SOIL BANKER

Tools for Soil Wealth Evaluation and Management

Clear and intriguing science questions.

Describe the question at the heart of the sustainable economic development, human well-being, and nature conservation we propose to address.

Introduction. Soils provide food, fiber, and fuel to our growing world population. Soils are also key constituents in five of Earth's nine planetary boundaries (Röckstrom et al., 2009; Steffen et al., 2015): they regulate freshwater resources, nitrogen and phosphorus flows, and climate via long-term organic matter and carbon sequestration; they also buffer human land-use change, and support biosphere integrity (biodiversity). From a global economy standpoint, soils are a cornerstone of all supply chains and jobs involving plants and animals and, to some extent, of water resource and energy production; they are also foundational to many recreational and touristic industries.

We know that global demands for food, fiber, fuel, and water will keep rising as human populations grow. We also know that historic periods and places have undergone soil degradation to extents severe enough to cause collapses of economies and indeed civilizations (REF). Today, over 75% of global land is actively being managed (Fig. 1), and land degradation is afflicting about 30% of soils globally (Harden et al., In Review). Yet despite human pressure on, and potential degradation of, soils (Hurtt et al., 2011), there is no index or accounting framework to monitor or compare soil quality, health, or capacity to provide services. Being able to measure the maintenance and enhancement of the many ecosystem services and resources that provide must become a priority.

[Fig 1 – Global land-use change map and data]

Our Working Group (WG) brings together a group of individuals and organizations to develop and implement Soil Banker, an open-source and flexible management tool aimed at quantifying soil services and offering management strategies at any scale, for any stakeholder. **Our main implementation and science questions are:** (1) What are the most important soil services valued by land stewards and planners? (2) Which soil-data metrics can be used to quantify each soil service? (3) What are the steps required to quantitatively index the baseline value of soil services and their vulnerability under different land-use and climate change scenarios? (4) How do we simulate future soil service pathways (or trajectories) under changing management regimes using process-based ecosystem models? (5) What is the potential cost (economic, social, and other) of soil degradation under these scenarios?

Once Soil Banker and the Soil Service Index are established and linked to management and socio-economic models, our assessments lead to answers regarding (6) How sensitive or resilient are soil services to prescribed management practices, and how does sensitivity vary over space and time? and (7) Which management practices and intervention schemes would prevent and/or restore lost soil services, and could we enhance them in some cases?

The Soil Service Index within Soil Banker is a simple approach to a complex, interactive medium (soil). Yet, its simplicity makes it scalable and adaptable for evaluating the state of many soils from the perspective of diverse stakeholders. Soil Banker can be applied locally, regionally, or globally and it can be used by land stewards for choosing land-use practices, tracking tradeoffs among potentially competing soil uses or ecosystem services, comparing degradation states among lands, assessing capacities and costs for improvement, or linking specific conservation values to soil service indices (biodiversity, carbon offset, endemic species value, etc.).

Explain why these questions are critically important right now and how our work will add value to the current state of knowledge and under work underway in this area.

The case for prioritizing peatlands. Within the next 2 years under SNAPP, **our WG will establish a generalizable framework for soil services while focusing on peat-accumulating wetlands (peatlands).** Peatlands store about 600 billion tons of carbon in the form of thick soils that account for ⅓ of the world's soil carbon (Yu et al., 2010). The build-up of these vast quantities of carbon occurs over many thousands of years and results from the slow accumulation of partly decomposed plant remains (carbon-rich organic material) under water-saturated, oxygen-depleted conditions (Charman, 2002). Peatlands have dynamic greenhouse gas (GHG) exchanges of methane and nitrous oxides with the atmosphere which plays a role in regulating global climate (Joosten, 2008; Strack et al., 2014). These ecosystems also provide local and regional ecosystem services: they constitute important components of the nitrogen and phosphorus cycles, they store ~10% of the world's freshwater (Bartalev et al., 2004) and buffer large fluxes of freshwater on an annual basis, and they support much biodiversity, including iconic species such as the orangutan in Indonesia and the guanaco in Chile. While these ecosystem services have been recognized in many sectors (e.g., Joosten and Clark, 2002) and a voluntary standard for a peatland carbon market is emerging (e.g., UK's Peatland Code and VCS's VM0007 methodology now including REDD+ activities on peatlands), **peatland services have not been systematically quantified, or accounted for, at the global level.** Our work group's first major milestone will be to deploy an accounting of peatland stocks, a quantitative measure of peatland health, and projected peatland degradation or enhancement under different use cases, all that can be interrogated through the Soil Banker platform.

There are many potential stakeholders for the peatland module of Soil Banker. Peatlands are drained for agriculture, forestry, and harvesting, all of which are capable of significantly altering the role of peatlands in the global carbon cycle (Frolking et al., 2011). Once a peatland is drained, the peat layers get rapidly metabolized into carbon dioxide (CO_2) by fungi and microbes (Laine et al., 2009). This CO_2 is then released into the atmosphere where it contributes to the greenhouse effect and associated global warming. **Studies indicate that peatland degradation releases about 2-3 billion tons of CO_2 to the atmosphere annually** (Joosten et al., 2012). The **global demand for peat** has drawn large companies in many regions rich in *Sphagnum*-moss peatlands such as southern Patagonia, where an increasing number of peatlands are being drained and exploited to produce **highly marketable organic fertilizer, growing media, and garden bedding**. Peat is considered an exploitable subsoil mineral in Chile, and mining rights are not tied to land ownership (REF). In tropical and high-latitude areas, the industry is taking advantage of fertile peat soils to develop **large-scale plantations and silviculture**; in Sumatra and Borneo, large peatland areas have been converted to oil palm and rubber plantations. As of 2015, less than 6.4% of the regional tropical peat swamp forests were still intact (Graham et al., 2016). In the north of Alberta, landscape changes caused by currently approved **open-pit tar sand mining** are expected to release 12-52 million tons of stored carbon to the atmosphere (Rooney et al., 2012). In this region, peatlands are expected to be replaced by upland forest and tailings storage lakes.

Many groups aim to conserve and restore peatland resources (e.g., Quinty and Rochefort, 2003; Strack et al., 2013; Graham et al., 2016), but **metrics for soil services are urgently needed to inform and justify conservation efforts.** Science information is needed for preserving and restoring water storage (e.g., canal blocking and backfilling), revegetation, and general risk reduction particularly in relation to wildfire. In the scientific realm, global circulation models still lack the capacity to adequately represent peatlands (Baird et al., 2009). The same is true in local to regional ecosystem service models, where peatland dynamics (and soils in general) are often simply represented as categorical and static land cover/land-use (B. Chaplin-Kramer, Natural Capital Project, 2017). Overall, we argue that data and tools generated by our WG will help improve current and emerging hydrological management practices.

How will data synthesis and analysis by our group will be poised to make a high-impact contribution to science.

<u>The need for openly shared soil databases</u>. Several international organizations are interested in further developing and implementing natural solutions to climate change, including the **soil climate regulation function**. Regarding soils, The Food and Agriculture Organization (FAO)'s World Soil Charter, the Global Soil Partnership (GSP), the Intergovernmental Technical Panel on Soils (ITPS), and the 4 per 1000 initiative all recognize the following needs: (1) a digital resource center on soil-related issues and data dissemination (including freely accessible datasets and software tools), (2) model simulations regarding net soil carbon balance under different scenarios of land-use change and adaptation, mitigation, and conservation decisions, and integration in Earth System Models, (3) a collaborative platform to enable discussion at the science/policy interface and share local- to regional-scale practical implementation experience, and (4) identify, and agree upon, geographically relevant means to measure, report, and verify carbon stocks. **Our WG will contribute to each of these goals.**

<u>Vulnerability of global soil services to degradation under land-use and land cover change (LULCC) scenarios</u>. The present generation of land surface and ecosystem models included in the CMIP6 process only partially include soil processes that interact with soil health indices such as soil organic carbon stocks and fluxes, or water-holding capacity. Likewise, LULCC scenarios do not account for soil health vulnerability and risk assessment. Many emerging efforts show that soils can be managed for organic carbon accumulation (e.g., 4 per 1000 Initiative), but the interaction of such practices with other ecosystem services remain unclear.

<u>Critical data and knowledge gaps pertaining to peatlands</u>. Regarding peatlands, there have been recent efforts to compile and harmonize peat depth data, carbon and nitrogen stocks, and radiocarbon ages (Yu et al., 2010; Page et al., 2011; Loisel et al., 2014; Treat et al., 2016). Likewise, some data on other properties of peatlands, including GHG fluxes, water holding capacity, and biodiversity are available at the level of national statistics (e.g., Joostens, 2008). However, datasets that would be useful for quantifying peatland services have not systematically been synthesized from individual sites. Likewise, there are large uncertainties in current peatland extent estimates, with figures varying from 3.8 to 4.4 million km^2 based on national inventory data (Loisel et al., 2017) and from 3.3 to 4.7 million km^2 in spatially explicit global soil maps at different scales (Batjes, 2016; Hengl et al., 2017). **One of our outcomes includes a global peatland service map.**

List existing datasets and analytical methods we intend to use.

[Fig 2 - Venn diagram showing key datasets and analytical tools]

<u>Datasets</u>. Experts in this WG have access to the most comprehensive databases that currently exist on peatland stock and flux data (Fig. 2). That said, many datasets are still missing from these syntheses, including biodiversity and water storage data. **We propose to hold a series of hackathons** to rescue, gather, and ingest missing information that will be required to launch Soil Banker. The first hackathon will be sponsored by the International Soil Carbon Network (ISCN; chair: SNAPP co-PI Harden) and will be held at the American Geophysical Union Fall Meeting in New Orleans.

<u>Analytical methods</u>. We are familiar with the use of all analytical methods proposed, as the majority of them have been developed by members of our WG (Fig. 2). **We propose to add 'management routines' to the Holocene Peat Model** such as peatland drainage, canal blocking and backfilling, revegetation, and fire risk reduction via water table depth manipulation.

Outcomes that impact policy or practice.

Identify outcomes or results we expect our group to accomplish in the 24-month period in each of the following categories and list the target audiences who will use our product and how.

[Fig 3 - 9 Tasks with circles]

Our proposal to SNAPP. **We propose to develop and implement Soil Banker, a tool to evaluate and quantify a suite of soil ecosystem services, monitor change of these services, and guide management.** Our WG uses a bottom-up approach to initiate and facilitate the exchange of knowledge and expertise among soil scientists, modelers, social scientists, ecosystem service economists, and conservation specialists to inform soil services (Figs. 3-4; Table 1). **For the next 24 months, we will work toward completing the following tasks/outcomes:**

(1) rescue, compile, and synthesize all datasets useful for quantifying peatland services: these include organic matter, C, N, and water content, GHG fluxes, net primary production (NPP) and harvested NPP, biodiversity indices, etc. Data rescue will be done via a series of hackathons;

(2) establish open-source, community datasets and standards for data analysis: ISRIC has agreed to ingest all data that overlaps with their needs (see letter); other datasets will be archived at Lawrence Berkeley National Laboratory (WG member Abramoff).

(3) develop and share a Soil Service Index (SSI) for peatlands (Fig. 4): for any given site, we will: (a) assess a value to each specific soil service by comparing it to the data range and distribution from other sites, (b) weigh each service on the basis of socio-economic valuation, which will be aided by the InVEST team at Stanford University (WG member Chaplin-Kramer), and (c) calculate the SSI; soil services include: C and N storage, water-holding capacity, net C balance, functional biodiversity, habitat for iconic, rare, and endangered species, ecosystem productivity, and annual harvest.

(4) assess peatland sensitivity to management scenarios using a process-based model: management scenarios include drainage, harvesting, silviculture, mining, agriculture, flooding, and restoration; the ecosystem model we intend to use is the Holocene Peat Model (Frolking et al., XXXX). For non-peatland soils, routines will be implemented in Century (YYY) and Millennial (ZZZ).

(5) generate future Soil Service Pathways and associated changes in peatland valuation: these pathways or trajectories will show changes in peatland services over time under different scenarios of management; they will be implemented in global peatland models such as CLIMBER2 (Kleinen XXXX) and integrated into Earth System Models such as the LPJ (REF).

(6) develop and publish a suite of informative Soil Service Maps and Infographics: a global peatland service map will be made to identify priority areas, most vulnerable areas and which mechanisms are exacerbating their sustenance will

be identified, along with best practices, potential cost (economic, social, and other) of peatland degradation, net carbon balance, etc;

(7) launch Soil Banker as a free, online platform:
to provide intervention tools that make peatland services more risk-averse and resilient, identify a 'manageable range' for different peatland types under alternative climate and socio-economic scenarios, and educate the business community, the government, and our civil society on the importance of soils in our daily lives. The Soil Banker tool will be hosted by ISCN or GCP (contact).

(8) use Soil Banker to inform peatland managers for the following case studies:
(i) southern Chile (with the help of the Chilean Government (see letters)), (ii) Indonesia with the help of WG members S. Page, L. Rochefort, and L. Graham, northern Alberta with the help of WG members L. Rochefort and M. Strack, and others (TBD during our meetings in Santa Barbara); site selection may be aided by UNEP's Global Peatlands Initiative (chair: WG member H. Joosten).

(9) propose a carbon-based protection status for peatland conservation.

(10) define paths forward for modules in Soil Banker for crop, grazing, and forestry lands, and urban soils.

The power of our approach lies in distilling a comprehensive dataset and expert analysis into a one stop platform easily useable by a diverse set of stakeholders (Fig. 4). For example, scientists in charge of data compilation (Tasks 1-2), needing inputs from implementers, will establish values of services (Tasks 7-8), to capture the essence of soil valuation. Datasets will be gathered (Task 3) and provide soil modelers with scenarios for linking Soil Service Pathways to socio-economic valuation (Tasks 4-5). The collaboration also requires that the team understands how management practices influence peatland structure and function to provide realistic Soil Service Pathways and valuations (Task 5). Lastly, Soil Service Maps (Task 6) will to be adapted to the scale and specific needs of selected case studies (Tasks 8-9).

[Table 1 – task + associated target audience + how they will use our outcomes]

[Figure 4 ('case study', includes what the output of Soil Banker would look like)]

Implementation partners for our group who will continue to work toward longer-term outcomes after the SNAPP is concluded. Describe the evidence that these audiences need or are looking for the above results and how we will engage them from the inception.

[add text here on Monday]

Diversity in sectors, disciplines, and members.
List participant names, emails, affiliations, expertise, and confirmation status. Explain how our WG addresses diversity considerations (including discipline and sector, job function and career stage, country of origin/residence, additional demographic info on gender, etc.).

Our WG is composed of XX, YY, and ZZ early-, mid-, and late-career scientists, AA women and BB minority American citizens. Our group also includes CC workers living outside of the United States and DD in developing countries. All members have confirmed their participation. Affiliations and expertise are listed in Table 2. [and identify member who will serve as Technical Liaison (Kathe?)]

[Table 2 – list of participants and expertise]

Timetable of activities.
List proposed dates for meetings and milestones such as key outcomes and periods of implementer cultivation.

[Table 3 – list of participants and expertise]

Cost-effective use of SNAPP funding and leveraging other funds.
Detailed budget (worksheet) and list other funding sources.

. National Geographic Society -- Chile peats
. ISCN – hackathon #1
. graduate student support (TAMU, Stockholm)

. $$ for other hackatons

Literature cited.

[add text here on Monday]