Recent Advances in Biofarming Show Potential for Rapid Soil Restoration, with Carbon, Health and Livelihoods Benefits

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February 2021

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Submission on 'food and the recovery of nature, communities and livelihoods', call for evidence by the IPPR

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Foundations for the recovery of nature, communities and livelihoods cannot be provided without addressing the depletion and degradation of soils. The FAO have reported that there are only 60 years of harvesting left (Arsenault 2014), whilst a recent study suggests that 90% of conventionally farmed soils are thinning, with many soils facing complete exhaustion within 100 years, including the UK's and China's (Evans *et al.* 2020). This implies that the current agricultural system cannot feed the world; it can only do so temporarily at the expense of future harvests. It is also uncontroversial that this system is a huge net contributor to greenhouse emissions.

Food grown on degraded soils is also linked to adverse human health outcomes. Whilst this has long been postulated (Balfour 1943), modern research reveals biological mechanisms for this influence, including via the immune and digestive systems (Brevik *et al*, 2020; Blum *et al*. 2019; De Felippo *et al*. 2010 and Hirt 2020). Such effects may contribute significantly to many of the health problems facing modern societies (Miller 2013), since for example the human gut biome is linked to cancer risk (Davis and Milner, 2009), incidence of allergies (Dotterund et al. 2010; Aguilera et al. 2020) and obesity (Ley, 2010). Soil degradation also provides a plausible explanation for observed deterioration of the conventionally-measured nutritional content of foods, documented e.g. by Thomas (2007).

Significant recent advances in biological agriculture have potential to address these problems simultaneously. These work via the recently-demonstrated microbial pathway for the formation of soils, which may actually account for most soil formation (Kallenbach *et al*., 2016). This is a discovery of profound significance since it was previously believed that soil formation takes place principally via slow geophysical weathering of rock and incorporation of litter. The researchers created soil over 15 months *in vitro* by inoculating inert sand and minerals, then feeding the microbes synthetic root exudates. *In vivo*, soil microbia make diverse nutrients available to plants, including via root ingestion of microbes (Paungfoo-Lonhienne et al. 2010), and the plants in turn feed the soil microbia via root exudates, driven by photosynthesis, with beneficial effects in microbe-rich soils including pest and disease resistance (White *et al.* 2018, 2019). New soil organic matter results from the process via new microbial mass and microbial residues.

Paradigm shifts facilitated by this new understanding include one from *conservation* and *sustainability*-oriented agricultural practices to *regenerative* practices (Perkins 2020). Interventions aligned with this microbial pathway, to restore soil microbia and / or boost the plants' photosynthetic ability to feed microbia, have demonstrated potential to rapidly rebuild depleted agricultural soils and pastures, as I now document.

Examples include firstly increasing plant diversity. This has been observed to increase both soil formation and plant productivity (Chen *et al.* 2019; Prommer *et al.* 2020), with results contradicting conventional wisdom that soil carbon reaches saturation at relatively low levels. The effects of increased plant diversity on soils are exploited in biological farming via multispecies swards, crop and cover crop diversity, and are believed to extend to livestock diversity.

Secondly, appropriately managed livestock grazing can restore and build soils (Savory and Parsons, 1980; Wilson *et al*. 2018; Gillmulina *et al*. 2020). This is partly because the biome of the grazing animals and that of soils is intimately connected. Evidence shows that as part of holistic agricultural management (that is, with the agricultural enterprise and production system adaptively managed as a whole; Savory and Butterfield 1999), rotational grazing systems can be designed to restore soils such that pastures become a significant net carbon sink, notwithstanding enteric emissions of methane (Follet *et al*. 2001 ch. 16; Teague *et al*. 2011; Machmuller *et al*. 2015; Wang *et al*. 2015; Rowntree *et al*. 2016; Teague *et al*. 2016; Stanley *et al*. 2018). The evidence for this, and associated potential for intensive rotational grazing to reverse desertification, now cumulative, had been controversial, partly because holistic and adaptive managements systems do not lend themselves to evaluation methods designed for single-point interventions (Teague *et al.* 2013). (Since context is multidimensional and highly variable from site to site, it is necessarily not "the same" intervention that is repeatedly observed across sites, and adaptive management implies changes to the system in the course of observation.) The degree of adherence to these methods by farmers who have adopted them, is noted universally (Stinner et al. 1997; Sherren *et al.* 2012; Mann and Sherren 2018). The scientific literature on these grazing methods currently covers rangelands in the USA and Africa, reflecting the origin and early uptake of these methods in response to desertification. However, early reports of rotational grazing under holistic management in a European context by farmers also appear strongly beneficial to pasture productivity and soil formation (e.g. Perkins, 2020 in Sweden; Soil Association, 2020 in Scotland).

Thirdly, tillage has been shown to damage soil structure and soil carbon formation. Minimum till and no till techniques have been developed and taken up worldwide, for example as part of conservation agriculture, that have demonstrated positive effects on soil carbon formation and retention (Kassam, 2019). At the moment no-till is generally practised with herbicides, however, to terminate cover crops. Progress has been made in no-till organic techniques, which would optimise soil health, but these require further research, development and extension.

As indicated above, the restoration of soils sequesters carbon. Since root systems can extend deep into healthy soil, well below the 30cm depth regarded as labile, there is demonstrated potential for stable forms of carbon sequestration, stability increasing with depth. In addition to this, soil structure and moisture retention is improved under organic management (Durer et al. 2009), reducing flood risk and damage caused by flooding when water contains too much soil runoff.

The above developments suggest that, as a matter of urgency, significant encouragement is given to farmers to take up, and develop further, biological farming methods. These are agricultural methods that proceed via producing abundant and diverse populations of soil microbia, which then work for the famer in place of artificial inputs to produce healthy crops and animals. The autocatalysis identified between soil health, nutritional health of plants, and carbon sequestration has potential also to restore prosperity to farmers, including those on small farms, by reducing their costs (Perkins 2020), and to boost welfare generally by increasing health levels if widely adopted. Reduced inputs include artificial fertilizers and insecticides, and mineral additives. This has potential to significantly reduce costs to farmers, health risks from chemical inputs, and biodiversity loss.

Since there is increasing acceptance amongst the policy community that farmers should be paid for producing public goods, as under ELMS proposals, there is potential for near-term policy uptake. Policies should take the form of rewarding farmers for measurable positive ecological outcomes, as under carbon maintenance fee proposals (Byrne, 2010), *not* by rewarding departures from hypothetical baselines or by carbon trading, which generate too many opportunities for moral hazard (gaming the system). An example of a policy which is currently paying significant amounts for measured soil carbon sequestration is provided by the Australian Government's Emission Reduction Fund, which since March 2019 has been paying for measured carbon sequestration on agricultural land. This has rewarded biological agriculture adoption (Calver, 2019). In addition to such incentives there needs to be support for research and development into organic no-till techniques.

To optimise population benefit from uptake of biological farming, the relationship between farms and their surrounding communities needs also to be considered. On grounds of enhanced ecological resilience through increased localisation, consumer confidence in claimed ecological practices, and independence of communities from external economic shocks, community supported agriculture models merit wider support and adoption (Douthwaite 1996 ch6; Perkins 2020).

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