the factors permitting him to do so' (Dyer 1997, 52). The polarization of arguments that are displayed around the inverse relationship privileges technological determinism at the expense of understanding social-property relations.

6. Capitalist objections and counterobjections

Agroecology as a practice, science and movement can be distinguished from the standards of contemporary capitalist agriculture, and capitalist agricultural techniques, whether it be small-, medium- or large-scale, in that for capitalist agriculture: farm practice is based upon the standardization of inputs and processes supplied by large-scale corporate capital to produce uniform outputs; science is approached from a monodisciplinary lens that emphasizes the positive feedback loops that produce short-run productivity maximization based upon market-based costs and revenues, in order to ensure the profitability of large-scale corporate capital in the food system; and that as a movement capitalist agriculture embraces the market-led globalization of food systems and food provisioning and the central role of large-scale corporate and finance capital operating on a global scale in such a food system.

Advocates of capitalist farming techniques argue that technologically-engineered reforms within it, in terms of soil management, water use, plant protection measures and seed varieties, along with the management of livestock, can 'green' capitalist farming and make it both more sustainable and more efficient. This is the logic of what I earlier referred to as 'climate smart' agriculture. Indeed, within the advocates of capitalist agricultural practices some use the 'language' of agroecology to present a set of tools, techniques and technologies that cumulatively suggest that there are technical means by which to 'green' capitalist agriculture.

In this light, advocates of 'green' capitalist agriculture make two strong challenges to agroecology. The first is that it is the productivity of capitalist agricultural practices that generates the income that provides a livelihood for hundreds of millions of rural people around the world, and shifting to more labour-intensive production methods would threaten their livelihood. Moreover, advocates of capitalist farming techniques suggest that where soils are still fertile, or where water is abundant and accessible, and where plant protection measures are relatively cheap, capitalist farming techniques still make sense, even for small-scale petty commodity producers seeking to improve farm incomes and access cheap food. Indeed, even where this is not the case, in developing countries in particular small-scale farming is simultaneously a site of production and a site of reproduction. As a site of reproduction, despite the integration of small-scale producers into market imperatives many of the products of small-scale petty commodity production are not marketed and are thus not necessarily adequately captured in measures of productivity or reflected in income or livelihood status. Thus, the benefits of capitalist farming techniques may, it is suggested, be understated.

While it is of course true that capitalist agricultural techniques continues to provide incomes and livelihoods for hundreds of millions, including those small-scale petty commodity producers utilizing extractivist methods, this argument has four flaws associated with it. The first flaw is that the strong casual relationship between continued capital accumulation and continued access to new stocks and flows of energy suggest that a 'green' capitalist agriculture, including a purportedly 'agroecological' one, would still by implication rely on increased stocks and flows of energy and energy-carrying material inflows across time and space, and such increases would in turn require the further appropriation of the unpaid work of nature through the pruning open of webs and the accompanying depletion of resources, which is not an outcome that advocates of capitalist farming techniques note. Second, while capitalist farming techniques used by small-scale petty commodity producers sustain farm incomes for some, this is for the short run only, and not for those petty commodity producing farmers that are being slowly and unevenly pushed over time into the ranks of the relative surplus population. Even a cursory examination of the stated characteristics that apparently make capitalist farming practices sensible, along with the data displayed in Figures 1–5, clearly suggests that intertemporal limits are being reached, as soil fertility diminishes, water becomes scarce, and plant protection becomes both more expensive and less effective. Third, agroecology facilitates the utilization of degraded land for both production and reproduction, land that capitalist agricultural techniques have bypassed specifically because it is degraded, and this has the potential to increase the productive potential of many small-scale farmers. Finally, and possibly most importantly, an activity can be labour-intensive and more renumerative, in terms of incomes and livelihoods. Labour intensity

may generate greater productivity when there are diseconomies in the use of physical or working capital. This can be the result of an inappropriate choice of technique in small-scale petty commodity production. It can also happen if capital is unable to substitute for labour, as in many service-based activities. In these circumstances, the capital-intensive technical coefficients of production used by some small-scale petty commodity producers need not generate higher incomes.

The second objection that advocates of capitalist production techniques in farming offer is to state that agroecology is not capable of feeding a growing global population. It is to this that I now turn.

7. How does agroecology compare?

Can agroecology feed the world? This requires addressing a central question: what is the comparative productivity of agroecology when compared to more conventional extractivist capitalist farming techniques? There is a central challenge to answering this question: conventional data collection on farming systems does not disaggregate on the basis of differences in production functions that reflect alternative farm management and production systems driven by alternative behavioural motivations and logics (Patnaik 1979). This means that any comparisons must be very carefully drawn and judged.

There are a number of studies that compare conventional chemically-based extractivist capitalist farming with organic farm production processes and systems. This is not the same as comparing extractivist capitalist farming with agroecology. While organic farming can be agroecological, it need not be; organic agriculture can be carried out on an industrial scale, and so studies comparing organic farming and extractivist capitalist farming can be comparing different approaches to the same type of farm production. Having said that, conventional wisdom is that on average organic farming has 80 per cent of the productivity of conventional farming, subject to numerous caveats. At the individual crop level rice, soybeans, 'other pulses', and maize perform considerably better than the average, but still have slightly lesser productivity, in terms of relative yields. In terms of those major crops that perform considerably below average, the only major crop is barley (de Ponti, Rijk, and van Ittersum 2012).

In light of this conventional wisdom, it is worth reviewing seven studies undertaken in the twenty-first century and which are summarized in Table 2. These are worth reviewing because they have insights into the relative merits of organic and agroecological farming when compared to conventional extractivist capitalist farming techniques, cover a large number of data points, and are the most commonly-referenced in the literature.

A meta-study by Badgley et al. (2007) uses a global dataset of 293 examples that compares organic to conventional extractivist capitalist farms, using both paired farms and research stations over a period that varied from one growing season to 20 years, to estimate differences in yields between the two farming systems. The study found that across across 10 individual food categories used by the FAO on average organic yields were 32 per cent higher than non-organic yields around the world (Badgley et al. 2007). The meta-study found that in developed countries organic systems produced 8 per cent lower yields than extractivist capitalist agriculture, while in developing countries organic systems outperformed extractivist capitalist farms by an average of 80 per cent.

Table 2. Comparing organic/agroecological to conventional farming systems.

	Yields	Can context raise yields further?	Profit	Agroecosystem benfits	Societal benefits
Badgley et al. (2007)	Higher	Yes			
Seufert, Ramankutty, and Foley (2012)	Lower	Yes			
Ponisio et al. (2015)	Lower	Yes			
Rodale Institute (2015)	Marginally Lower	Yes	Higher	Yes	Yes
Reganold and Wachter (2016)	Lower	Yes	Higher	Yes	Yes
Pretty and Hine (2001)	Higher				Yes
Pretty (2006)	Higher	Yes		Yes	Yes

A wide-ranging meta-analysis was conducted by Seufert, Ramankutty, and Foley (2012), which compared organic and conventional extractivist capitalist yields from 66 studies and over 300 trials. Their overall finding was that extractivist capitalist farms had yields that were some 25 per cent higher than organic systems. However, the analysis did not examine the water or energy-efficiency of production or the cost of the ecological externalities produced by extractivist techniques. It did not recognize the highly significant difference in public and private research support enjoyed by US extractivist capitalist farms over the last 65 years; it has been estimated that publicly-funded research and development dedicated to agroecology receives less than two percent of funding in the United States and less than one percent globally (DeLonge, Miles, and Carlisle 2016), while total research spending has been suggested to favour extractivist capitalist farming by a ratio of 99–1 (Holt-Giménez 2012). Moreover, the study found the yield differences to be highly contextual; while for conventional grain crops which were bred to be rapid consumers of biologically available nitrogen yield gaps were considerable, in part because nitrogen was being obtained from conventionally-fed manures applied as compost,[9] in certain conditions and for certain crops the yield gap between organic and extractivist capitalist farming was in fact minimal.

A meta-study by Ponisio et al. (2015) reviewed 115 studies, containing more than 1000 observations, that compared organic and conventional chemically-based extractivist capitalist farming yields. The study found that organic yields were 19.2 per cent lower than conventional yields. The study also found that the yield gap all but disappeared depending upon crop type and management practices. For leguminous versus non-leguminous crops, perennials versus annuals or developed versus developing countries there was no significant difference in yield. The study also found that multi-cropping and crop rotation all but eliminated the yield gap when applied to organic farming. The researchers concluded that there was a need for investment in agroecological research to improve organic management systems, as this could reduce or eliminate the yield gap for some crops or regions.

The Rodale Institute is home to the world's longest running side-by-side study of conventional chemically-based extractivist capitalist farming with organic farming. Although the Rodale Institute's study, which started in 1981, is of organic farm practices, it is of interest because it more closely resembles agroecological farm management practices.

[9] I am grateful for an anonymous referee for making this point.

A summary of this research (Rodale Institute 2015) showed that organic yields almost matched extractivist capitalist yields in good years and had higher yields when subjected to environmental stresses such as drought, and were thus less vulnerable, which in turn reduced the vulnerability of livelihoods. Maize and soybean crops in organic systems tolerated much higher levels of weed competition than extractivist capitalist farms while producing equivalent yields, demonstrating the increased health and productivity of organic soil. Indeed, organic farming outperformed extractivist capitalist farming with regard to building, maintaining, and replenishing soil organic matter, which is the basis of soil health. Finally, revenues from organic farming were much greater than revenues from extractivist capitalist farming, while expenses were similar across both farming systems, resulting in organic farming having between three and six times the profitability per acre when compared to extractivist capitalist farming. Indeed, it is the profitability of organic farming that explains the shift of some capitalist farms, particularly in the developed countries, into what might be called 'extractivist organic production' in that it meets formal organic requirements while still being based upon mining the soil of micronutrients.

A recent comparative study (Reganold and Wachter 2016) reviewed hundreds of research studies and meta-analyses produced over more than 40 years comparing organic and conventional chemically-based extractivist capitalist farming. The study focused upon four key 'metrics': productivity, environmental impact, economic viability and social wellbeing. It found that organic farming systems produced lower yields of between 10 and 25 per cent compared with extractivist capitalist agriculture. It also found that context matters: that yield gaps can all but disappear under certain production and management conditions. The study found that organic farming was more profitable, in the range of 22–35 per cent; had far fewer environmental costs, the externalities of which were often not accounted for in much research; delivered greater ecosystems services, including biodiversity, soil health, greater energy-efficiency and lower greenhouse gas emissions; delivered equally or more nutritious foods that contained lesser – or no – amounts of pesticide residues; and had greater social benefits, including the terms and conditions of employment for farm workers.

These studies are of interest because they indicate that under sets of conditions where institutional, infrastructural and economic support is available, and when attention is paid to the landscape within which the farming is carried out, the yield differences between extractivist capitalist farms and organic farms are at worst minimal, that the environmental benefits of organic farms are significant, and that the benefits for farm households, in terms of earnings and work conditions, are better on organic farms.

In terms of attempting to compare conventional chemically-based extractivist capitalist farms with agroecology there is no doubt that the leader in this research is Jules Pretty. Two studies in particular standout. In a groundbreaking study with Rachel Hine in 2001 208 projects from 52 countries involving 9 million farmers working on around 3 per cent of all the farmland in Africa, Asia and Latin America found that 'a more sustainable agriculture' that was 'resource-conserving' (Pretty and Hine 2001, 10), which in its definition matches that of agroecology, produced yield increases of between 50 and 100 per cent for rain-fed crops and yield increases of between 5 and 10 per cent for irrigated crops. Yield increases were typically bigger for households with smaller holdings of land and greater food insecurity, indicating that the benefits to poorer farmers were higher.

Table 3. Average increase in crop yields for farms in developing countries adopting agroecological practices on 286 projects in 57 countries.

FAO farm system category	Increase in crop yields, %
Smallholder irrigated	129.8
Wetland rice	22.3
Smallholder rainfed humid	102.2
Smallholder rainfed highland	107.3
Smallholder rainfed dry/cold	99.2
Dualistic mixed	76.5
Coastal artisanal	62
Urban-based and kitchen garden	146
All projects	*79.2*

Source: Pretty 2006: Table 2.

In 2006 Pretty produced a second study that explicitly sought to construct a comparative database of developing country projects involving farms transitioning from conventional chemically-based extractivist capitalist farming to agroecological farming. Pretty (2006) examined eight different categories of FAO farming systems across 57 countries in order to evaluate the impact on yields resulting from such a transition. In all, 286 projects were included in the study involving 12.6 million farmers operating 37 million hectares, or 3 per cent of the cultivated area in developing countries. The results of the study are displayed in Table 3.

In all but 3 of the projects yields increased after a shift to agroecology; these 3 projects involved rice. One-half of all the projects reported yield increases of between 18 and 100 per cent, and 25 per cent of the projects reported yield increases of more than 100 per cent, indicating that after the shift to agroecology yields more than doubled. Moreover, the shift to agroecology had significant positive externalities. In terms of the agroecosystem, projects demonstrated increased water retention in soils, increases in the water table, reductions in soil erosion, enhanced soil organic matter, increased biodiversity and improvements in carbon sequestration. In terms of farming communities, the shift to agroecology saw projects demonstrate increased employment, improved health and nutrition, enhanced women's status, improvements in and an increase of local social organizations, and a better capacity to experiment and problem-solve within communities and households. Pretty's 2006 results closely resemble those for organic versus non-organic yields in developing countries produced by Badgley et al. (2007).

Finally, it is worth noting the results of the West Africa Productivity Program's Scaling Up of the System of Rice Intensification (SRI) in West Africa project (Styger and Traoré 2018). SRI is one specific variant of agroecological farm production that has received much attention, and come in for important criticism (Taylor 2019). SRI was developed in Madagascar and has spread to more than 55 countries. Like agroecology more generally, SRI focuses on principles: of early plant establishment; of reduced competition among plants; of soils rich in organic matter; of reduced water use; of reduced chemical use; and of increased labour intensity. SRI methods have produced yield increases of between 20 and 100 per cent (and in some instances even more), a reduction of up to 90 per cent in seed requirements, savings of up to 50 per cent in water utilization, and a significant increase in employment. Moreover, SRI methods have extended out of rice and into wheat, sugarcane and teff, all of which have witnessed similar benefits. The West Africa project involved more than 50,000 small-scale rice farmers directly and

reached more than 750,000 people in total – of whom 31.6 per cent were women – across 13 participating countries in West Africa. Yields for farmers using the SRI method increased overall by 56 per cent for irrigated rice and 86 per cent for lowland rain fed rice. Irrigated rice was 2.37 times more productive under SRI methods when compared to conventional methods, while lowland rice was 2.18 times more productive. Average incomes for farmers using SRI was 41 per cent higher than for those using conventional practices.

Across the studies one minimal conclusion is reasonable: agroecology can, depending upon location, crop selection, farm management practices, institutional setting, infrastructural base and economic conditions generate near-comparable yields to the historically unparallelled yields of contemporary extractivist capitalist agriculture. The four studies that examine the impact of agroecology on livelihoods suggest that it increases employment and incomes, among other social benefits. The three studies that examine the impact of agroecology on the agroecosystem show that it enhances soil health, fosters biodiversity, economizes on water, and cuts greenhouse gas emissions, thus enhancing resilience to climate change. Recalling the trend decline in the rates of growth of major crops, that global farming already produces enough food to feed more than 10 billion people (Akram-Lodhi 2021), that massive amounts of global food is wasted, that yield differences can be reduced to a minimum, and that research spending is currently almost exclusively centred upon extractivist capitalist farming systems, the conclusion seems inescapable: agroecology can feed the world.

This is because, I have suggested, knowledge and energy flows are productive forces and as such are the sources of the productivity witnessed in agroecology. Pretty (2006) states that one of the drivers of the productivity outcomes witnessed in 286 projects across 57 countries was the way in which agroecology fostered local knowledge-based problem-solving skills. That knowledge, embodied in and expressed through labour, worked with and on land in an effort to not only sustain but enhance the soil fertility that is the bedrock of the productive forces in farming and agriculture. Moreover, the quality of labour working the land can be reflective of a knowledge of local conditions that allow productivity to thrive. In historical materialist terms: agroecology developed the forces of production. In its use of knowledge as a productive force agroecology also challenges the alienation of labour that results in commodity fetishism. It is further the case that agroecology seeks to maximize the energy returned on the energy invested in production through nutrient recycling and the continual regeneration of the natural resource base in agriculture. This was the case in the labour-intensive farming systems displayed in Table 1, demonstrating that such systems were sustainable virtually indefinitely, given the energy surpluses that they generate. Again, in historical materialist terms: agroecology developed the productive forces. In both instances, the development of the productive forces in agroecological farm systems reconfigure the technical coefficients of production in ways the provide the potential basis for labour-intensive patterns of accumulation.

8. Politics of the agroecological transition

There is one objection that agrarian political economy consistency makes to those that promote agroecology. Mechanisms of social differentiation within petty commodity producers have led to differences in command over assets, differences in the character of the

production process, differences in productivity, differences in market integration, and differences in the behavioural motivation behind production. There have been, in short, processes of differentiation at work within petty commodity producers, albeit unevenly. As a consequence, petty commodity producers are not a homogenous social group; rather, differential interests can emerge within petty commodity producing peasantries as they are or are not incorporated into capitalism as it develops (Bernstein 2014).

At the same time, the set of social-property relations within which the pursuit of agroecological production can take place is capitalist – the means of production are under the control of a socially-dominant class, labour is 'free' from significant shares of the means of production and free to sell its capacity to work, and the purpose of commodity production is the seeking of profit. The localized small-scale farming model that is central to agroecology cannot be abstracted from capitalist social relations, which are defined by relations of exploitation between capital and classes of labour. Small-scale farming is currently subordinated, through a range of mechanisms under the corporate food regime, to capitalist social-property relations (Holt-Giménez 2017). Thus, agroecology cannot be about trying to reconfigure the existing social conditions and relations of capitalism; it requires transcending those social conditions and relations and developing a post-capitalist agrarian – and non-agrarian – alternative.

In order to transcend class contradictions, agroecologists must build power within the fissures of existing capitalist social-property relations, in order to transform food systems in favour of peasants and other small-scale farmers, fishers, food system workers and underserved communities.[10] That this is possible was strongly argued by Erik Olin Wright before his death (for example, Wright 2010) and has been increasingly the basis of much political practice around the world, including among rural social movements. Working within the fissures of capitalism in order to challenge capitalism requires recognizing and confronting differences in interests, aspirations and sites and forms of political organization and building alliances within and between agroecologists and other classes of labour. The basis of constructing such alliances is already clear: the corporate food regime is implicated in the glaring livelihood inequalities that define the current conjuncture and which go far beyond the concerns of petty commodity producers, encompassing the wide-ranging numbers of those that work in the food system (Akram-Lodhi 2015). Notwithstanding the class contradictions of capitalist social-property relations, there are potential class linkages within and across the food system capable of bridging divisions between workers, farmers and eaters. It is by bringing out the intersecting, interacting and interrelated livelihoods between those who work in different parts of the food system that wider traction for the idea and practice of agroecology can be constructed. A broad democratic alliance of transformational, progressive and reformist 'food movements' (Holt-Giménez 2017), with different and contrasting ideological perspectives on capitalism and thus different agendas, needs to build 'the moral and intellectual hegemony necessary for … a broad social consensus' that welds together dispersed wills into a new 'hegemonic bloc' around a new 'common sense' (Akram-Lodhi 1992) that seeks not just to transform the food system but transcend capitalist social-property relations by building a post-capitalist alternative based upon the intersectional democratization of economic power.

[10]This is similar to, but different from, the argument of Clapp (2020).

9. Conclusion

This article has argued that the agrarian question continues to have salience. Marx's agrarian political economy is not hostile to the place of small-scale petty commodity peasant farming; rather, it requires a critical interrogation of the structural constraints under which it operates. Nonetheless, to sustain small-scale petty commodity peasant production it is necessary to develop the productive forces. The productive forces in farming and agriculture are the combination of labour-power with a broadly-defined means of labour that consists not only of land, infrastructure, material resources, tools, equipment and machinery but also conscious theoretical and applied knowledge as well as energy. Indeed, rethinking the means of labour as energy flows can lead to the proposition that the three essential productive forces are labour-power, knowledge and energy flows.

The article has also argued that contemporary agroecological farming develops the productive forces in a way that contemporary extractivist capitalist agricultural techniques do not. Agroecology is: more energy-efficient; more knowledge-intensive; on conventional measures of productivity is almost as productive as extractivist capitalist agriculture; and on intertemporal and environmental measures of productivity more productive than extractivist capitalist agriculture. It is better for employment and incomes, tackles the injustices behind the growth of the relative surplus population, and is predicated upon more localized and democratized food systems.

Agroecology is consistent with Marx's views on the progressive possibilities of politicized small-scale petty commodity producers shaping an emerging post-capitalist future within actually-existing capitalism. In this light, an understanding of agroecology that is grounded within the problematics of the agrarian question strengthens the understanding of both. Moreover, there is a common ground between Marxist agrarian political economists and agroecology. The ties that bind the agrarian question and agroecology is that they are components of a post-capitalist future that is being built in the present.

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A. Haroon Akram-Lodhi teaches agrarian political economy. He is Professor of Economics and International Development Studies at Trent University in Peterborough, Canada, Editor-in-Chief of the *Canadian Journal of Development Studies*, and an Associate Editor of *Feminist Economics*.