Sediment fingerprinting:

A methodological framework

Workshop Summary

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Prepared by:

Alex Koiter (koiter@unbc.ca)

Leticia Gaspar Ferrer (Leticia.GasparFerrer@unbc.ca)

Kui Liu (kui.liu@umanitoba.ca)

1. Introduction

The sediment fingerprinting technique is becoming a widely used tool to assess the sources of sediment within a watershed. Despite the increase in the numbers of researchers using the technique no standardized approach exists. The lack of standardization in the approach is due to: 1) the infancy of this discipline; and 2) the uniqueness of individual watersheds in terms of its physical and biogeochemical characteristics. If the technique is to move from a research tool to a management tool some standardization of the approach, or set of guiding principles, is needed.

A sediment fingerprinting workshop was held at the University of Manitoba July 7 – 11, 2014. Participants were graduate students and researchers from across Canada representing a wide range of watersheds. The purpose of this workshop was to share knowledge, discuss some the current methodical issues and develop some guiding principles. This report is the outcome of the five day workshop and can serve as a starting point for people beginning a sediment fingerprinting project. As mentioned earlier, there is no standard approach so this report is not a step-by-step instructional manual but rather it provides advice and suggestions to help guide decision making on designing and executing a successful sediment fingerprinting project. It is also important to note the steps involved in sediment fingerprinting are not necessary sequential or independent from one another and that each step of the approach needs to be given some consideration prior to starting a project. This report contains: 1) a brief description and outline of the major steps in sediment fingerprinting; 2) guiding principles and advice; 3) future research directions (if applicable); and 4) suggested readings.

Suggested readings

Davis CM, Fox JF (2009) Sediment fingerprinting: Review of the method and future improvements for allocating nonpoint source pollution. Journal of Environmental Engineering 135:490–504.

Krishnappan BG, Chambers PA, Benoy G, Culp J (2009) Sediment source identification: a review and a case study in some Canadian streams. Can J Civ Eng 36:1622–1633. doi: 10.1139/L09-110

Mukundan R, Walling DE, Gellis AC, et al. (2012) Sediment source fingerprinting: Transforming from a research tool to a management tool. Journal of the American Water Resources Association 48:1241–1257.

Walling DE (2005) Tracing suspended sediment sources in catchments and river systems. Science of the Total Environment 344:159–184. doi: 16/j.scitotenv.2005.02.011

2. Watershed description

2.1. Objectives

Knowledge of the study area and the watershed characteristics is strongly needed. The description of the watershed must be one of the first information to be obtained on environmental studies, as well as, on sediment fingerprinting technique. Information related about the geomorphology, hydrology and climate, land use, soils or location, among others, provide an understanding and criteria for 1) the sampling design; 2) the potential physical and biogeochemical changes that can occur during the transport of sediments, and for 3) interpreting the results obtained by putting these data into the appropriate spatial and/or temporal context.

2.2. Watershed data acquisition and management (advantages of GIS)

It is important to collect as much information as possible on the watershed before start the project. It is essential to be familiar with the watershed by describing the land use, soil type, topography, geomorphology, hydrology and climate characteristics. By combining all of the information, one can begin to understand the behaviour of the watershed.

The use of Geographical Information Systems (GIS) allows us to capture, store, manipulate, analyze, manage, and present all types of geographical data. GIS use the existing digital and geo-referencing information, as well as the no digital information after digitalizing these data. From the information contained in the Geospatial Database - Canada's servers (see below few websites recommended), GIS produces by combining the data and maps available, new and very useful maps (land uses, soil types, geomorphology maps...), topographic data (Digital Elevation Model – DEM, cartography, LIDAR data), orthophotos, hydrological data, and information derived in different formats (vector and raster) and scales of the watershed. GIS tools are highly recommended because allow users to create interactive queries (user-created searches to identify in the watershed area with specific conditions or properties), analyze spatial information, edit data in maps, and present the results of the watershed. It is worth mentioning the surface analysis and hydrological tools in GIS, which have become a useful way to understand the water connectivity of the watershed. DEM data are layered with hydrographic data so that the boundaries of a watershed may be determined. Watershed delineation and topography aid in understanding where runoff from precipitation or snowmelt will eventually drain, and consequently, identify potential areas of erosion. In the case of snowmelt, snowpack coverage may be determined from ground stations or remotely sensed observers and input into GIS to determine or predict how much water can be counted on to be available.

2.3. Field reconnaissance & photographs

Once collecting all information and maps are has been completed, a reconnaissance of the study area "in situ" shall be carried out. This step is important to 1) recognize "in situ" changes between different soil types; 2) identify the limits between different land uses; 3) identify geomorphological elements that control the basin, and 4) define potential areas of erosion. Taking photographs of the study area some field description, can be used to design the sampling strategy and may help to interpret the results. It is highly recommended to work in a systematic way.

The understanding of the study area and all the information collected about how the different soil types, land uses, geomorphology elements, among others, are related, is extremely important in the interpretation of the results estimated with fingerprinting techniques.

Suggested websites

Canadian GIS Data Sources [FREE] - National and Provincial & Regional Canadian Data. *Find all the official links for the different Canada regionis in* http://canadiangis.com/data.php

Natural Resources Canada - GeoGratis http://www.geogratis.gc.ca/geogratis/Home?lang=en

Natural Resources Canada - Remote sensing & High spatial resolution image (10 to 100 cm/pixel) http://www.nrcan.gc.ca/forests/remote-sensing/13435

Agriculture and Agri-Food Canada - Canadian Soil Information Service http://sis.agr.gc.ca/cansis/index.html\

The Canadian System of Soil Classification http://www.pedosphere.com/resources/cssc3rd/index.cfm

3. Sampling design and methods

3.1. Objectives

The aim of outlining the sampling methods, in complementary to the existing standard operating procedures (SOP), is to provide a guideline of sampling in the sediment fingerprinting study, ensuring that both source and sediment samples are collected properly and represent the potential sediment sources within the watershed.

3.2. Soil/source

The first step in deciding where and how to sample is to understand the erosional processes you are trying to characterize (e.g., rill vs gully erosion). Source samples should be collected at locations where the sediment is being generated. The typical sediment sources include surface soil (e.g., agricultural topsoil) and subsoil (e.g., streambanks). To capture the spatial and temporal variation of surface soil sources, transect sampling is recommended. The sampling transects should be established along a toposequence parallel to the dominant slope gradient and extend from the edge of the streambank to the hilltop. Each transect should be comprised of four to eight individual sampling points. In many sediment fingerprinting projects samples are only collected in the surface soil (e.g., 0-5 cm) as this often best represents potential sediment sources (i.e., sheet or rill erosion). It is also recommended that sample be taken throughout the soil profile as the information gathered from these samples can be used to understand the erosional history of the landscape as well as the vertical distribution of soil properties. For subsoil sources it is recommended that samples be collected through out the entire profile. It is also recommended that composite samples are taken to better characterize the spatial variation. It is recommended to have at least 500 g of soil per composite sample to ensure sufficient mass for analysis. Sampling sites should be marked by GPS coordinates for future reference.

3.3. Sediment

Many different types of sediment have been used in sediment fingerprinting projects including: suspended, channel bed, floodplain, wetland, lake sediments. Suspended sediments are the most common type of sediment used as it has the greatest environmental impact. Suspended sediment is typically collected at the watershed outlet, however, it is advised that the sediment be collected at multiple sites along the study river. Depending on the research objectives time-integrated sediment traps (e.g., Phillips, 2000) or point samples can be taken using a continuous flow centrifuge. The site selection normally reflects the changes in the landscape, land use, or sediment sources. Replicated sediment traps at a single site are recommended. Sediment traps are placed in parallel with flow ensuring water and sediment flow through the trap. Sediment traps are normally attached to a heavy concrete objects such as a patio stones or a steel rod to prevent loss. The sediment trap should be checked regularly to ensure the in-and out-let are unclogged. The sediment trap should be emptied as least twice a year to capture seasonal changes. As a complementary measure of suspended sediment, bed load and/or floodplain deposit samples close to the suspended sediment traps can also be collected for the sediment fingerprinting study.

3.4. Labelling

A systematic labelling is important measure to avoid future confusion in a long-term study. Labelling information normally include project title, sample information, site, date including year, and person who collected samples. Sample information should include sample type, soil depth, transect information, and GPS coordinates. Labels can be made using WORD in combination with EXCEL.

Suggested readings

Phillips JM, Russell MA, Walling DE (2000) Time-integrated sampling of fluvial suspended sediment: a simple methodology for small catchments. Hydrological Processes 14:2589–2602.

Fryirs K (2013) (Dis)Connectivity in catchment sediment cascades: a fresh look at the sediment delivery problem. Earth Surface Processes and Landforms 38:30–46.

4. Sample analysis

This step of the sediment fingerprinting approach aims to characterize the potential sediment sources and collected sediment. Sediment and soil properties commonly used in sediment fingerprinting can be broadly separated into three categories; (1) geochemical, (2) biochemical and (3) physical fingerprints. As is the case in many sediment fingerprinting studies the exact suite of sediment properties that will yield good results are not known prior to analysis. Other information about the watershed including soil types and geology can help the determine the appropriate suite of analysis. However, the suite of properties that are analyzed for will often depend on the instrumentation and budget available. Common analysis used in the characterization of soil and sediment include: particle size distribution, organic matter content, colour, geochemical analysis, radiochemical analysis, and compound specific stable isotopes.

4.1. Sample preparation and storage

Become familiar with the theory and standard operating procedures of any proposed analysis prior to any storage and preparation. Familiarity with the analysis is important as some analysis are very sensitive to how the samples are stored and prepared. Improper storage and preparation can lead to problematic analysis. Common storage options include: air drying, freeze drying, refrigeration and freezing. Sample preparation options include: sieving, grinding and oven drying. If sieving is required in the preparation of samples it is important to record the weight of stones or other material being removed. It is generally good practice to never throw away parts of samples as it may be need later on for different analysis. Grinding or pulverization of a sample is an irreversible process and it generally a good practice to set aside a subsample of the original sample. If a subsample is taken for any reason it is very important that the mass of the sample is recorded. It is advisable that a protocol be written to ensure all samples are stored and prepared the same way.

4.2. Order of analysis

The order in which different analysis is done can be very important, especially when sample sizes are small. It is generally advisable that a flow chart, or order of operations, be created prior to any analysis. When creating the flow chart it is important to note the mass of sample needed for each analysis to ensure that you have an adequate total sample mass for each analysis. When you have small samples it is also important to do the nondestructive analysis first to ensure sufficient sample mass is available for each analysis. In cases where there is insufficient mass for all the proposed analysis it is important that priority order is established.

4.3. Quality control

Good quality control measures ensure good accuracy and precision. One of the most important aspects of quality control is that appropriate standard operating procedures (SOP) are followed. Many laboratories have established SOPs but it is important to ensure that the SOP being followed is applicable for your sample type (i.e., different soil types may require different SOPs). Any deviations made from an SOP needs to be noted. Following an SOP allows data to be compared both within a watershed and between different watersheds. If no SOP exists it is important to document the methodology used with sufficient detail that the methods can be used by other researchers.

The use of standards and/or reference samples is strongly encouraged and is part of many SOPs. The use of standards and reference samples helps ensure that the equipment and instrumentation are functioning properly and the reagents are of good quality. Any major deviations in the results typically indicate that there is an issue with one of the instrument or reagents.

Suggested readings

Carter MR, Gregorich EG (2007) Soil Sampling and Methods of Analysis, 2nd ed. CRC Press, Boca Raton, FL, U.S.A

Foster IDL, Lees JA (2000) Tracers in geomorphology: theory and applications in tracing fine particulate sediments. In: Foster IDL (ed) Tracers in geomorphology. John Wiley & Sons, Chichester, UK, pp 3–20

5. Identifying and classifying potential sources

All sources that contributed to the suspended sediment noticeably should be included as potential sources in sediment fingerprinting studies. Sources can be classified based on land use, soil survey information, geology, field observations, and erosion history obtained through communication with land lowers. Ideally, sources should be distinguished from each other (section 6), if the tracers are unable to discriminate between sources they may need to be grouped together. As a rule of thumb, the minimum number of tracers is n-1 in order to discriminate among n sources. When there are a limited number of tracers, the number of sources might need to be reduced by source grouping. Sources can be grouped based on their individual contributions to suspended sediment and the sources with less contribution can be potentially pooled together. Potential sediment sources can also be grouped by erosional process (e.g., rill and gully erosion). The potential sources that are identified need to remain meaningful. It should be noted that the greater number of sources included generally results in a greater amount of uncertainty in the mixing model results (section 8). The mixing model can be run using separately using different groupings of sediment sources (i.e., based on landuse and geology). The information provided can be used to understand the interactions between multiple factors (i.e., where two or more source sets overlap).

Suggested reading

Russell MA, Walling DE, Hodgkinson RA (2001) Suspended sediment sources in two small lowland agricultural catchments in the UK. Journal of Hydrology 252:1–24.

6. Selecting appropriate tracers

6.1. Fingerprinting tracers selection

The discrimination of sediment sources is based on identification of differences source material properties and quantification of the relative contributions from these sources to sediment delivered downstream in river catchments. The fingerprinting procedure employs statistical testing of a range of source material tracer properties to select a subset that can discriminate between the different potential sediment sources.

Depending if the data present a normal or non-normal distribution of the different properties, there are different statistical testing. Additionally, if the data does not have a normal distribution, there are different transformations (e.g. *Log Transformations*) that can be applied to normalize the data before the tracer selection process.

Despite having no standardized protocol to identify the optimum combination of sediment properties to include in a composite fingerprint, Cluster analysis coupled with analysis of variance and Discriminant Function Analysis (DFA) coupled with a multivariate stepwise algorithm, based on the minimization of Wilks' Lambda, have been successfully employed to identify the smallest number of tracer properties that provide maximum discrimination of source properties. The application of these procedures was frequently preceded by the use of statistical tests, such as the Kruskal–Wallis H-test to identity tracer properties that are statistically different between source areas. However, a purely statistical approach may not be the most appropriate method as the conservative behavior of sediment properties and the underlying processes that lead to their ability to discriminate between sources are not considered. Understanding the physical basis for discrimination for a given tracer as well as the behaviour of the fingerprinting properties will have to be taken into account to choose the potential fingerprinting properties

It is recommended that a combination of statistical- and process-based selection criteria are used to determine appropriate sediment properties to include in the mixing model. The most effective tracers for discriminating sources in a watershed should allow: 1) to obtain quantitative estimates of the relative contributions from different sources; and 2) to identify changes in spatial patterns and timescales of suspended sediment transfer in response to changes in the landscape (e.g., recent agricultural land cover change, or management change of the watershed). As we mentioned in section 4, depending on the instrumentation and budget available, different sets of soil and sediment properties are going to be able to be used as potential fingerprinting tracers.

6.2. Tracer correlations

As a preliminary filter, the correlations between fingerprint property concentrations and, for example, depth have to be considered. If a strong correlations with depth exist, this suggest that the variations with depth could reflect changes in suspended sediment source, rather than other factors such as the age of the sediment. For this reason certain sediment properties may be eliminated from the selection process.

Some of fingerprinting properties are often correlated with one another and the impact of elemental correlations on modelling results has not been investigated deeply. The incorporation of correlations is important as it re-introduces the interrelationships between distributions directly into the modelling process. More research is required to fully understand potential impacts of correlations and correlation modelling approaches on sediment tracing modelling results.

Suggested reading

Blake WH, Ficken KJ, Taylor P, Russell MA, Walling DE (2012) Tracing crop-specific sediment sources in agricultural catchments. Geomorphology 139-140:322-329.

Collins AL,Walling DE (2002) Selecting fingerprint properties for discriminating potential suspended sediment sources in river basins. Journal of Hydrology 261:218–244.

Foster IDL, Lees JA (2000) Tracers in geomorphology: theory and applications in tracing fine particulate sediments. In: Foster IDL (Ed.) Tracers in Geomorphology. John Wiley & Sons Ltd., Chichester, pp. 3–20.

Laceby JP, Olley J. An examination of geochemical modelling approaches to tracing sediment sources incorporating distribution mixing and elemental correlations. doi: 10.1002/hyp.10287

Koiter AJ, Owens PN, Petticrew EL, Lobb DA (2013) The behavioural characteristics of sediment properties and their implications for sediment fingerprinting as an approach for identifying implications for sediment fingerprinting as an approach for identifying sediment sources in river basins sediment sources in river basins. Earth-Science Reviews 125:24-42.

Russell MA, Walling DE, Hodgkinson RA (2001) Suspended sediment sources in two small lowland agricultural catchments in the UK. Journal of Hydrology 252:1–24.

Smith HU, Blake WH (2014) Sediment fingerprinting in agricultural catchments: A critical re-examination of source discrimination and data corrections. Geomorphology 204:177–191.

Walling DE (2005) Tracing suspended sediment sources in catchments and river systems. The Science of the Total Environment 344: 159–184.

7. Accounting for the fate of sediment and tracers

One of the key assumptions of sediment fingerprinting approach is that the sediment behaves in a conservative manner. In other words, the physical and biogeochemical properties of the source materials does not change during the erosion, delivery and transport processes allowing for a direct comparison between source and sediment. This assumption is rarely met and steps need to be taken to account for the differences between source and sediment.

One of the most common properties that change is the particle size distribution as the sediment generally enriched in fine-grained material compared to the sources. This is important to consider as many of the properties used as fingerprints are sensitive to changes in the particle size distribution (e.g., metal concentration). The primary way to reduce the effects of particle size is to sieve the samples to a size that closely represents the sediment being transported in the watershed. In many sediment fingerprinting projects all source and sediment samples are sieved to <63µm, however, other researchers have used <10µm or <2µm. Even with sieving there can still be differences in the particle size distribution and many researchers use a particle size correction factor to account for the difference. In most cases, the correction factor used is the ratio of the specific surface areas of the suspended sediment and source material samples. There is debate in the literature on whether this type of particle size correction factor is appropriate as it assumes that the relation between the specific surface area is linear and is the same for all tracers. There is evidence that both of these assumption may not be met in may cases and that data correction can results in is. It is advised that relation between particle size and a given tracer be known prior to applying any correction factor.

Another common difference between sources and sediment is the organic matter content as the sediment generally enriched in organic matter compared to the sources. Similar to the issue of particle size, the organic matter content can have an affect on the sediment fingerprint. Some researchers use organic matter correction factors similar to the particle size correction factor to account for the differences between source and sediment. However, there is some concern that the use of both particle size and organic matter correction factors will over correct as the two properties are often correlated. Other researchers have removed the organic matter by loss on ignition (LOI) negating the need for a correction factor.

Other considerations need to be given to the biogeochemical changes that can occur during transport. Some process that can affect the biogeochemical properties of sediment include: precipitation/dissolution, adsorption/desorption, reduction/oxidation and microbial processes (e.g., decomposition). Currently there are no correction factors to account for these changes. One of the best ways to deal with these issues is to exclude tracers, as part of the tracer selection process (section 6), that are known to be reactive in the environment (e.g., phosphorus). Biogeochemical changes may be more of a concern depending on the type of sediment collected. For example, biogeochemical changes may be less of a concern with suspended sediment compared to sediment collected from a lake sediment core. The characteristics of the watershed (section 2), and the environment in which the sediment is collected can help inform the decisions on whether biogeochemical changes are a concern and need to dealt with.

It is important to note that any sieving needs to be done before sample analysis and that data corrections need to be applied before selecting appropriate tracers (Section 6) and using a mixing model (Section 8).

Suggested readings

Smith HG, Blake WH (2014) Sediment fingerprinting in agricultural catchments: a critical re-examination of source discrimination and data corrections. Geomorphology. doi: 10.1016/j.geomorph.2013.08.003

Koiter AJ, Owens PN, Petticrew EL, Lobb DA (2013) The behavioural characteristics of sediment properties and their implications for sediment fingerprinting as an approach for identifying sediment sources in river basins. Earth-Science Reviews 125:24–42. doi: 10.1016/j.earscirev.2013.05.009

Smith HG, Dragovich D (2008) Improving precision in sediment source and erosion process distinction in an upland catchment, south-eastern Australia. Catena 72:191–203. doi: 10.1016/j.catena.2007.05.013

8. Mixing models

Mixing models (also known as unmixing or source apportionment models) is a tool that is used to quantitatively link sources and sediment in terms of the proportion derived from each potential source. At its core, mixing models are a mass balance equation; what goes into the river must come out of the river. Currently there are two main groups of mixing models, multivariate and Bayesian methods, and there is little consensus as to which type of mixing models are most appropriate for sediment fingerprinting. The models are generally run using programs like MATLAB, R or Python, and require some experience in using the programs. There are mixing models available that have graphic user interfaces (GUI), including IsoSource and MixSIAR, and these models are typically more user friendly. Many of the mixing models available have been developed for different applications (e.g., ecology) so not all the options available will be applicable for sediment fingerprinting.

It is important to understand some of the limitations and assumptions of the models being used. Some of the main assumptions of mixing models (adapted from Ward, 2012) are:

1) All sediment samples come from the same set of sediment sources

2) All sediment sources are equally available in terms of amounts of sediment being delivered to the stream (in some cases this can be modified)

3) No potential sources of sediment are missing

4) Sediment sources are fully characterized in terms of their sediment fingerprints

Some models will have other assumptions and caveats (e.g., normality of data) and it is important to ensure that the all of the assumptions are reasonable met or, have an understanding of how it will affect the outcome, before applying a model.

An equally important step in the mixing model is interpreting the data and putting it into the appropriate spatial and/or temporal context. Here is where the watershed characteristics (section 2) and the sampling design (section 3) are very important. The location of the sediment sampling site within the watershed and with respect to the potential sediment sources need to be considered when interpreting the results. It is also advised that other lines of evidence (e.g., visual observations) be used to support the results of the mixing model (i.e., do the model results fit with other observations).

Suggested readings

Parnell AC, Inger R, Bearhop S, Jackson AL (2010) Source partitioning using stable isotopes: Coping with too much variation. PLoS ONE 5:e9672.

Nosrati K, Govers G, Semmens BX, Ward EJ (2014) A mixing model to incorporate uncertainty in sediment fingerprinting. Geoderma 217–218:173–180. doi: 10.1016/j.geoderma.2013.12.002

Ward EJ (2012) Introduction to (Bayesian) Isotope Mixing Models. http://afsuw.files.wordpress.com/2012/05/intro-to-mixing-models.pdf

Koiter AJ, Lobb DA, Owens PN, et al. (2013) Investigating the role of connectivity and scale in assessing the sources of sediment in an agricultural watershed in the Canadian prairies using sediment source fingerprinting. Journal of Soils and Sediments

9. Archiving the data

9.1. Creating a database

Although open source software is often recommended, Microsoft office is well-known and standardized software. Normally, Microsoft Office Excel is used to create the database in a research project. In this workshop we have considered start using Microsoft Office Access to try to solve few problems that have been recorded, especially when in the research groups there are many people involved, and when large volume of data are registered.

When you have a lot of data and it needs to be organized, and different people are involved do you use Excel or Access? Well, it depends! So, what is the difference?

In Access, you can specify the types of information (fields) you want to store about soil samples, GPS location of sampling points, soil properties measured, or whatever you're recording. But you can do the same thing in Excel. Just substitute columns for fields and rows for records. Access and Excel are alike in many ways. They can store millions of records. Both can run queries, a fancy word for an advanced search that allows you to see which records meet certain conditions. They even look similar, because in Access, you can view your data in a giant table, which looks a little like an Excel worksheet but is important to understand their differences.

- If your data are primarily numbers probably your best option is Excel, but if you plan to store also large chunks of text like description of sampling points, you should probably put it into an Access database.
- Both programs are great at searching through your data to answer any question you might have, but if you plan to pose especially complex or highly varied queries, you may want to use Access. It can almost instantly generate a list of all the samples that have, for example, values higher than

7 of pH, with values of organic matter between 2-5%, a clay content higher than 70%, situated in cultivated sites located in the steepest areas of the watershed.

- If we want to store pictures of the sampling points, then we should definitely use Access. Also Access can store pictures, web links, and most other types of information as easily as someone's name.
- Finally, Access is probably your best bet if many people need to use or add information at the same time, but both programs are part of the Microsoft Office system, so it's easy to transfer your data back and forth. You may want to have your master data stored and maintained in an Access database and then pull out appropriate cross-sections to analyze in Excel.

The entire database or spreadsheet has to be updated to correct or include new data. To save different database versions, I personally recommend include the date and initialed at the end of the file's name (e.g. *SouthTabacco_2014.07.04_LG.xls* = South Tabacco Creeck database was modified in **July**, **4**th **2014** by **L**eticia **G**aspar)

9.2. Provide enough information

A systematic recording of the data is important measure to avoid future confusion in a long-term study. All labelling information (section 3.4) has to be included in the database, as well as all the sample information and all the results of the different soil properties analysed in the lab. We have to be very much aware to for example, include unit of the soil properties, identification number of each sample and subtract the tare or weight of plastic bags. The data base should be clear, simple and data have to be sorted. The database must provide enough detail for someone who is new in the project. The Excel or Access files have to allow everybody the use and knowledge of all the data collected in the past for different people, including background information to provide context in which the samples were collected.

Suggested readings

Microsoft Office Access http://office.microsoft.com/en-ca/access/

Import, export, and link data between Access and Excel http://office.microsoft.com/en-ca/access-help/import-export-and-link-data-between-access-and-excel-HP001095095.aspx