Terms of Reference
National Soil Survey
Commonwealth of Dominica

Table of Contents

1.0 Introduction

The Government of the Commonwealth of Dominica (GoCD) has entered into financing arrangements with the World Bank, the proceeds from which have been allocated towards the financing of the Disaster Vulnerability Reduction Project (DVRP). The support from the Pilot Program for Climate Resilience (PPCR) and the World Bank under the DVRP is aimed at providing the GoCD with financial and technical assistance to reduce vulnerability to natural hazards and climate change impacts. Among the specific aims of the project are the goals to integrate disaster vulnerability reduction and climate resilience in national development planning.

One of the specific projects for integrating disaster vulnerability reduction and climate resilience is the development of a National Soil Survey. The information gained in this endeavor will aid many departments across the government. There is a great need for the information that can be gained in a National Soil Survey. The Lands and Surveys Division would benefit from the information through the combining of detailed soils data with the newly acquired detailed topographic and bathymetry data. Updated soils information would provide a sound basis for the development of planning and zoning regulations that preserve the country's ability to grow food and protect natural resources while guiding development in an environmentally responsible manner. The government water utility, DOWASCO, has a great need for the information related to the natural resources around their water catchments and how best to manage them. Farmers will benefit from obtaining detailed soils information that will help in determining which soils are suitable for which crops. Detailed soils information, including mineralogy, will provide the Agriculture Division with information to provide farmers about composting, fertilizers, and their most efficient use. The Forestry, Wildlife and Parks Division would have a need for information about the relationship between soils and tree species. Soil chemical, physical, and mineralogical properties will allow the Ministry of Public Works and Ports to plan for infrastructure that is suited to the existing soil conditions; detailed testing would be required for design and construction of individual projects. plan, design, and construct infrastructure that is suited to the existing soil conditions.

2.0 Background

2.1 Technical Working Group

This project is funded through the World Bank as a part of the Disaster Vulnerability Reduction Project (DVRP). The National Soil Survey is being administered by the Project Coordination Unit (PCU), an agency within the Ministry of Environment, Climate Resilience, Disaster Management and Urban Renewal. This project is being supervised by a Technical Working Group (TWG) to assist with the evaluation of data gaps and the identification of needs not addressed by the current soil map system. As of the date of this Term of Reference, the Technical Working Group consists of the following individuals:

<u>Project Coordination Unit</u>
Collin Guiste - Project Coordinator
Andrea Marie - Environmental Specialist
Wynyard Esprit - Project Engineer

<u>DOWASCO</u>
Louise Alfred - Water Resource Officer
Sherbert Riviere - Water Operator

<u>Division of Agriculture</u>
Dr. Al-Mario Casimir

<u>Forestry, Wildlife and Parks Division</u>
Bradley Guye - Assistant Forest Officer

<u>Office of Disaster Management</u>
Mr. Fitzroy Pascal - Coordinator

<u>Physical Planning Division</u>
Lyn Baron - GIS Technician

Ministry of Public Works and Ports	Lands and Surveys Division
Mr. Kendell Johnson - Chief Technical Officer	Mr. Vivian Eugene - Land Surveyor
Mr. Emile Lancelot - Deputy Chief	Mr. Kendell Barrie - GIS Technician

The Individual Consultant that will be overseeing the National Soil Survey will be Steve Dadio, Certified Professional Soil Scientist and Soil Classifier. Mr. Dadio will be the primary point of contact between the Selected Consultant and the Technical Working Group; however there will be interaction throughout the project between the Selected Consultant and individuals from the TWG.

2.2 Dominica Soils and National Soil Survey Justification

It is generally accepted that soils which have developed on the deposits of volcanic ash usually have a predominance of non-crystalline alumino-silicates such as allophane, imogolite and allophane-like constituents in the clay fraction and as such a number of chemical and physical parameters are significantly affected by the presence of these minerals. Increasing anthropogenic interference and climate change impacts are causing unprecedented soil degradation affecting the capacity of the soil resources in Dominica to carry-out their functions sustainably. Additionally, soil characteristics and properties (agricultural and engineering) are key inputs for assessing watershed behaviour, erosion, land use suitability and hazard susceptibility analysis, particularly with respect to land slip potential, which ultimately provide data to guide long and short-term development and investment decisions.

In light of these requirements, there is an urgent need for an updated and comprehensive National Soil Survey (NSS) for the island of Dominica. The volcanic soils of the Commonwealth of Dominica were first studied in a relatively detailed way in 1967. The report which followed was part of a wider scheme undertaking soil surveys across all the territories of the British or former British West Indies which commenced in 1947. Since then a number of contemporary studies in Dominica have been undertaken within the general thematic area of volcanism, geothermal and geochemistry which has added insights to the country's soil properties.

However, with the paucity of current information there is an urgent need to develop up-to-date soil datasets which will enable key stakeholders to implement land use strategies guided by edaphic information with regards to the soil's productive capacity and limitations. With its unique climatic conditions and given the difficult challenges with regards to its very steep and finely dissected topography, which accounts for a significant percentage of the country's productive base, the development of soil maps with soil boundaries becomes even more of an imperative in order to guide agricultural development and implement suitable management systems. The development of up-to-date soil maps is even more urgent to guide engineering activities given the role of apparent cohesion in the stability of Dominican soil slopes.

Volcanic soils generally have high physical fertility (tilth) and mature soils are relatively resilient to erosion and compaction and to this extent, these soils are among the most productive soils globally. To maximize their productivity, proper management based on a comprehensive understanding of the unique physical, chemical, and mineralogical properties must be encouraged, particularly as it relates to the structural stability in relation to their erodibility.

Indeed, the hydrological characteristics of the Commonwealth of Dominica, with a relatively high concentration per surface area of streams, rivers and ravines warrants that soil management be reviewed amidst growing environmental concerns of ecological pollution brought about by poor husbandry practices associated with agriculture. Likewise, the volcanic origin of the soil parent material warrants that classification be pursued to meet engineering and construction objectives of soil mechanics. Understanding these mineralogical and chemico-physical differences opens up numerous opportunities in applying knowledge of volcanic soils to important agronomic, environmental, and engineering issues.

Hence current agronomic and engineering challenges highlight the need to critically re-classify these tropical volcanic soils in accordance to international norms such as (e.g. FAO, 1988, 1998, SSS, 2003; FAO, 2006; 2014) which would increase the understanding of their behaviour and hence their management, ultimately leading to increased functionality and well-organized use. In this regard a number of international institutes and organizations, notably the Food and Agriculture Organization of the United Nations (FAO), the National Resources Conservation Service of the United States of America (NRCS), the European Soils Bureau (ESB) hosted by the Joint Research Centre of the European Commission (JRC), the West and Central African Union of Soil Scientists Association, and the International Soil Reference and Information Centre (ISRIC) – World Soil Information, to name only the major ones have all recognized the WRB as the official reference soil nomenclature and soil classification as the preferred tool to harmonize and exchange soil information. In consideration of geotechnical concerns, the Unified Classification system (ASTM test designation D-2487) is the primary standard for these specific purposes.

Edaphic conditions have been greatly influenced by the Commonwealth of Dominica's volcanic origin and the relatively uniform and recent andesitic–dacitic eruptive history has led to variations in rainfall as being the dominant determinant for soil types. Soils of a given type or local classification are in most cases a product of the extent to which volcanic parent material has weathered. As a consequence, the reclassification of these soils is based on soil properties defined in terms of diagnostic horizons, properties and materials, which to the greatest extent possible should be measurable and observable in the field. More importantly, the reclassification exercise is not meant to substitute for national soil classification systems but rather to serve as a common denominator for communication at an international level. This implies that lower-level categories, possibly a third category of the WRB, could accommodate local diversity at country level.

In re-classifying these tropical volcanic soils, the objective would be to align soil classification with international norms. This would allow for the correlation of soil classification systems and the harmonization of ongoing soil classification work. In addition to serving as a link between existing classifications systems, the WRB also serves as a consistent communication tool for compiling global soil databases and for the inventory and monitoring of the world's soil resources. According to the world reference base (FAO, 2006), soil classification consist of three fundamental steps namely: (1) The expression, thickness and depth of layers are checked against the requirements of WRB diagnostic horizons, properties and materials, which are defined in terms of morphology and/or analytical criteria, (2) The described combination of diagnostic horizons, properties and materials is compared with the WRB key in order to find the reference soil group, which is the first level of WRB classification, and (3) For the second level of WRB classification, qualifiers are used. The qualifiers are listed in the key with each RSG as prefix and suffix qualifiers. The use of a common language is of prime importance notwithstanding the availability of reliable information on soil morphology and other characteristics obtained through examination and description of the soil in the field (FAO, 1998, SSS, 2003).

The soils of the Commonwealth of Dominica have been mapped in detail by Lang (1967) who demonstrated that the distribution of soil types is largely a function of climatic factors which control the leaching effectiveness. Soil development has not proceeded very far along the evolutionary path envisaged by Lang and large areas of the island are characterised by smectoid (montmorillonite-rich), allophane (allophane-rich) and kandoid (halloy- site-rich) latosolics along with allophane podsolics in the interior (Fig.l). To the extent possible at a high level of generalization, diagnostic features are selected that are of significance for soil management.

3.0 Required Tasks

For the National Soil Survey, it is required that the Selected Consultant complete soil profile descriptions, map unit delineation, sampling and laboratory analysis in accordance with the provisions set forth in the following sub-tasks.

3.1 Documentation Provided

For the completion of this National Soil Survey, it will be essential for the Selected Consultant to review all published documentation relative to the geology, soils, vegetation, and land-use in Dominica. All published documentation will be made available by the Land and Surveys Division; these include, at a minimum:

- Geology maps
- Existing topographic maps
- 1967 Soil Survey for Dominica
- Hazard Maps
- Natural Resource Datasets
- Existing GIS data layers

Additionally, there is a LiDAR survey being completed for the entirety of the country. This data will be made available to the Selected Consultant as it becomes available.

Please note that there may be additional resources that an individual may find through web-based searching. If requested, the government will search to locate any documentation that is not readily available.

3.2 Soil Sampling Concepts

Throughout Dominica, there exists great variability in the detail of soil pattern, produced by the very steep, finely dissected topography. Hence the recommendation from Lang (1967) confirms that mapping landscape rather than soil boundaries would give a map as valuable as the soil map for land-use planning. In the consideration of a soil map, it should be stated that the “map” will consist of several maps, each one highlighting physical, chemical, and mineralogical properties that are of importance for specific land uses (e.g. agriculture, forestry, natural resources management, road construction, landslide stability, on-site wastewater disposal, etc. These types of maps will include information gathered during this project as well as incorporation of data from previous projects in Dominica.

The purpose of a soil map is to identify consistencies and patterns in soils over various landscapes. A soil scientist can accurately predict soil types and their associated properties using the relationships between soil and landscape features. The combination of the five (5) soil forming factors (parent material, relief, organisms (vegetation), climate, and time) on particular landscapes results in a unique soil (Jenny, 1941). Wilding and Drees (1978) found a relationship between a change in soil properties and landscape position. As soils are sampled across Dominica, it is believed that consistent soil properties can be observed at landscape positions; this will allow the Selected Consultants to develop predictive models on soil properties across the country. From these models, land use interpretations for each landscape can be determined and provide a baseline for evaluating the impacts of management practices.

3.2.1 Considerations of Scale and Sampling Density

The soil sampling plan will optimize, to the extent possible, the number of sampling locations required to support the development of the National Soil Survey. While the focus of the National Soil Survey will be on mapping landscapes, there needs to be a determination of a minimum number of observations across Dominica. This metric will provide surety amongst the various constituencies throughout the country (forestry, fisheries, natural resources and water source protection, urban) that this national effort will provide coverage across Dominica. The minimum number of observations is not intended to be viewed as a grid sampling protocol, but to ensure that there is a baseline of coverage for the soil properties across the entirety of Dominica.

Ultimately, a soil survey is the identification of unique soil properties that are common to a particular landform. This zonal-type of analysis provides the foundation upon which the soil survey is developed.

In determining the appropriate scale for this National Soil Survey, one may consider the use of multiple scales beyond the foundational zonal-type of analysis. Additional observations may be required in urbanized areas/cities, near major roadways, or in agricultural producing areas.

The consideration of scale can be viewed from different perspectives. One perspective is to consider slope classes (Table 1). Generally, urbanized areas and prime agricultural soils are located in less sloping areas. From a physical effort perspective, more samples can be collected on less sloping land.

Table 1. Soil Sampling Density by Slope

Slope Class (%)	Total Hectares	Sampling Density	Minimum Number of Total Sample Points
0 - 8	5,353	1 observation/10 ha	540
9 - 15	11,786	1 observation/100 ha	118
16 – 25	20,071	1 observation/100 ha	201
26 – 40	20,170	1 observation/1000 ha	21
41 – 60	11,608	1 observation/1000 ha	12
>61	3,983	1 observation/1000 ha	4
TOTAL	72,971	1 observation/81.4 ha	896

Another perspective on determining soil sample density is to utilize land-use categories. Nine general land-use categories were identified in the existing Dominica GIS dataset. In consideration of the various land uses, differing densities were determined for each land-use category. These densities are included in Table 2. Please note that the area of the land-use categories is less due to the fact that bare ground and rock-face areas are not included as a land-use; however for these features there will be observations made and this information will provide a basis for determination of slope stability susceptibility.

Table 2. Soil Sampling by Land-Use

Land Use	Total Hectares	Sampling Density	Minimum Number of Total Sample Points
Elfin Alpine Meadow	1,704	1 observation/100 ha	4
Littoral Woodland	376	1 observation/100 ha	4
Mature Rainforest	19,966	1 observation/500 ha	40
Montane Rainforest	4,799	1 observation/500 ha	10
Montane Thicket	735	1 observation/100 ha	8
Savannah and Grazing Lane	5,066	1 observation/10 ha	507
Scrub Woodland	2,830	1 observation/100 ha	29
Secondary Rainforest	23,644	1 observation/500 ha	48
Urban	29	1 observation/1 ha	29
TOTAL	56,319	1 observation/82.9 ha	679

Both of these sampling density tables are to be used as a guide in completing this soil survey. However, the ultimate goal is to complete a detailed soil survey for the various landscapes in Dominica; this very well may involve the completion of many more sample points.

Additionally, there are considerations of equity across the various constituencies within the country. There also needs to be a minimum level of density within each of the 10 parishes in Dominica. It is estimated that there will be a minimum time of 2-3 weeks of field time spent within each parish.

Utilizing the criterion listed above as well as any other knowledge/experience from similar types of projects, the selected consultant will provide a sampling plan to the TWG for their review. This will occur prior to any soil sampling occurring.

3.2.2 Mitigating Factors in Soil Sampling and Responsibilities of the TWG

One challenge in determining the soil sampling density for a given area is site access. Dominica is unique in that the agricultural land consists primarily of small plots where the owners often do not reside on their land. In order to collect a sufficient amount of data points, it is imperative to minimal delays for the timely completion of the project through the proactive policy of outreach and extension

For any investigation on agricultural land, coordination and cooperation will be critical. It is the responsibility of the TWG to provide communication outreach with the public for several weeks prior to an area being investigated. This outreach will explain what is occurring and what the Selected Consultant will be doing on their property and should alleviate any concerns from the farmers about their land being negatively impacted. During the time of the site investigation, a local agricultural agent will accompany the Selected Consultant during their data collection.

In the forested areas, the Selected Consultant will have limited means to travel within the rainforest and will likely have to stay within the existing trail system. The majority of field observations will be made within 50 meters of this existing trail system. Accordingly, soil properties will have to be extrapolated across landscapes from these points.

It is also expected that the Selected Consultant may not be well versed in the unique flora present in Dominica. For all investigations in the rainforest, the TWG will provide the Selected Consultant with a local guide that will assist in forest vegetation identification. It will be the responsibility of the Selected Consultant to compensate the local guide(s) for their efforts. The compensation will be an agreed-upon rate between the Selected Consultant and the local guide, in consultation with the TWG. It is also recommended that a member of the forestry ministry be present during these days to ensure that the public is aware of this field work as part of the National Soil Survey.

For investigations in urbanized areas and cities, the Selected Consultant will opportunistically view construction sites, erosional features and slides, road cuts, and new home construction to gain an understanding of the soils in these urbanized areas. It is the responsibility of the TWG to request access for the Selected Consultant onto these sites.

3.2.3 Expected Level of Effort

It is expected that the level of effort to complete the soil sampling plan will take between 25 and 30 weeks to complete. Assuming an April, 2019 start, this project may be completed entirely within 2019 or may carry over into 2020. The soil sampling ideally takes place after the completion of the LiDAR mapping, which is currently being undertaken. Should the LiDAR mapping be completed over this winter, then it may be possible for this task to be completed entirely within 2019, weather permitting.

3.3 Soil Data Collection

The Data Review and Needs Assessment has been completed for the National Soil Survey of Dominica. The database template will include landscape, land-use, and vegetation characteristics, soil morphological information, as well as chemical, microbial, and physical properties determined in a laboratory. This developed database template will be compatible with ARCGIS.

The ultimate goal of this task is to develop technical requirements that will support the highest degree of spatial resolution that can be achieved within the confines of the available budget. Given the confines of the existing budget, there will be an emphasis on the morphological data, with supporting chemical and physical data being collected in the laboratory. There also will be an emphasis on utilizing analyses that can be completed by government officials of their representatives in Dominica.

3.3.1 Soil Sample Types

When possible, standard test pits at a depth of 1 meter (1x1x1) should be utilized. However it is unrealistic to consider that the Selected Consultant will be utilizing test pits exclusively due to access, time, and manpower concerns. When possible, the Selected Consultant will utilize erosional slides, road cuts, and auger borings as their principal form of soil sampling.

The TWG will effort to advance soil test pits wherever possible on either national agricultural or forestry facilities to provide a basis of understanding of the expected soils within a particular region of Dominica. By providing this information for the Selected Consultant, it will facilitate a more comprehensive soil sampling outcome as there will be a basis of comparison for what will be observed in erosional slides, road cuts, and auger borings.

3.3.2 Sample Location Recording

It is expected that the Selected Consultant will be locating all observation points utilizing Global Positioning System (GPS) technology. Soil sampling point locations will be archived in GIS format using the 1:25,000 national topographic maps as a foundation or as recommended by the Lands and Surveys Division. Working with the Lands and Surveys Division sample locations will be projected to UTM 20N, WGS 84 to facilitate site location using GPS technology. Additionally, the Selected Consultant will be utilizing the exiting LiDAR data and incorporating that information into their data points as well.

3.3.3 Soil Sample Collection

The Selected Consultant will be responsible for collecting soil samplings from each discreet soil horizon. These samples will be stored at the agriculture ministry's office for processing. Soil samples will be analyzed both in Dominica and abroad. The Selected Consultant will be responsible for cataloging soil samples are shipping the appropriate samples to the appropriate laboratory for chemical and physical analyses.

3.3.4 Landscape, Land-use, and Vegetation Characteristics

For each site that is going to be evaluated, the following landscape features will be collected:

- Weather conditions
- Location (latitude, longitude, elevation)
- Landform (slope shape, hillslope profile)
- Slope and aspect

- Drainage, soil moisture, ponding, and flooding information
- Surface stoniness and bedrock features
- Erosion and potential
- Existing land use and cultural practices
- Site photographs (North, South, East, West)

Additionally, vegetation characteristics will be collected at each location. While there are general landforms identified in the existing GIS layers for Dominica, there is the need to develop a more definitive relationship between vegetation and soils, i.e. what types of crops or trees are present on which soil types. There are three general land-uses in Dominica: agricultural fields, forests, human-manipulated landscapes (developed ground, i.e. cities). For agricultural fields, the crops grown within a 15-meter radius from the test location will be described. As cropping practices change over time through rotations or general changes in markets, this information may not be entirely relevant. For forested soils, trees, shrubs, and understory will be characterized within a 7.5-meter radius. This information will be critical in developing soil/plant relationships and will provide a basis for selection of species for areas that are proposed for reforestation. For human-manipulated landscapes, the land-use (e.g. house, road, bridge, etc) will be identified within a 7.5-meter radius.

At each soil sampling location, the landscape, land-use, and vegetation descriptions will be completed in accordance with standards of the USDA-NRCS Field Guide for Describing and Sampling Soils.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

3.3.5 Soil Morphological Characteristics

For soil investigations, basic soil morphological information will be collected, including:

- Depth
- Horizon name
- Color
- Texture (class and % clay and % sand)
- Rock fragments (size, shape and quantity)
- Structure and Moist Consistence/Tilth
- Redoximorphic Features
- Roots
- Density (measured with a pocket penetrometer)

- pH
- Effervescence
- Boundary

These soil morphological descriptions will be completed in accordance with the standards of the USDA-NRCS Field Guide for Describing and Sampling Soils.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

The soils will be sampled through either backhoe excavated test pits, shovel-dug test pits, auger borings, road cuts, or erosional slides. The selected soil scientist will be opportunistic in order to collect a sufficient number of data points for the National Soil Survey of the entire country.

3.3.6 Establishment of Benchmark Soils

The Selected Consultant will encounter similar soils on landscapes with comparable geology, slope, aspect, moisture regime, land-use, and vegetation. Throughout the duration of the National Soil Survey, Benchmark Soils (similar to the concept of the Soil Series) will be established.

The original classification used for the soils of Dominica was developed in 1960 largely from Hardy's work (Hardy and Beard, 1950) which owed much to Kellogg and Davol (1949). The classification attempted to define soil classes more precisely using the development of a single important group of soil characteristics with observable stages. The basic process chosen was weathering together with the weathering-leaching balance. This process of classification is similar to the process currently utilized by the FAO in the World Reference Database (WRB) classification system.

The resultant classification was as local as far as possible based on a number of specific, albeit inferred, processes rather than a universal and open classification. These classes are as follows (with both WRB and Soil Taxonomy analogs):

- Protosols – young soils with little to no weathering
    - WRB – Cambisols, Fluvisols, Luvisols
    - Soil Taxonomy – Entisols or Andisols

- Young soils with some weathering
    - WRB – Cambisols, Luvisols
    - Soil Taxonomy – Inceptisols or Andisols

- Highly weathered soils with allophanoid – gibbsoid clay
    - WRB – Plinthosols, Ferralsols,
    - Soil Taxonomy – Oxisols

- Highly weathered soils with kandoid clay
    - WRB – Ferralsols, Nitisols
    - Soil Taxonomy – Oxisols or Ultisols

- Highly weathered soils with smectoid clay
    - WRB - Vertisols
    - Soil Taxonomy – Vertisols

It is estimated that there will be 30 – 40 Benchmark Soils identified during the course of this National Soil Survey. The amount of analyses required as part of this project is based on the number of Benchmark Soils identified.

For each Benchmark Soil, samples will be collected, labeled, and preserved for laboratory analysis. It can be reasonably estimated that there will be at least 10 replicates of each Benchmark Soil. Should there be 40 Benchmark Soils and with each soil having 5 discreet soil horizons, that would include the collection of 2,000 samples. The number of analyses will ultimately be dependent upon the budget for this National Soil Survey. The Selected Consultant will be responsible for collecting, labeling, and storing all soil samples for subsequent testing. Soil samples that are collected, but not tested, will be stored by the GoCD in accordance with standard techniques and held for a period of up to five (5) years for future analyses, if funds become available.

3.4 Classification, Testing, and Data Archive Requirements

The soils in Dominica are unique with the steep contrast between minimally and highly weathered parent materials. On large portions of the island that consist of young materials, formed in volcanic materials (Andosols). According to the Soil Science Society of America, these soils are generally fertile due to their high capacity to hold both nutrients and water. However, these soils have low phosphorus availability due to the presence of the amorphous clays (e.g. allophane, imogolite, halloysite). These clays pose a significant challenge for both physical and chemical analyses.

On stable landscapes, given the warm temperature and moist climate, there is rapid weathering of the clays and low-activity clays predominate (Ultisols and Oxisols). These soils are generally not fertile with few cations present with the exception of aluminum; phosphorus availability in these soils is also low as allophane binds it and renders it unavailable for plant uptake. These clays pose an additional set of challenges as some analyses are suited to soils within a specific pH range and these soils are often below this pH range.

There are specific methods to determine the presence of andic properties; these methods include the following:

World Reference Base (WRB)

- Acid oxalate extractable Al + 1/2Fe oxalate values of 2.0% or more
- Bulk density of 0.90 kg/dm3 or less
- Phosphate retention of 85% or more
- Less than 25% organic carbon

Soil Taxonomy (U.S.)

Same as WRB, except that it allows for an additional set of criteria:

- 30% or more of soil particles are between 0.02 and 2.0 mm in size
- Phosphate retention of 25% or more
- Acid oxalate extractable Al + 1/2Fe oxalate values of 0.4% or more
- Volcanic glass content of 5% or more

In discussions with laboratories in the United States (USDA-NRCS Kellogg Laboratory in Lincoln, NE) and other countries with substantial areas of volcanic soils (Korea, New Zealand), it is not practical to complete these analyses for every soil sample.

To determine the presence of andic materials, both field analysis and completion of pH tests in sodium fluoride (NaF) will first be utilized as a screening tool. In the field, the presence of andic materials can be observed through the morphological soil description as well as during texturing. Given the stark contrast between the relatively young andic soils and the much more weathered soils with low activity clays, identifying andic materials in the field should be feasible to complete.

The laboratory analysis of andic materials will be completed in accordance with the procedures of Field and Perrott (1966). A pH value of greater than 9.5 indicates the presence of andic materials.

Fieldes, M., Perrott, L.W. 1966. The nature of allophane in soils. III. Rapid field and laboratory test for allophane. New Zealand Journal of Science. 9: 623-629.

There are other methods to determine the presence of allophane as well, such as the toluidine blue test. While not referenced in the WRB database, this method has been proven to be effective.

Koji Wada & Yasuko Karwto (1985) An Evaluation of the Toluidine Blue Test for the Assessment of Allophane and Imogolite, Soil Science and Plant Nutrition, 31:3, 383-389.

When soils meet the andic field and pH indicators, selected subsamples will be sent to a laboratory to verify that the soils meet the WRB criteria listed above.

3.4.1 Field Physical Properties

Soil physical properties will be measured in the field. These properties include the following:

- Surface permeability
    - Saturated hydraulic conductivity (Ksat)
- Sub-surface permeability (in the most restrictive soil horizon to the depth of investigation)
    - Saturated hydraulic conductivity (Ksat)
- Available water capacity (AWC)
- Bulk Density
- Penetration Resistance

ASTM methods

Dane, J.H., and Topp, G.C., eds., 2002, Methods of Soil Analysis, Part 4, Physical Methods: Madison, WI, Soil Science Society of America, Soil Science Society of America Book Series Number 5.

Soil Survey Staff. 2014. Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Zhang, Renduo. (1997). Infiltration Models for the Disk Infiltrometer. Soil Science Society of America Journal - SSSAJ. 61. 10.2136/sssaj1997.

Should the Selected Consultant identify another method for measuring soil physical properties in the field (to supplement or as a substitute for the methods referenced above), they may present these methods to the TWG for their consideration.

The Selected Consultant will be responsible for bringing the appropriate testing equipment for the analysis. It may be possible for some of these analyses to be completed by government professionals in Dominica. This would provide both a cost and time savings in the overall collection of data for this project.

The amount of surface and subsurface hydraulic conductivity measurements will be at a minimum of five (5) set of measurements per Benchmark Soil.

3.4.2 Chemical Analysis

These analyses are applicable to all soil samples and horizons. Currently, crops in Dominica are selected to plant based on a cultural and historical basis. The collection of data regarding the soils will provide a scientific basis to select plants that are best adapted to the particular soil conditions in an area.

Additionally, very little is known about the dynamics of carbon in Dominica, particularly in the forested areas of the country.

While it is critical to understand the basic fertility of the soils, it is equally vital to understand the presence and concentrations of metals as well. The soils in Dominica are unique as they are dominated by volcanic materials and possess high levels not only of allophane but also of other metals, such as cadmium. Cadmium can be readily taken up by plants (especially at lower pH levels) and chronic exposure to cadumium has been found to lead to kidney disease, osteoporosis, diabetes, cardiovascular disease and cancer. For this reason, the European Union has responded to these findings by announcing the introduction on January 1, 2019 for limits on the amount of cadmium in cocoa products. From that date, a 100 g bar of dark chocolate containing more than 50 percent cocoa solids must not have more than 0.08 mg of cadmium. For the preservation of public health and the development of a viable export industry for cocoa, it is critical to know where the soils have elevated cadmium levels. Given this information, farmers can make responsible decisions on where to plant their cacao tress. This is just one example of the importance of collecting this soils information as it relates to agriculture.

Through many discussions with soil scientists both in the United States and other countries, it has been determined that the following analyses would be both of value and economically feasible for the National Soil Survey.

- Cation Exchange Capacity
- pH
- pH using NaF (Sodium Flouride)
- Extractable Phosphorus, Potassium, Calcium, Magnesium, Aluminum, Base Saturation, cation exchange
- Soluble Salts
- Organic Matter
- Total Carbon
- Total Nitrogen
- Nitrate Nitrogen
- Ammonium Nitrogen
- Total Sorbed Cu, Zn, Pb, Ni, Cd, Cr, Mo

Acceptable methods for completing these analyses are provided below:

D.L. Sparks (ed). Methods of Soil Analysis, Part 3. Chemical Methods. Soil Science Society of America Book Series Number 5. American Society of Agronomy, Madison, WI.

J.T. Sims and A. Wolf (eds.) Recommended Soil Testing Procedures for the Northeastern United States. Northeast Regional Bulletin #493. 3rd edition. Agricultural Experiment Station, University of Delaware, Newark, DE.

Soil Survey Staff. 2014. Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

USEPA. 1986. Test Methods for Evaluating Solid Waste. Volume IA: 3rd Edition. EPA/SW-846. National Technical Information Service. Springfield, Va.

Should the Selected Consultant identify another method for measuring soil chemical properties (to supplement or as a substitute for the methods referenced above), they may present these methods to the TWG for their consideration.

Please note that while these methods are referencing universities and organizations based in the United States, the methods have been proven as accurate in characterizing soils in tropical climates and in both andic and highly weathered soils.

The Selected Consultant may choose to bring in equipment to complete the analyses while working on the National Soil Survey. It may be possible for some of these analyses to be completed by government professionals in Dominica. This would provide both a cost and time savings in the overall collection of data for this project.

For selected, Benchmark Soils, the full suite of these analyses should be completed for each soil horizon at ten (10) locations/Benchmark Soil. However, additional testing may be requested in the surface horizon(s) for all soils.

3.4.3 Microbial Analysis

Soil respiration is a measure of carbon dioxide (CO_2^-) released from the soil from decomposition of soil organic matter (SOM) by soil microbes and respiration from plant roots and soil fauna. Soil respiration reflects the capacity of soil to support soil life including crops, soil animals, and microorganisms. It describes the level of microbial activity, SOM content and its decomposition. In the laboratory, soil respiration can be used to estimate soil microbial biomass and make some inference about nutrient cycling in the soil. Soil respiration also provides an indication of the soil's ability to sustain plant growth. This analysis shall be completed following the procedure by Parkin et al (1996).

Parkin T.B., J.W. Doran, and E. Franco-Vizcaíno. 1996. Field and Laboratory Tests of Soil Respiration. In: Doran J.W., A.J. Jones, editors. Methods for assessing soil quality. Madison, WI. p 231-45. Physical Analysis.

Should the Selected Consultant identify another method for measuring soil microbial properties (to supplement or as a substitute for the methods referenced above), they may present these methods to the TWG for their consideration.

The Selected Consultant will be responsible for bringing the appropriate testing equipment for the analysis. It may be possible for some of these analyses to be completed by government professionals in Dominica. This would provide both a cost and time savings in the overall collection of data for this project.

This analysis will be completed in the surface layers of Benchmark Soils at 5 locations/Benchmark Soil,

3.4.4 Physical Analysis

It has been determined that the following analyses will be of top priority for this National Soil Survey. These analyses are applicable to all soil samples and horizons.

- Grain size analysis (sieve analysis)
- Hydrometer particle size analysis
- Moisture content
- Atterberg Limits

Soils that formed in volcanic soil materials presented many problems in the analysis of physical characteristics. The amorphous clays behave differently upon drying and subsequent re-wetting, as is common in physical analyses. Consideration of the soil mineralogy must be taken into account when completing these analyses.

Acceptable methods for completing these analyses can be found through the following references:

ASTM methods

Dane, J.H., and Topp, G.C., eds., 2002, Methods of Soil Analysis, Part 4, Physical Methods: Madison, WI, Soil Science Society of America, Soil Science Society of America Book Series Number 5.

Soil Survey Staff. 2014. Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

The Selected Consultant may choose to bring in equipment to complete the analyses while working on the National Soil Survey. It may be possible for some of these analyses to be completed by government professionals in Dominica. This would provide both a cost and time savings in the overall collection of data for this project.

The full suite of these analyses should be completed for each soil horizon at a minimum of 10 locations/Benchmark Soil.

3.4.5 Engineering Analysis

For other soil test locations, physical analyses should be focused on the horizons near public infrastructure (e.g. roads and buildings) as well as in human manipulated landscapes. There would be value in completing the following analyses:

- Cone Penetrometer
- Soil Bearing Capacity
- Shear Strength
- Specific Gravity

These tests will be completed at the depths of approximately 1.0 to 2.0 meters, which is the depth frequently associated with the sub-base of roads or of residential foundations.

Acceptable methods for completing these analyses can be found through the following references:

ASTM methods

Dane, J.H., and Topp, G.C., eds., 2002, Methods of Soil Analysis, Part 4, Physical Methods: Madison, WI, Soil Science Society of America, Soil Science Society of America Book Series Number 5.

The Selected Consultant may choose to bring in equipment to complete the analyses while working on the National Soil Survey. It may be possible for some of these analyses to be completed by government professionals in Dominica. This would provide both a cost and time savings in the overall collection of data for this project.

This analysis will be completed for the subsoil horizons in Benchmark Soils at a minimum density of ten (10) locations/Benchmark Soil.

3.4.6 Mineralogical Analysis

In discussion with various experts in the field of soil mineralogy both in the United States as well as other countries, it is not feasible to complete a wide-scale mineralogical analysis of the soil properties. There are very few laboratories in the world that complete soil mineralogical characterization (x-ray diffraction) for commercial use. Additionally, the process for determining soil mineralogy in andic soil materials is not through x-ray diffraction, but through the presence of aluminum and iron oxalates. According to the latest version of the UN-FAO World Reference Base for Soils (2014), andic properties require meeting the following laboratory criteria:

1. an Al_{ox} + ½Fe_{ox} value of ≥ 2%; and

2. a bulk density value of ≤ 0.9 kg dm-3; and

3. a phosphate retention of ≥ 85%.

For this reason, there will be an emphasis on the determination of andic properties by using the sodium fluoride field test of Fieldes and Perrott (1966). A pH value in NaF of ≥ 9.5 indicates allophane and/or organo-aluminum complexes in carbonate-free soils.

When soils meet the andic field indicator for pH values in NaF of ≥ 9.5, selected subsamples will be sent to a laboratory to verify that the soils meet the WRB criteria listed above.

Should the pH values in NaF be less than 9.5, the soils will contain clay minerals that will be detected utilizing x-ray diffraction. For these soils, XRD analysis will be completed.

It is anticipated that there will be mineralogical analyses for at least five (5) samples per Benchmark Soil. It is recommended that the selected consultant team with a university or institute that has the capacity to complete these types of analyses. If this resource is not available to the selected consultant, the number of required samples may be reduced, if agreed to by both the selected consultant and the TWG.

3.5 Soil Map Unit Delineation

It is expected that the Selected Consultant will be making preliminary map unit delineations based on their soil, slope, vegetation and field observations. These delineations will be completed and submitted to Mr. Dadio for his review in accordance with the Reporting requirements in this Term of Reference.

4.0 Reporting

It is required that the Selected Consultant apprise the Technical Working Group of the status of the National Soil Survey on a regular basis. This will include direct contact with Mr. Dadio as well as coordination with the TWG. The reporting requirements will include:

- Weekly agendas (4 weeks in advance) for Soil Survey efforts. This will allow the TWG sufficient time to secure access for future sampling.
- Weekly summary reports for work completed.
- Conference calls on a monthly basis.

- Submission of completed soil descriptions, map unit delineation, laboratory analyses within 2 weeks of completion.

Additionally, there may be additional meetings requested by the GoCD or the TWG regarding the status of the National Soil Survey.

5.0 Qualifications

The Selected Consultant will answer to the Technical Working Group, but will be working primarily with Mr. Dadio. All administrative and financial matters related to the consultancy will be handled by the PCU.

The minimum qualifications and experience of the Selected Consultant are as follows:

- Postgraduate degree (MSc or PhD) in soil science, land management or other suitable disciplines.
- 5 years experience in soil mapping, description and analysis, land use planning and land management
- Certification by the Soil Science Society of America (SSSA) as a Certified Professional Soil Scientist (CPSS) or Certified Professional Soil Classifier (CPSC). Certifications by other organizations may also be considered, pending review by the Technical Working Group.
- Demonstrated experience in projects having similar geomorphology and landscapes to those found in Dominica
- Demonstrated experience with GIS data systems particularly as it pertains to digital soil mapping
- Demonstrated experience with the conduct of soil mapping surveys and related technical and analytical equipment as well as laboratory procedures.
- Working competence in English language

Working under the direct supervision of the Selected Consultant, the soil survey team may consist of 2-4 (or more) soil scientists that will be primarily responsible for data collection and laboratory analysis. The minimum qualifications and experience of the soil survey team members are as follows:

- Bachelor's (BSc) in soil science, land management or other suitable disciplines.
- 2 years experience in soil mapping, description and analysis
- Certification by the Soil Science Society of America (SSSA) as an Associate or Certified Professional Soil Scientist (APSS; CPSS) or Certified Professional Soil Classifier (CPSC). Certifications by other organizations may also be considered, pending review by the Technical Working Group.

- Demonstrated experience with GIS data systems particularly as it pertains to digital soil mapping
- Demonstrated experience with the conduct of soil mapping surveys and related technical and analytical equipment as well as laboratory procedures.
- Working competence in English language

The Technical Working Group will review the qualifications of each member proposed for the soil survey team. Should the qualifications of a particular individual not meet the requirements set forth above, the Technical Working Group may request that the Selected Consultant replace that individual with another whom meets these qualifications.

The Selected Consultant will be responsible for all expenses incurred during the National Soil Survey. These costs include:

- Travel
- Lodging
- Meals
- Transportation
- Laboratory Equipment
- Shipping of Samples
- Lab Fees
- Local Guide Compensation