Can small-scale regenerative agriculture feed the world?

An annotated bibliography for Soul Fire Farm

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Summary:

A review of the literature written between 2007 and 2020 indicates that small-scale regenerative agriculture can indeed feed the world, but would require economic, dietary, policy, and cultural shifts. In terms of yields, smallholder farming already accounts for well over half of the world's food supply. Additionally, while conventional (industrial) forms of agriculture have previously been thought to be more efficient, current research has found that organic production can have greater yields in various contexts. Local and organic farming can also be more resilient to shocks and a changing climate, which can support a more reliable food supply over time. However, while it is technically possible to continue to produce the calories needed for a growing global population through small-scale regenerative agriculture, there are social, economic, and political barriers that need to be addressed. Small-scale organic farming alone can only provide enough calories with a dietary shift away from animal products such as meat and dairy, and if inequities in food distribution can be eliminated. The reduction of food waste also needs to be prioritized. Furthermore, in many places around the world, local and organic food is often more expensive and therefore only accessible to privileged groups. As such, in order for alternative agriculture to feed the world, we need to address underlying inequalities, such as class, gender, race, and educational disparities. Additionally, organic forms of agriculture tend to be labor-intensive. This is a major concern when scaling up alternative food production in a just way, given that many organic farms depend on cheap or voluntary labor. It is also argued that producer and consumer networks must be strengthened in order for small-scale regenerative agriculture to successfully reach all groups of people over the short and long terms. Finally, in order to feed the world, alternative agricultural initiatives need to be scaled up or massified through social organization and mobilization of participating producers and consumers, the horizontal dialog of knowledge, and favorable public policies. Overall, based on this review, it is arguable that the potential of small-scale regenerative agriculture to feed the world is promising. This is particularly so when considering the additional benefits that this type of food production can provide.

Emerging themes:

- **Yields (production) vs accessibility**: we are currently producing enough food to feed the world (Badgley and Perfecto 2007), and at least half of that comes from smallholder farms (Samberg et al., 2016). However, underlying social inequalities limit the wider accessibility of alternative foods, meaning that local and organic foods are often only

accessible to privileged groups (Broad and Cavanagh, 2012; Grauerholz and Owens, 2015; Bruce and Castellano, 2017; Jouzi et al., 2017). Some research has shown that organic yields tend to be lower than those of conventional agriculture, but some studies are finding those data to be biased and highlight that organic yields will differ based on context (Jouzi et al., 2017; Taheri et al., 2017). In fact, some studies find the opposite to be true, that many factors make alternative agriculture more efficient (yield per hectare) and stable (yields over time) (Chappell and LaValle, 2011).

- **Industrial agriculture vs local agriculture:** there currently exists a contradiction within the dominant discourse of the global food system. Large institutions like the FAO and the World Bank recognize the importance of local smallholder agriculture for local and regional food security while at the same time releasing policies and recommendations favoring agribusiness (Tomlinson, 2013; Giménez Cacho et al., 2018).
- **GM versus organic:** while GM crops have previously been promoted as the (only) way forward in our growing and warming world, more and more research is showing that organic farming can potentially meet food demands in many contexts (Broad and Cavanagh, 2012; Taheri et al., 2017; Jouzi et al., 2017).
- **Scale:** in order to provide enough calories for a growing population it will be crucial to scale up or "massify" alternative agriculture initiatives through social and political organization and mobilization of producers and consumers (Giménez Cacho, M. M. T. et al., 2018).

Benefits:

- **Climate resilience:** looking forward, agriculture must increasingly become climate resilient. Small-scale, traditional, and organic forms of agriculture have in many cases modeled resilience (Altieri and Nicholls, 2013; Jouzi et al., 2017).
- **Traditional and local knowledge**: several studies have revealed the role of local knowledge mobilized in small-scale agricultural practices. Local knowledge and practices can serve to build sustainable and resilient food systems and hedge against food crises (Gregory et al., 2017; Zimmerer et al., 2018; Giménez Cacho, M. M. T. et al., 2018). At any rate, it is imperative that critical systems of learning competence are developed in order to utilize available agroecological knowledge to meet food security needs, as evidenced in the cases of Nepal and India (Pant, 2014).

Challenges:

- **Labor**: organic forms of agriculture are labor-intensive, which is a major factor preventing the scaling-up of alternative food production (Bruce and Castellano, 2017).
- **Producer and consumer networks:** in order for alternative food networks to be successful, producer and consumer alliances must be strengthened (Gregory et al., 2017). Critiques of industrialized agriculture suggest voluntary cooperatives and socially-conscious economies to combat the treadmill of technological innovation (Peng 2020).

- **Social equity:** there are often social inequities underpinning the production and consumption of local and organic foods. Farmers belonging to economically or socially constrained groups do not exercise the agency to select production methods (regenerative, or otherwise), which is more often the result of their socioeconomic realities (Bernstein, 2015)

Annotated bibliography:

1. **Altieri, M. A., & Nicholls, C. I. (2013). The adaptation and mitigation potential of traditional agriculture in a changing climate. *Climatic Change, 140*(1), 33-45.**

Altieri and Nicholls (2013) reveal that small-scale agroecology-based farming practices present viable and robust paths to increasing productivity, sustainability, and climate resilience in food production systems. This paper argues against 'climate smart genes' as the only viable option for small-scale farmers to adapt to climate change, highlighting the myriad of strategies that many smallholders have used and still use to mitigate and adapt to a changing climate. An estimated 50% of peasant farmers use resource conserving farming systems, which highlights the resilience of traditional agroecosystems despite rapid environmental and economic change. This paper also underlines the large number of smallholder farmers that contribute substantially to food security at local, regional, and national levels. The authors present different models of climate smart traditional agriculture including raised fields and dryland agriculture, and discuss the performance of biodiverse agroecosystems under extreme climatic events. Indigenous technology is highlighted as a key source of information on adaptive capacity centered on the selective, experimental and resilient capabilities of farmers in dealing with climate change.

2. **Badgley, C., & Perfecto, I. (2007). Can organic agriculture feed the world? Renewable Agriculture and Food Systems, 22(2), 80-86.**

This study makes two important contributions through analyzing global datasets. First, using 293 yield ratios from plant and animal production, they propose that organic production methods provide enough calories to support the human population. Second, they conclude from 77 published studies that nitrogen-fixing legumes can provide enough nitrogen to replace synthetic fertilizers. The authors underline that enough food does not equate to food security, which includes accessibility and pricing.

3. **Bernstein, H. (2015) 'Food sovereignty: A skeptical view | Soberania alimentar: Uma perspectiva cética'. *Sociologias,* 17(39), 276–336.**

The research situates itself in the food sovereignty discourse and its opposition to corporate-industrialized agriculture. It centers on the conceptualization of the farmer (peasant), choice of farming methods (conventional or otherwise), and the ability of these

two to feed the world. Bernstein highlights the definition of ‘peasants’ or ‘small medium farmers’, and their socioeconomic characteristics that afford them a choice (or lack thereof) for practicing a certain method of farming (like regenerative). He argues that current choices of many farmers are a result of social and ecological constraints, rather than at-will decision making. Hence, adoption of any alternative practice will depend upon the socioeconomic realities of farmers. Further, he raises an important concern pertaining to such shift to an alternative: can small-medium farmers, based in the historic tradition of subsistence and self-sufficiency, generate sufficient surplus food for non-farmers? He poses this question as centric to developing any program for ‘feeding the world’, which uses a “low (external) input and labor-intensive” farming approach.

4. **Broad, R., & Cavanagh, J. (2012). The development and agriculture paradigms transformed: Reflections from the small-scale organic rice fields of the Philippines. *The Journal of Peasant Studies, 39*(5), 1181-1193.**

This paper highlights the fact that we continue to grow more than enough food to feed the world’s population, so it is argued that we should not be concerned about yields, production nor scarcity; rather, the problem in our food system today is “conventional plantation agriculture combined with a neoliberal development model that prioritizes cheap experts over food crops” (p. 1189). Broad and Cavanagh (2012) mobilize the concept of ‘rootedness’ rather than sustainability or resilience to understand the ways in which small-scale farming is stronger when it is socially, environmentally, and economically anchored in place. This article suggests that food production should be primarily done locally and with local inputs. Neoliberal industrial agriculture is exposed as being increasingly vulnerable. A field study on rice farming in the Philippines shows how farmers who shifted away from ‘vulnerable’ chemical agriculture became more ‘rooted’ through small-scale organic production. Economic, social, and environmental dynamics of this transition are presented. On the debate between Monsanto and small-scale farmers, this article concludes with a discussion on how consumers and policies should support more rooted alternatives to vulnerable neoliberal agriculture.

5. **Bruce, A. B., & Som Castellano, R. L. (2017). Labor and alternative food networks: challenges for farmers and consumers. Renewable Agriculture and Food Systems, 32(5), 403-416.**

This paper addresses a significant barrier to scaling up small-scale sustainable agricultural production: labor. Bruce and Som Castellano (2017) suggest that small-scale farmers who engage in sustainable agricultural practices spend significantly more time maintaining the health of their soil through crop rotation, growing diverse crops, and building organic matter. They are usually not paid for these activities and rely upon volunteers or interns willing to work for low wages or trade. The authors argue that this limits the long-term financial viability and social sustainability of these practices.

Ultimately, the intensity of labor required limits the potential to scale up such practices in order to reach more people. This paper also highlights the additional costs that make alternative food networks inaccessible for people with lower socio-economic status. This paper calls for more institutional support for organic production so that small-scale, alternative farmers could hire (and fairly pay for) the labor they need, and so that organic or sustainably grown produce is more widely physically and financially accessible.

6. **Burris, V. (2014) 'Sustainability of small scale farming in a mountain region: Case study of the khaling rai population of the Solukhumbu, Nepal',** ***Future of Food: Journal on Food, Agriculture and Society*****, 2(2), pp. 9–21.**

The research explores the practice of small-scale farming among the Khaling Rai population in Nepal, and its impact on people's self-sufficiency as well as the financial component of their livelihood strategy. The study deploys mixed methods research with quantitative data collected on the five components of Sustainable Livelihood Approach (human, natural, physical, financial and social assets) and qualitative data through key informant interviews. Burris concludes that small-scale farming is sufficient to fulfill their basic needs of food security; however, due to the non-monetized non-market nature of the region's agriculture, it does not improve their financial capital as part of a holistic livelihood strategy. A shift towards monetized agriculture is suggested to be made with improved low-cost technologies for staple crops and new cash crops, in order to aid financial remuneration. At any rate, this would entail a shift in the established cropping pattern and (possibly) farming methods, in turn impacting the region's environment.

7. **Chappell, M. J., & LaValle, L. A. (2011). Food security and biodiversity: can we have both? An agroecological analysis. Agriculture and Human Values, 28(1), 3-26.**

This report finds that, while current agricultural systems provide sufficient food globally, they do so at the expense of biodiversity. At the time the article was written, one billion people were malnourished and extinction ranged between 1,000 and 10,000 times the "natural" rate. -In this context, the authors ask two questions: can alternative agriculture provide the same level of food security? And can these alternative methods improve biodiversity conservation? The article concludes that yes, alternative agriculture can be scaled up to feed the world, with more efficiency than industrialized agriculture, in fact. Further, biodiversity protection and food security can be achieved using complementary means. Several factors make small, alternative production schemes superior to industrialized agriculture: a) small farms are more efficient (multiple cropping systems, higher yields, higher labor quality, more efficient irrigation, non-purchased inputs), b) alternative production can produce between 95 and 157% of calories currently produced without and expansion (statistic taken from Badgley 2007), c) small farms require investment in ecological stability to prevent risk which decreases long-term variability in

production, d) detail-oriented production methods (integrated plant nutrient systems, integrated pest management, etc.) create more reliable and higher yields, and, finally, e) alternative methods, while perceived as risky, create higher profits for farmers due to decreased input costs.

8. **Erb, K.H. et al. (2009). Eating the Planet: Feeding and fuelling the world sustainably, fairly and humanely – a scoping study. Commissioned by Compassion in World Farming and Friends of the Earth UK. Institute of Social Ecology and PIK Potsdam. Vienna: Social Ecology Working Paper No. 116.**

This study assesses how to feed and fuel the world sustainably, fairly, and humanely in the future by developing a biomass balance model calculating the balance between global biomass (food and fiber) demand and supply from cropland, grazing and livestock, as well as bioenergy potential. The authors developed many different scenarios based on different crop farming systems (intensive, intermediate, organic), livestock production systems (intensive, humane/free range, organic), and diets (western high meat; current trend; less meat; fair less meat). The authors found that it would probably be feasible to feed the world population in 2050 with both the western high meat and the fair less meat diets, however, the crop farming and livestock production systems would have to be very different. With the western high meat diet intensive industrial crop farming and livestock production systems have to be used, whereas with a more modest diet of approximately 80% less meat and dairy products organic systems could feed the 9.2 billion people given an equitable global food distribution. The authors specifically stress the importance of smallholder agriculture for organic crop and livestock production systems. They recommend directing research and technical development toward organic agricultural practices and to adopt measures to reduce the share of meat and dairy products in our diets.

9. **Fiebrig, I., Zikeli, S., Bach, S., & Gruber, S. (2020). Perspectives on permaculture for commercial farming: aspirations and realities. Organic Agriculture, 1-16.**

This article reframes permaculture as a set of “viable solutions towards sustainability,” rather than the “romanticising idealism and cult-like ideology (aspirations)” that it usually occupies. The authors discuss the history of permaculture, its origins in the 1970s in Australia, as well as its basic principles and global diffusion. The article then dives into a case study comparing organic agriculture and permaculture practices, underlining the increased flexibility and improved resilience of permaculture farms because of its landscape-wide scope. The authors also point out that, while permaculture and organic agriculture are compatible, there are unclear and non-uniform practices of permaculture, which lead to skepticism in academic analyses, as well as a potential lack of scalability.

10. **Grauerholz, L., & Owens, N. (2015). Alternative food movements. *International encyclopedia of the social & behavioral sciences, 1*(2), 566-572.**

This encyclopedia entry summarizes alternative food movements including the local food movement, plant-based diets, genetically modified organisms, permaculture and food justice. Then, the authors highlight the challenges and considerations of alternative food movements. Notably, Grauerholz and Owens (2015) contend that in order to feed the world through sustainable, ethical farming methods, it is important to address the social disparities underpinning food systems. Echoing some of the other articles cited within this annotated bibliography, this source suggests that while there is an increasing demand for local, organic, non-genetically modified foods and community-supported agriculture, alternative foods are usually only accessible and affordable for privileged groups. However, it is argued that alternative food movements will have increasingly stronger and visible presence in food production and distribution in the years to come, particularly if there is more commitment to addressing social justice and sustainability.

11. **Gregory, L., Plahe, J., & Cockfield, S. (2017). The marginalisation and resurgence of traditional knowledge systems in India: agro-ecological 'islands of success' or a wave of change?. *South Asia: Journal of South Asian Studies, 40*(3), 582-599.**

Gregory et al. (2017) take a food regime analysis and use an agroecology framework to demonstrate that small-scale, traditional knowledge-inspired agri-food practices are resurging in response to the crisis in India's industrial food system. The authors begin by outlining the history of agricultural development in India that has served to marginalize traditional knowledge and that situates the food crisis today. Then, through three case studies across India, this paper explores the revival of traditional knowledge in agroecology. The cases all demonstrate environmental, economic, social, and cultural benefits, but show varying degrees of success and capacity to connect with broader food networks. The transition to agroecology requires a strong alliance between producers and consumers. For now, each case represents an 'island of success', but the authors suggest that increased government support of such small-scale traditional knowledge-inspired practices (particularly by increasing farmers' ability to connect to buyers) could lead to increased sustainability and wider transformations in the food system.

12. **High Level Panel of Experts (HLPE) (2019). Agroecological and other Innovative Approaches for Sustainable Agriculture and Food Systems that Enhance Food Security and Nutrition. A report by the HPLE on Food Security and Nutrition of the Committee on World Food Security: Rome, Italy.**

This report explores debates in food security and nutrition (FSN), focusing on agroecology as a potential pathway for creating a more sustainable food system. The HLPE uses the seven PANTHER principles of Participation, Accountability,

Nondiscrimination, Transparency, Human dignity, Empowerment and the Rule of law as a jumping off point to support the four aspects of FSN (availability, access, stability, and utilization). They conclude that agroecology is a holistic ecological and social approach to creating a more resilient and sustainable food system. The definition of agroecology is purposefully difficult to pin down, making it both academically understudied, but also highly flexible and therefore effective in the food production context. Innovations are broadly clustered into two categories: sustainable intensification, which generally improves the availability and stability aspects of FSN; and agroecology, which tends to improve access, utilization, and equity. The report, notably, proposes adding "agency" as a fifth dimension of FSN. The report identifies five barriers to innovation: governance, economic factors, knowledge, socio-cultural factors, and resources. Finally, they identify institutional habits that prevent innovation uptake, and suggest pathways to change the current inertia that guides hegemonic food system production and consumption.

13. **Jouzi, Z., Azadi, H., Taheri, F., Zarafshani, K., Gebrehiwot, K., Van Passel, S., & Lebailly, P. (2017). Organic farming and small-scale farmers: Main opportunities and challenges. Ecological Economics, 132, 144-154.**

Despite its challenges, Jouzi et al. (2017) argue that small scale organic farming is part of the solution to feeding a growing population. The opportunities that organic farming presents are shown to outweigh its drawbacks. This article suggests that organic farming offers mitigation and adaptation strategies which enhance small-scale farmers' resilience to climate change. Organic farming is also shown to increase food security and reduce poverty for smallholder farmers. The authors suggest that many food shortages in rural areas are due to failures of monoculture systems, while the multi-culture of organic farming reduces the risk of crop failure and food insecurity. Recognizing that organic farming tends to have lower yields, the authors suggest organic production could be enough to feed the global population (p. 149), but the social, political, and economic aspects underlying food access need to be addressed. The authors highlight that the exact potential yield of organic farming is context specific. They also question the reliability of data on organic yields, suggesting bias toward higher yields in conventional systems in some studies (p. 149). Other challenges addressed include nutrient management, certification and market, and education and research.

14. **Mier y Terán Giménez Cacho, M. M. T. et al. (2018). Bringing agroecology to scale: key drivers and emblematic cases. Agroecology and Sustainable Food Systems, 42(6), 637-665.**

This article examines the process of scaling up agroecological practices through a review of 5 case studies in the Americas as well as in South Asia. By definition agroecology focuses on smallholder farmers, and in all case studies agroecological practices led to higher yields and lower costs for the participating farmers. The authors identified 8

drivers working in tandem to bring agroecology to scale: the existence and identification of a crisis in the local food system; social organization in farming communities; constructivist learning practices focusing on a horizontal dialog of knowledges; effective agroecological practices that reduce costs and external inputs as well as environmental and ecological impacts; mobilizing discourse that allows the framing of a common problem, a shared adversary, a common identity and principles; external allies based for example in government agencies, NGOs, and universities; and finally favorable markets and policies.

15. **Pant, L. P. (2014) 'Critical systems of learning and innovation competence for addressing complexity in transformations to agricultural sustainability',** ***Agroecology and Sustainable Food Systems*****, 38(3), pp. 336–365. doi: 10.1080/21683565.2013.833157.**

The study claims that agriculturally biodiverse-rich countries have failed to leverage their agroecological competence to achieve food security goals. Pant conducted a comparative study of two neighboring countries' State policies in agriculture: improvement in subsistence agriculture to meet national food security needs in Nepal, and promotion of high value crops to integrate into global commodity supply chains in India. Pant uses a socio-ecotechnical (SET) systems thinking and practice approach that integrates social, ecological and technical aspects. His findings suggest that both countries have fallen behind on their food security goals, despite an abundance of agroecological knowledge. His central argument supporting this outcome is the lack of 'critical systems of learning and innovation competence'; the ability to utilize existing agroecological knowledge and complement it with technological advancement to achieve food security goals.

16. **Peano, C., Massaglia, S., Ghisalberti, C., & Sottile, F. (2020). Pathways for the Amplification of Agroecology in African Sustainable Urban Agriculture. Sustainability, 12(7), 2718.**

The authors emphasize the importance of agroecological model for small-scale farming, using a series of case studies of the Slow Food association in school and community gardens in Africa. Agroecology is thoroughly defined according to a number of scholars (Altieri, Gliessman, and Rahbi). The authors then further define agroecology in the African context by its focus on indigenous farmer knowledge of crop diversification, composting, irrigation, and crop rotation (among many other practices). The major takeaway is that these garden projects that are linked up with strong Slow Food groups are successful due to the integration of farmer experience, community sharing, and educational/outreach programs. They conclude with a call for alternative economies, de-growth thinking, food as a human right, and a focus on democratic institutions as the heart of food systems change.

17. **Peng, Z. (2018). Upscaling Agroecology: A Marxist Political Economy Approach to the "Feed the World" Debate. World Review of Political Economy, 9(2), 188-210.**

This article points out the limited focus of both the sustainable intensification and agroecology movements. The article does an excellent job outlining the current struggle to increase environmental sustainability through both movements. The author explores several flaws. First, that the repackaging of industrialized agriculture as sustainable intensification is potentially just greenwashing ecologically harmful practices. Second, that both movements center technology as key to either making agriculture efficient, in the case of sustainable intensification, or that technology is the antithesis of peasant agency and supplants agroecological principles. The author investigates socialism as a clear path to embracing some of the technological innovation of industrial agriculture, while establishing "conscious social control of the choice and implementation of concrete agricultural technologies." He advocates for embracing certain parts of industrialized agriculture to complement agroecology, especially those that reduce labor burdens, and focus on putting in place socialist local economies to pass those labor savings onto the workers. In this way, the author proposes to "feed the world" with an agroecological approach to farming.

18. **Pretty, J. et al. (2018). Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability,1, 441-446.**

This article evaluates if agriculture can still provide sufficient nutritious food for a growing world population while doing so in a sustainable way without environmental degradation and loss of biodiversity. The authors focus on sustainable intensification as one important way to help transform the wider food system. Sustainable intensification (SI) refers to agricultural practices, which deliver yields comparable or higher than current levels while also improving environmental outcomes. SI practices can be applied to any size of farming enterprise and does not require predetermined technologies, production types or design components. The authors analyzed transitions from current agricultural practices towards ecosystem-level SI practices in agricultural systems worldwide to deliver sustainability across all dimensions to facilitate food, fiber and fuel production at increased rates. The authors produced a typology of seven system types classified as such a redesign: (i) integrated pest management, (ii) conservation agriculture, (iii) integrated crop and biodiversity, (iv) pasture and forage, (v) trees in agricultural systems, (vi) irrigation water management and (vii) intensive small and patch systems. Of the approximately 570 million farms worldwide, 84% are smallholder farms, which make up only about 12% of total agricultural area but produce 70% of food in Africa and Asia. Furthermore, 74% of all farms are in Asia, 9% in sub-Saharan Africa, 7% in central Europe and central Asia, 3% in Latin America and the Caribbean, and 3% are in the Middle East and north Africa. The authors identified 47 SI initiatives covering

each more than 10,000 farms or ha, and estimate that about 163 million farms or 29% of all worldwide have crossed a redesign threshold, practicing some forms of sustainable intensification on 453 Mha of agricultural land (9% of worldwide total). The authors conclude that sustainable intensification may be approaching a tipping point where it could be transformative.

19. Rahmann, G., Grimm, D., Kuenz, A., & Hessel, E. (2019). Combining land-based organic and landless food production: a concept for a circular and sustainable food chain for Africa in 2100. Organic Agriculture, 1-13.

In this review article of food security, Rahmann and colleagues propose ten actions to feed ballooning global populations in the year 2100. They lay out a series of assumptions, including a range of population totals 11.2 to 16.6 billion people, which they term "medium" and "worst" case population growth scenarios. The actions include 1) understanding dietary needs, 2) produce enough food for 9-11 billion people, 3) develop ecologically-sound cradle to grave food chains, 4) make food chains economically viable and equitable, 5) define ethical and social standards for food chains, 6) explore/invent new food sources, 7) decrease livestock use, 8) educate consumers in sustainable food choices, 9) protect/develop local food sources, and 10) develop "landless" production systems (bioreactors, aquaponics, fermenters, etc.). The authors particularly explore the landless options as a solution to the efficiency/equity issues posed in the beginning of the article, as such technologies are usually dismissed as too expensive due to investment costs. They propose the concept "LandLessFood" for high-density, low-income countries where one hectare of cropland could be replaced by one square meter of bioreactor space.

20. Samberg, L. H., Gerber, J. S., Ramankutty, N., Herrero, M., & West, P. C. (2016). Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters*, *11*(12), 124010.

Small-scale farming is the most widespread form of agriculture globally. Samberg et al. (2016) fill a research gap by mapping the concentration of small-scale farming households at subnational scales across the developing world. Through this method, they calculate that smallholder agricultural systems are responsible for providing more than half of the world's food calories and for producing over half of some of the world's major food crops. Therefore, this paper concludes that small-scale farming is not only important for maintaining the food security of the rural poor; smallholder farms are also essential for agricultural production and sustainability at national, regional, and global scales. This study is one of the first to utilize available large-scale household microdata in this way, and urges future research and policy to consider the methodologies and results presented in the paper.

21. Smith, J., Yeluripati, J., Smith, P., & Nayak, D. R. (2020). Potential yield challenges to scale-up of zero budget natural farming. *Nature Sustainability*, *3*(3), 247-252.

The United Nations has recognized the importance of smallholder farms to global food security and has launched a global action plan to target family-run farms. Zero budget natural farming (ZBNF) is a grassroots movement that attempts to help increase India's capacity to feed its population by reducing input costs for poor farmers (zero budget) and emphasizing the importance of co-production of crops and animals (natural farming). Smith et al. (2020) suggest this approach could provide yield benefits for low-input farmers while reducing soil degradation. Farmers have observed higher yields in the first season after conversion to this form of farming. Authors suggest ZBNF should initially be encouraged to only low-income farms where lower inputs of nitrogen to crops can be more easily maintained in comparison to high income farms. Promoting ZBNF to high-income farmers across the country would likely lead to a temporary but national food shortage due to a lack of nutrient supplies. More research is needed to understand the impacts of ZBNF on soil organic matter and ensure that higher levels of nutrients continue to be available to crops so that yields can be maintained over short and long terms.

22. **Taheri, F., Azadi, H., & D'Haese, M. (2017). A world without hunger: organic or GM crops? Sustainability, 9(4), 580.**

Taheri et al. (2017) offer a literature review to address the question of whether increasing organic farming or the production of genetically modified crops would best meet the world's growing food demands and eradicate hunger. They find that organic farming (despite yields being often 20-25% lower than conventional farming) can be a solution in developed countries where farmers' productivity is high. Economic profitability of organic farming was shown to be significantly higher (22-35%) when compared to other farming systems around the globe, due to reduction in production costs and price premiums for organic products. However, small-scale farmers in the developing world are limited in their ability to break through to organic farming as the transition phase means a decrease in yields while not yet qualifying for higher priced certifiable organic crops. In the US, organic farming has the potential to be a low-risk strategy, but this is not the case everywhere. In developing countries where small-scale farmers have lower agricultural productivity and limited access to agricultural technologies and information, the authors conclude that an approach that includes both organic farming and genetically modified crops would be best to address food security concerns in developing contexts.

23. Tomlinson, I. (2013). Doubling food production to feed the 9 billion: A critical perspective on a key discourse of food security in the UK. Journal of Rural Studies, 29, 81-90.

This paper critiques the dominant discourse of food security and specifically the claim that to feed the projected 9.2 billion people by 2050 food production needs to be at least 70% to 100% higher. The dominant discourse frames food security as a problem of inadequate agricultural production while largely ignoring inequities in food distribution and land ownership; food waste; and environmental degradation associated with the global food system. If food waste and inequities in food distribution could be reduced or eliminated, it would be feasible to feed the projected 9.2 billion people with only about a 25% increase in food production. Furthermore, organic agriculture can probably feed the world population in 2050 without large increases in yields or costs (relative to current levels) if a more modest diet is adopted with a much smaller share of meat and dairy products. The framework of food sovereignty is emerging as a promising alternative to food security as it stresses the right to food as well as to food production of peoples, communities, and countries. Agroecology is an important discourse within food sovereignty as it combines ecological science with goals of equity, resilience, and sustainability to design and manage sustainable food systems.

24. Zimmerer, K. S., Lambin, E. F., & Vanek, S. J. (2018). Smallholder telecoupling and potential sustainability. Ecology and Society, 23(1).

This paper presents a conceptual framework for understanding the ways in which small-scale farming can contribute to sustainability through telecoupling. Telecoupling is described as “the linking of local and regional social-ecological systems to large-scale, networked socioeconomic and environmental drivers operating at distance” (p.1). This paper recognizes the importance of the world’s 2-2.5 billion smallholders in resource management and global food production. It suggests a rethink of earlier ecological categories such as ‘traditional’ farmers. A range of case studies examine the limits and opportunities for sustainable smallholder farming around the world. Some cases highlight a lack of governance support serves to undermine sustainability. Global supply chains of commodities are exerting a major impact on the land use of smallholders worldwide. The authors highlight smallholder capacity to be responsive and take advantage of lower levels of investments and more labor, which cannot be afforded by larger landholders. Smallholders also have an awareness of extra-local information and growing technological savvy. This paper argues for the importance of smallholder telecoupling in efforts to improve food and nutritional security in smallholder-based ecological intensification.