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GRASSROOTS VOICES

Agroecology and the reconstruction of a post-COVID-19 agriculture*

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ABSTRACT
The COVID-19 crisis has created a moment where existing calls for agroecology acquire new relevance. Agroecology provides a path to reconstruct a post-COVID-19 agriculture, one that is able to avoid widespread disruptions of food supplies in the future by territorializing food production and consumption. There are five main areas in which agroecology can point the way to a new post-COVID-19 agriculture: overcoming the pesticide treadmill, enriching nature's matrix, revitalizing small farms, creating alternative animal production systems and enhancing urban agriculture.

KEYWORDS
Agroecology; COVID-19; vulnerability; equitable food systems; resilience

1. Introduction

It is only in the last few decades that a general awareness emerged about the real magnitude of the impacts of extractive and intensified economic activities on the biosphere. These impacts include, among others, (a) changes in the atmospheric composition driven by a fossil fuel economy which has led to climate change, and (b) the alteration of ecosystems with the consequent accelerated rate of species of extinction (FAO 2019). Trisos, Merow, and Pigot (2020) predict that as anthropogenic climate change continues the risks to biodiversity will increase over time, with future projections indicating that a potentially catastrophic loss of global biodiversity is on the horizon.

In spite of the known value of biodiversity and its ecosystem services to the quality of human life, uncontrolled technological development, economic growth and consumption have proceeded unabated (Constanza et al. 2014), until the COVID-19 pandemic exposed the socio-ecological fragility of the world's dominant capitalist development path. At this

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*Editorial Note: The *Journal of Peasant Studies* is launching a rolling forum with experiences from the frontlines of the current crisis: 'Grassroots Voices: pandemics and critical agrarian studies' – in collaboration with the Transnational Institute (TNI – www.tni.org). As the pandemic unfolds, many of the fatal flaws of capitalism are being laid bare. It is a moment when new alliances are being formed and new militant organizing is springing up, as are new forms of authoritarianism and repression. This is a moment of potentially great rupture – but in what direction and for who is up for grabs. The Grassroots Voices section seeks to document what is happening from the grassroots perspective. Migrant workers, domestic laborers, peasant farmers, small-scale fishers, informal food vendors, and rural-urban migrants all have had their lives upended. We expect this conjuncture to affect potentially radical changes in long-term trends towards authoritarian governance, industry consolidation, marginalization of migrant workers, land grabs and financialization, as well as creating a surge of left organizing, food worker strikes, mutual aid networks, and new grassroots alliances. What is the experience on the ground? These experiences of course are conditioned by the historical changes that came before, by rising populism, and the history of movement organizing. We hope to put these new experiences in historical context, track them longitudinally, and highlight emerging strategies.

moment of ecological and economic rupture, the pandemic could well be the tip of the iceberg of a cascade of catastrophes that will impact humanity if particular types of extractive and consuming patterns persist.

The rapid expansion of agriculture and its disruption of wild ecosystems, combined with specific mechanized, genetic and agrochemical technologies have become a major force reshaping the biosphere. The vast monocultures that dominate 80% of the 1.5 billion hectares of arable land are one of the largest causes of global environmental changes, leading to soil degradation, deforestation, depletion of freshwater resources and chemical contamination. Recent estimates show that food production is responsible for up to 29% of global greenhouse gas emissions (Campbell et al. 2017). It is a paradox that technologies designed to improve livelihoods and feed people have also made the planet less hospitable to human life.

Long before the coronavirus pandemic, agroecologists have warned that industrial agriculture became too narrow ecologically, highly dependent on off-farm inputs, and extremely vulnerable to insect pests, diseases, climate change (Altieri et al. 2015) and now as demonstrated by the COVID-19 pandemic, prone to a complete shut down by unforeseen crisis. Like never before, COVID-19 has revealed how closely linked human, animal and ecological health are.

Agroecology is a powerful systemic approach that allows us to understand that the way we practice agriculture can provide opportunities for improving environmental and human health, but if done wrongly, as in the case of industrial farming, agriculture can cause major risks to human and ecosystem health. Agroecology shows a different way forward by providing the principles on how to design and manage agricultural systems best able to withstand future crises – whether pest outbreaks, pandemics, climate disruptions, or financial meltdowns.

Agroecology offers the best agricultural system able to cope with future challenges posed by ecological ruptures like COVID-19, by exhibiting high levels of diversity and resilience, both emergent properties increasingly recognized for their potential to reduce risk from climate change or other threats, while delivering reasonable yields and providing key ecosystem services to society (Nicholls, Altieri, and Vazquez 2016). We contend herein that given the current situation posed by the pandemic, as millions more families join the ranks of the food insecure, agroecology provides a path to reconstruct a post-COVID-19 agriculture, able to avoid widespread disruptions of food supplies in the future by territorializing food production and consumption.

2. Impacts of industrial agriculture on human health

2.1. Large-scale animal production

There is a large list of deadly pathogens that emerged due to the ways in which we practice agriculture, anong which are: H5N1-Asian Avian Influenza, H5N2, multiple Swine Flu variants (H1N1, H1N2), *Ebola, Campylobacter, Nipah* virus, Q fever, hepatitis E, *Salmonella enteritidis*, foot-and-mouth disease, and a variety of influenzas (Weiss 2013). Most of these were linked to large-scale animal production, known to create opportunities for many viruses to mutate and spread. The practices at these industrial operations, where all animals are genetically similar, not only leave animals more susceptible to viral infections, but also sponsor the conditions by which pathogens can evolve to more infectious types. In the case of industrial poultry, genetically uniform broiler chickens have been selectively bred to grow three times as fast on half the amount of feed as their wild relatives. This 'productivity' comes at the cost of a robust immune system (Wallace 2016).

The likelihood of broiler populations contracting low-pathogenic strains increases as climate change and deforestation forces wild bird populations into closer proximity with industrial farms (Wallace 2020). COVID-19 reminds us that these types of pathogen outbreaks are occurring at an increased frequency and will continue to affect the planet under a 'business as usual' scenario.

The massive and indiscriminate use of antibiotics in industrial livestock models makes things worst as factory farmers dose animals with antibiotics, many of which are also used to treat human illnesses. About a third of the antibiotics produced in United States (about 17,000 tons) are now used in animal feeds. A direct link between antibiotic use on farms and the spread of antibiotic resistance to human populations has been recognized. It is estimated that 23,000 persons in the USA die of antibiotic-resistant infections each year, and the annual cost of such infections exceeds 20 billion USD per year (Spellberg et al. 2016). The types of bacteria that cause many of these infections are found in livestock and retail meat, such as the opportunistic pathogens *Escherichia coli* and *Klebsiella*, which are the most common causes of urinary tract infections and among the most common causes of bloodstream infections in patients, followed by *Staphylococcus aureus* (CDC 2013).

As large-scale monocultures advance at the expense of natural habitats, possibilities for disease emergence increase. Soybean production in South America now covers over 57 million ha, more than on any other continent. This expansion has taken place through the direct extension of highly capital and chemical intensive agroindustrial practices into areas that had been considered marginal for agriculture, such as the fringes of the Amazon, the Cerrado and Caatinga in Brazil, across Bolivia's and Argentinian Chaco forests, and parts of the Atlantic forests (Oliveira and Hecht 2017). Deforestation triggers processes by which previously boxed-in pathogens in natural environments are spilling over into livestock and human communities. Thus, habitat destruction due to commercial agriculture exacerbates risks by amplifying human-wildlife interactions (Robbins 2012).

The fragmentation of the natural landscape by large monocultures can also reduce ecological services like biological control by directly affecting abundance and diversity of natural enemies. In four US Midwest states where biofuel-driven growth in maize and soybean planting resulted in lower landscape diversity, the supply of pests' natural enemies decreased, reducing bio control services to farmers by 24%. This loss of biocontrol services cost soybean and maize producers in these states an estimated 58 million USD per year in reduced yield and increased pesticide use (Landis et al. 2008).

2.2. The simplification of agricultural diversity

Another consequence of the intensification of agriculture has been the decline of crop diversity in agrolandscapes. On the one hand, despite the fact that humans could eat more than 2500 plant species, the current diet of most people is composed of three major crops: wheat, rice, and corn, which provide more than 50% of the calories consumed globally (UNCSN 2020). Mostly pushed by a corporate globalized food system and free trade agreements, many developing countries are moving from traditional diverse and rich diets to highly processed, energy dense, micronutrient-poor foods and drinks. As a consequence, obesity, diabetes, heart disease and other diet-related chronic diseases have proliferated (Popkin, Adair, and Ng 2012).

The fact that few crop species are feeding the world raises concerns about human nutrition and also the resilience of the global food system as crop diversity is key for agricultural climate adaptation. Crop diversity loss and attendant homogenization of agroecosystems could have major consequences for provision of ecosystem system services as well as food system sustainability (Jackson, Pascual, and Hodgkin 2007). The food supply of the United States has undergone a process of 'cornification' and most of the corn consumed is invisible, having been heavily processed or passed through food animals before it reaches the people. Most chickens, pigs and cows today subsist on a diet of corn. Most soft drinks and snacks consumed in the USA contain high-fructose corn syrup, which has been linked to the epidemic of obesity and Type 2 diabetes (Pollan 2002). In developing countries, agricultural modernization has led to a loss of food security linked to the disruption of traditional rural communities and their diversified food production systems. Replacement of traditional varieties by high yielding varieties promoted by the Green Revolution led not only to the reduction of crop species diversity but the erosion of indigenous crop varieties adapted to particular environments and tolerant to adverse climatic conditions (Maikhuri et al. 1999). In India, of the 3,000 varieties of rice that were being cultivated before the green revolution, only 50 are found now (Shiva and Prasad 1993). Crop diversity appears to be the key as it *contributes* significantly to the production of critical vitamins and minerals, particularly when that diversity includes green leafy vegetables (Rajendran, Afari-Sefa, and Shee 2017). Traditional crops provide higher energy equivalents in comparison to improved crop varieties on unit basis and contribute significantly to the provision of critical vitamins and minerals, particularly when that diversity includes green leafy vegetables, including edible weeds (Duke 2001).

The cost of failure of any of these three major crops (wheat, rice, and corn) can be very significant for food security, impacting even more the nutritional status and health of poor and vulnerable people.

2.3. Agrochemical intensification

About 80% of the 1.5 billion hectares devoted to agriculture in the planet are occupied by industrial large-scale crop monocultures. Due to their low ecological diversity and genetic homogeneity these systems have proven to be highly vulnerable to weed infestations, insect invasions and disease epidemics, and recently to climate change. To keep pests at bay, as early as 40 years ago, already each year about 2.3 billion kgs of pesticides are applied worldwide, of which less than 1% reach the target pests; most end up in the soil, air and water systems causing in the US alone no less than $10 billion in environmental and public health damages, including human pesticide poisonings, which globally reach about 26 million people annually (Pimentel et al. 1980).

There is substantial experimental and epidemiological evidence that many pesticides widely used around the world are immunosuppressive (Repetto and Baliga 1996). Many studies indicate that during environmental or occupational exposure, pesticides can exert some intense adverse effects on human health through transient or permanent alteration of the immune system (Nicolopoulou-Stamati et al. 2016). There is a link between pesticide-induced immune alteration and prevalence of diseases associated with alterations of the immune response (Corsini et al. 2008). This poses a potentially serious health risk to populations exposed to infectious and parasitic diseases such as COVID-19.

In the U.S., chronic diseases such as obesity, diabetes, diseases related to liver and kidneys, cardiovascular disease, respiratory diseases including asthma, allergy, emphysema, and chronic obstructive pulmonary disease (COPD), as well as autoimmune diseases, have been steadily increasing over the past 50 years, associated with the dramatic increase in chemical pesticides, plastics, and many other products (Corsini et al. 2008). All of these diseases involve disruption of normal immune system function, resulting in inflammation. Chronic inflammation primes the body to react with a heightened response to immune system insults, such as COVID-19 infection (Vom Saal and Chen 2020).

Originally the pesticide DDT, later organophosphates and carbamates, and now neonicotinoids have been linked to declines in several animal species such as pollinators, natural enemies of pests, as well as a 58% decline in non-target butterflies and beetles in crop fields, and also soil biota, all of which contribute to key ecosystem services in agriculture. This loss of agrobiodiversity can cost hundreds of billions of dollars annually. Natural pest control is estimated to be worth 100 billion USD, the role of soil biota in increasing soil fertility is worth $25 billion and the value of dependent crops attributed to all insect pollination is estimated to be worth 15 billion (Constanza et al. 2014).

The appearance of about 586 species of insects and mites resistant to 325 insecticides and about 195 species of weeds resistant to 19 herbicide modes of action, coupled with secondary pest outbreaks that commonly occur in pesticide-loaded crops due to elimination of natural enemies, indicate that chemical technology is reaching its limits and that agriculture has been set on the path of a pesticide treadmill (Brattsten et al. 1986). Progress in malaria control is threatened by emerging resistance to insecticides among *Anopheles* mosquitoes (WHO 2020).

3. The consequences of COVID-19 on agriculture and food access

At least 820 million people around the world experience chronic hunger, 149 million children are stunted, and an estimated 2 billion people suffer micronutrient deficiencies. Some 736 million people live in extreme poverty and do not eat enough caloric energy to live normal lives, which is a root cause of ill health, as deprivation weakens their immunity (FAO 2015). These people cannot afford any further disruptions to their access to food, which COVID-19 is triggering. Even under an effective COVID-19 containment scenario, 14 million to 22 million people globally could slip into extreme poverty and as COVID-19 leads to widespread income losses, increasing number of consumers may not be able to afford food, enhancing the food security crisis (IPES-Food 2020). Sumner, Hoy and Ortiz-Juarez (2020) estimate that under the most extreme scenario of a 20% income or consumption contraction, the number of people living in poverty could increase by 420–580 million. These trends are worrisome but as agroecologists, we question productivist arguments about hunger, and understand hunger today as something that is not so much a consequence of yields being too low or of global supplies being unable to meet demand; rather, we understand it as something that is due to poverty, deficient food distribution, food waste, lack of access to land and other factors (Lappe, Collins, and Rosset 1998).

In most countries, restrictions on travel, trade and lockdown of entire cities have constrained the influx of imported foods with devastating consequences on the poor's access to meals. This is problematic in cities with 10 million or more people which need to import 6 thousand tons of food per day, traveling on average about 1000 km (Altieri and Nicholls 2018). A sharp decline in trucking and air traffic has limited the capacity to move fresh produce long distances, thus getting plentiful supplies to people, many of whom have suddenly lost their income, is a major challenge. Paradoxically food is being dumped as demand from closed restaurants, hotels, schools, stadiums, theme parks and cruise ships has plummeted. No doubt blockages to transport routes are particularly obstructive for fresh food supply chains and result in increased levels of food loss and waste (Purdy 2020).

The pandemic impact on the livestock sector is particularly acute due to reduced access to animal feed and slaughterhouses' diminished capacity, linked to logistical constraints and labor shortages as many workers have become ill. In South Dakota, Smithfield Foods, which produces 5% of US pork, closed its huge facility in Sioux Falls after testing revealed that the plant accounted for nearly half the coronavirus cases in the city and the surrounding county (Lussenhop 2020). Today in the USA, four firms control 82% of beef packing, four control 75% of all hog processing and four control half of all chicken processing. It is well known that the industrialization and consolidation of meat production generates higher risks for the emergence of global pandemics like COVID-19 (Corkery and Yaffee-Bellany 2020).

Small-scale farmers that produce vegetables crops and fruits are particularly affected by labor shortages and lack of markets due to wide closure of restaurants and farmers markets. Demand for fresh produce is also diminishing as many people worried about potential supply chain disruptions are shifting towards greater consumption of heavily processed items which exhibit longer shelf life. This could increase diabetes and other diet-related non-communicable diseases which are risk factors for COVID-19 mortality (IPES 2020; UNCSN 2020). This has huge implications as the majority of patients hospitalized with COVID-19, such as in the case of the New York City area, had one or more underlying health conditions (diabetes, high blood pressure, obesity, heart disease). Once infected with the coronavirus, people with such conditions (mostly from lower-income groups and communities of color) are at particular risk for severe illness, including hospitalization and death (Popovich, Singhvi, and Conlen 2020).

Food supplies are also impacted in countries dependent on poor migrant farmworkers. Many live in crowded households and commute to work together, providing them with little opportunity for social distancing, making them easy targets for COVID-19. 888,000 people are hired to pick fresh produce in US crops and groves; if this workforce were impacted by illness, commercial farms in central California, Florida, Washington state, and Texas would collapse (Wozniacka 2020).

In Latin America and the Caribbean, over 10 million children rely on school nutrition programs as one of their primary food sources, making them highly vulnerable to school closures. Poor people, immigrants, workers, people of color are all groups having greater difficulties in obtaining food and as a consequence are increasingly deprived from healthy diets that contain sufficient fruits and vegetables, all foods crucial in protecting people's immunity (UNCSN 2020). The loss of remittances from other parts of the world where the economy is in recession will complicate things even more for families in developing countries that depend on such monetary transfers.

4. Agroecology and a new food system

Clearly COVID-19 has revealed the socio-ecological fragility of current industrial-globalized food systems. The effects of the pandemic on farming and food supply chains raises concerns about widespread food shortages and price spikes. A transition to more socially just, ecologically resilient, localized food systems is therefore urgently needed.

The long-standing problems in the food system, now exacerbated by the COVID-19 crisis, could be addressed, among a number of proposals, through a 'Green Stimulus' plan, a plan proposed by a group of mostly urban activists and intellectuals to accelerate the creation of a twenty-first century green economy (Green Stimulus Proposal 2020). This so-called green new deal (not endorsed by the US government or the powerful corporate sector, and thus with small chances of becoming legislation) aims at making societies stronger and more resilient in the face of pandemic, recession, and climate emergency. The plan supports – family farming, sustainable – farming and land use practices that increase soil health with the ultimate goal of building a more sustainable food system that ensures universal access to healthy food. Achieving such goals requires novel rural agricultural programs that increase rural prosperity and ensure localized food systems by helping farmers become more self-reliant and resilient to severe events (Patel and Goodman 2020a, 2020b).

In this regard, agroecology as a transformative science, practice and movement that is explicitly committed to a more just and sustainable future, by reshaping power relations from farm to table, is of strategic importance in the reconstruction a post-COVID-19 new food system. Agroecology is being advocated by strong transnational agrarian and food justice movements that oppose the corporate-dominated global agrifood system, under the banner of food sovereignty (Mier et al. 2018). They call for a fundamentally different vision of food and the way we produce and consume food, while contributing to the creation of local, inclusive and equitable food systems.

There are many initiatives and actors around the world driving alternative food system practices. Some of the most promising initiatives include short food supply chains, direct marketing schemes, cooperative marketing, farmers' markets, sustainable local public procurement, community and school gardens, exchange systems, and on-farm direct consumption (FAO 2016). With the COVID-19 crisis new and spontaneous solidarity economic movements have sprung up, driven by community-based initiatives designed to meet local needs, including producer and consumer cooperatives, local credit associations, collective kitchens organizations and local food procurement programs to support marginalized populations.

Agroecology shows a way forward by providing the principles on how to design and manage agricultural systems best able to withstand future crises – whether pest outbreaks, pandemics, climate disruptions, or financial meltdowns. Agroecology offers the best agricultural system able to cope with future challenges by exhibiting high levels of diversity and resilience while delivering reasonable yields and ecosystem services (Nicholls, Altieri, and Vazquez 2016). There is an urgent need to develop agricultural solutions to some of the new situations emerging from the pandemic. Agroecology can point the way to the reconstruction of a post-COVID-19 agriculture and can constitute the foundation of a new food system by strengthening action on five main areas, which allows a re-thinking of the relationship between farming, nature and human health, and how agriculture can be re-territorialized to prevent future supply chain disruptions (Figure 1).

4.1. Overcoming the pesticide treadmill

Total removal of insecticides is desirable given that most pesticides cause a large number of negative health and environmental effects which can aggravate the

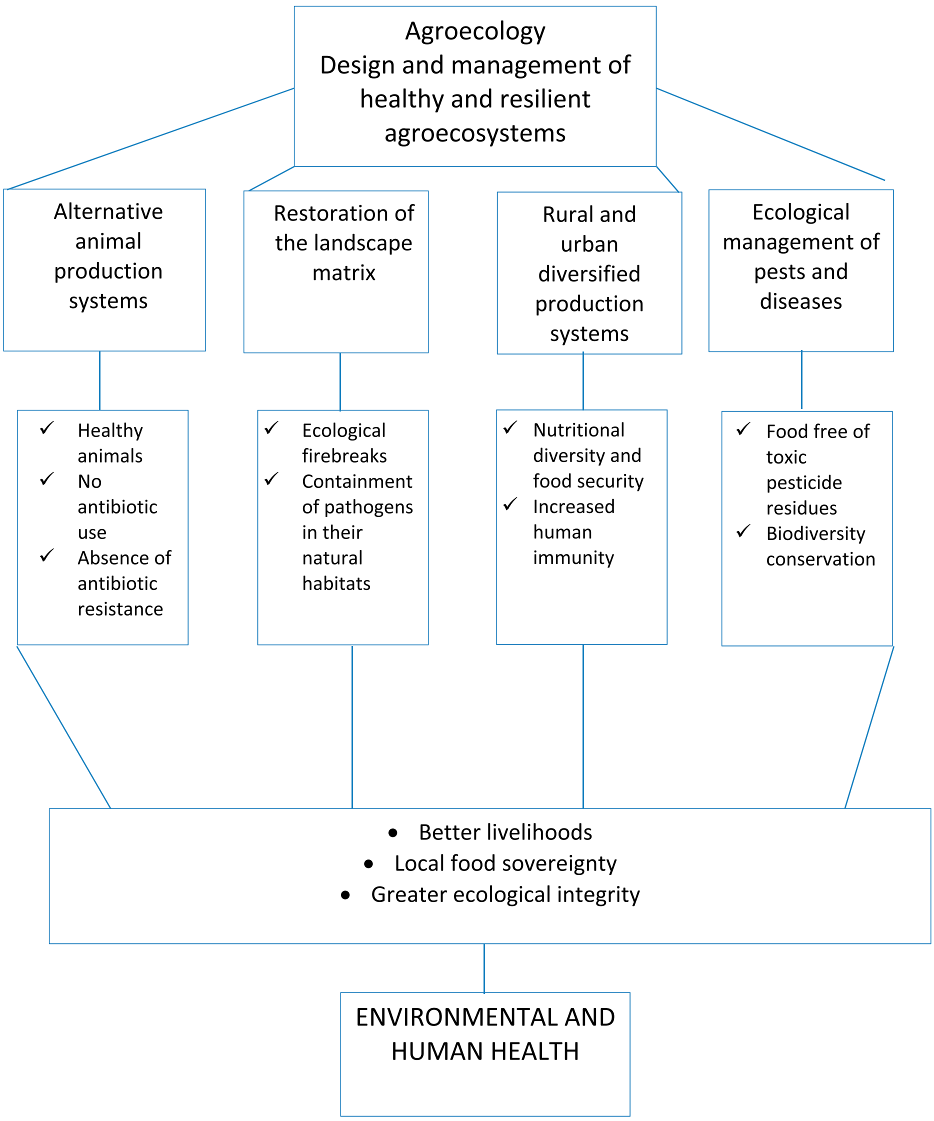

Figure 1. Connections between agroecology and environmental and human health.

current and future pandemics (WHO 1990). Agroecology provides principles and practices to stop reliance on agrochemical inputs that destroy biodiversity and affect people's health, allowing for the restoration of wildlife, pollinators and particularly natural enemy diversity which can lead to renewed biological control of specific pests. Within two years, virtually all banana insect pests in Golfito, Costa Rica dropped to below economic threshold levels, due to enhanced parasitization and predation, after stopping insecticide (dieldrin and carbaryl) sprays. Similarly, in California's walnut orchards, natural biological control of the frosted scale and the calico scale was soon achieved by encyrtid parasitoids after removal of DDT sprays (Croft 1990). In insecticide-free agroecosystems, such as organic farms, communities of predators tend to be exerting even stronger pest control pressure (Crowder et al. 2010). Despite the fact that organic farming potentially offers a means of augmenting natural pest control, by adding plant diversity to monocultures, it is possible to exert changes in habitat complexity which in turn favors even more natural enemy abundance and effectiveness due to enhanced availability of alternate prey, nectar sources and suitable microhabitats (Altieri and Nicholls 2004).

There is a large body of literature that has emerged over the last 40 years documenting that diversification of cropping systems (variety mixtures, polycultures, agroforestry systems, etc.) often leads to reduced herbivore populations (Altieri and Nicholls 2004). Andow (1991) analyzed results from 209 studies involving 287 pest species, and found that compared with monocultures, the population of pest insects was lower in 52% of the studies, i.e. 149 species, and higher in 15% of the studies, i.e. 44 species. Of the 149 pest species with lower populations in intercrops, 60% were monophagous and 28% polyphagous. The population of natural enemies of pests was higher in the intercrop in 53% of the studies and lower in 9%. The reduction in pest numbers was for monophagous insects almost twice (53.5% of the case studies showed lowered numbers in polycultures) than for polyphagous insects (33.3% of the cases).

In a meta-analysis of 21 studies comparing pest suppression in polyculture versus monoculture, Tonhasca and Byrne (1994) found that polycultures significantly reduced pest densities by 64%. In a later meta-analysis, Letourneau et al. (2011) found a 44% increase in abundance of natural enemies (148 comparisons), a 54% increase in herbivore mortality, and a 23% reduction in crop damage on farms with species-rich vegetational diversification systems than on farms with species-poor systems. Unequivocally, earlier reviews and recent meta-analyses suggest that diversification schemes generally achieve significant positive outcomes including natural enemy enhancement, reduction of herbivore abundance, and reduction of crop damage, from a combination of bottom-up and top-down effects.

Overcoming the pesticide treadmill will require replacing monocultures with complex agricultural systems in which ecological interactions between biological components replace inputs to provide mechanisms to sponsor soil fertility, productivity and crop protection. This model gives farmers greater autonomy, so that they do not depend on expensive inputs from companies for pest control, but rather depend on the ecological processes that are unleashed on their biodiverse farms (Altieri and Nicholls 2014).

4.2. Enriching nature's matrix

Promoters of agricultural intensification affirm that the best way to reduce the impact of agricultural modernization on ecosystem integrity is to intensify production in order to increase yields per hectare, and in this way spare natural forests from further agricultural expansion. By doing so, intensification supporters adhere to two pervasive assumptions: (a) that alternatives to a chemically-based crop-production system necessarily require more land to produce the same amount of output, and (b) that the adverse ecological and health consequences of industrial farming are minor in comparison to those that would be wrought by expansion of agroecology, which would need more land as it yields less (Phalan et al. 2011).

Recent evidence from agroecological surveys of small-scale coffee producers in Chiapas, Mexico, reveals an important relationship between farm size, technology used and production. Conventional coffee producers had larger landholdings averaging 7 hectares, devoting most of their land to coffee production. Since their systems used shade trees, they conserve some biodiversity but their dependence on external markets for cash, food and inputs was very high, making such farmers very vulnerable to the vagaries of an economic system out of their control. Conversely small organic producers' average farm size was 4 hectares, exhibiting the highest average coffee yields, and they devoted about 30-50% of their land to maize and beans for food security, pasture for animals and forest reserve. Given the heterogeneous patchy nature of such farming systems, their contribution to biodiversity was significant, but such services were achieved without sacrificing farmers autonomy and food security (Martinez-Torres 2003).

The enhancement of biodiversity is at the heart of the agroecological strategy. The idea is that agroecosystems should mimic the biodiversity levels and functioning of local ecosystems. Such agricultural mimics, like their natural models, can be productive, pest resistant and conservative of nutrients. This ecosystem-analog approach uses biodiversity to enhance agroecosystem function, allowing farms to sponsor their own soil fertility, plant health and sustained yields, therefore eliminating totally the need for external agrochemical inputs or transgenic technologies. As a result of the biodiverse designs and absence of toxics, the opportunities for a variety of wildlife species to thrive are much greater (Altieri 2004). Many studies have demonstrated increased abundance of beneficial insects and more effective biological control in crops bordered by wild vegetation, from which natural enemies colonize adjacent crop fields (Marino and Landis 1996).

Thus, under a landscape-level agroecological strategy, the preferred pattern is a complex matrix with fragments of forest separated by a variety of small farms (Perfecto, Vandermeer, and Wright 2009). In such environments conservation is a product of the assemblage of productive agroecosystems rich in functional biodiversity (organisms that perform services for agriculture such as biological pest control, pollination, organic matter decomposition, etc.) and wildlife species, embedded in a complex ecological matrix creating 'ecological firebreaks' that may help contain pathogens from ecological release (Wallace 2020). This is crucial given that there are millions of viruses and bacteria that reside in wild animals and can potentially infect humans. These emerging diseases are on the rise everywhere as humans disrupt ecosystems and exploit animal habitats across the globe (Tobias and D'Angelo 2020).

In traditional systems, the crop-production units and adjacent ecosystems often are all integrated into a single agroecosystem. Many peasants utilize, maintain, and preserve within or adjacent to their properties, areas of natural ecosystems (forests, hillsides, lakes, grasslands, streamways, swamps, etc.) that contribute valuable food supplements, construction materials, medicines, organic fertilizers, fuels, etc. Thus, subsistence patterns in peasant societies include plant gathering, hunting and fishing as productive activities, in addition to agricultural production (Altieri, Anderson, and Merrick 1987).

4.3. Revitalizing small farmers

Evidence shows that agroecology restores the production capacities of small-scale farmers, by suppressing pests and weeds and enhancing soil fertility in ecological ways. By producing stable crop yields with low external inputs, biodiverse farms generate income and dietary diversity, thus improving smallholders' nutritional status and livelihoods (Altieri 1999; Pretty, Morrison, and Hine 2003; UK Government's Foresight Project 2011).

Since the early 1980s peasant organizations in partnership with NGOs and other organizations have promoted and implemented alternative, agroecological-featuring, resource-conserving yet highly productive systems. Analysis of several agroecological field projects in operation in Africa, Asia and Latin America have shown that traditional crop and animal combinations can often be adapted to increase productivity when the biological structuring of the farm is improved with agroecological principles and when labor and local resources are efficiently used (Rosset and Altieri 2017). In fact, the most promoted agroecological practices improve traditional agricultural yields, increasing output per area of marginal land from 400–600–2000–2500 kg/ha, enhancing also the general agrobiodiversity and its associated positive effects on food security and environmental integrity. Some projects emphasizing green manures and other organic management techniques can increase maize yields from 1 to 1.5 t/ha (a typical highland peasant yield) to 3–4 t/ha (Uphoff 2002).

In Cuba, it is estimated that agroecological practices are used in 46–72% of the peasant farms producing over 70% of the domestic food production, e.g. 67% of roots and tubers, 94% of small livestock, 73% of rice, 80% of fruits and most of the honey, beans, cocoa, maize, tobacco, milk and meat production (Rosset et al. 2011). Small farmers using agroecological methods obtain yields per hectare sufficient to feed about 15–20 people per year with energy efficiencies of no less than 10:1 (Funes and Vazquez 2016).

The amplification of agroecology among peasant farmers is not only possible but crucial for the food sovereignty of most communities, as small farmers who control only 30% of the global arable land produce between 50 and 70% of the food consumed in most countries (ETC 2017).

4.4. Ecological animal production systems

Agroecology also promotes alternative livestock production systems, such Silvopastoral systems (SPS) which combine fodder plants, such as grasses and leguminous herbs, with shrubs and trees for animal nutrition and complementary uses. Such agro-landscape favors biodiversity by creating complex habitats that support diverse plants and animals, harbor a richer soil biota, and increase connectivity between forest fragments. Trees and palms provide farmers with marketable wood products but also fruits, seeds, and pods that feed humans, cattle, and wild animals. At the same time, trees in SPS also provide a range of indirect benefits such as maintenance and improvement of soil fertility, nitrogen fixation and nutrient uptake from deep soil horizons, while their litter helps replenish soil nutrients, enhance organic matter, and support complex soil food webs including dung beetles and other decomposers that quickly recycle nutrients (Murgueitio et al. 2011)

Silvopastoral systems ensure healthy animal production. In addition, they restore landscapes and are less conducive to promoting epidemics. Antibiotics are rarely used in these systems, since animals live outdoors and their diet is based on plants grown in organic matter rich and biologically active soils, thus strengthening the immune systems of these animals. The rotational grazing systems used in silvopastoral systems have allowed an increase in stocking rates to 4.3 cows per hectare and milk production by more than 100% while completely eliminating the use of fertilizers (Murgueitio et al. 2015).

4.5. Enhancing urban agriculture

In the midst of the COVID-19 crisis a number of people have bolstered urban agriculture as a major sustainable alternative to enhance food security on an urbanized planet, where 60% of the world's population live in cities, including 56% of the world's poor and 20% of the undernourished (de Bon, Parrot, and Moustier 2009). Urban production of fresh fruits, vegetables, and some animal products near consumers can improve local food security and nutrition, especially in underserved communities (Smit, Nasr, and Ratta 2001). In 1993, just 15% of food consumed in cities worldwide was grown in cities. However, by 2005, that proportion increased to 30%. In other words, urban food production doubled in just over 15 years. This trend of expanding urban agriculture continues today. Projected global production was estimated at 100–180 million tons of food per year, providing 15–20% of global food (Martellozzo et al. 2014).

The same well-established agroecological principles used in rural areas for the design and management of diversified farms where external inputs are replaced by natural processes can be applied to urban farms. Agroecological principles are applied by way of various practices which lead to optimal recycling of nutrients and organic matter turnover for soil fertility, closed energy flows, water and soil conservation and enhanced pest regulation – all key processes necessary to maintain urban agriculture productivity (Altieri and Nicholls 2018). In Cuba agroecological 'organoponicos' (intensive gardens) reach on average 15-20 kg/m^2/year (Funes and Vazquez 2016). During the 1984–1985 season in central Chile, Infante (1986) conducted an evaluation of an 11.05 m^2 vegetable garden containing 16 crops species displayed in complex rotations and mixtures which produced 177.4 kg for one year, or 16 kg/m^2/year. The secret of the high production potential of the Cuba and Chile examples is the application of agroecological principles to guide the intensive cultivation of a diversity of vegetables, roots and tubers, and herbs in relatively small spaces.

Agroecologically well-designed urban farms can be up to 15 times more productive than rural holdings. In Cuba, an area of just one square meter can provide 20 kg of food per year (200 tomatoes = 30 kg) throughout the year, 36 heads of lettuce every 60 days, 10 cabbages every 90 days and 100 onions every 120 days. Considering the average requirements for one person of vegetable crops is about 72 kg/year, a 10 m^2 bed in an intensive garden can yield up to 200 kg of vegetables per year, potentially providing about 55% of the yearly vegetable needs of a family of five (Clouse 2014). High production and yields surplus can also create opportunities to generate cash income and employment (Nugent 2002).

Increasing the productivity of urban agriculture contributes to local food security by enhancing the ability of households to access food and improves nutrition by increasing the ability of families to diversify diets (Maxwell 2002). It is likely that urban food production will expand as more people realize that in times of crisis, access to locally produced food is strategic. Eating nutritious, plant-based foods derived from local organic farms can fortify people's immune systems. Plant-based foods increase and help the intestinal 'good' bacteria and the overall gut microbiome health, which comprises up to 85% of the body's immune system (Tilg and Moschen 2015).

5. Conclusions

COVID-19 has exposed the tragedy of animal factory farming and endless monocultures which lead to dramatic losses of biodiversity, obesity, malnutrition, food waste, and appalling working conditions for migrant laborers, and have undermined livelihoods of small farmers. Given this grim reality, agroecology is positioning itself as a key agricultural path that can provide rural families with significant socioeconomic and environmental benefits, while feeding the urban masses, equitably and sustainably. Agroecology has grown into a global movement backed by peasants, farmers, and activists seeking to insure food sovereignty, agrarian reform, the establishment of cooperative models, and the protection of biodiversity. Agroecology entails a fundamentally different vision of the way we produce and consume food, while contributing to the creation of equitable food systems.

One of the lessons from the current pandemic so far is the urgent need that food production be in the hands of small producers, peasants and urban farmers. It is the only way to ensure the supply of fresh food, at affordable prices and in local markets, away from the chains of the capitalist market (Holden 2020). This implies promoting redistributive land reform, which should become one of the main areas for changing public policy post-COVID-19, to directly impact on the underlying inequalities of the dominant global agri-food system.

Now that the global supply chains are in disarray, it is the opportunity for regional food systems to emerge to handle disruptions, including those projected to increase with climate change (Gustine 2020). It is important however to realize and stay vigilant as agribusiness already has its post-COVID plan, which entails more concentration, megafarms, drones, and precision farming. As Holt-Gimenez and Altieri (2013) warned earlier, the dominant players in the industrial food system are keen on converting smallholders and agroecology into means for, rather than barriers to, the expansion of industrial agriculture.

This retooling of the food system based on short supply chains will require providing smallholder farmers and herders with land, seeds, tools, food storage systems, poultry and other small stock, animal feed and other organic inputs, so that they can improve household nutrition and generate income while continuing to produce food for their and nearby communities. It will also require the understanding from urban dwellers that eating is both an ecological and political act. When consumers support local farmers instead of the corporate food chain, which is more vulnerable than small farmer food webs, they create socio-ecological sustainability and resilience.

The key point here is whether the crisis unfolded by COVID-19 will provide the impetus to change industrial agriculture for a transition towards agroecologically-based food systems. Transformational change in agriculture must be accompanied by a shift from a market economy to a solidarity economy, from fossil fuel to renewable energy, from big corporations to cooperatives. Such a new world should be led by allied social, urban, and rural movements aware that a return to the way agriculture was before the pandemics is not an option; instead they will be actively involved in turning local farms into a vital asset for providing food and promoting autonomy, while consolidating sustainable and healthy agroecological territories.

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