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More effort is needed to implement and disseminate soil protection measures for tropical soils

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1. Introduction

Soils deliver key ecosystem services upon which society is reliant; these include provisioning services (e.g. food production), supporting services (e.g. carbon storage), regulating services (e.g. climate regulation, nutrient cycling and flood control) and cultural services (e.g. aesthetically pleasing landscapes). Yet, despite their fundamental importance, a growing global population is exerting an unprecedented pressure on soil ecosystem services (SES). Increased food production, to sustain consumption demand, has undermined supporting and regulating SES on a global scale. Specifically, land conversion and unsustainable land management over the past two centuries have caused 176 gigatons of carbon Gt C (or 8% of the soil carbon stock) to be lost from soils [1]. The efflux of soil carbon has made a significant contribution to present day levels of atmospheric carbon dioxide: 18% of the total CO_2 emissions is caused by land use change [2] . By 2050, land degradation, the associated loss in soil fertility and climate change are predicted to reduce crop yields by an average of 10% and up to 50% in some regions [1]. Although there are measures and initiatives that recognise the importance of soil, land degradation remains a global problem [3]. Those who benefit economically from land exploitation should principally be encouraged to recognise the urgency to reduce land degradation [4]. Furthermore, the negative impacts of land degradation on human well-being are likely to be most pronounced in locations where degradation overlaps with weak social safety nets [2]. In the future, land transformation and soil degradation are forecasted to prevail in Central and South America, sub-Saharan Africa and Asia [2].

A soil-centric approach is required to protect soils, to enable these soils to deliver their SES at edaphic maxima and thus support wider above- and below-ground ecosystems. In Brazil, the second biggest agricultural producer worldwide, farmers and other land managers must be more active in safeguarding soils and the ecosystem services soils deliver. There are 140 million hectares of degraded land in Brazil and about 30 million hectares are pasture areas at some stage of degradation [5]. These soils anchor tropical biospheres and must be prioritised for protection. Brazil is also the country with the largest area of organic soils in the tropics and the degradation of these soils remains unaccounted [6]. In Brazil and other developing countries, where upfront finance for environmental protection is limited, largely because of poverty and often complex political situations, soil protection is not given adequate attention. There is also a difficulty with a common language that facilitates effective dialogue between scientists, farmers and policy makers [7]; and insufficient technical assistance to deliver knowledge exchange on the ground. This is reflected in the marginalisation and scarcity of explicit soil protection laws and the ongoing pervasive land degradation in Brazil. This degradation continues apace to produce inexpensive food for the world at the expense of fragile and vulnerable soil resource.

To protect Brazil's wider natural capital, and that of other tropical countries, soil protection measures, such as the incorporation of SES in decision-making needs to be explicitly considered in environmental policy and laws. The consequences of inaction will be

far reaching, not only for the global population that consumes products cheaply produced in the developing world, but more acutely, for the local populations who are the least resilient to accommodate the consequences of SES impairment. In order that soils can provide local and global 'goods' we urge the governments responsible for tropical regions to develop effective strategies to protect soil natural capital and the ecosystem services they deliver.

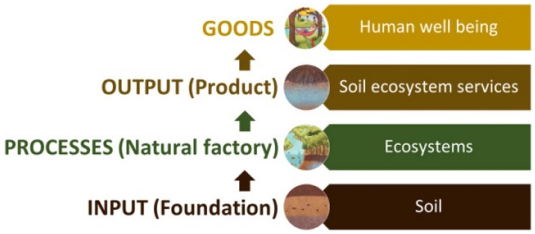

Figure 1. Soil as a fundament for ecosystems functioning and goods provided to the environment and humans.

2. World view

Benefits from soil, in their aggregation are often invisible, and thus are poorly appreciated by decision-makers and wider society [7]. Several concepts are discussed in the literature to support the assessment of the status of soils, such as soil quality, soil health or soil functioning. Soil quality and soil health are based on the concept of continued ability of soils to function as a living and vital ecosystem that sustains plants, animals and humans. Soil quality has been be used to a greater extent in scientific works, whilst the concept of soil health has been more prevalent in non-scientific circles [8]. The concept of soil function can be understood as flows that derive from natural capital stocks that benefit all of nature (human and non-human) [9].

The SES approach was proposed to highlight the vital role of well-managed soil for human well-being, and to instigate a better dialogue between science and decision makers [9]. This better dialogue can take place through the valuation of natural resources to better translate scientific results into an intelligible language for decision-makers and society. However, there is still disagreement as to whether a SES approach would be effective in protecting soils; or, if other paradigms such as soil quality, soil health or soil functioning would better support soil protection goals. To explore this further, we engaged key international experts and applied questionnaires to gauge perceptions of SES approach and its importance. Experts were selected on the basis that they have an interest in SES, they benefit from them and/or they could have an active or passive influence on ES provision [10].

Our survey highlighted that the majority of Brazilian and international respondents (15 out of 23) believed that it is important for farmers to understand the term SES and that a SES approach should be used as a mechanism to communicate with farmers regarding how their activities affect the natural cycles and processes that regulate the services provided by soils (see all responses in supplementary methods). Our results are aligned with a survey carried out by The Food and Agriculture Organization of the United Nations in the 'RECSOIL: Recarbonization of global soils' forum on July 17th, 2020. In this survey more than 700 researchers agreed that the focus of the Global Organic Carbon Agenda for Soil should focus on the provision of multiple SES. Respondents asserted that a SES approach would help landowners/users to better acknowledge the links between management of soil and environmental degradation. Therein, land managers, appreciating these links, may decide to invest greater effort and resource to care for soil with a view to maintaining agricultural productivity in the long term. In addition, a SES approach was perceived as a fundamental step towards valuing SES. In our survey, the claims that a SES approach would not be important for communication were linked to views that the term itself is not important; but rather, communicating the connections between land management and the flow of soil based 'goods' would be more effective.

The differences in perception of SES approach, as observed in our study, are reported both in tropical [11] and temperate regions [12]. These differences suggest that practitioners, policy makers and researchers should be more explicit in their uses of the ecosystem services concept in order to be correctly understood and to foster improved communication among stakeholders (see supplementary information—SES (e)valuation approaches provide opportunities to communicate the holistic 'worth' of soils).

One of the strengths of the ecosystem services approach is that it can accommodate values outside farming and highlight the dependence of socio-economic activities on the functioning of ecosystems. We go further, and propose an approach that sets soils as the foundation upon which other ecosystem services are reliant, and in which soils ultimately are linked to the provision of 'goods' (figure 1).

Soil needs investment to be able to continue delivering goods. To the ecosystem, these inputs can be endogenous (maintaining vegetation cover, rotation of crops, intercropping and mixed systems) and exogenous (such as fertilization or liming). We perceive soil as a natural factory (ecosystem) in which processes such as decomposition, nutrient build up, mineralisation and respiration occur. This leads to products, which are SES such as food provision and climate regulation that ultimately benefit human well-being.

3. Soil and natural capital (e)valuation

SES and natural capital valuation help to estimate future scarcity of soil resource and translate it into monetary value. Valuation is complex as environmental goods do not have substitutes and markets show 'divergence between private and social costs' [13]. Furthermore, the depletion of natural resources tends to increase with economic growth, and consequently there is an increase in the value of environmental resources over time [13]. Despite these paradoxes, the application of environmental economic approaches has been decisive in influencing and defining policies and governance for the protection of global natural capital [14, 15]. When the monetary and non-monetary benefits are more inclusively evaluated, including the long-term costs of inaction, the costs of environmental recuperation can be evened up by the benefits for human well-being [16]. Ecosystem values, both monetary and non-monetary, must therefore be understood and communicated as a basis for which decisions should be made for ecosystem management. Valuation may also improve the ability of decision makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that alter the use of ecosystems and the multiple services they provide [9]. For instance, an analysis of land use change in the watershed of Mogi-Guaçu and Pardo (Minas Gerais state, Brazil) highlighted that the value generated in terms of ecosystem services per unit of forested area was greater than the value that would be generated if the same unit was used differently, such as for sugarcane or pasture [17].

Land degradation occurs locally, even when driven by large-scale and transboundary processes, and it is spatially heterogeneous, and sensitive to the local context [4]. Communities that invest in the prevention and reduction of degradation must therefore have tangible and direct benefits from the land they depend on. To this end, natural capital accounting can be used to systematically describe nature's environmental, social and economic values [1] (see supplementary information and supplementary figure S1 available online at stacks.iop.org/ERL/15/111004/mmedia).

4. Plan of action

To improve soil protection measures we need to diminish the fundamental gap that exists in communication. There is a body of knowledge about soil provisioning of goods and this knowledge should be efficiently communicated. This process is not easy. To engage different audiences, scientists must leave their comfort zones and consider how non-scientists communicate [18]. We propose a seven-steps communications strategy to effectively disseminate soil protection measures using a SES approach (figure 2). The proposed model was designed based on the Brazilian example but can be adapted to different countries according to local scenarios.

Step 1 is to clearly define the issue the strategy must address. Here we consider weakening of SES delivery. Having defined the issue, the strategy must address the stakeholders to be targeted (step 2). From Brazilian experience, the stakeholders are landowners/users, decision-makers at policy level, technical assistants and a wider society. We consider specific outcomes relevant to each group that are linked to the loss of SES delivery (step 3). To effectively reach the defined outcomes through communication, it is important to understand the rationale behind it—why this communication is important for the audience (step 4). The benefits provided to the stakeholders through communications will ultimately promote the delivery of SES, as measured against a set of bespoke indicators previously defined (these depending upon the particular context). A top-down, bottom-up approach in messaging design (step 5) includes disciplines such as ethnopedology, that encompasses traditional and modern soil knowledge systems of local rural populations [18]. It is paramount that the message takes into consideration local traditional soil practices and incorporates landowners´ knowledge aligned with the scientific findings and existing policies. Information alone will not motivate audiences to listen and change their attitudes and behaviour [15]. To achieve effective communication, message design must translate scientific evidence into concepts in a way that will appeal to stakeholders and connect with their emotions, traditional and cultural values and beliefs, and personal benefits [19]. In addition, storytelling can benefit from textual, graphical, audiovisual or even theatrical narratives. Also, exploring scenarios and situations that are familiar to the target audience, using local cases as examples are a powerful way to stimulate the adoption of new habits and promote behavioural change. The media through which the message will be transmitted should be defined according to the profile of each audience, its habits and access to technology and communication channels (step 6). Farmers appreciate when scientists communicate in ways that are similar to 'people like me' [18]. Technical assistants/extensionists also play a fundamental role in communicating to farmers, as they need to hear the message from *plain language from plain-clothed people* [20]. It is then crucial to evaluate the performance of all steps of the communication strategy to understand the reason of failure and which step might be revisited within an adaptated approach (step 7). This strategic communication approach encompasses the expected outcomes and benefits for each of the audiences. It also indicates how different stakeholders can be reached through appropriate message channels.

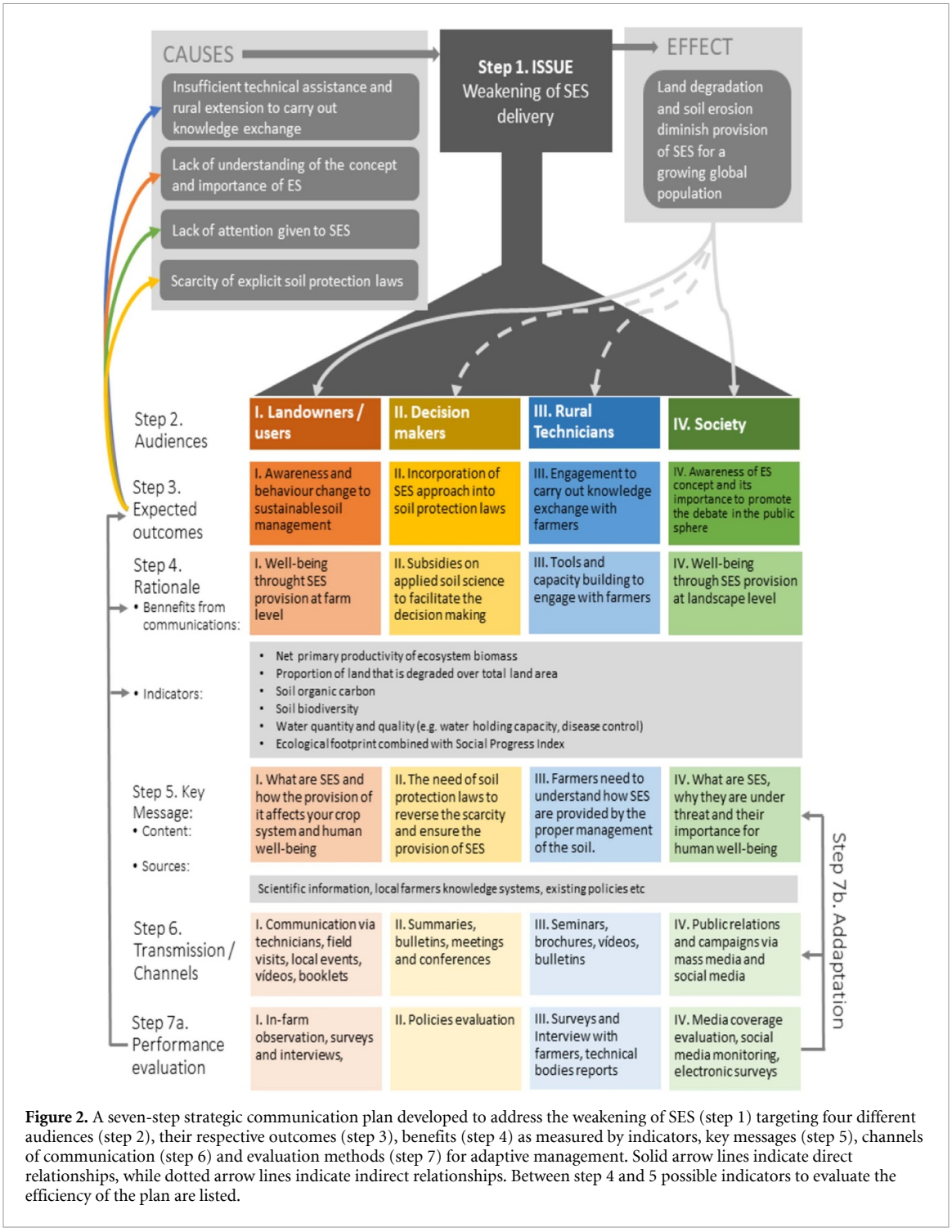

Figure 2. A seven-step strategic communication plan developed to address the weakening of SES (step 1) targeting four different audiences (step 2), their respective outcomes (step 3), benefits (step 4) as measured by indicators, key messages (step 5), channels of communication (step 6) and evaluation methods (step 7) for adaptive management. Solid arrow lines indicate direct relationships, while dotted arrow lines indicate indirect relationships. Between step 4 and 5 possible indicators to evaluate the efficiency of the plan are listed.

Soil is a fragile resource that crosses geopolitical boundaries. Damaged soil cannot provide public goods. Poorly managed soils and lack of knowledge on soils represents multiple threats to human health and well-being. This Perspective treats an urgent and neglected issue of soil conservation and regeneration in tropical regions, with Brazil as a case study. Brazil will only achieve Sustainable Development Goals number 2 (End Hunger), 11 (Sustainable cities and communities), 12 (Responsible consumption and production) and 15 (Life on land) by 2030, if investments in public policies that reach the most vulnerable populations continue. This means that SES need to be incorporated into public policies at all levels. Combining a SES approach with monetary and non-monetary valuation, and subsequently communicating it using our strategic plan, our paper proposes corridors of understanding about the value of soil and importance of adequate land management for biodiversity and goods provision for local and global population. Through such an apprach, a range of stakeholders can be reached and mobilised to encourage sustainability of soil stewardship. Appropriate management of soil resource must finally be

elevated on decision-makers' agendas so as to ensure future generations inherit this common good in its best possible quality.

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Author contributions

AEL and BR conceived the study; AEL, BR, AFR, IABP, FG, VP and BBNS developed the approach that sets soils as the foundation upon which other ecosystem services are reliant; AEL, AFR, IABP developed, performed and analysed the questionnaires; FG conceived and designed the strategic communication plan; AEL, BR, AFR, IABP, FG, VP wrote and revised the paper.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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