CHAPTER 6

Strategy, Feasibility and Recommendations

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Introduction

Since 2010, MEPA has embarked on a project (which attracted co-funded ERDF assistance) (1) to develop a multi-thematic environment strategy that would lead to updating of its data/ information monitoring capabilities for a number of environmental sectors. The monitoring and continuous evaluation of soil properties is one important sector within this project. Essentially, a multi-criterion assessment of existing available information has been carried out with a view to objectively chart the most appropriate process to carry out a pilot field sampling by testing a pre-agreed set of indicators. The latter were established after taking into consideration all degradation pressures threatening the continued sustainability of this resource.

Multi-criterion analysis was carried out by means of a limited set of soil-related datasets published in past editions of Malta's State of the Environment Report in order to support a number of objectives stipulated within the Project's ambitious Terms of Reference. Information was derived from earlier attempts to establish a soil information system for Malta.

All soil degradation threats, officially determined by the European Commission's Technical Working Groups, have been taken into consideration within the aforementioned project and its research methodology with a view of establishing a shared GIS environment in accordance with state-of-the-art information dissemination standards.

Context and Objectives

The Maltese National Environment Policy, as well as the European Commission's Seventh Environmental Action Programme (EAP) and the Soil Thematic Strategy (STS), emphasize the need to monitor a wide range of soil indicators as a base for the development of effective and feasible strategies to eventually enable updatable soil protection plans. Besides the recently-unveiled EU's Cohesion Strategy (2) for 2014-2020 adopted for Malta (under sub-heading 2.2: Environmental protection and improved management of natural resources and of waste) - which was itself quoting the National Climate Change

Adaptation Strategy Consultation Document published in 2010 - emphasizes the need for Malta to have:

"… long term strategies (which) are essential for soil conservation and to increase soil organic matter which will render the land more able to cope with future climatic changes…"

Soil management also features amongst the country's recently-established national thematic priorities (3) to attract future investment and funding opportunities. Local authorities published this statement under the heading 'Climate Change adaptation, risk Prevention and Management' with reference to the Programming of European Funds for Malta (PEFM) 2014-2020:

…Soil is one of Malta's most important natural resources, with socio-economic and ecological importance. Malta's soil resources are important for the maintenance of the ecosystem relating to health, agriculture and water management, as well as for supporting tourism and recreation-related activities in the countryside. Additionally, unsustainable practices and poor management within the agricultural sector are posing serious risks which are resulting in the lowering of soil quality through salinisation, erosion, soil sealing, soil contamination and desertification.

In terms of sustainable development, an integrated approach to soil management is being adopted in order to undertake corrective action and identify and implement adaptive solutions that balance effective nutrient, crop, water, soil and land management. Additionally, efforts to further protect against soil degradation and erosion will continue. Sustainable soil management will be supported by strengthened quality monitoring to ensure for on-going soil health diagnosis.

Efforts will continue to be directed towards the dissemination of knowledge, the undertaking of training, the availability of technology to encourage the adoption and application of practices and methodologies that will remedy and improve the soil quality, protect it from erosion, secure its desalination and prevent further loss of organic matter. (PEFM, pp.68-69)

Legislative Framework and International Developments

No comprehensive overarching procedures exist at the national level, to address all forms of soil degradation and spatial assessments of soil functions in a coordinated manner in order to ensure compatibility of methods and data with the STS and full coverage of provisions addressed by the European Commission's proposed Soil Framework Directive (hereafter referred to as pSFD).

Act X of 2010 (Environment and Planning Act) empowers the Malta Environment and Planning Authority (MEPA) to conduct measures to better regulate soil protection

in terms of environment protection and land use planning. Article 8 (2) describes the Authority's functions and indicates that the Authority is, amongst other, responsible for the formulation and implementation of policies related to the sustainable management of natural resources. In particular, sub-article 4 of the same provision stipulates that the Authority shall be responsible for the conduct of consultations and to undertake and promote research on such matters. Furthermore, it shall enable,

...the provision, of either alone or in collaboration with others, education, training and public awareness programmes relating to environment protection, and the sustainable management of the environment and natural resources.

Besides, Article 51 (5) of the same Act (under Part IV - 2. The Strategic Plan for Environment and Development), stipulates that,

for the preparation and review of the SPED, the Authority shall carry out surveys of those matters which affect the character and quality of the environment, its conservation and development, including but not limited to:
...(g) the conservation and preservation of natural and man-made resources....

In addition, Article 61 (2) (under section Part IV 4. Regulation and Orders) is also of relevance to sector under review in that provide context to empower Authority to undertake capacity building initiatives. Amongst other, the aforementioned Article states that,

without prejudice to the generality of sub-article (1), such regulations may in particular:
...(d) give effect to any international treaty or instrument, including directives, regulations and decisions, relating to any matter governed by this Act to which Malta may from time to time be a party or subject and to set up structures and make other provisions forthe implementation thereof;....

Meanwhile, it must be emphasized that agricultural soils data / information in Malta have been managed, since 2007, through a set of cross-compliance measures stemming from national reporting obligations related to the Common Agricultural Policy framework.

Maltese legislation, directly or indirectly addressing aspects of soil protection, can be found within the following legal instruments and/or initiatives:

- 1973 Fertile Soil (Preservation) Regulations (and as amended);
- 2012 National Environment Strategy (NEP);
- 2012 Draft Strategic Plan for the Environment and Development (SPED);

- CoGAP (4) & GAEC (5) - SMR (6) / Cross-Compliance (CAP):
- Cross-Compliance related to EU Aid Applications in terms of the Paying Agency Regulations, 2005 (7);
- MEPA 2007 Policy and Design Guidance for Agriculture, Farm Diversification & Stables (regulating Outside Development Zone planning permits);
- Various Waste Management regulations transposed into local action (e.g. Waste Management (Landfill) Regulations, 2002 (LN 168 of 2002 as amended by LN 289 of 2002, LN 70 of 2007, LN 146 of 2007));
- Various Plant health protection regulations which address, amongst other, risks resulting from actual use of pesticides (incl. biocides) and their impact upon soil contamination and biodiversity (due to soils being an important source of the gene pool); and
- Birds and Habitat/ Natura 2000 regulations which include amongst other compensation payments to protect habitats by avoiding deterioration of agricultural soils.

On the other hand, regulatory protection of soil resources is not the subject of specific legally-binding provisions at European level. Indirectly, some soil quality rules are incorporated within other strategic sectors, such as waste management, agriculture and rural development. Attaining Union-wide legislation on soil protection is a challenging task, considering the transversal role that soil plays in environmental, or economic and social spheres already perceived as complex to manage, such as water, waste, pollution, industrial production, agriculture, pesticide use, urban planning and so on. Nonetheless, integration with existing legislation, at both Community and national levels is still required *"to address areas affected by soil degradation and properly implement measures to reverse degradation processes"* (Montanarella, 2014, p.9).

Below is a non-exhaustive list of initiatives undertaken to indirectly coordinate regulation of this resource:

- Seventh Environmental Action Programme (to support Roadmap to a resource-efficient Europe under the Europe 2020 Strategy) (8);
- Multi-Annual Financial Programme for 2014-18;
- Horizon 2020 – Environment Working Programme (of measures);
- Updated Common Agricultural Policy framework through a set of mandatory and optional agri-environmental measures (supported by cross-compliance initiatives);
- Climate Change Policy (Post-Kyoto & Post-Copenhagen debate, LULUCF) detailing provisions adopted during the UNFCCC;
- (Alternative) Energy Policy (Renewable Energies Directive);
- Biodiversity Protection Policy (EU & National Biodiversity Strategy, Nature, Birds and Habitats Directives, and so on);

- Water Protection Policy (namely Water Framework and Groundwater Directives)
- Forest Protection Policy (Forest FOCUS, ICP Forest);
- Regional Strategy and Development Policies (INTERREG, Territorial Cohesion Programmes);
- Waste Policy (e.g. Biowaste, Sewage Sludge, Urban Wastewater, Landfill Directives and other daughter directives);
- Integrated Pollution Prevention and Control Directive (IPPC) and the recently enacted Industrial Emissions Directive (IED);
- EU thematic strategy for air quality, and integrated EU strategy for target values and for transboundary pollution emissions established in the CAFE programme (Clean Air for Europe);
- European Commission's Communication on "Planning and Environment – the territorial dimension"; and
- European Spatial Development Perspective (ESDP).

As an interim arrangement, this situation effectively means that any soil-related issues shall have to be included in each intervention when updating these regulatory instruments given the impact of soil on the general status of the environment. So far, the European Commission has prepared a Soil Thematic Strategy (in 2004), a Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions and a draft Framework Directive (in 2006) to provide further impetus to harmonize practices adopted by Member States in relation to this sector.

On a global level, legislative framework, regulation and guidance, relevant to protection of various soil aspects, is broadly structured around a significant number of non-EU legislative initiatives and/or multilateral agreements. The following is a (non-exhaustive) list of relevant instruments, policy measures, strategies and multilateral/ international initiatives and/or documents (9) where comprehensive action and guidance is directly or indirectly setting the scene for holistic protection of this non-renewable resource:

- Multilateral Agreements (e.g. UN Conventions for Combating Degradation (UNCCD) and its flagship target of 'Zero Net Land Degradation' by 2050; some of the Aichi targets emerging from global CBD-related events; FAO's Soil Biodiversity Initiative; and Rio+20's statements on soil protection (included in approved document 'THE FUTUE WE WANT' all of which reinforce pioneering global declarations introduced during the 1992 UNCSD Conference of Parties);
- Bonn Memorandum on Soil Protection Policies in Europe (1998);
- World Soil Policy (UNEP, 1982);
- Food Safety & Food Security & 1982 World Soil Charter encouraged by FAO;

- Global Earth Observation System of the Systems (GEOSS) initiative;
- Council of Europe's 1972 Soil Charter.

Persistent legal lacuna of specialized legislative instruments, comprehensively addressing the various facets of soil protection, have become even more problematic over the past decade as global soil degradation has intensified.

This trend is likely to continue if global issues like the relentless lateral expansion of urbanized areas, conservation of soil organic matter, intensified use of this natural resource through a widening range of agro-commercial activities and socio-economic impact of soil degradation on various categories of ecosystem services (e.g. cultural, regulatory), are not properly addressed at regional and national level within a focused yet consolidated legislative instrument.

Previous Nationwide Soil Assessments

On its part, the soil component of the environmental monitoring project, managed by MEPA, in collaboration with the University of Malta, Environmental Health Directorate, the National Statistics Office and Malta Resources Authority, was preceded by two important comprehensive initiatives related to soil protection in Malta. These are briefly described below:

(i) 1960 Nation-wide Survey by D.M.Lang

This detailed soil survey, the first of its kind for Malta, was carried out by Dr. D.M.Lang during the 1950s. In essence, it had concluded that Maltese soils are mainly derived from local sediment geology, that is rock structure and composition, geomorphology and stratigraphy setup. Moreover, it was contended that all local soils are highly calcareous (i.e. parent material is predominantly calcium-carbonate), slow forming and closely related chemically with the natural and cultural landscapes prevailing at the time.

The study's main objective was to provide basic qualitative descriptions of the soils (based on Kubiena's classification system) as an aid to agricultural planning. Within said project, Maltese soils formations were classified under three broad categories: carbonate, xerorendzinas, terra and soil complexes. Subsequently, these were further subdivided into subtypes or series named after the localities where the first examples were noted.

Essentially, Lang's study measured the following set of indicators/parameters: total organic matter, C:N ratio, phosphorus as P_2O_2 total availability, total exchangeable cations, calcium carbonate and its active component, soil electrical conductivity and its pH and colour (10).

(ii) 2004 Maltese Soil Information System (MALSIS)

The multi-criterion model adopted for the project under review in this paper (ERDF156) drew its major source of support from past Maltese soil data available to meet preliminary Soil Thematic Strategy requirements. In essence, soil data was derived from metadata obtained from MapInfo-based workspaces showing datasets prepared on knowledge gained from the creation of a Maltese Soil Information System. The latter project entailed the setting up of a soil inventory and soil monitoring system at the national level, which was deemed to be a necessary condition for the elaboration of any strategic policy on soil and its eventual harmonization with the European-wide requirements.

While a detailed soil survey was carried out in 331 geo-referenced sites as part of MALSIS deliverables (much higher than the 40 monitoring points investigated for the 2012 soil baseline survey (i.e. Activity 5) included within the project under review , its laboratory tests do not match current ISO standards for data gathering, sample storage, laboratory accreditation processes and cost requirements which are essentially coming about as a result of better INSPIRE-led draft data reporting standards developed since 2007 and a wider range of soil quality information objectives mirroring contemporary knowledge about soils.

A follow-up to this 2004 project was, not carried out. and a closer inspection to its deliverables reveals that not all degradation threats (11), were addressed. As a matter of fact, said project indicated that Maltese authorities did make an effort to establish a structured evaluation of soil degradation threats such as erosion, organic matter decline, diffuse and local contamination and salinisation. However, evaluation of sealing rates (a increasingly crucial land use issue), compaction conditions, local situation with reference to soil landsliding/ flooding, soil horizons biodiversity decline and desertification components featuring in the aforementioned Strategy, were not within the remit of responsibilities delegated to agriculture authorities who managed this LIFE project.

Soil Theme Deliverables for Environmental Monitoring – Activity Reporting

The 2010-2013 project under review was designed along the following benchmarks:

i) Inception report

A detailed document submitted to MEPA provides a broad description of scope of work undertaken in relation to Project's Activities 1 to 5 intended to address this project component.

ii) Activity 1: Legislative background review

Report associated with this Activity provides an analysis of relevant (national,

European, international) legislative and regulatory environment addressing aspects of soil management. Main objective entails the assessment of current status of environmental monitoring for soil theme.

iii) Activity 2: Setting of strategy

The main purpose behind design of this activity comprises the development of a long-term strategy for monitoring at the national, regional and local levels to comply with existing and emerging comprehensive project monitoring obligations for the soil theme. The monitoring strategy also includes recommendations for cross-thematic data analysis and models required for forecasting of the environmental theme.

This document the steps required for establishing an appropriate institutional structure covering this environmental theme. Administrative support would be required in order to establish a Soil Information Monitoring Unit (SIMU) tasked with facilitating the organisation of a soil quality monitoring network including a soil (data) information system which "is the key to understanding the soil resource" (MEPA, Activity Report 2, p.15).

The final report also describes relevant driving forces, pressures, states and impacts affecting soil protection with reference to the pSFD. The document also includes definition of all soil degradation threats (i.e. erosion, desertification, contamination, soil sealing and compaction, organic matter decline, landslide/soil flooding, salinization and biodiversity loss. It identifies factors generating cause-effects associated with each specific threat.

Furthermore, the report also provides an extensive description and evaluation of indicators required in order to measure and appropriately evaluate level of each soil degradation threat.

Besides, Annexes associated with this Project deliverable also provide the following specific information:

- a detailed description (definition, methodology used, analysis against SFD parameters) of proposed indicators associated with the aforementioned soil degradation threats;
- detailed listing of all soil screening values adopted in other Member States (limit, trigger or intervention thresholds or clean-up levels to monitor an extensive set of substances or pollutants in order to mitigate or prevent potential contamination of this non-renewable resource); and
- the development of a land and groundwater monitoring strategy. An important component of this strategy entails the description of a Conceptual Site Model and preferred testing and evaluation methodology for baseline investigations in relation to land and groundwater contamination within and around installation complexes/ operating plants subject to IPPC regulations and Industrial Emissions Directive procedures).

It also provides information about the soil characterization plan. This incorporates design and implementation of emergency corrective measures (ECMs) in case of soil contamination. This plan also has a procedure detailing development of a criteria-based sampling program, and planning process to implement direct surveys (e.g. drilling operational methodology, specification for groundwater monitoring wells).

Annexes of this report also include detailed guidelines indicating how to implement an appropriate risk analysis (e.g. analysis of contamination exposure routes) and also parallel guidelines for remediation through several alternatives of biological treatment technologies (e.g. bioventing, enhance bioremediation, phytoremediation, composting, and so on) and physio-chemical treatment (e.g. oxidation, soil vapor extraction, washing, dehalogenation, bioslurping, and so on).

Monitoring of remediation processess (through sampling methods for in-situ and for ex-situ treatments) is also included in this voluminous final report.

iv) Activity 3: Design of the Programmes

Final report for this project phase incorporates a detailed definition of the short and long term soil monitoring strategy, development of a multi-criteria evaluation soil model and choice of preferred strategy following analysis conducted on short-term monitoring. Preparation of a tender monitoring plan and related terms of reference are also included under this deliverable.

Annexes associated with this deliverable include the following components:

- a detailed tabulation listing grid-based modelling values outlining soil degradation risk potential over the entire Maltese land-based territory. Established values cover all degradation threats;
- a graphic illustration of multi-criteria model used to select investigated monitoring points to be tested during a soil baseline survey (refer to Activity 5);
- a set of maps showing georeferential information of each monitoring site subdivided by level of assessment required (e.g. basic, general and biodiversity points); and
- another set of maps indicating location of all monitoring sites (selected through aforementioned model) superimposed over areas identified as potential high-medium-low risk sites for soil degradation.

The activity involved the creation of a detailed implementation plan to map out steps required to establish the monitoring programme for soil at the national, regional and local levels taking into account the current data gathering and reporting methodologies as employed through EU reporting procedures, European Environment Agency (EEA) dataflows and other international commitments.

v) Activity 4: Feasibility assessment of programmes

This stage of the baseline monitoring programme for the soil theme describes the different phases for the managment of the soil monitoring network included a discussion of the estimated (operational and total) costs related to in-house technical capacity of human resources, procurement of laboratory facilities (layout, sample management structure, method validation, accreditation, operational and sampling standards and personnel complement), laboratory materials/ equipment required and field surveying activities required in order to manage an ISO 17025-compliant service.

Final Activity 4 report provides details of operations related to the preparation of potential options for institutional capacity building for continuous soil monitoring (i.e. direct management and autonomy of the whole network (termed as *in-house scenario*); total sub-contracting management service of the monitoring network and analytical analysis (referred to as the *outsourcing scenario*) and/or direct management of soil monitoring network and outsourcing of the analytical activities to a laboratory overseas (the *hybrid scenario*) and proposes the most cost effective scenario from these three options.

Main aim of this part of the aforementioned EU-funded project was the development of cost-effective strategies and programmes which are designed to be efficient and technically feasible. Feasibility study on the Management Information Systems and Executive Information Systems is required for the reporting cycle of the environmental data acquired during the project.

vi) Activity 5 : Development of comprehensive monitoring strategies and design of long term monitoring programmes

This deliverable incorporated the preparation of operational Terms of Reference to generate primary soil information. This ToR was issued for public consultation in the form of a Maltese departimental tender which was prepared in accordance to standard public tendering procedures. Point sampling methodology was adopted during this survey. Examination of a set of physio-chemical and biological parameters, to be tested in 40 monitoring sites, was eventually completed by January 2013.

Deliverable also included the compilation of an Analysis Report to describe and evaluate all information gathered during this survey and correlate this data with past local studies including but not limited to those described earlier in this paper. Thereafter, a recommended integrated course of action was established in accordance with the Project's pre-agreed short term monitoring strategy.

Soil Radiation Monitoring

A separate technical assessment, to investigate a set of radiation-related parameters, was also carried out for the ERDF project under review.. Soil sampling was performed

within a monitoring survey carried out from 30th May to 7th June 2012. Monitoring of specific radiation indicators included rural and background sites (representative sample covered some 60 sites). Selected sites were determined following a preliminary assessment of the Maltese Islands geology and land use.

The final report describes the specific approach adopted to measure/ define natural background value of ^{232}Th, ^{238}U and ^{7}Be (natural radionuclides) and spatial distribution of ^{137}Cs (artificial radionuclides). Gamma spectrometry was used to calculate the aforementioned radionuclides. Where it was not possible to detect directly a radionuclide concentration the value was obtained by measuring their daughter radionuclides and supposing secular equilibrium.

In this study ^{208}Tl has been measured to determine ^{232}Th and ^{214}Bi to calculate ^{238}U concentration. Top soil (0-20 cm) has been collected in order to investigate radionuclides.

Identification of Soil Indicators for Baseline Survey to Evaluate All Degradation Threats

The process to establish permanent systematic measurements, of a wide range of pre-agreed soil parameters, is described below. Identified soil parameters were categorized within short-term and long-term monitoring strategies since project under review suffered from a limited financial allocation and was subject to tight milestones and reporting deadlines.

Short-term indicators with results provided

The actual sampling survey, carried out during the fourth quarter of 2012, investigated 40 sites which were chosen by MEPA and their consultants as a representative profile of the various soil types present within the Maltese Islands. All sampled sites were grouped into three classes: 20 'basic' (reference code: ST), 4 biodiversity-related (reference code: BD) and 12 'generic' (reference code: GP) monitoring points, respectively (12).

The 20 'basic' points aforementioned include the investigation of a combined list of indicators associated with the following soil degradation threats: erosion, desertification, organic matter decline, diffuse contamination, salinization, soil flooding/ landsliding and compaction.

Specifically, all samples have been tested to generate the following reference information:

- soil bulk density,
- underlying rock formation,
- soil profile depth characteristics,
- electrical conductivity,
- soil texture,

- soil typology unit and
- an assessment of heavy metal contaminants (to determine the likelihood presence of arsenic, cadmium, chromium, copper, lead, mercy, nickel and zinc quantities), hydrocarbons, pesticides and soil organic carbon which may be present within the topsoil and subsoil horizons.

Within the 12 'generic' monitoring points, soil analysis indicators tested provide information about soil's pH, moisture, texture, organic carbon and nitrogen content, ratio C:N, bulk density, calcium, potassium and phosphorus.

On the other hand, presence and concentrations of earthworms, micro-arthropods and microbial respiration have been studied within 4 pre-agreed monitoring sites in order to initiate a preliminary investigation of local topsoil and subsoil biodiversity qualities.

Subsequently, laboratory-based verifications (in the form of analytic reports) were carried out to report any traces/concentrations of the following contaminants within each soil sample: pesticides, herbicides, dithiocarbamates, fungicides-acilalanine, fungicides-benzimidazoles, fungicides dicarboximides-tioflatalimides, fungicides – strobilurin, triazole fungicides – phyrimidine and other, insecticides – carbamate, pesticides chlorine nicotinic, oraganophosphurus insectides, insectides organioclorurates, insecticides phrethroid, growth regulators.

Moreover, a pre-agreed set of fieldwork characteristics, addressing the various soil threats, has been prepared as part of Activity 2 of the ERDF project under review. Information requested is listed below for ease of reference:

- type of degradation threat and indicator reference code;
- a technical definition (with unit of measure in relation to international standards);
- type of indicator (in relation to DPSIR framework);
- indicator's target and Strategy (objective/s and its importance within wider context defining degradation threat sub-theme);
- methodological description (procedure used, materials/equipment utilized, benchmarks used, limitations to data acquisition, and so on);
- evaluation of data needs and availability; and
- additional relevant information (e.g. temporal coverage, intended/ required frequency of updates, expected spatial resolution).

Long term indicators not yet tested in any contemporary research or evaluation initiatives

Intensification of Maltese soil data is expected for a 2 by 2 km grid and is expected to cover around 80 monitoring points in order to address in greater detail the various soil sub-themes. Soil indicators identified in this project, which are important in terms of future testing of sampled soil resources (once EU funding and national soil budget

assistance are secured), are listed below.

Desertification – drainage, fire risk, erosion protection, drought resistance, land use intensiveness;

Contamination – site characterization, dioxine, PCBs, organic chlorinated;

Soil biodiversity loss – all macrofauna present in soil, acari sub-orders, nematodes, bacteria and fungal DNA, bacteria and fungal activity. In Malta, this type of soil degradation threat can be monitored effectively once a repeat soil survey is carried out, at national level, to evaluate a total of 40 sampling points. Specific attention shall be taken to sample soil health conditions within environmentally-sensitive areas (that is, sites already scheduled for protection from development due to their ecological and scientific importance);

Soil sealing and **compaction** – land consumption, fragmentation, air capacity;

Organic matter decline – soil organic peat, wild fires, crop residue burning, exogenous OM application (including farmland manure and biowaste), organic farming, cultivation practice;

Landsliding – soil depth (including the C horizon (13)), occurrence/ density of existing landslides (updated landslide inventories), bedrock structure and quality, climate. Long-term assessment of this degradation sub-theme involves the construction of 20 specific monitoring points.

Salinisation – sodium, magnesium, calcium, potassium, chloride, sulphate, profile distribution, ion composition, pH/alkanity, cation exchange capacity, exchangeable sodium rate, determination of irrigated soil areas and chemical properties of irrigated water;

Effective calculation of hydraulic properties for the assessment of **erosion** and salinization may be achieved if soil data authorities distribute some 25 piezometers on a nation-wide basis.

2012 Soil Baseline Survey: Results and Emerging Preliminary Conclusions

This baseline sampling assessment, carried out as part of ERDF 156 project deliverables described earlier in this paper, constituted a major source of primary scientific information gathered in relation to current soil conditions in Malta since the extensive MALSIS project completed in 2004. Its main conclusions, grouped by specific degradation threats, are described below:

(i) Decline in Organic Carbon

The total organic carbon measured from samples collected during the baseline survey, ranges from 0.4 to 2.3%. Prima facie, figures therefore compare well in terms of consistency with those of Lang, (1960) and MALSIS (2004).

The following conclusions (14) were reported with reference to the baseline survey

data results associated with this soil degradation threat:

"For the purpose of this baseline study, the organic matter content of soil was determined for most of the sites. Considering the climatic characteristics of the region and soil management factors it was expected that the levels of organic matter in soil would be low. An analysis of the data indicate a mean organic matter level of 2.1% (S. Dev. + 0.1814 n=27) and minimum and maximum levels of 0.808 and 3.96% respectively. This average is considered to be low; however these levels are very similar to levels found in soils of this region. The data from this study were compared with soil organic matter data taken in 2002 and 2006".

The mean soil organic matter content for 2002 was 1.9 % (S. Dev. + 0.685 n = 16) and in 2006 the mean was 2.1% (S. Dev. + 0.636 n = 16). Information regarding the location of the sites for both 2002 and 2006 was not available, however a statistical analysis comparison between 2006 data and 2013 data did not reveal any significant change in organic matter content (p = 0.478) (Meli A., et.al, 2013, pp.68-69).

…the level of organic matter in these soils is rather low and that there was no change from that recorded in 2006. This is somehow an expected outcome considering the climatic conditions of the region and the fact that the majority of the sites are agricultural sites; cultivated soils in general have lower organic matter content than non-agricultural soil (Meli A., et.al, 2013, p.77).

(ii) Contamination

Project consultants entrusted with analyzing soil baseline survey findings provided the following conclusions with reference to diffuse contamination:

…"the picture that emerges from this study suggests that for the majority of the soil sampled, the level of the PTEs (15) *is within the NBVs* (16) *established for European soil. Only soil from sites ST01 and to a lesser extent ST03 indicate levels higher than NBV set for European soils of calcareous origin. Levels of organic contaminants (data not shown here) were also very low and should not pose any threat to the environment".*

Due to a small number of samples it was not possible to determine the PTEs NBV for local soil. It is recommended that for the purpose of establishing the NBVs for PTEs, the country will be divided in two domains, an urban domain that comprises mainly the inner harbour, outer harbour and the south east sectors, and a principal domain comprising the rest of the country, thus representing the rural areas. In order to establish the NBV at least a minimum number of 30 spatially distributed sample points, are required. The criteria for the determination of the NBVs should be based on ISO 19258:2011. "Soil quality: Guidance on

*the determination of background values" (ISO 2011) (*Meli A., et.al, 2013, pp.76-77).

(iii) Soil Salinization

Soil salinity within the sampled points also appears to display characteristics typical of encroaching desertification process within the Mediterranean region:

*…Salinity is on the high side, but again this is another characteristic of soils from arid or semi-arid regions. The fact that in some areas irrigation is carried out with water of relatively high conductivity further aggravates the situation (*Meli A., et.al, 2013, p.77).

(iv) Compaction

Significant changes were observed with reference to soil compaction even though analysis requires a larger representative sample in order to be compared with previous evaluations on a national level:

…Compaction is surprisingly high and differs substantially from what was reported in 2006. One should consider comparison of the methods used here and method used during the MALSIS survey before drawing conclusions in this respect. Recommendations for further surveys and studies are given in the text however the general aim of further studies should be to characterise the soils further and also more importantly to study the functioning of the soils and their response and reaction to external inputs. Meli A., et.al, 2013, p.77

(v) Landsliding

On landsliding, ERDF 156 project consultants generated a land hazard composite map using limited data available from the MALSIS project. Subsequently land condition variables, where information is already available such as slope gradient steepness, geology, fault aspects and some major soil components (e.g. higher distribution of the clay, and silt soil types as per MALSIS kriged data), was also factored in.

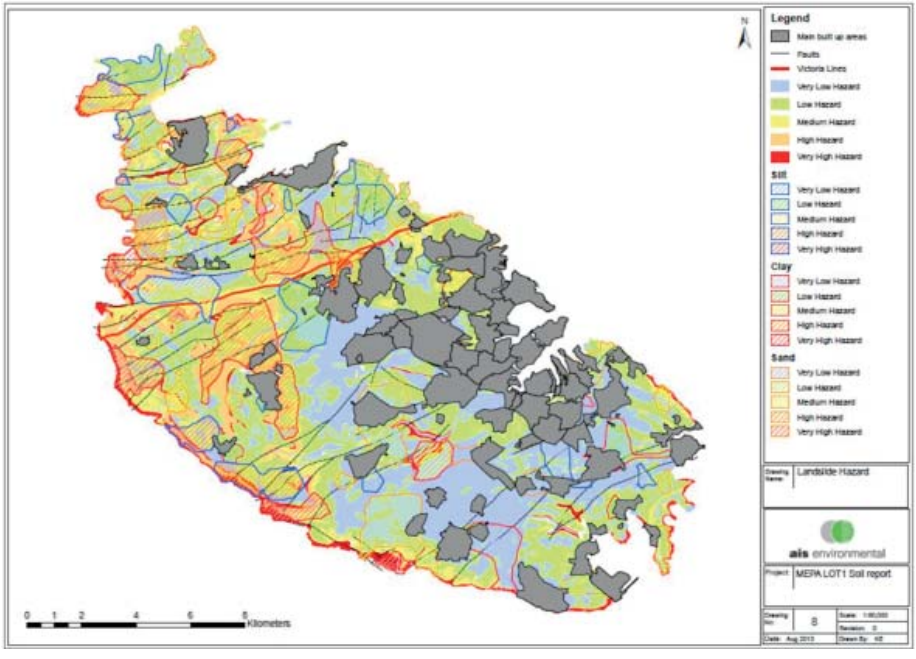
Potential for landslide hazard was thereafter categorized by assigning 5 categories to better display final interim results (i.e. Very Low, Low, Medium, High, High and Very High probability of occurrence). Following that, geological formations were then evaluated against prevailing surface soil types formed by local clay-sand-silt ratios.

Map shown below (Figure 1) is the final product of an evaluation of a series of composite maps showing the following geophysical conditions:

- an overlay of sand, silt and clay areas;
- GIS of a 1961 steepness of slope map;
- analysis of the previous map showing steepness of slope to produce coloured slope hazard values;

- a geological map of Malta displaying formations and respective sub-categories;
- a soil types map;
- a map combining overall picture for slope, geology and soils typology; and
- another geological map in this instance reduced to six types – those pertaining to the upper coralline limestone, in conjunction with steepness and areas where soil content is present.

Figure 1: Landslide Hazard Map for Malta (after Meli et al., 2013, Map 3.8)



Preliminary conclusions reached by project consultants, in relation with local landsliding conditions in the Maltese Islands, are described below:

*Results generally conform to Terracore satellite imagery and investigative report on rockfall hazard in the observation of the cliffs and the clay slopes that indicates that while several mechanisms can be simultaneously responsible of a single rockfall, the latter will be strongly conditioned by the local geological context with particular linkages to undermining of Upper Coralline Limestone over Blue Clay, though variations in temperature in faults cause scaling (*Meli A., et. al, 2013, p.48).

(vi) Other degradation threats

It should be noted that surveying sample designed to measure soil biodiversity losses was too small to merit a robust national assessment. Comparability with past studies is not possible as not even MALSIS addressed this degradation threat despite its rather spatially dense sampling monitoring system.

Information collected only indicated the soil microbial respiration of just four sample sites and the earthworm species. No figures were provided regarding number of earthworms and anthropod biomass and therefore it was concluded that biological status of local soils (let alone the entire biome) could not be determined at this point in time.

Similarly, a comparative evaluation of sealing patterns and soil desertification was not possible at this juncture given that the two sub-themes were not directly measured during the Project's baseline survey.

Recommendations for Future Research

Structured assessment of all degradation threats impacting on local soils is thereby recommended in order to encourage a holistic appreciation of this non-renewable natural resource.

Overarching proposals

A number of general issues and specific recommendations (related to the various degradation sub-themes discussed in this paper) were recommended by the project's consultant experts. Technical advice provided hereunder is important in relation to future soil surveys in Malta likely to be carried out as a follow-up to the 2012 baseline survey.

In a nutshell, improvements to survey quality are intended to address issues related to time, sample consistency, amount of tested samples, continuity or repeat monitoring to gauge changes in the resource's characteristics, and the preparation of specific studies on parallel, (albeit related) themes all of which are intended to establish a more robust information base.

These strategic issues (related to improvement of future survey methodology) are briefly described below:

- Project timing – In Malta seasonality may allow division into a dry and wet period. Regularity in effecting the same seasonal period under study, or a different one to observe any changing trends, shall need specific consideration.
- Sample consistency – Single samples are not advisable. As per MALSIS systems of procedure, a four-metre square grid around a GPS point in which some 25 subsets would be collected is deemed a more representative sample. Additionally, topsoil and subsoil should be differentiated whenever possible.
- Number of samples – Land area studied should be assessed thoroughly in order to

produce a robust sampling and study strategy in accordance with ISO compliant procedures. A logical series of selected area points, non-single but composite, should be investigated and investigations should not be limited to single fields in an area but extended over a much larger area, to cover every locality and, where applicable, its immediate rural area. The MALSIS original number of 320 points, each per square kilometre grid, is more representative, though closer to half this number should provide the basis for more analytical options, given, as per MEPA's 2004 data, that some 242 square kilometres are unbuilt land. Soil type, slopes and size of fields should be taken into consideration prior to soil sampling and measurements. The latter activity shall be carried out within a laboratory managed with an appropriate accreditation standard.

- Continuity – There is an illogical break of continuity of the MALSIS baseline data with limitations to data availability and analysis. Building on MALSIS data with due correlation is the rational way forward. The presence of a soil scientist and an agriculturalist in the entity responsible for soil should ensure sustained conformity within a scientific dimension.
- Specific studies – Particular evaluations of soil property could necessitate more detailed studies than those effected, and at times, if needs be also incorporate new parameters and, in this regard, it is being recommended that infiltration be included in desertification and erosion studies. More detailed studies of coastline landscapes are also suggested.

Specific proposals

Project consultants recommended that the above considerations shall be supported by a set of technical proposals, studies and processes to enable the widest structured coverage of all soil degradation sub-themes. All action points are outlined below for ease of reference:

(i) Sealing

- The preparation of a Construction Code of Practice for the Sustainable Use of Soils on Construction Sites;
- Establish and monitor Good Practice Guideline for Soil Management; and
- Conduct soil monitoring analysis through setting up of land use planning indicators.

(ii) Erosion and desertification

- Future soil sampling surveys should include more coastal, areas on steep slopes and land exposed to the natural elements. Investigations should not be limited to single point sampling, but sampling should be extended over a much larger area. Linkage to erosion should also be considered.

- Visual evidence indicates that soil is washed to the sea with the onset of the rainy season following the dry months of the year.
- Sampling assessment for each studied site/area shall also include a parallel survey of crop growth and crop rotation (i.e. land use intensity and vegetation patterns) as this a significant factor confirming erosion processes.
- Cropping history survey of site should be obtained. This study shall be supported by a land management and land use assessment which should be prepared to acknowledge the fact that land management is a significant factor in terms of desertification. Information covered by this assessment shall incorporate data about the following aspects:
    * Identification of natural soil areas;
    * Agricultural cropland, and land use intensity (the latter should be determined according to stocking rate even though it is not common locally);
    * Identification of recreational areas (classified according to the visitor loading);
    * Extent of quarried areas (to be assessed from their effect on erosion).

- An agricultural practice assessment should be prepared and the area under study assessed by a competent agricultural or soil specialist. A thorough vegetation growth survey should also be carried out. This should include information on percentage plant cover, and vegetation type. The type of vegetation has a direct effect on fire risk assessment, erosion protection and drought resistance.
- Soil organic matter and soil water infiltration quantity (or rate) should be determined for all sites together with soil salinity and SAR (17) or ESP (18);
- With regards to the parent material, more information such as clay content, and whether the parent material is consolidated or not, should be obtained.
- Inclusion and study of wind erosion particularly that resulting from saltation, suspension and creep;
- The use of soil erosion models other than RUSLE (19) especially those more adapted to the region such as WEPP (20) should be considered;
- Soil models (to accurately assess extent, scale and direction of erosion problem), adopted for the purpose of extending and integrating the outcome from the model over larger areas, requires a thorough survey of the area and a better sampling strategy; and
- A project to monitor and measure actual soil erosion in key sensitive areas should be undertaken.

(iii) Contamination, organic matter decline, salinity, compaction

- Further characterization of local soils and study their function, response and reaction to external inputs;
- Establish a local thresholds matrix for the various potential contaminants of this resource by adopting a hybrid system established from the Italian, Dutch and German models;
- Determine and monitor PTEs and NBVs in local soils. The country should be divided in two domains; an urban domain that comprises mainly the inner harbour, outer harbour and the south east sectors, and a principal domain comprising the rest of the country, thus representing the rural areas for the purpose of establishing the NBVs for PTEs;
- In order to establish the NBV at least a minimum number of 30 spatially distributed sample points, are required. The criteria for the determination of the NBVs should be based on ISO 19258:2011 (21);
- Organic matter - At least carry out a survey every 5 years on selected sites to establish a trend on any fluctuations. The sites studied should comprise both uncultivated and cultivated land, the latter representing land that is under intense cultivation, sustainable cultivation practice, forage land, irrigated, non-irrigated and fallow. Agricultural practice of all sites used for the study should also be monitored closely and recorded; and
- Monitor soil bulk density and/or soil strength to assess management change.

(iv) Landsliding (soil displacement)

Recommendations for further research shall involve the surveying of more data collection points with the proviso that there are more specific area studies through geomorpholigical studies. The latter shall also incorporate the use of:

- Geomorphological field surveys and mapping;
- Soil/ clay core physical analysis also covering Atterberg Limits, Plasticity Index and Activity Index including soil penetrometer readings plus piezometers to measure pore water pressures;
- Procurement of a Global Position System device plus extensometer / fissurimeter for monitoring purposes;
- Ground Penetrating Radar surveys correlated to hydrogeological implications;
- Multi-temporal analysis of aerial photographs and digital photogrammetry to determine extent of progression and directional flow of soiled land displacement (including but not limited to monitoring of mudslides);
- Synthetic Aperture Radar /Differential Interferometric SAR analysis Field surveys;
- Specific studies on Blue Clay slopes with more comprehensive site coverage - both

shoreline and inland;
- Recording plus correlation of climatic data including rainfall intensity and mareographic data; and
- Retrospective research on landslide occurrence, plus landslide modelling and hazard mapping with Joint Research Centre's digital landslide database conformity.

(v) Soil biodiversity decline
- Biomass studies should focus on both the diversity of the organisms in the soil and their function.
- As for the other physical and chemical parameters, examples from both cultivated and uncultivated land should be investigated.
- Soil with contrasting properties such as texture, structure, chemical properties (contaminant level perhaps), location and management should be selected. Investigations should be carried out both seasonal initially and also repeated for a number of years in order to investigate seasonal variation patterns and long term trends.
- As the cost of such research could be significantly high, long term experiments should be carried out only on a number of selected sites following thorough preliminary investigations. (This approach not only produces a clear point in time information on the biological status of local soil but also an understanding of how external factors might affect the soils' biological properties over the years).
- Investigations should cover a quantitative aspect, type and number of organisms, as well as biochemical. Quantitative surveys should focus mainly on earthworms, nematodes, molluscs, and arthropods. Quantification and species identification should be according to standard protocol.
- Site surveys should not be restricted to single point sampling but the samples should be representative of the whole area taken in a line transect or grid pattern and should be taken in a way which can be repeated whenever required. With regards to microbial population studies, considering the low rate of cultivation, conventional culture methods should not be attempted, but the use of molecular techniques should be encouraged.
- From a microbial aspect, microbial activity and soil biochemistry would be a more important study. The microbial activity of different soils, under different management strategies should be investigated.
- The following (topic) areas were recommended for further detailed technical investigation:
    * nitrogen cycling activity that includes nitrogen fixation, ammonia oxidation and denitrification;

* local situation with reference tsoil respiration;
* soil and fungal microbial biomass;
* Nutrient cycling potential such as that involving phosphorus and sulphur;
* degradation rates of specific substrates using specific enzyme assays such as protease activity, arginine deaminase activity, phosphotiesterase activity and others; and
* humification and organic matter degradation potential.

Conclusion

Completion of a local soil baseline survey, containing a wider range of parameters investigated in accordance with prevailing contemporary data dissemination standards is, as the name suggests, the start of a long journey intended to introduce regular monitoring of soil quality in a consistent and comprehensive manner to significantly improve primary soil data infrastructure in Malta.

Knowledge gaps regarding local soil monitoring require significant funded (albeit focused) research efforts and continuous integrated monitoring initiatives in order to effectively provide a realistic snapshot of current situation on the ground at equally distributed time intervals.

Emerging cross-cutting themes addressing soil protection and management highlight the following overarching targets:

i. the continued elaboration of a holistic (i.e. multi-layered) national soil strategy and its nested policies (with the latter developed primarily from existing Good Agricultural and Environmental Conditions (GAEC), stakeholder guidelines on Statutory Management Requirements (SMRs) and MEPA's environment assessment process all of which systematically target a number of soil threats;
ii. the pressing ongoing need to enable robust multi-level soil data infrastructure, covering the various degradation threats, to monitor and evaluate the effectiveness of existing and future policies and current soil conservation practices;
iii. the need for structured communication and constant cooperation both between agricultural, environmental-resource authorities as well as between governmental and non-governmental stakeholders; and
iv. advertising of the necessary mix of mandatory and voluntary incentive-based instruments coupled with sufficient information and better fine-tuned advisory service to the rural community i.e. farmers and landowners.

Preparation of sound multi-scale initiatives, to attain and build on the achievements and recommendations described in this paper, are urgently becoming a critical concern

in order to provide comparability with similar information systems across the European Union. Furthermore, support recommendations outlined throughout this contribution undoubtedly coincide with commendable efforts adopted by multi-national organizations such as the United Nations to introduce systemic global awareness about the complexities and hard choices that are required to protect this resource from depletion and cumulative degradation pressures.

The designation of 2015 as the International Year of Soils should provide further impetus towards similar project initiatives in Malta intended evaluate further the state of, and action taken to protect this vital natural heritage feature.

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Notes

1) Developing National Environmental Monitoring Infrastructure and Capacity (ERDF156).

2) EU-wide Framework guidance is provided by Cohesion Policy Regulation, COM(2011) 612, and European Regional Development Fund, COM(2011) 614.

3) Funding Priority 2: Sustaining an environmentally-friendly and resource-efficient economy.

4) Code of Good Agricultural Practice.

5) Good Agricultural and Environmental Conditions.

6) Statutory Management Requirements.

7) Local cross-compliance is regulated through LN 346 of 2005 as amended by LN 207 of 2009.

8) Publication of a comprehensive report titled The State of Soil (issued by European Commission/ Joint Research Centre) may shed further insight at a continental level of constraints identified (e.g. capacity building is not a priority in most MS) which are delaying progress related to a revised in-depth assessment of all soil degradation threats.

9) Some have binding legal obligations, most have a non-binding status.

10) Soil colour was determined according to the Munsell colour chart system notation guide.

11) as identified by the Commission following preparation of its 2004 Soil Thematic Strategy.

12) The values determined for the monitoring sites terms 'general points' have been compared to the values established for the monitoring sites classified as 'biodiversity points' in order to correlate the information emerging from examining the biodiversity indicators to the entire Maltese territory.

13) The C-horizon is the unconsolidated material underlying the solum (A and B horizons). It may or may not be the same as the parent t material from which the solum formed. The C horizon forms as the R horizon weathers and rocks break up into smaller particles. The C horizon is below the zones of greatest biological activity and it has not been sufficiently altered by soil genesis to qualify as a B horizon.).

14) Source: LOT 1, Soil Monitoring Analysis. Consolidated report, interpreting Soil Baseline Survey sampling results prepared in part fulfillment of ERDF 156 project deliverables (Activity 5), as edited by AIS Environmental.

15) Potentially Toxic Elements.

16) National Background Values.

17) Sodium Adsorption Ratio.

18) Exchangeable sodium percentage.

19) Revised Universal Soil Loss Equation.

20) The Water Erosion Prediction Project (WEPP) model – This is a process-based, distributed parameter, continuous simulation, erosion prediction model for use on personal computers running Windows 95/98/NT/2000/XP/Vista/Windows7. The current model version (v2012.8) available for download is applicable to hillslope erosion processes (sheet and rill erosion), as well as simulation of the hydrologic and erosion processes on small watersheds (information source: http://www.ars.usda.gov/Research/docs.htm?docid=10621).

21) "Soil Quality Guidance on the determination of background values" (ISO 19258:2011).