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Soil stewardship as a nexus between Ecosystem Services and *One Health*

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Separate concepts

Change and intensification of land management has resulted in degradation of the structure, status and functions of our landscapes (Foley et al., 2005; Jones et al., 2013). Agricultural activity, in particular, has led to depleted levels of natural capital and to the homogenisation of biodiversity and landscapes. The concerns over such widespread environmental change were a major stimulus for the Millennium Ecosystem Assessment. The Ecosystem Services framework, which this landmark assessment promoted, has since become firmly embedded in research and policy to improve land management and encourage sustainability.

The ecosystem services framework, updated under The Economics of Ecosystems and Biodiversity (TEEB) initiative, is comprised of cultural, habitat, regulating, and provisioning services (Figure 1). Soils contribute to various cultural services including intrinsic values and education, and as a habitat they contain an array of lifeforms with a vast genetic and functional diversity. Regulating services include decomposition of waste, disease/pest control and air quality regulation, and provisioning services include food, raw materials and medicinal resources. There are also, of course, trade-offs between regulating and provisioning services (Maskell et al., 2013). Both regulating and provisioning services are sustained by the interaction between natural capital and ecosystem processes. Furthermore, Dominati et al. (2010) made a clear distinction between soil ecological processes and ecosystem service delivery in a framework for the provision of ecosystem services from soil natural capital. This included both supporting processes for soil formation (e.g. nutrient cycling,

water cycling, biological activity) and degradative processes (e.g. loss of organic matter, erosion, decline in biodiversity) (Dominati et al., 2010). It is now fully evident that soils make important contributions to ecosystem services and that soil security can be seen as a centre-point for many global environmental sustainability challenges such as food security, water security, climate stability and biodiversity protection (McBratney et al., 2014).

The developing One Health approach (http://www.onehealthinitiative.com) aims to improve health by integrating and promoting collaboration between disciplines related to human, animal and ecosystem health (e.g. ecology, veterinary medicine, public health, microbiology, health economics). It encapsulates the idea that individual health, population health and ecosystem health are inextricably linked and, while giving One Health a precise definition is difficult, the scope for its applications is wide (Gibbs, 2014). Many initial One Health activities have been related to interdisciplinary measures to control zoonotic diseases but there is a growing realisation that many other topics are pertinent (Gibbs, 2014).

Overlap and nexus

One Health shares characteristics with other more holistic approaches to land management (e.g. biological agriculture) but it has broader applications beyond the physical, biological and chemical sciences, incorporating socio-ecological, cultural and economic elements (Zinsstag et al. 2011). It has a vision for interdisciplinary education between medical/veterinary schools and schools of public health and the environment, and, as with the Ecosystem Services

framework, there is focus on food security and disease regulation under a One Health approach (Figure 1). There is also awareness of the key potential trade-off between agricultural production (in terms of both crop production and stocking density of animals) and disease mediation (McMahon et al., 2015). Consequently, there is also a vitally important role for soils within this approach and this merits further exploration.

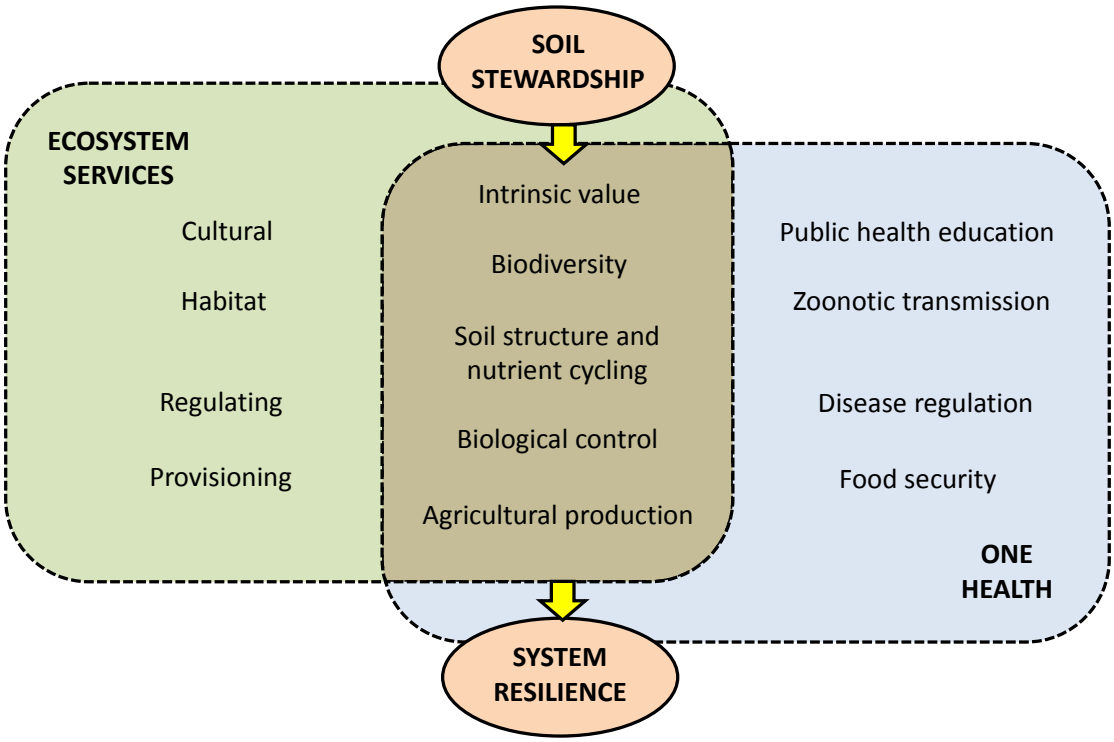

Figure 1. Soil stewardship as a nexus for better integration between Ecosystem Services and One Health. A synergistic research agenda could provide a platform toward more sustainable agricultural production and greater resilience and health in our socio-ecological landscapes.

There is clear overlap between the Ecosystem Service and One Health approaches. We consider this overlap as a valuable opportunity and argue that a more synergistic research agenda could be realised through improved communication and integration between these areas. Given the inherent

benefits to ecosystem service delivery and human health of better managing soil, we would propose that soil stewardship be the nexus to encourage potential synergy between these approaches (Figure 1). We use the term soil stewardship here because it is rooted strongly in a call for practical care and protection of soils as a non-renewable resource, with a focus on agriculturally productive soils (e.g. see Gregorich et al., 2006). There are parallels to the Ecohealth concept that integrates human health, ecosystem management and development (e.g. Bunch et al., 2011). However, the approach advocated here has broader implications while it offers a concrete focus on soil stewardship and its connecting role between ecosystem services, including resilient agricultural production, and direct and indirect benefits on human, animal and ecosystem health. Soil stewardship acts as a flagship case for the intrinsic value of natural resources and provides a valuable example for education of links between land use and health (Figure 1).

Research avenues

A synergy between these approaches would benefit from a consolidation of relevant knowledge from the large body of existing literature, following which research gaps, or areas lacking in studies, could also be identified systematically. Studies examining the effects of land management and its change on a range of ecosystem services are becoming familiar, but those making links to animal, human and ecosystem health are less abundant (e.g. Rhodes et al., 2013). We would highlight four broad areas for consideration:

1) Relationships between soil stewardship practices and health metrics at farm and landscape scales.

2) Mediation of exposure to chemical contaminants by soil stewardship practices; contamination through the food chain (e.g. uptake by crops of veterinary pharmaceuticals via manures) and transport to air/water.

3) Mediation of the dynamics of pathogenic organisms important to crop, animal and human health by soil stewardship practices, including landscape configuration.

4) Correlations and trade-offs between ecosystem services and health metrics at landscape and regional scales.

Large-scale environmental and soil surveys (e.g. Land Use/Land Cover Area Frame Survey [LUCAS], GB Countryside Survey) and research site networks (e.g. Long Term Ecological Research network), which generally have an array of co-located measures, could be exploited to help investigate such relationships. The call for soil security risk assessments by McBratney et al. (2014) could also be adapted to incorporate risks to animal, human and ecosystem health, thus encapsulating potential knock-on effects to those dependent on these soils.

Breivik and Sauer (2015) highlight that interdisciplinary teams are needed with expertise in relevant areas for research linking soils and health. The integration of medical, veterinary and environmental disciplines as promoted by the One Health approach together with an Ecosystem Services approach could both increase our understanding and better influence behavioural change, promoting soil stewardship for more sustainable agricultural production with greater resilience and health in our socio-ecological landscapes. Though consideration of funding pathways and ways of establishing research priorities

to address work on soils and human health remain an issue (Breivik and Sauer, 2015), there have been relevant successes at a national level (e.g. the UK Joint Environment and Human Health programme; Moore and Kempton, 2009).

Positive examples

As greater awareness of and insight into relationships between soil and health develops (Sandifer et al., 2015; Oliver and Gregory, 2015) positive examples emerge. Van Elsas et al. (2012) tested whether and how microbial diversity might hinder pathogen establishment in soil. It was shown that increased diversity of the soil microbial community controlled invasion by an *E. coli* strain (van Elsas et al., 2012), suggesting that soil stewardship practices promoting soil biodiversity could aid disease regulation.

Another example that calls for an ecosystem services – One Health approach with soil stewardship as the nexus is the zoonotic, waterborne bacterial disease Leptospirosis. Leptospirosis outbreaks have been linked with flooding, impeded soil hydrology and erosion that mobilize bacteria into waterways (Raghavan et al., 2012), while flood attenuation is a regulating ecosystem service (McBratney, 2014). Therefore, land use and soil management that will protect soil functions will benefit the delivery of ecosystem services as well as animal and human health. With further examples, soil stewardship could be seen as a cornerstone for the effective adoption of a One Health approach, particularly within agricultural ecosystems. The direct link between soil stewardship and human health may appear diffuse due to the number of confounding variables present (Breivik and Sauer, 2015; Oliver and Gregory, 2015). However, if

158 agricultural food systems are to be sustainable into the future, they must
159 minimise the risk of emerging diseases and meet the food requirements of the
160 rising global population, while protecting human health and conserving soil,
161 biodiversity and the wider environment (Jones et al., 2013; Purvis et al., 2013).
162
163 In summary, it is recognised that good soil stewardship could improve the
164 delivery of a range of Ecosystem Services including resilience in food
165 production and disease mediation (Foley et al., 2005). A One Health approach
166 with interdisciplinary research and improved communication and education
167 could contribute to the sustainable delivery of soil ecosystem services. The
168 integration of approaches and realisation of the importance of soil stewardship
169 to human, animal and ecosystem health at landscape and regional scales is
170 required into the future (McMahon et al., 2015, Rapport et al., 1998). It would
171 appear fitting, with 2015 as the International Year of Soils, that soil stewardship
172 could provide the link to encourage synergy between the Ecosystem Service
173 framework and the developing One Health approach.
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