TP Organics Research Briefing
Scientific evidence on how organic food and farming contributes to sustainable food security

Introduction

This briefing aims to summarise the most relevant recent scientific publications that critically assess the productivity and sustainability of organic farming methods. The rapid increase in the quantity of scientific literature on this topic reflects the growing importance of the sector as well as the need for accurate data and analysis to inform policy makers. There are currently 2.7 million organic-certified farmers (of which 350.000 are in Europe) who have committed to sustainable farming practices. Can organic food and farming be upscaled in order to contribute to sustainable food system and food security?

Sustainability narratives

Local and global food systems are under pressure from a growing world population, changing consumer habits as well as pressing ecological problems. While scientists agree that there is no single solution, current political priorities focus primarily on increasing the efficiency of food production. By contrast, the Position Paper “Research & Innovation for Sustainable Food and Farming” (TP Organics 2017) presented three complementary narratives about the future of food systems: efficiency, consistency, and sufficiency. Systems should be efficient enough to feed a growing global population with considerably fewer inputs, less natural resource use, and lower environmental impact. Farm production methods should be consistent with the ecological balance, carrying capacity, and context of the region. Finally, the food system should become sufficient by reducing food waste, by limiting competition between food, feed and fuel production on arable land, and by the population consuming less animal protein.

A recent study in Nature Communication (Muller et al. 2017) measured sustainability outcomes for different organic farming scenarios in 2050, based on a series of models that considered a share of organic land of between 0 and 100 %, a reduction in food waste of between 0 and 50 %, and a reduction in arable land used for feedstuffs of between 0 and 100 %. These outcomes were compared to predictions provided by the FAO, assuming a 2050 population of 10 billion people. Implementing organic farming methods on a high share of agricultural land would require more land to feed the world population while not leading to higher GHG emissions. Instead, it would result in significantly reduced use of herbicides, pesticides as well as synthetic nitrogen, meaning a reduced nitrogen surplus, and thus enhancing biodiversity (Muller et al. 2017). To maintain a stable level of global cropland at 1. 54 billion hectares, and hence to avoid the increased land use while providing enough energy and protein per capita, it was recommended that less arable land should be used for feed production (-50 %), less protein and energy consumed from animal sources (-65 %), and considerably less food wasted (-50 %).

Sustainability trade-offs

The above study illustrates that when developing future food systems, there is a need to consider the trade-offs between social, ecological and economic performance. Maximising one aspect – such as the yield of crops and livestock – therefore conflicts with other aspects of sustainability. Organic farming (see Seufert et al. 2017), alongside other agroecological farming approaches and most ecological intensification strategies, shows lower yields. It still lacks scientific support, leaving potential for improvement. For this reason, TP Organics has advocated for a substantial increase in research spending to overcome technical difficulties and bottlenecks faced by organic farming and other system-oriented strategies.

While there is an important debate on whether organic farming is efficient only per unit of area rather than per unit of food output, this focus on efficiency only is partly misleading. Some negative environmental externalities such as GHG emissions are global in nature. In this case, organic farming tends to perform worse than conventional farming. For instance, nitrous oxides emissions per kg of food produced are higher for organic farming compared to conventional crops when the yield gap exceeds 17 % (Skinner et al. 2015). On the other hand, most environmental impacts are relevant within local ecosystem boundaries. Here, measures that relate impacts to total areas are most appropriate, and organic farming tends to perform better than conventional farming. For instance, nitrates or pesticides leaching into the ground water compromise the quality of local drinking water sources. Farming may harm the soil microbial and faunal biomass that is important to rebuild and maintain soil quality, and to reduce susceptibility to erosion. It may also adversely affect weed and insect diversity that, in turn, affects bird populations via the food chain. The latter are significantly higher on organic farms (Christensen et al. 1996, Kragten & de Snoo 2008). Thus, performance both per agricultural land area and per ton of food produced must be considered when looking at the ecological and social impact.

Economic performance

Yields and productivity

The per area yield gap between conventional and organic farming has been extensively investigated, with several hundred field trials and pair-wise farm comparisons (300-400 experiments), particularly in temperate zones (Europe, USA, Canada). Most scientific meta-analyses estimate the mean yield gap of the two systems in temperate climate zones to range between 20-25 % (Seufert et al. 2012, De Ponti et al. 2012, Ponisio et al. 2015). However, data from arid and tropical climates are anecdotal only, and hence excluded from these meta-analyses. The meta-analysis by Ponisio et al. (2015) shows that productivity in organic crop rotations is limited due to nitrogen use and availability, phosphorous uptake in very alkaline and acidic soils as well as shortcomings in organic management, particularly in terms of weed, pest and disease control. For organic farms to increase productivity per unit of land, a high level of crop sequence diversification and mixed cropping were recommended (Ponisio 2015).

Another meta-analysis indicates that organic farms are more resilient in water-restricted and drought-affected sites. It primarily gathered data from a study of more than one million farms in Africa (Hine et al. 2008), and further found that the yield of the organic farms was 116 % higher than on conventional farms. Organic farms are therefore likely to be more productive per area than conventional farms in such locations, both in the short and long term. The most important factors that positively correlated with higher output on these organic farms were those that made better use of natural capital such as building soil fertility, improved on-farm and in-field biodiversity as well as of socio-economic factors, e.g. improved human and social capital.

Many scientific studies consider productivity in terms of total factor productivity (TFP). As organic farms are usually low-input systems, their TFP is often better compared to conventional farms. Based on a 40-year comparative field trial with a seven-year crop rotation, Mäder et al. (2002) pointed out that there was 34-53 % less energy use and 97 % fewer pesticide inputs for organic than for conventional arable crops per unit of land area.

Farmer income

Many scientific studies have shown that organic farmers perform better in terms of income. This is due to lower input costs, organic price premiums in the market, and state support schemes (mainly in Europe) but also to the ability of organic agriculture to increase the economic resilience of farms through farm and crop diversification as well as soil fertility building. A meta-analysis of a global dataset spanning 55 crops grown on five continents compares the financial performance of organic farming. The profits of organic farms are 22-35 % higher compared to conventional farms due to organic premium prices (Crowder & Reganold 2015).

A long-term field study under tropical conditions in Madhya Pradesh, central India, compared the economic performance of rotations of soybeans, cotton and wheat (Foster et al. 2013). Although lower during the first year of conversion, for all crops and the first four rotations, the gross margin was significantly higher for organic compared to conventional farming. The field trial also included an evaluation of a conventional system with GMO Bt cotton that did not perform as well as the organic systems. In the second rotation cycle, the organic crops produced a 25 % higher gross margin than both the conventional and the GMO Bt crops (Foster et al. 2013).

Employment/job creation

Scientific evidence available regarding the labour requirements of organic compared to conventional farms indicates higher labour requirements per hectare of organic compared to conventional arable farms whereas similar or lower labour input is reported on organic livestock farms. Results for other farm types are mixed (Orsini et al. 2018). Additional labour is required when farms also engage with direct sale and on-farm processing. Organic agriculture increases the demand for labour in rural areas compared to other systems (Lampkin et al. 2015). In France, employment in organic farming increased by an average of 9.5 % per annum between 2012 and 2017 while average employment fell by 1.1 % in the rest of the agricultural sectors (Agence Bio 2017).

Demand/market data
When considering future research priorities, the strong growth in size of the organic market in recent years should be taken into account in order to better understand the impact of organic agriculture and its sustained potential. Organic-certified markets have grown – even throughout the global financial crisis – thanks to a new generation of health-conscious consumers that emerges both in Europe and globally. While most of the farming sectors in the EU have been facing a period of contraction, organic agriculture has demonstrated strong growth that even exceeds the number of farmers converting to organic. In 2016, EU retail sales of organic products totalled 30.7 billion euros, this market multiplying its size by 4.7 since 2007 according to data from the World of Organic Agriculture (Willer & Lernoud 2018). This very positive trend proves that there are still many market opportunities for certified organic food as well as clothing, cosmetics, and other non-food, organic-certified products in Europe.

Environmental performance

Above- and below-ground biodiversity
Organic agriculture is a system that relies on positive interactions with the landscape, farm diversification, mixed farming, crop rotation, closed nutrient and organic matter cycles as well as on nitrogen fixating plants. There is solid scientific evidence that organic farming increases species richness by 30 % (Tuck et al. 2014). Likewise, the abundance of both insects and weeds is higher in organic fields than on conventional farms (Niggli 2015), with positive impacts on bird populations (Kragten & de Snoo 2008, Goded et al. 2018). In the soils, where earthworm and microbial diversity play an important role for both yields and physical stability, organic by far outperforms conventional management (Lori et al. 2017, Mäder et al. 2002). There is moreover evidence that this below-ground biodiversity can have significant effects on the water-Infiltration rate (on permanent grassland with more than 10 years of organic management), and that this higher infiltration on a catchment level can reduce peak-flooding by 30 % (Sutherland et al. 2012, Wibbelmann et al. 2013). This also leads to substantially lower costs in flood defences due to lower peaks.

Carbon sequestration, soil quality and climate change adaptation
Recent studies highlight the potential contribution of organic farming to the mitigation of and adaptation to climate change (IFOAM EU & FiBL 2016, Altieri & Nicholls 2013). IFOAM EU and FiBL (2016) found, for instance, that a 50 % organic farming scenario in 2030 would see a potential 12-14 % reduction in GHG emissions in the agricultural sector in the EU. This is due to an increase in soil organic matter as well as a reduction in the use of mineral fertilisers. In a meta-analysis of 74 field trials with conventional and organic management, Gattinger et al. (2012) show that organic fields sequestered 450 kg more atmospheric carbon per hectare and annum than conventional fields. The mean difference in carbon stocks in the upper 20 cm of soil of the organic fields was 3.5 tons C per hectare higher compared to conventional fields, with an average duration of the field experiments of 14 years (Gattinger et al. 2012). Altieri and Nicholls (2013) additionally point out that the social and ecological management strategies used on organic farms could contribute to the development of “adaptive capacity” in light of increasingly extreme climatic events.

Reduction of nutrient losses, water protection

Water quality is an area where there is scientific consensus on the superior performance of organic agriculture. As no mineral fertilisers are used in organic farming, the risk of nutrient leaching and subsequent water pollution are much lower in organic than in conventional agriculture (Lori et al. 2017, Niggli 2015).

Health performance

Literature on this topic consistently demonstrates the positive health effects of organic diets, mostly thanks to lower levels of pollutants in organic food as well as to higher nutritional value. In terms of pollutants, there is a significant difference in the levels of pesticides, cadmium and nitrates between organic and conventionally managed agriculture (Baranski et al. 2014). This fact alone has greatly influenced consumer opinion, and organic is perceived as healthier and more nutritious (Seufert et al. 2017). While the evidence in favour of organic food having a higher nutritional value is less extensive, studies have shown a greater presence of beneficial nutrients in organic food such as Omega-3 fatty acids and anti-oxidants (Baranski et al. 2014, Baranski et al. 2017, Mie et al. 2017).

There is still a lack of literature on the impact of organic versus conventional diets on human health, particularly due to the positive correlation between organic consumption and other healthy habits more in general. A recent study, though limited in size, has demonstrated the superior performance of an organic diet in preventing metabolic syndrome (Baudry et al. 2017). Other research shows that a 100 % organic diet can help shift the balance away from diets heavy in meat and sugar if organic product prices are reduced. These studies compare a healthy diet as endorsed by, for instance, the UK government's "Eatwell" programme, to the current average unhealthy diet (Zasada et al. 2017, Schmutz & Foresi 2017). If both diets consisted of organic ingredients, the healthy diet would be cheaper for consumers because organic meat and sugar prices are relatively higher than organic vegetables, pules and cereals. While not implying that the healthy diet is vegetarian or vegan, it does reduce meat consumption, and increases the 5-a-day vegetable and fruit intake to one of 9-a-day, with potential added positive effects on health and wellbeing (Blanchflower et al. 2013).

Bibliography

Agence Bio (2017). L'agriculture biologique, un accélérateur économique, à la résonnance sociale et sociétale. http://www.agencebio.org/sites/default/files/upload/agencebio-dossierdepressechiffres-juin2018-bat_31.05.2018.pdf [Accessed 7 Jun. 2018].

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

Barański, M., Rempelos, L., Iversen, P. and Leifert, C. (2017). Effects of organic food consumption on human health; the jury is still out!. *Food & Nutrition Research*, 61(1), p.1287333.

Barański, M., Średnicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G., Benbrook, C., Biavati, B., Markellou, E., Giotis, C., Gromadzka-Ostrowska, J., Rembiałkowska, E., Skwarło-Sońta, K., Tahvonen, R., Janovská, D., Niggli, U., Nicot, P. and Leifert, C. (2014). Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. *British Journal of Nutrition*, 112(05), pp.794-811.

Baudry, J., Lelong, H., Adriouch, S., Julia, C., Allès, B., Hercberg, S., Touvier, M., Lairon, D., Galan, P. and Kesse-Guyot, E. (2017). Association between organic food consumption and metabolic syndrome: cross-sectional results from the NutriNet-Santé study. *European Journal of Nutrition*.

Christensen, D.K., Jacobsen, E.M. and Nohr, H. (1996). A comparative study of bird faunas in conventionally and organically farmed areas. Dansk. Orn. Foren. Tidsskr 90, pp.21-28.

Crowder, D. and Reganold, J. (2015). Financial competitiveness of organic agriculture on a global scale. *Proceedings of the National Academy of Sciences*, 112(24), pp.7611-7616.

de Ponti, T., Rijk, B. and van Ittersum, M. (2012). The crop yield gap between organic and conventional agriculture. *Agricultural Systems*, 108, pp.1-9.

Erb, K., Lauk, C., Kastner, T., Mayer, A., Theurl, M. and Haberl, H. (2016). Exploring the biophysical option space for feeding the world without deforestation. *Nature Communications*, 7, p.11382.

Forster, D., Andres, C., Verma, R., Zundel, C., Messmer, M. and Mäder, P. (2013). Yield and Economic Performance of Organic and Conventional Cotton-Based Farming Systems – Results from a Field Trial in India. *PLoS ONE*, 8(12), p.e81039.

Frison, E. (2018). Agroecology: Opportunities and challenges for European development policy.

Gattinger, A., Müller, A., Häni, M., Skinner, C., Fließbach, A., Buchmann, N., Mäder, P., Stolze, M., Smith, P., El-Hage Scialabba, N. and Niggli, U. (2012) Enhanced top soil carbon stocks under organic farming – a global meta-analysis, Working Paper. Proc. Natl. Acad. Sci. USA 109 (44), 18226-18231.

Goded, S., Ekroos, J., Domínguez, J., Guitián, J. and Smith, H. (2018). Effects of organic farming on bird diversity in North-West Spain. *Agriculture, Ecosystems & Environment*, 257, pp.60-67. [http://www.sciencedirect.com/science/article/pii/S0167880918300422]

Hine, R., Pretty, J. and Twarog, S. (2008) Organic agriculture and food security in Africa. (UNCTAD/DITC/TED/2007/15). United Nations, Geneva and New York.

IFOAM EU and FiBL (2016). *Organic Farming, Climate Change Mitigation and Beyond: Reducing the Environmental Impacts of EU Agriculture*. Brussels: IFOAM EU. Available online: https://www.ifoam-eu.org/sites/default/files/ifoameu_advocacy_climate_change_report_2016.pdf [Accessed on 25.07.2018].

International Federation of Organic Agriculture Movements (2008). Criticisms and Frequent Misconceptions about Organic Agriculture: The Counter-Arguments. Bonn: International Federation of Organic Agriculture Movements. Available online: https://www.ifoam.bio/sites/default/files/page/files/misconceptions_compiled.pdf [Accessed on 25.07.2018].

Kesse-Guyot, E., Baudry, J., Assmann, K., Galan, P., Hercberg, S. and Lairon, D. (2017). Prospective association between consumption frequency of organic food and body weight change, risk of overweight or obesity: results from the NutriNet-Santé Study. *British Journal of Nutrition*, 117(02), pp.325-334.

Kragten, S. and de Snoo, G.R. (2008). Field-breeding birds on organic and conventional arable farms in the Netherlands. *Agriculture, Ecosystems & Environment* 126, pp.270-274.

Lampkin N.H., Pearce, B.D., Leake, A.R., Creissen, H., Gerrard, C.L., Girling, R., Lloyd, S., Padel, S., Smith, J., Smith, L.G., Vieweger, A., Wolfe, M.S. (2015) The role of agroecology in sustainable intensification. *The Organic Research Center.*

Lori, M., Symnaczik, S., Mäder, P., de Deyn, G., Gattinger, A. (2017). Organic farming enhances soil microbial abundance and activity—a meta-analysis and meta-regression. *PLOS ONE* 12, p.e0180442.

Maeder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U. (2002). Soil Fertility and Biodiversity in Organic Farming. *Science* 296, pp.1694-1697.

Mie, A., Andersen, H., Gunnarsson, S., Kahl, J., Kesse-Guyot, E., Rembiałkowska, E., Quaglio, G. and Grandjean, P. (2017). Human health implications of organic food and organic agriculture: a comprehensive review. *Environmental Health*, 16(1).

Moakes, S., Mortimer, S., Nicholas, P., Padel, S. (2011). The Potential for Extending Economic Farmlevel Benchmarking to Environmental and Other Aspects of Farm Performance. Final report to Defra, Project DO0103. Newbury: Organic Research Centre.

Mueller, A., Schader, C., El-Hage Scialabba, N., Brüggemann, J., Isensee, A., Erb, K., Smith, P., Klocke, P., Leiber, F., Stolze, M. and Niggli, U. (2017). Strategies for feeding the world more sustainably with organic agriculture. *Nature Communications*, 8(1).

Niggli, U. (2014). Sustainability of organic food production: challenges and innovations. *Proceedings of the Nutrition Society*, 74(01), pp.83-88.

Ponisio, L., M'Gonigle, L., Mace, K., Palomino, J., de Valpine, P. and Kremen, C. (2014). Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B: Biological Sciences*, 282(1799), pp.20141396-20141396.

Orsini, S., Padel, S., Lampkin, N. (2018) Labour Use on Organic Farms: A Review of Research since 2000. *Organic Farming,* 4(1)**.** DOI: 10.12924/of2018.04010007.

Schader, C., Muller, A., Scialabba, N., Hecht, J., Isensee, A., Erb, K., Smith, P., Makkar, H., Klocke, P., Leiber, F., Schwegler, P., Stolze, M. and Niggli, U. (2015). Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. *Journal of The Royal Society Interface*, 12(113), p.20150891.

Schmutz, U. and Foresi, L. (2017). Vegan organic horticulture – standards, challenges, socio-economics and impact on global food security. *Acta Horticulturae,* (1164), pp.475-484.

Schmutz, U., et al. (2008) National-scale modelling of N leaching in organic and conventional horticultural crop rotations - policy implications. Poster at: Cultivating the Future Based on Science: 2nd Conference of the International Society of Organic Agriculture Research ISOFAR, Modena, Italy, June 18-20, 2008.

Schrama, M., de Haan, J.J., Kroonen, M., Verstegen, H., Van der Putten, W.H., (2018) Crop yield gap and stability in organic and conventional farming systems. *Agriculture, Ecosystems & Environment,* 256, pp.123-130.

Seufert, V., Ramankutty, N. and Mayerhofer, T. (2017). What is this thing called organic? – How organic farming is codified in regulations. *Food Policy*, 68, pp.10-20.

Seufert, V., Ramankutty, N. and Foley, J.A. (2012) Comparing the yields of organic and conventional agriculture. *Nature*, 485, pp.229-232.

Shewry, P., Pellny, T. and Lovegrove, A. (2016). Is modern wheat bad for health? *Nature Plants*, 2(7), p.16097.

Skinner, C., Gattinger, A., Mueller, A., Mäder, P., Fließbach, A., Ruser, R. and Niggli, U. (2014) Greenhouse gas fluxes from agricultural soils under organic and non-organic management – a global meta-analysis. *Science of the Total Environment,* 468-469, pp.553-563.

Soil Association and Sustain (2018). Myth and Reality. Organic vs non-organic: the facts. Soil Association.

Solagro (2014). Un scénario soutenable pour l'agriculture et l'utilisation des terres en France à l'horizon 2050. Toulouse: Solagro.

Sutherland, L., Gabriel, D., Hathaway-Jenkins, L., Pascual, U., Schmutz, U., Rigby, D., Godwin, R., Sait, S., Sakrabani, R., Kunin, W., Benton, T. and Stagl, S. (2012). The 'Neighbourhood Effect': A multidisciplinary assessment of the case for farmer co-ordination in agri-environmental programmes. *Land Use Policy*, 29(3), pp.502-512.

TP Organics (2017). Research & Innovation for Sustainable Food and Farming. Brussels: TP Organics. Available online: http://tporganics.eu/wp-content/uploads/2017/11/TPOrganics_FP9_position_paper_final_Nov2017.pdf [Accessed on 25.07.2018].

Tuck, S.L., Winqvist, C., Mota, F., Ahnström, J., Turnbull, L.A. and Bengtsson, J. (2014) Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. *Journal of Applied Ecology J Appl Ecol*. 2014 Jun; 51(3): 746–755. Published online 2014 Feb 7. DOI: 10.1111/1365-2664.12219.

Wibbelmann, M., Schmutz, U., Wright, J., Udall, D., Rayns, F., Kneafsey, M., Trenchard, L., Bennett, J. and Lennartsson, M. (2013) Mainstreaming Agroecology: Implications for Global Food and Farming Systems. Centre for Agroecology and Food Security Discussion Paper. Coventry: Centre for Agroecology and Food Security.

Willer, H., Lernoud, J. (2018). *The world of organic agriculture. Statistics and emerging trends 2018*. Rep., FIBL/ IFOAM, Frick, Switz.

Wittig, F., Heuer, T., Claupein, E., et al. (2010) Auswertung der Daten der Nationalen Verzehrsstudie II (NVS II): eine integrierte verhaltens- und lebensstilbasierte Analyse des Bio-Konsums. BÖL Abschlussbericht FKZ: 08 OE 056, 08 OE 069. Max Rubner-Institut; Georg-August-Universität Göttingen.

Zasada, I., Schmutz, U., Wascher, D., Kneafsey, M., Corsi, S., Mazzocchi, C., Monaco, F., Boyce, P., Doernberg, A., Sali, G. and Piorr, A. (2017). Food beyond the city – Analysing foodsheds and self-sufficiency for different food system scenarios in European metropolitan regions. *City, Culture and Society*.

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