Global Soil Partnership
Pillar 4 Implementation Plan

Towards a
Global Soil Information System

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Developed by Pillar 4 Working Group and participants from the INSII Workshop (8-10 December 2015)

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Summary

This implementation plan will provide the guidance to build the global soil information system. It will be based on soil data sets provided by national and other institutional soil information institutions according to product specifications. Data will be provided according to own national and institutional terms, minimizing centralized components. The design of the system is based on published standards for the exchange of digital spatial data, and also follows the architectural principles of the Global Earth Observation System of the Systems (GEOSS).

The plan offers background on each of the following data products:

- Soil Monitoring/SoilSTAT
- Soil profile data bases (Tier 1 and 2)
- Soil polygon data (soil maps)
- Soil property grids (Harmonized World Soil Database, low- and high-resolution soil grids)

Guidance through this implementation plan also includes issues such as data policy development and capacity development. For each data product and work item, the specific deliverables and responsibilities are mentioned, and a very rough budget figure is presented.

An important element for implementation plan is governance. A network of International Soil Information Institutions (INSII) will form the backbone of Pillar 4. The INSII network will be supported by a technical working group of soil information experts (Pillar 4 Working Group). Among other tasks, this working group will elaborate additional guidance for developing soil data products, which build on existing and new national and other local soil information, and for which extracts of such data fit the product scheme of the global soil information system. A Global Soils Spatial Data Infrastructure Centre (GSSDIC) will serve important elements of the spatial data infrastructure, together with FAO via SoilSTAT. The implementation plan contains the Terms of Reference (ToR) for each governance element.

Both the INSII network and the Pillar 4 Working Group will ensure that consistency is established between global level and regional level implementation actions. The global level data products and actions can be seen as the sum of national and regional-level products and activities, fitting together at a resolution suitable for global level assessments, for example the Status of the World's Soil Resources report, and the Sustainable Development Goals (SDG). At the same time, this global-level plan provides a framework for developing regional level implementation plans.

This implementation plan has been developed by a working group composed of representatives from the Regional Soil Partnerships, ITPS and the GSP Secretariat. The work started in December 2014 and after various iterations, the final draft was shared with focal points from the different regions to obtain their feedback. A revised version was prepared by the working group and shared with all GSP members that were invited to the INSII workshop (8-10 December 2015). During the first INSII workshop, that version was discussed, modified and finalized for its ample distribution.

1 Rationale and Background

1.1 The big picture: why this implementation plan?

The Global Soil Partnership (GSP) has been established by FAO members to promote sustainable soil management for addressing emerging issues such as food security and nutrition, climate change adaptation and mitigation, provision of ecosystem services, biodiversity, soil degradation and sustainable development. All of these require reliable, consistent and updatable soil information over the entire Earth to be used in various models, for example crop growth under different climate scenarios, hydrological cycle, C cycle, and land suitability for new or revised technologies.

As per the Rules of Procedure of the GSP, a Plan of Action[1] has been developed and was endorsed by both the Intergovernmental Technical Panel on Soils and the GSP Plenary Assembly. It provides recommendations for establishing an enduring Global Soil Information System. While the Plan of Action provides general recommendations, this Implementation Plan aims to identify the specificities to move into execution of the plan.

The endorsed Pillar Four Plan of Action outlines the three primary functions of the Global Soil Information System:

1. Answer critical questions at the global scale
2. Provide the global context for more local decisions
3. Supply fundamental data sets for understanding Earth system processes

Specific examples of critical global questions where the Global Soil Information System can provide needed information on the soil resource, include the following:

- Is there enough land with suitable soils to feed the world?
- Are soil constraints partly responsible for the often large gaps between actual and potential crop yields?
- Can changes to soil management have a significant impact on the seemingly unsustainable global demand for nutrients?
- To what extent and cost can changes to soil management contribute to climate change adaptation, particularly at the scale of smallholder agriculture?
- Can changes to soil management have a significant impact on atmospheric concentrations of greenhouse gases without jeopardizing other functions such as food and fiber production?
- How will the extent and rate of soil degradation threaten food security and the provision of ecosystem services in coming decades?
- Can water use efficiency be improved through better soil management in key regions facing water scarcity?
- How will climate change interact with the distribution of soils to produce new patterns of land use?

[1] http://www.fao.org/globalsoilpartnership/the-5-pillars-of-action/4-information-and-data/en/

The International Year of Soils (IYS) 2015 was very successful raising public awareness about the importance of soils for providing key ecosystem services that enable life on earth. The momentum developed by the IYS should be used in order to catalyze actions towards Pillar 4 implementation, especially now that soils are included in the Sustainable Development Goals[2].

1.2 Pillar 4 Plan of Action and its recommendations

This Implementation Plan is based on the Pillar 4 Plan of Action (PoA) endorsed by the second GSP Plenary Assembly (July 2014), and its four recommendations:

1. "An enduring and authoritative system for monitoring and forecasting the condition of the Earth's soil resources should be established under the auspices of the Global Soil Partnership to meet international and regional needs."

2. "The global soil information system [GSIS] should use soil data primarily from national and within-country systems through a collaborative network and the distributed design should include facilities for incorporating inputs from the new sources of soil data and information that are evolving rapidly."

3. "The global soil information system [GSIS] should be integrated into the much larger effort to build and maintain the Global Earth Observing System of Systems [GEOSS]. . . and close attention should be given to issues relating to the protection of privacy, intellectual property rights and terms of use."

4. "Implementation of the global soil information system [GSIS] should include a training program to develop a new generation of specialists in mapping, monitoring and forecasting of soil condition, with an emphasis on countries where improved soil knowledge is essential for food security and restoration and maintenance of ecosystem services."

The objective of the present plan is to implement the recommendations from the Plan of Action, subject to the following constraints:

1. Financial feasibility: in particular, earlier stages must use mostly in-kind funding, and a realistic budget estimate is provided for fund raising.
2. Technical feasibility to produce products with known and acceptable quality within the time and financial constraints.
3. Commitment to collaborative development consistent with GSP principles.

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[2] **SDG Goal 2, Target 2.4**: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that [...] progressively improve land and soil quality

SDG Goal 3, Target 3.9: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination

SDG Goal 12, Target 12.4: By 2020, achieve the environmentally sound management of chemicals and all wastes [...] and significantly reduce their release to air, water and soil (…)

SDG Goal 15, Target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

2 Governance

Although there is a formal governance structure explained in this section, it is important to recall that the principle of partnership applies – as in all GSP pillars – so that transparency and cooperation constitute the guiding principles.

2.1 Governance structure

The following figure summarizes the structure of the GSP implementation system focusing on Pillar 4:

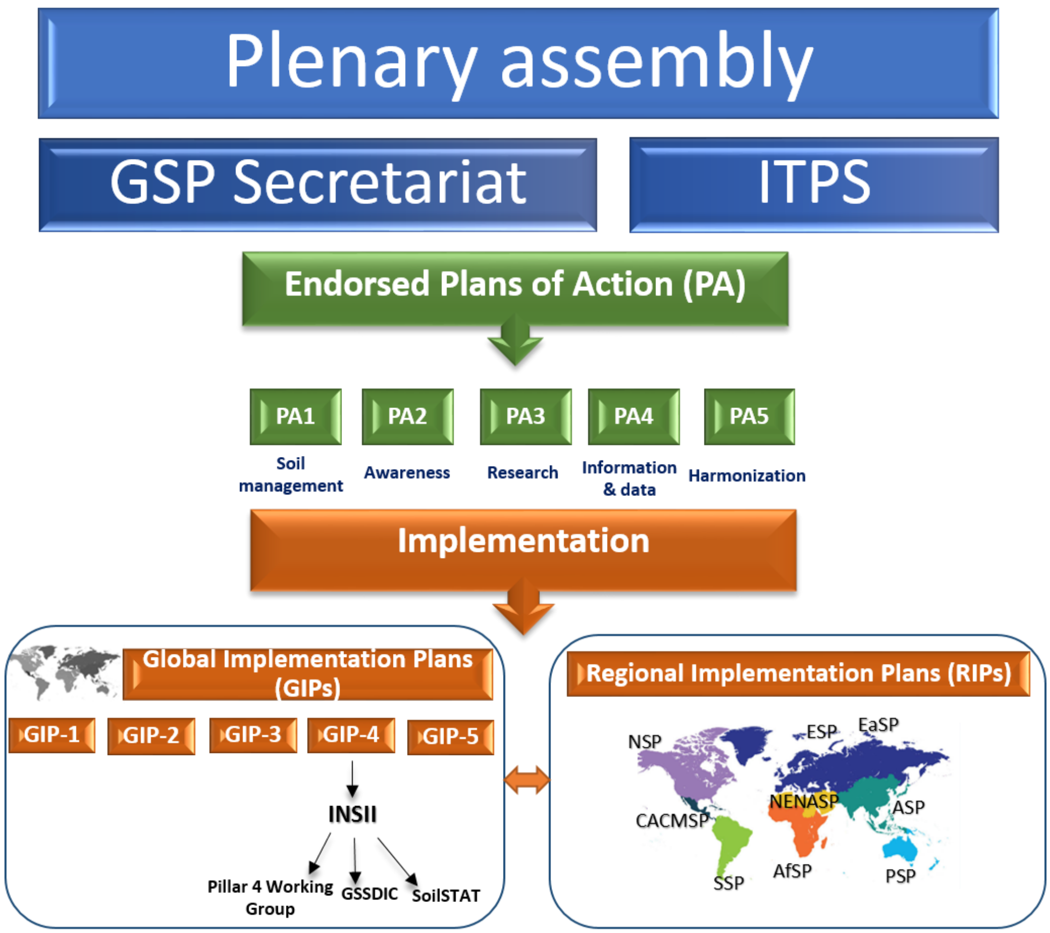

Figure 1: Structure of Pillar 4 in relation to the GSP Implementation process

The elements of the governance are the following; see below for details:

- the **GSP Plenary Assembly** as the main decision making body of the GSP where progress on Pillar 4 implementation is reported;
- the **GSP secretariat** to coordinate and facilitate the implementation of Pillar 4;

- the **Intergovernmental Technical Panel on Soils** (ITPS) as the body responsible for providing scientific advice to the Pillar 4 implementation;
- the **Regional Soil Partnerships** which operate via Regional Implementation Plans (which also include Pillar 4 regional activities). They are represented in the P4WG through their regional Pillar 4 Working Group Chairs, and ensure that regional and global implementation levels go hand-in-hand;
- the **International Network of Soil Information Institutions** (INSII) consisting of institutions nominated by their governments and GSP partner organizations that have the willingness to contribute to the Pillar 4 implementation. It is also the decision making body of Pillar 4;
- the **Pillar 4 working group** (P4WG) works as the supervisory body of Pillar 4 implementation. Also, it conducts tasks delegated by INSII;
- the **Global Soil Spatial Data Infrastructure Centre** (GSSDIC) as the technical backbone of the spatial data infrastructure.

a) International Network of Soil Information Institutions (INSII)

The INSII consists of nationally mandated institutions and other GSP partners that have the willingness to contribute to the global soil information system. The terms of reference are presented in Annex 1. In general, these institutions are also active members of the Regional Soil Partnerships. This Implementation Plan focuses on global level products that require regional and national inputs. This requires synchronization between the global and regional levels using this plan as orientation. Coordination may also be required to integrate various data holders within a country. All institutions which participate in the implementation of Pillar 4, whether sub-national or national, regional or global, can join the INSII network for collecting and distributing information on the status of the soil resource. INSII members are the main implementing institutions of this plan.

b) Pillar 4 Working Group (P4WG)

This group carries out the decisions of the INSII, and also makes decisions related to the efficient execution of the implementation plan, without going outside the strategic directions agreed on by the INSII. The terms of reference are presented in Annex 2. The P4WG has a term of three years from the date of acceptance of the present plan, renewable until the finalization of this plan in 2020. The P4WG is composed of:

1. GSP secretariat;
2. ITPS representative (chair of the ITPS Pillar 4 working group);
3. Representative from each Regional Soil Partnership (Pillar 4 chairs from each Regional and Sub-regional Soil Partnership);
4. Chair of the Pillar 5 Working Group (P5WG)
5. Representative of the Global Soil Spatial Date infrastructure Centre (GSSDIC)

The GSP secretariat will facilitate a kick-off meeting or video conference to elect a chair and to agree on a work plan based on the tasks specified through this Pillar 4 implementation plan.

Depending on the design of SoilSTAT (see below), the INSII may decide to add a representative from SoilSTAT to this group.

The group will monitor compliance with the implementation plan by all members, including the GSSDIC. Once per year, P4WG reports progress to INSII and the GSP Plenary Assembly.

The P4WG is also responsible for ensuring that products meet the agreed specifications, and are properly credited, before public release. It is also responsible for developing and establishing quality assurance and quality control procedures during the production of all products.

The exchange of harmonized soil information requires reference systems for harmonized soil classification, soil mapping, soil profile description, soil analysis and soil information modelling. A global soil information system also requires information and agreement about soil indicators and evaluation methodologies. These issues are dealt with in Pillar 5, so that action under Pillar 5 must be closely embedded into Pillar 4 implementation via membership in the P4WG.

c) Regional Soil Partnerships

Considering their fundamental role in the execution of Regional Implementation Plans the Regional Partnerships constitute a cell for the execution of this Pillar 4 Implementation Plan. Their representatives are members of the P4WG in order to ensure compatibility between regional and global actions and products under Pillar 4, and to look for synergies between the two levels. Most INSII members in fact are also members of their respective Regional Soil Partnerships. Therefore global and regional implementation plans must go hand-in-hand.

d) Global Soils Spatial Data Infrastructure Centre (GSSDIC)

The GSSDIC is a technical supportive body endorsed by the INSII network. It will host, develop, and maintain elements of the SDI needed for a distributed system. GSSDIC will be a member of the P4WG. Note that GSSDIC is not (in this role) a data provider; rather, it supports various technical elements of the Global Soil Information System.

The selection of an institute or organization to serve as the GSSDIC will be made by the P4WG. Upon that decision, the GSSDIC representative will join the P4WG as a member. The selection will be based on offers by institutions who express interest to an open call and demonstrate the institutional capacities fulfilling the following experiences and functions:

- Technical capability in hosting a distributed information system;
- Adequate permanent technical support staff;
- Experience with managing soil geographic databases;
- Experience with interoperable systems;
- Extensive experience in international collaboration, including intellectual property issues concerning soils data;
- Approval and support of its national government or regional consortium of its proposal, as expressed in its statutes or terms of reference, or explicitly by letter;

- Amount of self-funding complementing GSP contributions;
- Synergy of GSP and own SDI activities;
- Agreement to the Pillar 4 IPR/data policy requirements.

These selection criteria will be listed in an open call from the GSP Secretariat, which then also collects expressions of interest. Each submission shall contain a detailed proposal addressing the criteria listed before. The GSSDIC will be appointed during 2016, for three years, renewable (after decision of INSII) until the end of this plan in 2020.

2.2 Data policy

This section describes a starting point for a data policy for the Global Soil Information System, which will be extended and agreed by the P4WG as delegated by the INSII and submitted to the next GSP Plenary Assembly for approval.

- The GSP data policy will be influenced by the degree of access and exchange possible for primary data, metadata and derived data relevant to the aims and goals of the GSP.
- Wherever possible, the Global Soil Information System (GSIS) will implement and support a distributed data system where data are managed in custodial systems, published through web and other services and improved over time. For some custodians, this will not be possible and a central data repository will be needed, which is managed on behalf of the custodians, and with access controls driven by the custodian's laws and policies.
- Through partnership agreements, the GSP will encourage a full and open exchange of primary data, metadata and data derived for GSP purposes respecting relevant international and national policies and legislation with regard to intellectual property of the data and personal information. As an example of the latter, the name of the describing soil scientist may be considered protected information according to privacy laws.
- All data providers as well as all data users are required to respect national laws and policies and relevant international agreements.
- In addition, a code of ethics will be developed by the INSII to make explicit the mutual responsibilities and respect between INSII members for data access, citation and use.
- All metadata relevant to the GSP can be accessed by anyone so that the holdings are known and data providers can be approached for access under agreement or license.
- Some data (sets) may have inherited restrictions on accessibility to or use of the data, based on the conditions specified in the metadata provided by the data providers.
- It is possible to store information with geo-location. The precise geo-location could be degraded or removed from public access if privacy laws require this.
- The data will in no case be allowed to be sold by third parties.

In principle, INSII will strive for open access data sets if national and regional policies allow for it. This has proven to be a powerful multiplier, allowing for unanticipated uses of data, especially in multidisciplinary projects.

3 Activities

This section lists the activities to be undertaken; the following subsections summarize the deliverables which are produced as the result of these activities.

3.1 Monitoring, forecasting, and status reporting (SoilSTAT)

This activity is placed first in this plan, although it will not be the first to show results, because a main objective of the Pillar 4 Plan of Action is the establishment of a system for monitoring, forecasting and reporting periodically on the status of the global soil resources. This proposed system is referred to as SoilSTAT. This name mirrors the FAOSTAT family of global status databases and monitoring systems, for example the AquaSTAT global water information system[3], also from FAO. The FAO has other resource monitoring surveys, e.g., the Global Remote Sensing Survey of forest cover[4]. As with AquaSTAT, SoilSTAT is envisioned building on contributions from countries that have established baseline inventories and soil monitoring systems. A few countries have national programs to assess soil health, land degradation, soil pollution etc., but most of the world is not yet covered by any attempt to assess soil status. Beyond the AquaSTAT concept, SoilSTAT is intended to take the first steps towards consistent global monitoring and forecasting.

The detailed concept note for SoilSTAT, which includes the GSP soil information portal with products and services based on an underlying infrastructure for spatial soil data (SDI for soil), will be developed by FAO in the framework of the FAOSTAT family of global status databases and monitoring systems. Regarding soil monitoring, the Pillar 4 PoA explains: "before committing to a global system for monitoring and forecasting soil condition, a better understanding is required of the return on investment from these various sources of evidence. An initial task is to undertake a feasibility study to identify the most worthwhile components" (see "Actions", below). Such a feasibility study is then identified as the primary activity within this implementation plan.

Following are some considerations for the feasibility study.

- The first question is about the use of the statistics: which indicators are needed (input from Pillar 1 and Pillar 5), and which data are needed to derive them, by whom, and in which resolution? These may for example be data about the status of soil threats[5], which are also used in the first Status of the World Soil Resources report (FAO-ITPS 2015).
- A key question is how site-specific are the required statistics, in order to make useful reports on soil status to guide policy at the global and regional levels. AquaSTAT reports on a whole-country basis, with very limited mapping component (e.g., irrigated agricultural land per country); no spatial information about the resource condition or hazards is provided; the system relies on national reports containing mostly aggregated statistical data. A SoilSTAT system could be similarly constructed (and integrated into the overall FAOSTATS family), but this would have limited utility for decision making,

[3] http://www.fao.org/nr/water/aquastat/main/index.stm
[4] http://www.fao.org/forestry/fra/remotesensingsurvey/en/
[5] http://esdac.jrc.ec.europa.eu/content/esdac-themes

beyond country status reports. Ideally, soil status should be presented according to meaningful geographic units. Such spatially explicit soil status would allow decisions on priority areas for interventions. The size of reporting units needs to be supported by the map scale or grid resolution of national products. Once the global polygon coverage (see Section 3.2.2) has been established it may serve for stratification.

- Another question is the time interval of status reports. Any direct field observations will be fairly widely spaced; and emphasis is on long-term trends of degradation or soil quality improvement. Indirect indicators of soil status change may be inferred from short-interval or aggregated (seasonal, yearly) time-series of remotely-sensed imagery or derived products.

- For each required statistic, it must be decided what magnitude of change is relevant for policy, and what magnitude of change is detectable.

- Another question is, if a monitoring protocol is established, what indicators would be measured, using what measurement method, over what support (volume, i.e., surface area times depth), at what season, and with what time interval or continuous measurement method. The indicators may be region-specific, e.g., salinization is only a problem in drier environments. For consistency it is important that the same indicator is measured with the same, or at least compatible, method. The development of soil indicators – also required by Pillar 1 (soil management) - has been identified as a task for Pillar 5, because existing approaches to indicators need to be visited, compared and harmonized.

- Several countries have active monitoring programs, i.e., sites where repeated measurements of the same properties are made over time, so that trends can be determined. Examples are Scotland[6], Germany[7] and France (Reseau de Mesures de la Qualité des Sols, RMQS). Others have inactive monitoring systems that could be re-activated, e.g., Canada[8], or have set up new systems which are foreseen to be revisited in the future. However, for most of the world there is no program, no experience, and often no political demand for soil monitoring mostly because of a lack of awareness and/or useful information and associated lack of funding. Monitoring is expensive and although it is objective there is doubt as to its cost-effectiveness, compared to expert opinion based on opportunistic observations.

- Country and regional contacts could be asked to identify key locations from existing surveys which are indicative of soil status, and then asked to monitor those sites according to a protocol (see below), likely using soil spectroscopy as well as visual site assessments. Already AfSIS has a network of AfricaSoils sentinel sites and a Land Degradation Surveillance Framework (LDSF)[9]

- Another approach is to use the global soil information products developed in the other parts of this plan, in particular the HWSD2, along with global land use maps, to identify key locations that are

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6 http://www.sepa.org.uk/environment/land/soil/

7 http://www.umweltbundesamt.de/en/topics/soil-agriculture/soil-protection/soil-observation-assessment

8 http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3364

9 http://africasoils.net/services/data/field-data-collection/land-degradation-surveillance-framework-ldsf/

representative of soil / land use regions at a required resolution. The SoilSTAT system then would need to determine how to access and monitor benchmark sites at these key locations. There are other initiatives within the FAO such as the forest monitoring group[10] that includes some soil information, e.g. Tanzania[11]. Remote sensing (RS) may also be used; there are some RS-based approaches to estimate land degradation[12], and they might be used to infer soil status – although this is a tenuous link. However, the key point here is that through the distributed system countries can provide soil data in temporal dimensions so that the system can always have new data. This depends on appropriate training and technology transfer.

- If it proves impossible to locate sites according to a statistically valid sampling design, (part of) SoilSTAT would have to be based on representative sites, selected by expert opinion, each with its associated area of representativeness. Such a product might be open to the same criticisms as for earlier efforts to estimate global soil status, e.g., GLASOD[13].
- Another approach to monitoring is based on crowd-sourcing rather than expert opinion, although experts do evaluate the crowd-sourced information (for example, the GeoSurvey tool from AfSIS[14] or the LandPKS[15] initiative). Such a system can collect millions of visual observations and interpretations (from assessing aerial images) from properly randomly sampled geo-located sites. These can then be interpreted for surface features, e.g., presence and extent of gullying, proportion of visible bare rock, or salts, soil color, ground cover versus bare soil cover. These would only be surface observations via high-resolution imagery; another source would be field observations of simple and easily-identified soil properties, e.g., depth to rock or impeding layer, topsoil thickness, coarse fragment content, hand-determined general soil texture by depth, topsoil and subsoil color. If these were repeated over time, inferences could be made about erosion and changes in soil type due to loss of surface horizons.

Actions:

1. The P4WG will develop a concept note on SoilSTAT. This will be based on the FAOSTAT Family requisites as SoilSTAT aims to close an existing gap on soil information in this global tool. This will require the interaction with FAO and important partners and stakeholders such as the GSSDIC, IUSS working group on soil monitoring and others.

2. The following detailed aspects should be considered:

[10] http://www.fao.org/forestry/fma/en/

[11] http://www.fao.org/forestry/17847/en/tza/

[12] e.g., Bai, Z. G., Dent, D. L., Olsson, L., & Schaepman, M. E. (2008). Proxy global assessment of land degradation. *Soil Use and Management*, *24*(3), 223–234. http://doi.org/10.1111/j.1475-2743.2008.00169.x

[13] Sonneveld, B. G. J. S., & Dent, D. L. (2009). How good is GLASOD? *Journal of Environmental Management*, *90*(1), 274–283. http://doi.org/10.1016/j.jenvman.2007.09.008

[14] http://geosurvey.kutabiri.com

[15] http://www.landpotential.org/about.html

a. Who would use explicit spatial monitoring, forecasting and status information, and for what purpose, i.e., identify potential users and their needs for soil monitoring and forecasting. For example, the work of the ITPS requires an assessment on whether global-scale adoption of sustainable soil management is increasing or decreasing. If this need is accepted, also with the required spatial, temporal and thematic accuracy, it implies certain sampling and monitoring procedures.
b. Identify a set of representative empirical or simulation models to be used in forecasting and list their data requirements.
c. From this, determine what information is needed, and its granularity in space, time, and categorical detail. The PoA already suggests some targets: "Variables … should include the drivers of soil change: for example; land management practices, agricultural inputs (e.g., fertilizer, lime, energy costs, tillage), loss of high-quality agricultural land." For example, Brus (2014)[16] differentiates cases where areal means are needed, compared to others when point or block specific information is needed.

3. Investigate which national or regional reporting systems either directly report on soil status or from which soil status might be (partially) inferred. Starting points are the review by Morvan *et al.* (2008)[17] and the ENVASSO project report[18]

Notes:

1. Monitoring of so-called "soil condition", mainly related to soil fertility in low-input agriculture, via spectroscopy, has been demonstrated by Awiti et al. (2008)[19]

2. Some soil properties likely to be monitored: GlobalSoilMap[20] dynamic primary soil properties are organic C, pH, and plant exploitable depth (for the whole profile). Others that may be considered are Exchangeable Sodium Percentage, nutrients such as available and reserve P, plant-toxic ions such as Na^+ and Al^{3+} and surface properties such as crusting. Data are derived from "point" locations, which are either the centre of a grid cell or a grid cell spatial average. In addition, each grid cell (approximately 1 ha) could be assessed for proportion of erosion features.

Any property to be monitored must be measurable either at observation sites or with a calibrated whole-field sensor.

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[16] Brus, D. J. (2014). Statistical sampling approaches for soil monitoring. European Journal of Soil Science, 65(6), 779–791. doi:10.1111/ejss.12176

[17] Morvan, X., Saby, N. P. A., Arrouays, D., Le Bas, C., Jones, R. J. A., Verheijen, F. G. A., Kibblewhite, M. G. (2008). Soil monitoring in Europe: A review of existing systems and requirements for harmonization. Science of The Total Environment, 391(1), 1–12. doi:10.1016/j.scitotenv.2007.10.046

[18] http://eusoils.jrc.ec.europa.eu/projects/envasso/

[19] Awiti, A. O., Walsh, M. G., Shepherd, K. D., & Kinyamario, J. (2008). Soil condition classification using infrared spectroscopy: A proposition for assessment of soil condition along a tropical forest-cropland chronosequence. Geoderma, 143(1-2), 73–84.

[20] http://www.globalsoilmap.net/

Implementing institutions:

P4WG, FAO, INSII members

Budget:

- P4WG coordination 2016: $64k
- P4WG report writing 2016: $96k
- Statistician 2016: $128k
- P4WG members 2016 (5 @ 2 months each): $160k
- 2017-2020 Additional budget depending on design; estimate 2 FTE + field activities = $370k + $200k = $570k

Total budget: $1.108k

3.2 Information system development

The PoA calls for three kinds of data products to be provided as GSP outputs: (1) soil profile/point data, (2) global polygon coverage, and (3) global grids. The first two can also be inputs to the development of the third.

3.2.1 Soil profile and point data

A two-tier model is proposed by the PoA: Tier 1 (comprehensive, open) and Tier 2 (controlled, representative); Tier 2 may be a representative subset of Tier 1 in some systems or could be a separate collection. Both tiers can include legacy profiles (collected in the past, with date of collection noted) or newly-collected soil profiles. There is no provision in Pillar 4 for the collection of new point data; this is the responsibility of INSII members, within their mandates. In both cases, Tier 1 and Tier 2, data can be provided via web services from the data owing institution ("distributed system"; preferred) or via the development of a centralized data repository. This data can also be provided at the level of the Regional Soil Partnership, for example SISLAC in the case of the South America and Caribbean region. The host institution for the centralized approach will be decided depending on the design of the spatial data infrastructure and agreements and requirements by the data providing organization. The institution has to be neutral in terms of access (i.e., no preferential access for different GSP institutions). It must ensure that copyright and privacy policy, endorsed by the GSP Plenary, are respected. It will harvest data as far as possible through web services, and provide services for the data of the central repository.

The spatial component of the soil profile locations can be either the point location (x-y coordinates) in different accuracies (1m, 100m or 1km) or in relation to other soil spatial data sets relevant for this pillar (e.g. global soil polygon map, HWSD2). This is especially true for so-called derived soil profiles[21], which represent average properties of a spatial unit as in soil maps. Both, derived and observed soil profiles can

[21] A derived soil profile is a non-georeferenced profile that can be derived (e.g. averaged) from one or more observed profiles (INSPIRE ThematicWorking Group Soil http://inspire.jrc.ec.europa.eu/documents/Data_Specifications/ INSPIRE_DataSpecification_SO_v3.0rc3.pdf). A derived profile is meant to be representative of a certain extent of the soil cover at the reference scale; it is also used to avoid problems related to data ownership and privacy.

be included in the Global Soil Information System, at Tier 1 as well as at Tier 2, if this is clearly specified in the respective metadata.

3.2.1.1 Tier 1 – comprehensive soil profile and analytical database

This is a large soil profile and analytical database for the world without the stringent requirement for a minimum parameter set or representativeness which often severely limits the number of available profiles. The objective of such a database is to provide access to as many digital profile data sets as possible. This must include metadata describing the data sets (e.g. method of data collection and analytical procedures), so that utility can be assessed and some harmonization steps may be applied after Tier 1 soil profiles are accessed and used.

Actions:

1. Identify soil data providers and, in cooperation, collate metadata on their holdings (number of profiles, conditions for sharing, etc.) and their copyright, privacy and access protocols, as well as their willingness and capacity to share (a) to a distributed system, (b) to a centralized system. It is expected that soil data providers comply with their national or regional mandates and laws regarding contributions to the distributed system and these will guide the extent to which the system can be populated.
   - Contact INSII members, other research institutions and universities, leaders of relevant data collection projects and commercial holders of profile and other point data (e.g., soil testing records) and request contributions of data that meet the protocols.

2.a. Develop the data infrastructure: web platform and data templates
   - for a distributed system, including on-line access to this system.

2.b. Develop the infrastructure for a centralized system, including on-line access to this system.

3. Populate the Tier 1 database:
   - For submissions held at the original data provider (distributed access):
     a. Set up data transformation, discovery, view and download mechanisms to allow visitors to the Tier 1 portal to find relevant records which are interoperable with the data of the central facility.
   - For submissions to the central database:
     b. Initially, store such datasets as-is in the central database with appropriate metadata including URLs to the originating institutions.
     c. Screen submitted data sets for possible inconsistencies using simple checks (basic quality control of original values and expressions). This is not yet harmonization (see Tier 2, below).
     d. Compile data using agreed data exchange standards and encoding rules, with initial focus on a limited set of key soil attributes as considered for the other activities of this plan. Includes standardization of measurement units and automated quality control to flag unlikely values. Providers may have their own quality control systems that can be applied before the central database system.

e. Apply consistency and plausibility checks. If possible, after input from Pillar 5, develop and apply procedures for the harmonization of soil analytical data.

f. If possible, correlate/re-classify the soil profiles according to the World Reference Base (WRB) 2014. This is best done by the original data providers prior to submission to the central database. If this is not possible, existing conversion rules may be used. If a Universal Soil Classification (USC) is approved by IUSS, this step can be re-done with the new system, as part of an effort to correlate the UCS with widely used systems.

g. Release the first version of Tier 1 soil profiles, based on the present set of 'shared' datasets including data from the central repository.

h. Develop and apply a generic and simple template (data formats) for up-loading soil profile data sets. In case of data sources/providers with large quantities of soil profiles (> 500-1000 profiles) this template maybe individually adjusted (for exam-ple, in the case of SISLAC).

i. Data provision through web services requires that a uniform data ex-change standard is available, based on recommendations of IUSS WG SIS, ISO 28258 and GSP Pillar 5 SoilML-related work.

Implementing institution:

To be selected by the P4WG

Budget:

This project has two phases: the initial design and implementation, and the continued population of the database.

1. Initial design and implementation of all actions 2015-2017: $370k
2. Technical support 2016-2018: $64k a^{-1}$ = $192k total
3. System costs at the central institution: 2016-2018: $32k a^{-1}$ = $96k total
4. System costs for INSII members hosting nodes of the distributed system: as (3) for each.

Total budget: $658k

3.2.1.2 Tier 2 – world reference soil profile and analytical database

This is a "world reference-soil database" containing well-described and analysed soil profiles. Technically, it can be a subset of Tier 1, but it can also be compiled of other soil profiles. However, the Tier 2 specifi-cations will contain requirements on the content, quality and documentation of soil profile data. Tier 2 includes harmonized and quality-assured morphological, physical and chemical data for soil profiles which are globally representative of geographic regions, major soil types, and ecologically, agriculturally or sci-entifically significant soils. This database is intended as the most reliable reference possible to support the development of other products in this plan (e.g. soil profiles representative for the global soil polygon map, or the HWSD2). Depending on the national or institutional data policies, an exact location may not be provided. However, spatial referencing is often a key user requirement. At least, a spatial relation (e.g. soil mapping unit) should be provided for this Tier.

Note that some of these actions have already been taken for the WISE database, but also the GlobalSoil-Map project, and IUSS Universal Soil Classification working group, and that experience should be used as much as possible. This knowledge will be contained in the Tier 2 specifications document.

Actions:

1. Develop the Tier 2 concept description and technical specifications building on existing experiences from data bases such as WISE, including
   - minimum data requirements for Tier 2 soil profiles, including properties, profile description, site description, and analytic methods.
   - harmonization methods (along with GSP Pillar 5 implementation) to allow soil profiles to meet the minimum data requirements.
   - stratification, e.g. by geographic region and WRB reference soil groups
2. Invite INSII members and related institutions to nominate candidate profiles
3. Building on the Tier 1 technical web infrastructure, develop a web interface for uploading Tier 2 data sets.
4. For the nominated Tier 2 data sets that are either harvested from web services, or uploaded to the central repository, develop and document a generic database structure.
5. Populate the Tier 2 database:
   - Identify a set of harmonized, representative “reference profiles’’, using best available soil profile holdings, including nominated Tier 2 profiles, and evaluations of the Tier 1 soil profile data base
   - Develop and apply harmonization routines where necessary; conduct quality assurance
   - Add selected records to the database via GSP portal, each keyed to its soil-geographic stratum. Preference should be given to profiles that have a publishable geo-location, since these locations can be displayed on soil maps and base layers, e.g., Google Earth, to help visualize the profile’s context.

Implementing institution:

- Institution providing infrastructure, evaluations, quality control, to be selected by the P4WG;
- INSII members, to select and provide candidate soil profiles, if possible apply harmonization routines and upload profiles

Budget

- Database specialist 2017-2018: $48k a^{-1}$ = $128k total
- Technical support 2018-2019: $64k a^{-1}$ = $128k total
- Soil geography specialist 2017-2018: $90k a^{-1}$ = $180k
- Web developer 2017: $64k

- INSII members with national support and/or in-kind

Total budget: $500k

3.2.2 Global polygon coverage and supporting classification

The PoA discusses the merits of a world soil polygon map and the recommendation of the ITPS to replace the FAO/UNESCO Soil Map of the World (1:5M, 1971-1980). This product suits users requiring an overview of global soil geography. The polygon map consists of discrete map units with accompanying soil classification as well as soil properties at the map unit level. Soil classifications group soils for understanding soil-landscape relations, for land suitability evaluations, and for land management. This was recognized by the legend of the FAO/UNESCO Soil Map (FAO-UNESCO 1974).

It is a common observation that many users of soil geographic information are more easily able to visualize polygon maps that relate soil distribution to visible geography (terrain, hydrology, settlements, land use), especially at large or medium scales, rather than to understand gridded maps. Even at small scales, polygon maps show soil regions that can be easily explained to stakeholders and used for stratification (a similar concept to the GAEZ). Soil polygon maps can serve as covariates for digital soil mapping, often showing sharp boundaries that cannot be easily captured by point data, e.g., swamps and marshes.

In order to update and improve the above-mentioned Soil Map of the World, the Pillar 4 Plan of Action refers to SOTER[22] (acronym for "Soil and Terrain Database"). This was suggested because SOTER has provided the digital soil-related spatial assessment at 1:1Mio scale (or larger) for many countries in Africa, South America, and Asia. SOTER uses one of the two international standard soil classifications, the World Reference Base (WRB). The existing SOTER has covered large areas of the world at various scales (1:5M to 1:250k, corresponding to polygons with a minimum legible area (MLA) of 625 km^2 to 1.56 km^2, with most country products at 1:1M, i.e., MLA = 25 km^2).

Recently, the SOTER method has been updated through the EU FP7 project "eSOTER"[23]. There, a consistent digital (automatic, algorithmic) landform classification method was developed building on the globally available cost-free digital elevation model SRTM, combined with parent material data from re-interpreted geological maps. The advantage of e-SOTER is that it can rapidly produce a useful landscape segmentation in those areas where national polygon coverages at appropriate scale are non-existent or not yet provided by national institutions. It was also found that the eSOTER approach offers a simple approach to revise older SOTER maps, but also incorporate existing national soil polygon maps in an overarching harmonization system which would yield a consistent conceptual soil map. It is important to keep the update of the digital Soil Map of the World as simple as possible building on existing national soil polygon data sets. In fact, the progress of updating the Harmonized World Soil Database with underlying national soil polygon maps shall be utilized here (see also Chapter 3.2.3.1). eSOTER may be seen as an

[22] http://www.isric.org/projects/soil-and-terrain-database-soter-programme

[23] http://esoter.net

umbrella method for gap filling and for developing consistent content and geometries throughout the globe. eSOTER has also developed specifications for sharing eSOTER data sets in a distributed, web-based design (specifications for web-based data exchange through a common soil information model, see Pillar 5). The distributed approach to the revised Digital Soil Map of the World could resemble the OneGeology design[24].

Actions:

1. Develop the specifications and methodology for revising and updating the Digital Soil Map of the World with the design scale 1:1Mio. It will involve national soil polygon data sets (soil maps, SOTER maps) anywhere from published scales 1:500k (even 1:250k for smaller countries) up to 1:Mio. The methodology for integrating these data sources including gap filling may build on eSOTER.
2. Review and utilize polygon coverages 1:1Million or larger, that were the source for HWSD v1.2 and its update HWSD2 (see below). For remaining gaps, national soil maps shall be utilized. In case gaps still cannot be filled, eSOTER maps may be produced.
3. Establish links to representative Tier 2 soil profiles, fill gaps if necessary.
4. Implement central coordination of specification implementation (including capacity building); centralized provision of global level eSOTER covariates (land forms, parent material) and global topography; apply gap filling, legend development, generalization and aggregation where necessary, and according to the P4WG product specifications.

Implementing institution:

P4WG for developing the product specification, INSII members to fill data gaps, voluntary action by INSII partners and GSSDIC for centralized components.

Budget

- Soil database specialist: \$50k (2016), \$80k a^{-1} = total \$240k (2017-2019)
- In-kind contribution by the selected GSSDIC of \$150k from own sources, spread out over 2016-2019.

Total budget: \$240k

3.2.3 Global grids

Section 5 of the PoA specifies a staged approach to a global grid: “The recommended approach involves a pragmatic and short-term solution of improving of the existing global data products and then adopting a staged approach to eventually achieve a fine-resolution global soil grid using digital soil mapping”.

[24] http://portal.onegeology.org

The PoA identifies three gridded products: (1) an updated HWSD, (2) a moderately-fine resolution [1km] global grid of soil properties (Version 0); (3) a fine-resolution [3 arcsec] global grid of soil properties (Version 1).

3.2.3.1 Harmonized World Soil Database Version 2 (HWSD2)

With efforts made by the GSP in Latin America, the Near East and North Africa and Asia, there is new regional soil data and information that is available for updating the Harmonized World Soil Database (HWSD) as well as the global soil polygon coverage (see above). Both activities also feed back into the availability of soil profile data (Tier 1 and 2). The current HWSD is v1.2[25], the result of a collaboration between the FAO with IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), and the Joint Research Centre of the European Commission (JRC).

ISRIC has on its own initiative made recent progress in developing a product internally referred to as "WISE30sec"[26], which is an update of HWSD v1.2 with improved basis polygons, a single classification system (FAO Revised Legend 1990[27]), estimates of uncertainty and information at seven soil depths of representative synthetic profiles, following the SOTER specifications. Soil parameter estimates are recomputed for each component soil unit using an elaborate methodology that evolved from earlier work with FAO, IIASA and ISRIC (since 1997). This recent technical work from ISRIC can be used to complement the progress from other GSP partners to obtain new regional gridded information about soil properties.

Together these advances can stimulate the process of producing an updated HWSD, here referred to as HWSD2, as a collaborative project of the various data providers representing countries in the GSP. The HWSD2 is intended as a replacement for the HWSD v1.2, a rasterization of polygon maps with varying nominal scales from 1:1M to about 1:250k, some of which are coarser than the target grid cell size of 1 km. The HWSD is a familiar-looking product to soil surveyors and soil map users, because it is based on polygonal map units and representative profiles.

This action proceeds in parallel with the global polygon product (see 3.2.2, above). The following actions should be taken to produce the HWSD2:

Actions:

1. The P4WG coordinates the development of HWSD2, with the technical work assigned to a lead institution at the discretion of the P4WG, with a specified collaborative mechanism for data contributions, product checking and crediting. ISRIC has started to improve HWSD v1.2. Their product can be a part of the development of HWSD2.
2. Under the auspices of the GSP Secretariat, collect data that was generated by previous GSP actions in Latin America and the Caribbean (SISLAC), Near East and North Africa, and Asia (already harmonised to WRB2014 Legend).

[25] http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

[26] Batjes, N.H. (2015). World soil property estimates for broad-scale modelling (WISE30sec). Report 2015/01, ISRIC-World Soil Information, Wageningen (with data set, available at www.isric.org)

[27] FAO. (1990). *Soil map of the world : revised legend*. Rome: Food and Agriculture Organization of the United Nations.

3. Under the auspices of the GSP Secretariat, collect data that is available for North American and Pacific regional partnerships.
4. Use this GSP-collected data to produce an initial version of the HWSD2 in 2016, in consultation and cooperation with the above-mentioned data providers. These maps may also be used for parallel action towards the Global Polygon Coverage.
5. Present the fully revised HWSD2; target World Soils Day 2017.

Implementing institution:

Selected by the P4WG.

Budget:
1. Database preparation specialist 2015: $50k (GSSDIC)
2. Database preparation specialist 2016: $92.5k (FAO)
3. Technical writer 2017: $92.5k (FAO)
4. Correlation to WRB2014 from national systems 2017: $92.5k (FAO)

Total budget: $327.5k

3.2.3.2 Fine-resolution grid of soil properties (Version 0)

The fine-resolution grid Version 0 represents raster data sets based on the up-scaling of validated, measured soil profiles in conjunction with a large number of covariate layers that have some relation to soil geography (e.g., DEM, terrain indices, vegetation indices, soil polygon maps) and soil forming factors using digital soil mapping techniques. Predictions are made for a standard set of depth slices.

A widely-used specification for gridded soil property data maps is from the GlobalSoilMap project[28] (GSM), although that project specifies a consistent fine grid (estimates centred on the SRTM 3 x 3 arcsecond grid[29]). This includes the requirement that the reliability of the spatial estimates (uncertainties) be quantified.

[28] Science Committee, 2012. Specifications: Tiered GlobalSoilMap.net products; Release 2.3. GlobalSoilMap.net.

[29] The GlobalSoilMap specifications include provision for point estimates at the centre points of the SRTM grid (Tier 1 in their nomenclature) and block estimates for a 100 x100m square around each of these centre points (Tier 2 and higher Tiers). The Tiers are seen as a guide to versioning as the estimates and the assessment of uncertainty improve. The latest version of the specifications can be found at: http://globalsoilmap.net/system/files/GlobalSoilMap_specifications_december_2015.pdf

Examples of global and regional gridded maps, following partly the GlobalSoilMap specifications, have been developed by ISRIC at 1 km resolution[30] (SoilGrids 1km) and for Africa at 250 m resolution[31]. The deviation from the GSM specification is the more coarse resolution (1k and 250m rather than 100m). An example for a fully GSM-conforming national product is the Soil and Landscape Grid of Australia[32] that has point estimates at the centre of the SRTM 3 x 3 arcsecond grid.

The version 0 grid will be a collection of existing grids as a demonstration of gridded products with no attempt to invest into additional harmonization. P4WG will clarify, whether a specific design specification and scale (e.g. 1km, achieved after re-sampling of grids with deviating resolutions) will be recommended.

Actions:

1. Clarification by P4WG whether design specifications are needed, and if yes, facilitate the development of such.

2. Make a rapid inventory (by the GSSDIC in consultation with INSII members) of already-available gridded maps of soil properties at 1 km or finer horizontal resolution and their geographic scopes that fit the specifications for the global grids.

3. Harvest these data services for the GSP portal through GSSDIC to provide access to these gridded maps. This should include an overview map of coverages and their sources. No attempt will be made for harmonized or seamless coverage or harmonized specifications (properties, depths).

4. Develop a global product from national and regional Version 0 contributions as a proof-of-concept for a global Version 1 product. Use a consistent global product, e.g., SoilGrids by ISRIC, to cover areas where no national or regional coverages are available.

5. Develop a web portal to disseminate the Version 0 gridded maps.

Implementing institution:

GSSDIC

Budget:

- Development of the web portal: $92.5k (2016).
- Harvesting and composition of the existing grids: $32k (2016)
- Documentation of supplied maps: incidental by contributing institutions, at own cost

[30] Hengl, T., de Jesus, J. M., MacMillan, R. A., Batjes, N. H., Heuvelink, G. B. M., Ribeiro, E., … Gonzalez, M. R. (2014). SoilGrids1km — global soil information based on automated mapping. *PLoS ONE*, *9*(8), e105992. http://doi.org/10.1371/journal.pone.0105992

[31] Hengl, T., Heuvelink, G.B.M., Kempen, B., Leenaars, J.G.B., Walsh, M.G., Shepherd, K.D., Sila, A., MacMillan, R.A., Mendes de Jesus, J., Tamene, L., Tondoh, J.E., 2015. Mapping Soil Properties of Africa at 250 m Resolution: Random Forests Significantly Improve Current Predictions. PLoS ONE 10, e0125814. doi:10.1371/journal.pone.0125814

[32] http://www.asris.csiro.au/themes/NationalGrids.html

Total budget: $124.5k

3.2.3.3 Update of the fine-resolution global grid of soil properties (Version 1)

The Version 0 grid, as proposed in the previous section, has the following differences from the envisioned final Version 1 product:

1. Not all the world is represented by national/regional contributions to the v0 grid.
2. The v0 grid is neither harmonized nor seamless.
3. Unless P4WG will advise differently, there is no standard list of properties nor of their methods of measurement; there is no standard depth resolution.
4. There is no standard concept of the content of a grid cell.
5. The Version 0 horizontal **resolution** (1km) is significantly coarse compared to Version 1 (3x3 arcsecond, roughly 90 m). The resolution of Version 1 would correspond to many hill slope processes and reflect smaller landscape components, such as higher-order streams, by consistently building on the nominal 90 m SRTM-derived DEM as the basis for deriving key covariates.

The construction of the Version 1 grid will certainly take time depending on financial resources mobilized during Pillar 4 implementation. It would involve new statistical and data mining approaches, at least an order of magnitude more computation than the Version 0 grid, a distributed SDI, a set of data access and privacy procedures, and a different way of working. Because of the expected lack of capacity by many countries, and the lack of sufficient field observations, it will also require substantial external funding as well as in-kind funding from soil information institutions.

An important point is the relation between this Version 1 grid and the GlobalSoilMap project[33]. The latter is a consortium which ended in December 2015, which to date has produced specifications and results for some countries. The GlobalSoilMap technical specifications have been extensively discussed and revised by the members of the GlobalSoilMap consortium. These are the only specifications that have been agreed on by a consortium comprising some of the major soil institutes of the world, which are represented in the INSII. They could thus set the background specifications of the Version 1 global grid. The GlobalSoilMap specifications do not prescribe any modeling or upscaling approach and are thus flexible depending on resources and data available. For users, it is important to document the approach taken, and data used, which then becomes part of the metadata. The specifications specify the target set of parameters and the form of uncertainty reporting. Now that Regional Soil Partnerships have been formed, and more institutions will be represented in the INSII, and provided that broadly discussed and updated grid specifications (GSM) are already available, the development of Version 1 grid with full global coverage becomes a feasible objective.

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[33] http://www.globalsoilmap.net

There are several potential challenges with producing a fine-resolution grid of the world by a purely bottom-up (distributed) approach, as is required by the GSP.

- First, some countries do not have the capacity to implement a Version 1 grid; while others are lacking sufficient input data (mostly soil profiles) as to generate a grid quality which is significantly higher than, for example, a simple grid of any resolution derived from rasterized polygon data with only few soil profiles. Such a difference in quality is necessary in order to justify investments into 3 arcsec grids.
- Second, some countries are either lacking or have not yet identified a responsible agency for Pillar 4.
- Third, where centralized grids (i.e. grids derived by a central or distinct party separate to the country or region) are used, there is a potential challenge to maintain national sovereignty and trust, and consistency with relevant national soil policies, data sets and programs. In this case, careful product exchange and quality checks must be conducted together with the countries represented and should be seen as a stop-gap until capacity is developed for local ownership. This will be an important element of the GSP code of ethics (see Chapter 2.2).

Actions:

1. Facilitate a process among INSII members to familiarize with the opportunities and technical requirements and options involved with producing the Version 1 soil grids. Discuss and approve the technical specifications for the Version 1 grid. The GlobalSoilMap specifications will constitute the basis for this process.
2. The INSII members commit to producing and serving the Version 1 grid[34] in the distributed spatial data infrastructure (SDI) for the areas where they are the legal source of soil information. Member institutions of INSII may have cooperative agreements with institutions in partner countries who do not have the technical or logistical capacity to contribute directly, in which case these members will commit to aiding the development of the grid for those countries, this to be linked with capacity building of the partner institution (see “Capacity Building”, below). For other areas, either an institution in the region or the GSP Secretariat will have to identify resources (financial or in-kind) to cover its implementation.
3. Decide on the degree of harmonization required between the products of the various INSII members. One approach is to accept a map with clear “seams” at borders, informing the map user about each grid cell’s source. Another is to attempt *ad-hoc* harmonization at seams, leaving this up to the institutions meeting at the border. Another is to design a procedure for global harmonization. These options must be discussed according to their desirability from the user’s standpoint and feasibility from the producer’s standpoint.

[34] This technical term refers to providing information on-demand to a distributed system.

4. Develop a list of preferred soil attributes; identify estimation options (including pedotransfer functions) and a menu of tested approaches. It is likely that, for valid technology, capacity or institutional reasons, different approaches to estimation will be used. The specifications, however, will be the constant.
5. Design the exchange schema for data delivery. This is already underway in GSP Pillar 5 with the SoilML initiative, which builds on ISO 28258 for the exchange of digital soil data. SoilML templates[35] have been developed for Australia-New Zealand and for the Oceania node of the GlobalSoilMap project.
6. Design and implement the distributed system and web platform for serving the Version 1 grid in combination with a centralized system for those countries that are unable to develop, host and support their own system.
7. Agree on a method of showing the reliability of the displayed product; in particular, the locations of the calibration points that were used to generate the digital soil maps, if these are allowed to be shown.
8. Responsible institutions populate the grid in their area of responsibility, using national or regional soil knowledge according to the institutions' mandates.

Implementing institutions: INSII institutes under the coordination of the P4WG

Budget:

- Actions 1—4: three meetings (initial, revision, final) with global participation; if possible hold in conjunction with other international meetings
  - Meeting expenses 2015-2017: 3 x $50k = $150k
  - Extra travel expenses for participants not attending the global meetings: $60k
- Actions 5—6:
  - soil survey and monitoring expert 2016: $185k
- Action 7:
  - two programmers 2017: $370k
  - server and networking hardware 2016: $300k
  - server and network maintenance and support 2016-2019: $30k per year = $90k
- Action 8: Each participating institution (INSII) must prepare its own budget. Where needed, supportive funding sources may be exploited. Budget needs depend on the current technical capacity (so, need for internal capacity building), information system capacity (so, need to fund new systems and IT expertise), size of dataset to be contributed, and current status of data to be used in building the portion of the grid.
  For fund-raising purposes, the total budget has been estimated as $50k per each of 10 supported institutions in 2016 and 2017, rising to $100k per institution in 2019.

Total budget (Actions 1–7): $1.155M

[35] http://soilml.org

Notes

Time: The GlobalSoilMap specifications v2.4[36] already require estimated time of sampling for each soil property at each grid cell and a gridded date map for each soil property value which shows the date which the value most closely reflects. The Version 1 grid must provide a means to at least show the applicable date of the estimated soil property.

Link to the capacity building action: Member institutions of INSII which have cooperative agreements with institutions in partner countries will likely choose to integrate their preparation and delivery of the portions of the grid covering these countries with the capacity building activity of Pillar 4 (see below); however the time frame for delivery is too short to expect the trainees to establish fully-functioning systems to contribute to the Version 1 grid.

3.3 Integration into the Global Earth Observation System of the Systems (GEOSS)

There is a high demand for updated soil information globally for various GEOSS-societal benefit areas, in particular Agriculture and Ecosystems. For that reason, an initiative to deliver improved global soil data sets was started. The GEOSS 2012-2015 work plan[37] includes a task “IN-02 Earth Data Sets”, which contains the component IN-02-C2 “Development of Regional/Global Information and Cross-cutting Datasets (including socio-economic information)”[38]. This includes as a key output, with end date Q4 2015: “Develop a global soil information system incorporating data from global, regional and national soil data projects; Global soil data sets: significant efforts towards a new global soil map 1:1M”. This task is fully compliant with the Pillar 4 objectives.

Among the key activities, proposed to end 2014, is “Development of new governance structure for building a global soil information system (GSP Pillar 4) Data sharing working group.” This activity has been included in the “Governance” activity of this plan.

A second activity, with end date 2014, is: “Global products developed by World Soils Data Centre [ISRIC] in cooperation with other soil data centers”. This is an activity of ISRIC, not of the GSP. In this context, the initial SoilGrids1km product has been submitted to the relevant GEOSS task group leader in 2014 and registered in the GEOSS portal by the WDC-Soils through the ICSU World Data System. Similarly, the ISRIC update to the HWSD (see under Global Grids, above) has been submitted to GEOSS in 2015.

GEOSS is not a data provider or host, it is a registry and clearinghouse. The mentioned “integration” is thus a matter of registering the products of this plan with GEOSS. However, covariate coverages may be

[36] http://globalsoilmap.net/system/files/GlobalSoilMap_specifications_december_2015.pdf

[37] http://www.earthobservations.org/geoss_imp.php, menu choice IN-02, diagram box IN-02-C2

[38] http://www.earthobservations.org/ts.php?id=136

obtained via the GEOSS clearing house. Currently, while this Pillar 4 implementation plan is being developed, the GEO members are discussing a new task, to be starting in 2016 “CA-12 Soil mapping at regional and global level”.

Actions:

1. Improve the coordination of efforts by contributing organizations; report to GEOSS on completion of new or updated soil data products under this pillar; add to the GEOSS catalog.

Implementing institution:

P4WG, to designate the lead institution.

Budget:

- Incidental in-kind by identified liaison

3.4 Capacity development programme on soil information

Background:

This activity is to "develop a new generation of specialists in mapping, monitoring and forecasting of soil condition" who will work in the organizations responsible for these tasks (e.g., national soil survey institutes). These specialists should of course be technically competent; they should also be able to explain soil geography and the importance of spatially-explicit knowledge of the soil resource to policy makers and to scientists in related disciplines such as soil management. Other specialists to be trained may work in regional research institutes that want to develop capacity in these subjects.

By the end of this implementation (end 2019) it is expected that these specialists will be playing a major role on their institutions (that are part of INSII) for developing or maintaining national soil information systems.

It is not expected that the same people be trained in all topics. There will likely be a split between the soils and information technology specialists.

Actions:

1. Identify capacity development needs to support Pillar 4 activities.
2. Identify regional and national institutions, including universities, which can host and provide expertise to training sessions, collect their budgetary requirements for conducting courses.
3. Design a capacity development programme, including distance study, workshops, on the job training, internships and continuing education, webinars, etc.
4. Prepare training materials, available on-line to all interested people, in English and in the working languages of institutions where capacity is being developed (for example French, Spanish, Portuguese, Indonesian/Malayan).
5. Prepare detailed budgets for the different activities.

Example of topics to be included in the training plan

1. Digital soil mapping (DSM) theory and principles
2. (Open-source) computer programs for DSM.
3. Data management and handling
4. Production of gridded maps of soil properties and classes from point observations and gridded covariates, with special emphasis on preparing maps for national and project needs.
5. Sources of soil spatial variability, uncertainty, uncertainty propagation, uncertainty reporting, communicating uncertainty to data users.
6. Methods of evaluating ("validating") gridded maps and reporting the results.
7. Conversion of analog products (e.g., paper maps) to legacy digital products as covariates for DSM.
8. Preparation of point observations (soil profiles) for the Tier 1 (open) soil profile database.

9. Selection of representative point observations and their preparation for the Tier 2 soil profile database.
10. Requirements for delivery of soil status information to SoilSTAT; methods to collect this.
11. Design and implementation of soil condition monitoring systems, including the use of field and laboratory spectroscopy with associated statistical analysis and use of spectral libraries.
12. Digital soil morphometric methods of field data collection.
13. Direct-to-digital field survey.
14. Use of field photographs, soil quality and soil fertility test kits to engage farmers in data collection.
15. Design and implementation of soil monitoring programmes.
16. Empirical and simulation models for forecasting soil condition and functions.

Implementing institutions:

Implementation is open to any INSII member having and offering the sharing of knowledge and experience through particular events. In addition, other training institutions such as universities can be included. A capacity development programme will be prepared by the P4WG.

Budget:

1. Needs assessment and design of a capacity development programme (2016): $48k
2. Preparation of training materials (2016-2020): $185k
3. Capacity development activities:
    a. short courses at regional centres
    b. internships at regional centres

Total budget (excl. capacity development activities): $233k.

Budget item (3) depends on the number of courses/internships, the number of participants in each, and the travel and local costs for each course/internship, which vary by region; these are specified in the design and needs assessment. An estimate for fundraising is $38,400[39] for a two-week course with 20 participants from a region. A similar course with all local participants (no lodging, meals or travel) is estimated at $20,400. An internship of three months is estimated at $15,300, of which $11,100 is for institutional support (staff time), $600 for travel, and $3600 for the intern's room and board. For funding purposes we estimate four regional and five local courses per year in 2016 and 2017, and five internships per year 2016-2017, thus $623k total. This is a large sum but a critical element of this plan.

[39] Lodging and meals $600 per week per participant, regional travel $600 per participant, local costs $1200 (classroom, materials, excursion etc.), 2 foreign teachers at $7200 per week total costs (including overhead and travel), 2 local teachers at $2400 per week.

4 Deliverables

This section summarizes the deliverables per activity of the previous section.

General items:

1. Copyright and data use policy: by end 2016
2. Code of ethics: by end 2016
3. Develop a Pillar 4 brochure for resource partners: by end 2016
4. Selection of GSSDIC: by end Q1 2016

SoilSTAT:

1. Concept note including feasibility and design principles for soil monitoring and SoilSTAT: by end 2016.

Tier 1 soil profile database:

1. List of institutions that hold profile data[40] and list of institutions willing and capable to serve data: by end 2016.
2. Web platform and templates for collecting soil profiles and accompanying analytical data: by end 2016.
3. Infrastructure, including web-portal, for distributed access: by mid-2017.
4. Infrastructure, including web-portal, for centralized access: by mid-2017.
5. Populated Tier 1 distributed and centralized database following P4WG specifications and GSP and national data sharing policies: by end 2017.

Tier 2 soil profile database:

1. Soil-geographic stratification: by Q3-2016.
2. Tier 2 specifications: by end 2016.
3. Document database structure, soil-geographic stratification, harmonization methods for soil profiles in order to meet the minimum data requirements: by end 2016
4. Web portal for access and download of Tier 2 product: by end 2017.
5. Populated and shared database according to specifications: open-ended starting 2017

Global soil polygon coverage:

1. Specifications for integrating eSOTER, SOTER, and legacy soil maps in a consistent global polygon coverage with harmonized content, considering the target scale 1:500k to 1:1M: by Q2 2017.
2. Collected set of 1:500k to 1:1M national and regional polygon data sets: as soon as the data policy is agreed (2016/2017).
3. eSOTER maps for areas not covered with 1:500k to 1:1M national soil maps : by end 2018.
4. Global Polygon Coverage according to specifications distributed through a web-service: 2019.

[40] CIAT (via SISLAC), ISRIC and JRC of the EU, among others, already have such lists.

HWSD V2:

1. Specifications based on HWSD v1.2: mid-2016.
2. Polygon data sets for LAC, NENA and Asia regions: mid-2016.
3. Polygon data sets at 1:1M scale for areas represented by the Digital Soil Map of the World in the HWSD v1.2: end 2016.
4. HWSD v2 according to specifications. Proof-of-concept: 2016; final product: 2017.
5. Web page at GSP portal linking to the HWSD v2: by end 2017.

Low-resolution grid v0:

1. Clarification by P4WG whether design specifications are needed, and if yes, facilitate the development of such: by Q2 2016.
2. List of readily available maps that can serve as Version 0 national and regional products: by Q3-2016.
3. Collected set of readily available Version 0 maps: by Q3-2016
4. Web-portal for display and access to Version 0 maps: by end 2016.
5. Version 0 gridded product with global coverage utilizing existing global top down layers as a backbone: proof-of-concept by 2016; final product mid-2018.

Fine-resolution grid v1:

1. Technical specifications document of Version 1 grid designed and approved (incl. level of harmonization, soil attributes, uncertainties): by mid 2017
2. Exchange schema for data delivery designed: by mid-2017.
3. Distributed system and web platform for serving the Version 1 grid: by end 2018.
4. Populated high-resolution global grid: by end 2020.

Capacity development programme:

1. Capacity development programme: 2016
2. Training materials: 2016-2020
3. Implemented training (different modalities) according to the programme: 2016-2020

5 Budget summary

For planning purposes, a proper budget spreadsheet shall be developed by the P4WG based in input by INSII members. There, each task and deliverable should be more precisely calculated and presented, including necessary in-kind contributions by INSII members. This would also improve the overall budget management, for example to better identify required funding not yet met by donations or other sources of support.

In order to provide a first overview, the sums for the various items in the implementation plan are summarized by year. This estimate **leaves out in-kind contributions** from eventual INSII members to the v1 grid, profile databases, and SoilSTAT.

2015: $208k

2016: $2.228M

2017: $2.958M

2018: $1.930M

2019: $0.714M

2020: $0.570M

Total external funds to be solicited: $8.608M

6 Annexes:

6.1 Annex 1: Terms of Reference INSII

Each GSP member (government and other partner organization), willing to support the Pillar 4 Plan of Action (PoA), may select one or several institutions to participate in the implementation of this PoA. These institutions have already, or will develop, the technical ability to develop and share selected national soil information and data. The discussion of methodologies and product specifications, as well as a shared data infrastructure throughout the globe, will be coordinated in a participatory approach through the International Network of Soil Information Institutions (INSII). While ensuring consistency with national data sets and data policies, each institutions acts through the respective regional partnership and is also embedded in the global soil information system.

Therefore, INSII is the implementing organization of Pillar 4. The process is facilitated by the GSP secretariat. By agreeing to the PoA, and by its participation in the drafting of this implementation plan, all GSP partners have in principle already agreed to the establishment of INSII. However, this plan, and the respective terms of reference, will be presented to the 4th PA 2016 for information.

The INSII will:

- convene an annual meeting to monitor progress on Pillar 4 implementation; the relationship to the regional soil partnerships shall be regularly addressed and developed
- appoint a Chair for a period of 2 years, extendable via INSII decision to a second term; the chair will moderate the annual workshop and the Pillar 4 Working Group
- contribute to the execution of the Pillar 4 implementation plan by serving as its strategic decision making body, within the constraints of the Pillar 4 Plan of Action approved by the GSP Plenary Assembly;
- report on progress and outstanding issues at each GSP Plenary Assembly
- oversee the P4WG and the GSSDIC;
- delegate the P4WG tasks, as needed, to support the efficient implementation of Pillar 4;
- provide access to soil geographic information in order to populate the products of the Global Soil Information System under specified conditions (Pillar 4 code of ethics and IP policy);
- support the process by providing overall guidance and advising on matters related to funding and implementation of actions;
- endorse a code of ethics for privacy, data sharing, and use and submit this to the GSP Plenary for approval;

6.2 *Annex 2: Terms of Reference P4WG*

The technical challenges to develop the global soil information system are immense. INSII is a large network which requires specific technical, operational support. This can be achieved through a smaller, but representative team of experts, supported by their governments/GSP partners. This operational team will be the Pillar 4 Working Group (P4WG).

The P4WG will:

- be chaired by the INSII Chair
- meet regularly (using electronic means and if needed physical meetings) to review progress and provide necessary guidance;
- report progress to INSII
- closely cooperate with FAO in the development of the plan for SoilSTAT;
- monitor compliance with the implementation plan by all members; ensure that products meet specifications, and are properly credited, before public release;
- develop an intellectual property rights (IPR) assessment and report, and propose the modalities of data publication, including data licensing;
- select the GSSDIC following an open call according to the criteria listed in the present document;
- cooperate with Pillar 5 in the development of a technical standard for data exchange (e.g., SoilML) and in developing harmonization methods;
- develop quality control protocols and perform its evaluation;
- develop the data infrastructure concept for SoiLSTAT: data portal, ontology, thesaurus, metadata standards and editor

6.3 Annex 3: Terms of Reference GSSDIC

The GSSDIC will:

- host, develop, maintain important elements of the SDI needed for a distributed system;
- if needed, provide centralized infrastructure components for INSII members who choose not to develop and host own web services, and who intend to delegate technical tasks to GSSDIC;
- actively participate in the P4WG where issues about implementation should be addressed;
- support various technical elements of the Global Soil Information System;
- design and implement the distributed Global Soil Information System and web platform jointly with FAO for SoilSTAT;
- provide information to GEOSS on completed data products.

6.4 *Annex 4: Abbreviations*

$1k	One thousand US dollars
1M	1 Million
AfSIS	Africa Soil Information System (Earth Institute of Columbia University, USA), http://africasoils.net
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe; German Federal Agency for Geological Sciences and Natural Resources
DOI	Digital Object Identifier, uniquely identifies publications and datasets, see http://www.doi.org
DSM	Digital Soil Mapping: the production of soil maps primarily by automated means from databases of point observations and covariates representing soil-forming factors.
DSMW	FAO Digital Soil Map of the World (v3.6, 2007)
FTE	Full time equivalent - work equivalent to one year of a full-time scientific worker; also the cost of such a worker per year
GEO	Intergovernmental Group on Earth Observations http://www.earthobservations.org/index.php
GEOSS	Global Earth Observing System of Systems of the Intergovernmental Group on Earth Observations (GEO)
GSIS	Global Soil Information System
GSM	GlobalSoilMap http://www.globalsoilmap.net
GSP	Global Soil Partnership
GSSDIC	Global Soils Spatial Data Infrastructure Centre (here proposed)
HWSD2	An updated version of the HWSD.
HWSD	Harmonized World Soil Database http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/

ICSU	International Council for Science, a non-governmental organization with a global membership of national scientific bodies (121 Members, representing 141 countries) and International Scientific Unions (32 Members)
INSII	International Network of Soil Information Institutions (here proposed)
IP	Intellectual property
IPR	Intellectual property rights
ITPS	Intergovernmental Technical Panel on Soils
IUSS	International Union of Soil Sciences
IYS	International Year of the Soil 2015
MLA	Minimum Legible Area of a polygon at a given map scale; corresponds to a Minimum Legible Delineation (MLD) on the map of $25mm^2$.
mo^{-1}	Per month
NRL	Land and Water Division of the Natural Resources and Environment Department, FAO
NRCS	Natural Resources Conservation Service, US Department of Agriculture
PoA	GSP Pillar 4 Plan of Action, Adopted by the GSP Plenary Assembly 2014
RSP	Regional Soil Partnerships
SDI	Spatial Data Infrastructure, "the technology, policies, standards, human resources and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data." (The White House, Office of Management and Budget (2002) Circular No. A-16 Revised, August 19, 2002). Generally refers to distributed systems where original data providers maintain the data for which they are legally responsible.
UCS	Universal Soil Classification system, a working group of the IUSS
WDC-Soils	World Data Centre for Soils; at ISRIC, accredited by the ICSU World Data System, registered with GEO. See http://www.isric.org/content/world-data-centre-soils
WG SIS	IUSS Working Group Soil Information Standards

WoSIS	ISRIC World Soil Information Service; see http://www.isric.org/data/wosis
WRB	World Reference Base for soil resources soil classification. Reference: FAO. (2014). *World reference base for soil resources 2014: International soil classification system for naming soils and creating legends for soil maps*. Rome: Food and Agriculture Organization of the United Nations. Retrieved from http://www.fao.org/3/a-i3794e.pdf
yr^{-1}	Per year