



A COMPLETE GUIDE TO SMART SPATIAL ANALYSIS

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Preface

We would like to thank our sponsors. Without their support we would not have been able to research, design and implement this SMART Spatial Analysis. Without their trust, our vision to develop tools that assist the conservation of animals and fauna would have not materialised. We hope in the future our tools will help you in preserving wildlife and natural habitat.

This document has been written for several types of readers in mind:

Advanced users and computer administrators:

This document is a detailed installation guide. Some minimum requirements are stated before SMART Spatial Analysis can be installed. This will ensure any computers continuing working with a good overall performance.

These users can install an operating systems and other applications. They have full administrator rights on the personal computer or laptop where they install SMART Spatial Analysis. These users will the following chapters useful:

- ❖ [Introduction](#)
- ❖ [Installation guide](#)
- ❖ [User guide](#)
- ❖ [Concept](#)

Existing SMART users:

SMART users will find it useful to learn about new concepts behind SMART Spatial Analysis. This guide will familiarise SMART users with the user interface as well as some other concepts that may be unfamiliar. These users may find it useful to read the following sections:

- ❖ [Introduction](#)
- ❖ [Concept](#)
- ❖ [User guide](#)

New SMART users:

New SMART users can use SMART Spatial Analysis without learning using SMART applications. They need to have access to a SMART application and database with a valid username and password.

We would recommend these users to download the *SMART 5 Technical Training Manual*; this document can be download from <http://smartconservationtools.org/support/>. The following sections should be the most informative.

- ❖ [Introduction](#)
- ❖ [Concept](#)
- ❖ [User guide](#)

Researchers:

We understand that SMART application have been successfully the tool of choice to conduct some academic research on law enforcement and other interests. We therefore believe that SMART Spatial analysis could also help any researchers to complete their data analysis. We would recommend these researchers to read and reference the following articles:

Critchlow, R., Plumptre, A. J., Alidria, B., Nsubuga, M., Driciru, M., Rwetsiba, A., & Beale, C. M. (2017). Improving Law-Enforcement Effectiveness and Efficiency in conservation areas Using Ranger-collected Monitoring Data. *Conservation Letters*, 10, 572-580.

Critchlow, R., Plumptre, A. J., Driciru, M., Rwetsiba, A., Stokes, E. J., Tumwesigye, C., & Beale, C. M. (2015). Spatiotemporal trends of illegal activities from ranger-collected data in a Ugandan national park. *Conservation Biology*, 29, 1458-1470.

We would also recommend any researchers to read the following sections of this document:

- ❖ [Introduction](#)
- ❖ [Installation guide](#)
- ❖ [User guide](#)
- ❖ [Concept](#)

Minimum prerequisite IT skills

SMART Spatial Analysis users need the following prerequisite IT skills:

- ✓ Log in and out of a personal computer using Windows or any other operating systems.
- ✓ Running from applications (such as Microsoft Windows)
- ✓ Navigate through a folders architecture using a file manager or Save from Microsoft Office.
- ✓ Save files from Microsoft Office in *My Documents* or other folders

Introduction

What is SMART Spatial Analysis?

Welcome to the user manual for the SMART spatial analysis program! This program is designed to complement and function alongside a SMART application. Its first purpose is to create some analyses of the spatial probability of a threat occurring within a conservation area. Temporal trends impact of a management intervention can also be analysed in the same manner. These analyses can be adapted to other activities of interests, where SMART application has been adopted.

Essentially, the analysis uses information on where rangers go and what they find to identify patterns in where illegal activities happen and uses this information to predict where illegal activities may be happening but the rangers haven't been. The better the analysis is able to identify patterns in the illegal activity data, the better it will be able to predict where to send rangers. Users need to provide maps that give extra information about the conservation areas that can help understand the patterns in poacher behaviour. For example, snares are often set around waterholes and along rivers, so if you have a map of rivers and waterholes the analysis will be able to use this information to check whether there is a strong pattern in your conservation area and, if so, identify where snares might be found in areas with water holes that are rarely visited by rangers.

The outcome of these analyses are shown as maps with areas of different colours to highlight the variation in threat across space and time. These maps can help improve patrol efficiency by identifying where in the conservation area needs to be patrolled in the future.

Why do I need SMART Spatial Analysis?

Rangers in the field are usually the experts when it comes to knowing where some illegal activities of different types occur. However, our research has shown that sometimes rangers miss some of the hotspots that our program can identify, and that rangers can often spend more time than required in some areas with relatively lower rates of illegal activity; knowing where illegal activities are more likely to happen can dramatically improve detections. In practice, rangers also know some of the hotspots but not all of them. Poachers also change their activities over time to avoid the areas where rangers regularly visit.

SMART Spatial Analysis is designed to help conservation managers to analyse the data collected during ranger patrols. For example, this new application can assist in answering the following questions:

1. Where do most activities of a certain type occur within my conservation area, independent of reporting bias?
2. Are there any places within my conservation area where some activities are the most common and changing over time?
3. Are there overall changes in the occurrence of illegal activities in my conservation area?

4. Has a specific management intervention changed the numbers of illegal activities that are occurring?

SMART Spatial Analysis applies some advanced statistical methods to observations made during ranger patrols. These methods correct the tendency that some statistics related to the predictions of patrols are overestimated or underestimated. This common phenomenon (i.e. *bias*) would not represent accurately the observations made are recorded in SMART.

Bias occurs in many statistical methods we use everyday. Correcting this bias can improve the planning of future patrols by highlighting where hotspots of illegal activities or other activities of interest exist. The results of these analyses can then complement the query tool of SMART 5 and previous versions. Currently, SMART can filter and summarise the observations made in the past. The results of these queries provides information using some tables and some maps. Some conversation managers would need work out for themselves the hotspots of activities that are of interest.

Instead, SMART Spatial Analysis provides an analytical tool that uses knowledge from past ranger observations. Two types of information are identified: (1) spatial and temporal patterns of illegal activities (or other activities of interest) and (2) areas where rangers haven't been but should visit because they are identified as high risk areas and because changes in the spatial distribution of activities might occur. This knowledge therefore becomes useful to predict where some activities of interest may occur in the future and where known hotspots can be targeted.

More detailed information on accurate predictions of illegal activities in space and time can then be used by conservation managers for planning future patrols. Knowing where illegal activities or other activities of interests are more likely to happen can dramatically improve detections.

Will this program tell me where to send rangers, day to day?

In time we hope to develop features that will allow the user to plan patrol routes to increase ranger patrol efficiency. For now we simply provide maps that managers can use to direct patrols more generally, knowing the underlying pattern of illegal activities.

Concepts

This section introduces some concepts that are useful to understand before using SMART Spatial Analysis. These ideas have been applied during the development of this application and will enhance your experience.

Overview of SMART applications and data storage

SMART database

A database stores information in a structure on a computer's hard disk that makes it more easily accessible and manageable. A SMART database stores all data entered into SMART that is associated with a conservation area. This includes, for example, ranger-collected data, some links to some geographic data and employees details.

SMART file storage

Some files hold some geographic data and other information required for the functioning of some SMART applications. These elements are created and updated automatically by SMART applications.



Backing up a SMART database and a file storage

Module 8 of the Training manual explains how to complete a system backup. This type of procedure is often required to prevent the loss of data. It is also required to upgrade to a new version of a SMART application.

The settings of SMART Spatial Analysis needs to be updated before logging ([see step 3 and 4 of the installation guide](#)). Otherwise, the predictions may not retrieve all the more recent observation.

SMART application

An application is a computer program designed to perform some tasks for the benefits of the users. The SMART application provides the tools manages a conservation area. It has been design to record ranger-collected, employees details as well as some intelligence information. SMART Application can report on observations made in the past.

The SMART application require a SMART database and SMART file storage to function appropriately. The data stored in a SMART database and a SMART storage may not be retrieved and updated with a SMART application; it can become irretrievable.



Downloading SMART Application and its training manual

SMART Application can be downloaded from the following website:
<http://smartconservationtools.org>

Its training manual can be downloaded from the following web page:
<http://smartconservationtools.org/support/>

SMART Spatial Analysis

SMART Spatial Analysis is also a computer program. It also designed to retrieve some information from a SMART database and SMART file storage. Its purpose is to predict some hotspots of illegal or other activities in the future. SMART Spatial Analysis analyses some ranger-collected data and other geographical data to suggest some information related to some hotspot of illegal or other activities. The results of these analyses can be used to plan future patrol activities.



Downloading and installing SMART Spatial Analysis

SMART Spatial Analysis can be downloaded from the following website:
<http://smartconservationtools.org> [need to be verified]

A [installation and setup guide](#) is provided in this document.

Overview

SMART Spatial Analysis and SMART Application complement each other to aid the management of a conservation area and the planning of future patrol activities. We can, therefore, represent SMART Application as a layer on top of a SMART database and SMART file storage.

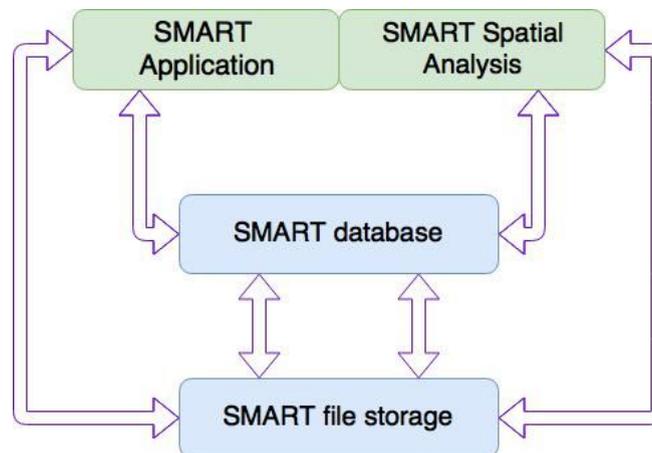


Figure 1: A graphical representation of the SMART Applications and data storages used in SMART.



Access to SMART Database

A SMART database can only be accessed by one user and one application at a time: to run the SMART Spatial Analysis, SMART must be closed.

SMART user to close or quit SMART Application before opening SMART Spatial Analysis.

Geographic data and geographic information system

Geographic data associates a location clearly and exactly to Earth. Some standards formally define the methods used to represent, access and process the information describing some objects and some phenomena that are associated with our planet. For example, some coordinates, some elevations and some land cover. It is worth noting a geographic information system (GIS) stores, captures, analyses geographic data.

We consider SMART application as a geographical information system specialised in managing a conservation area. SMART application defines the boundaries of a conservation area using some points, polygons and lines; those are referred as shapes. These shapes are often defined using a Cartesian system (i.e. x and y coordinates) corrected to the earth curvature.

Shapefiles

Some geographic data is stored in files referred as *shapefile*. This standard was developed and is regulated by Environmental Systems Research Institute of the United State of America (ESRI). Several types of files are required to store various geographic information; those are summarised in table below. For more information, the standard can be downloaded from this website: <https://www.esri.com/library/whitepapers/pdfs/shapefile.pdf>.

File ending with	Type of data
.shp	Geometry features (shapes)
.shx	Shapes indices
.dbf	Shapes Attributes
.prj	Coordinates system information

Raster

Rasters are geographical data that represents an image with a group of cells; the latter are organised in rows and in columns (i.e. a matrix). Rasters can show maps and images captured from satellites. Raster can be useful to represent real-work phenomena such as elevation and land cover. Each cell store a specific value that provide some categories of land usage or even some altitude. This type of files can end with the extension ".shp", ".tiff", ".tif", ".geotiff", and ".asc".

Basemaps

Some background information can add some context to a map. This context can be some water features, a road networks, some vegetations and also some elevation. Basemaps are specialised map that can provide this type of information to a location. Raster can provide this type of background effectively.

The information contains these basemaps provides the required information to calculate the distance to the nearest features of a conservation area.



Uploading some geographical data in SMART database

Modules 1 and 2 of the Training manual shows how to upload some geographical data into a SMART database. This can only be completed via a SMART application.

The settings of SMART Spatial Analysis can be updated after logging to a conservation area ([see step 3 and 4 of the installation and setup guide](#)).

Importing geographic data from a SMART database

SMART Spatial Analysis extracts all the geographic data that have been added to a SMART database for a specific conservation area. Our process reads all the information encrypted in a SMART database and calculate the boundaries from these entries. Those are then saved into a unique file in a SMART file storage.



Conservation area boundaries

Ranger patrols and records of illegal activity can only occur within the conservation area. If many of the ranger patrol records fall outside the the existing conservation area boundary, it may be sensible to update the boundaries in SMART Application.

Modules 1 and 2 of the Training manual shows how to upload this geographical data into a SMART database. This can only be completed via a SMART application.

Analyses

Analyses are processes that break down some elements into smaller ones, with the purpose to gain a better understanding. Various analysis techniques exist for a different purpose. For example, the reporting and query tools provided by SMART Application aims at monitoring the patrol's activities and findings. The analyses summarise some observations made in the past. Some data from a SMART database are retrieved, and some elementary statistical methods are applied. All these analyses aid developing a better understanding of what has been happening in a conservation area. The SMART users can evaluate and make some strategic planning.

Spatial and temporal analyses

SMART Spatial Analysis breaks down differently the data stored in a SMART database. Instead, some *spatial and temporal analyses* can assist with some strategic planning and complement the rangers knowledge. Some hotspots of illegal or other activities that need to be patrolled are identified.

Firstly, the spatial element suggests some locations and geographic data are both analysed; Some locations of some observations and other features (see covariates) needs inputted. Secondly, the temporal element indicates these data are examined to provide a model over a period of time. The date and time of the patrols and other ranger entries are also extracted from a SMART database.

From the ranger-collected data, (1) some locations where some illegal or other activities have occurred and (2) the current rangers activities have taken place are both identified. The conservation area is then split into cells; for each cell the likelihood that some illegal or other activities that may occur is then computed. These probabilities aid to compute some statistics that would indicate where some illegal and other activities may occur in the future. Overall, this process interpret some information to gain some knowledge. Then it uses again this knowledge to update the outcome in the light of new evidences.

Types of analyses

SMART Spatial Analysis run three types of analyses; Single-time continuous analysis, Trend analysis, and test-management intervention analysis. We will introduce each of them below.

Single-time continuous analysis

This analysis identifies the places within a conservation area where a particular set of illegal activities happened most frequently during a specified period. Figure 2 shows an example of this analysis output. The red regions indicate the locations to target for some increased ranger activity.

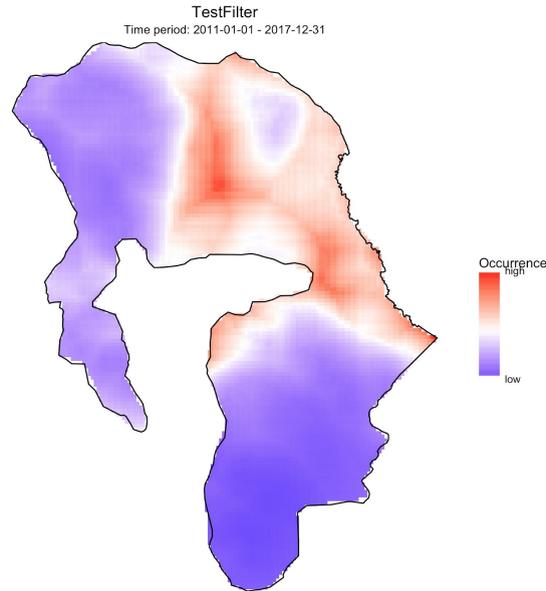


Figure 2: Output from a single-time continuous analysis

Trend analysis

This analysis identifies how numbers and distribution of illegal activities are changing over time. The outcome shows the occurrences of unlawful or other activities for each different period of time; several maps are consequently produced. This sort of analysis might be useful to run once a year on annual time steps for annual reports, identifying how the past year fits into changes over recent years.

Add here some examples outputs.

Figure 3

Test-management intervention analysis

This analysis runs two single time-continuous analyses and automatically identifies changes between the two period of times. This type of analysis is ideal for evaluating the effectiveness of an intervention.

Add here some examples outputs.

Figure 4

Single time-period analysis:

Test management intervention analysis:

This analysis allows you to run two single time-period analyses before and after a particular change in management. For example, from the 1st March 2017 you may have increased the number of ranger patrols in one area and want to know whether this has resulted in a decrease in illegal activities. To test this, you will need to identify two time periods, one before and one after the intervention and you need to compare the two. Ideally, these will be the same length of time and otherwise matched. In the example of an increase in ranger activities, it might be sensible to pick a six month period from 1st March 2016 as the baseline conditions and compare that with the 6th month period from 1st March 2017 when the new management was in place.

Both time periods should have a suitable number of observations for analyses (at least 50 data entries). The analysis will run two single time-period analyses for the two time periods and will automatically identify changes between the two.

Trend analysis:

This analysis allows you to identify how numbers and distribution of illegal activities are changing over time (remembering that all analyses require at least 50 data entries). You need to specify an end date, the length of each time period (e.g. one year) and the number of time periods you want. The program will use this information to identify time periods and will analyse each time period separately, before summarising the patterns of change over time and geographically. At the end of the analysis you will be given maps of occurrence of illegal activities within each time-period, as well as the trend in activities over time and space (for example, some areas of the conservation area may have increasing levels of illegal activity, while others are decreasing) and the overall trend in time. This sort of analysis might be useful to run once a year on annual time steps for annual reports, identifying how the past year fits into changes over recent years.

Once you've decided what type of analysis you want to run, click on open and select the analysis type you want to create.

Covariates

Covariates are data that are expected to influence the distribution of illegal activities and can be used in the modelling process to help identify patterns and provide more accurate results. In SMART Spatial Analysis the covariates are inputted as maps from the list of basemaps that have been uploaded to a SMART database. These maps include information such as roads and river networks, habitat types and elevation that are converted to covariates in SMART Spatial Analysis. If there are no basemaps loaded in SMART this will be blank and this can be ignored!), but they can also be uploaded at a later date.

Six categories of covariates

Six types of covariates have consequently been defined in SMART Spatial Analysis; two of them are non-optional. Each of them describes some features of a conservation area such as boundaries, roads and water.

Boundaries (obligatory)

SMART Spatial Analysis requires the limits of a conservation area to run some are not optional and are required to run any analyses. This type of covariates provides the geographical data of the boundaries of the conservation area. Boundaries are non-optional, otherwise, no analysis can run in SMART Spatial Analysis.



Uploading boundaries to SMART

The spatial boundaries are defined and stored as [shapefiles](#) files. Module 1 and 2 of the *Training manual* will show you how to upload such geographical data in SMART Application.

Every time the spatial boundaries are updated, SMART Spatial Analysis need to be updated too (see [the installation and setup guide](#)).

Projection (obligatory)

The boundaries are defined with a projected coordinate system. These coordinates are computed to take into consideration the spherical surface of planet earth onto a x and y coordinates. SMART Application uses by default the standard WGS84. SMART Spatial Analysis must extract this geographic information from a SMART database; otherwise, no analysis can run.

**Setting in SMART Application some projection**

The projection is defined and stored as [shapefiles](#) files. Module 1 and 2 of the *Training manual* will show you how to upload such geographical data in SMART Application.

Every time the projection is updated, SMART Spatial Analysis needs to be updated too (see [the installation and setup guide](#)).

Roads (optional)

Rangers, poachers and other people rely on some road networks to make a journey through a conservation area. Road networks often include some roads, paths or even some tracks. The interpretation can be quite broad.

Some illegal and other activities are more likely to occur closer some elements of a road network; these areas are more easily accessible. Therefore the distance to the nearest roads can beneficially predict some future hotspot of illegal or other activities.

**Uploading some Road network in SMART Application**

You could download many types of road networks from the NASA website; <https://lpdaac.usgs.gov/>.

Once downloaded you will need to upload these shapefiles in SMART Application as basemaps. Module 2 of the *Training manual* will show you how to upload them.

Water (optional)

The water category represents some ponds, waterholes, lakes, rivers and perhaps reservoirs. These natural or human-made elements support the fauna and flora; they attract many animals as they promote and support their survival. As a result, areas close to water are more likely to be hotspots of illegal or other activities, particularly poaching. If a conservation area has some of these water elements documented, we would therefore strongly encourage them to upload them. It would positively influence the predictions of illegal and other activities hotspot.

**Uploading some water basemaps in SMART Application**

The most accurate maps of water (rivers, lakes and waterholes) will be those that have been digitised manually for the conservation area. Once created, these will need to upload these shapefiles in SMART Application as basemaps. Module 2 of the *Training manual* will show you how to upload them.

Other numeric (optional)

Other types of files must be provided in raster format. Other numeric (often referred to as continuous rasters) are maps including variables such as altitude, slope and numerical measures of soil wetness. Each grid cell contains a gradually changing variable (i.e. values). If other raster variables are provided, they do not need to be in the same projection or cell size structure as the other variables; this process is included as part of SMART Spatial Analysis.



Downloading some other numeric covariates and uploading them in SMART Application

Many types of numeric data can be downloaded free from the NASA website; <https://search.earthdata.nasa.gov/search>.

Once downloaded you will need to upload them in SMART application. Module 1 and 2 of the *Training manual* will show you how to upload them.

Other classified (optional)

Other class maps must also be provided in raster format (rather than spatial polygon shapefiles). Other class (sometimes referred to as discrete rasters) are maps like habitat or land use where each grid cell contains a number that identifies how the cell relates to a class of values. For example, in a vegetation map, '1' may be used to indicate grasslands, '2' indicates woodlands and '3' indicates forest, but intermediate values make no sense. These variables are useful if there are major differences of the map (e.g. habitat) within your conservation area, but must not be finely classified: the analysis will only work with 3 or 4 different classes identified, so use these very sparingly!



Downloading other classified covariates

You could download many types of classified data free from the NASA website <https://lpdaac.usgs.gov/>. An example of a classified variable is the habitat product MCD12q1.

Once downloaded you will need to upload them in SMART application. Module 1 and 2 of the *Training manual* will show you how to upload them.

Covariates data storage

Every type of covariate is either stored in the SMART database or in SMART file storage. SMART Spatial Analysis only retrieves this geographical information. The SMART application offers the tools to upload the files in the SMART database or in SMART file storage.



Setting up the covariates in SMART Spatial Analysis

[Step 3 and 4 of the installation and setup guide](#) provide more information.

Applying covariates to an analysis

When any analyses are created or edited, the distance to a conservation area features can be set. By default, the distance to the boundary is set and cannot be removed. This include the two non-optional covariates (i.e. boundaries and projection).

All the geographic data labelled as “Road” are grouped together in one subset. Similarly, all the geographic data labelled as “Water” forms another dataset. Other features labelled as “Other numeric” and “Other classified” can be also be added and removed (see below).

A maximum number of 6 items can be selected for any single analysis.

Boundaries, Roads, water and other features.... (6 maximum)



Filtering observations

A data filter takes some information out that users feel may not fulfil the desired outcome. These articles demonstrate and illustrate how some data can be filtered in Microsoft Excel ([link to article](#)) and Microsoft Access ([link to article](#)).

SMART Spatial Analysis filters observations that are recorded during ranger patrols. Users can select data using two methods: 1) a tree structure summarising the data model entries recorded against some observations and 2) by using dates that define a period of time.

Data model entries

The SMART application relies on a well-defined and well-structured data model to record observations made during patrols. The query tool in a SMART application can also filter data using data model entries (see module 4 of the SMART Training manual).

SMART Spatial Analysis provides a simpler filtering tool; it only shows the data model entries recorded against some observations in a SMART database. Consequently, the filter criteria should identify any observations and their data that matches the condition(s).

A hierarchical structure can consequently be slightly more condensed than the whole data model in a SMART Application (see Figure 5). Some of the entries of the data model may not be used and hence not shown.

Similarly as a SMART Application, some tree structures represent a data model and its hierarchical property. A complete ‘tree’ includes all the categories, attributes and values defined in a SMART database. Each folder represents the categories, sub-categories, and attributes. Each folder models the values. For example, Figure 5 (left hand-side) illustrates four values have been recorded against some observations for the attribute referred as *ageofanimal*. This attribute has been classified under the category *animal.carcass*. On the right hand-side, some observations have been recorded for the category *people.chased*. As a result, the *noattribute* and *novalue* indicates no defined attribute and value has yet to be matched against some observations.

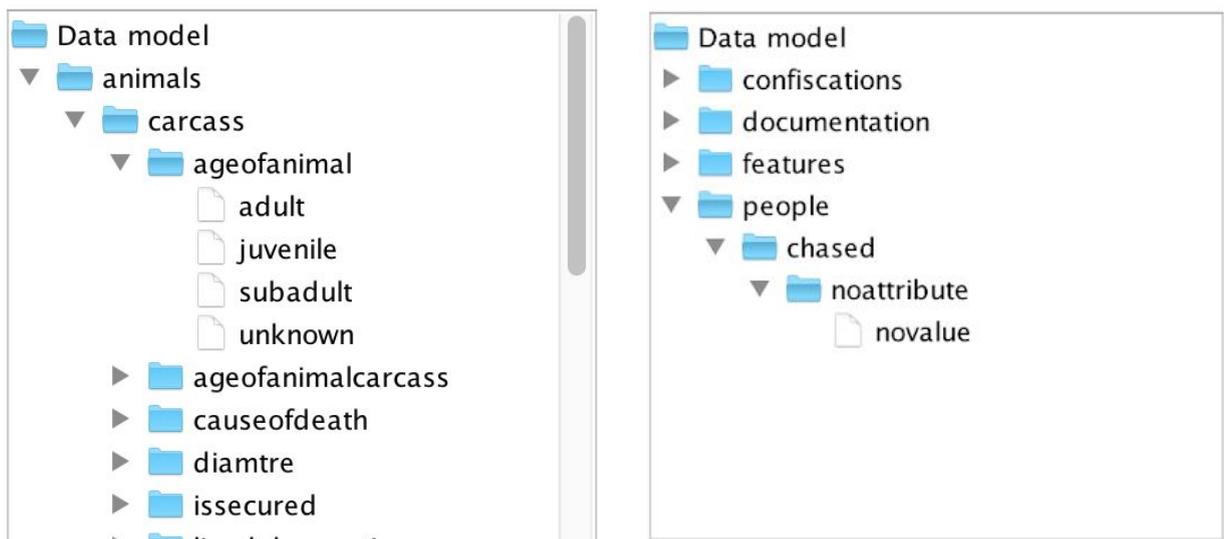


Figure 5 : Some tree structures representing a data model

These tree structures provide the following functionalities:

The left-hand panel summarises the data model entries against the most recent observations (i.e. the last 12 months). We are likely to be interested to report on the most recent information entered. The middle panel provides the entire data model entries recorded against every observation. Once selected (the right-hand panel), the entries are formatted as a path where the categories and attributes of a data model separated with a “/”.

- ❖ **Selection of a folder:** The whole content of a branch is selected. Then its sub-branches and its leaves are also selected, when the user click on the blue → arrow.
- ❖ **Selection of a document:** Only one entry copied when the user click on the blue → arrow.

- ❖ **Deleting a selected entry:** An entry is selected from the observation category. Then the entry is removed when the blue ← arrow is clicked.



Data model in a SMART application

Module 7 of the Training manual documents how to manage a data model in SMART. No observation can be recorded in SMART application without a well-defined data model. SMART Spatial Analysis cannot create any filters without any observations stored in a SMART database.

It is worth noting, if the observations have focused on some illegal activities, then the filters will also relates on such interests. Otherwise, the tool can filter some observations based on other concerns, such as ecology. The tool is, therefore, general and abstract enough to adapt to any data models.

Dates

Observations can also be filtered by dates, as continuous time period. Each time period is defined by a start and end date. These dates can only be selected between the first and the last observation recorded. Other dates cannot be selected. We can either use a little calendar tool (calendar icon) or type some valid dates (see Figure 3).

From  To 

Figure 3: A time period selection

Recycling bin

In many operating systems, deleted files are moved to a recycling bin. These files can then be restored or removed from the hard disk. Analyses and filters can be moved to a recycling bin when they become obsolete. They can be restored at any time to be used again.

User guide

This section of the document provides the information needed to use SMART Spatial Analysis efficiently. We would recommend any types of users to read this user guide and perhaps refer to it in the future.

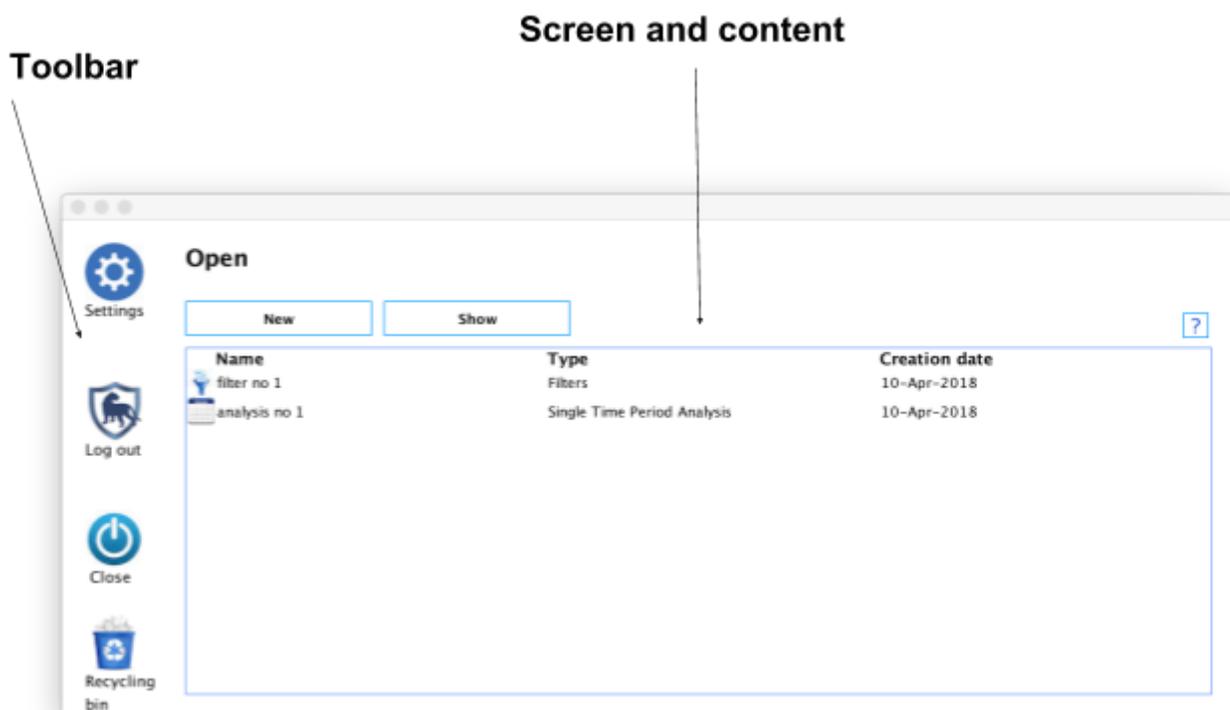
The *concepts* section introduces any particular keywords and technical aspects. The readers can refer to this section if they need to consolidate their understanding of the terminology in this context.

Finally, it is understood the reader has a working version of SMART Spatial Analysis already installed. If it is not the case, the reader can refer to [the installation and setup guide](#).

Navigating between screens

SMART Spatial Analysis provides several tools; those are briefly described alongside some their matching icons on the next page. These icons are often displayed on the left hand-side of the main screen.

This design is very similar as the file creation and opening of documents in Microsoft Office. Users can navigate from on screen to another using a toolbar. The latter is automatically populated. The screen and content part of the interface let the users complete some specific task. (see below).



Tools and icon	Description
	<p>Help</p> <p>This is a help icon. When clicked some informative messages are displayed. Some suggestions and some background information are also given.</p>
 Log out	<p>Logout</p> <p>This feature offers a user to logging out. Another user can log in to the same or another conservation area. A SMART database can be selected. This screen is first shown when SMART Spatial Analysis is launched.</p>
 Analyses and Filters	<p>Analyses and filters</p> <p>This icon opens a screen that lets the user creating, viewing and executing some analyses. Some filters can also be created and viewed. Some elements can also be moved a recycling bin.</p> <p>This screen has similar functionalities as Google Drive or the file manager in Windows.</p>
 Recycling bin	<p>Recycling bin</p> <p>This icon give access to all the analyses and filters that have been moved the recycling bin. If no filter or analysis has been “deleted”, then this icon is not shown. It is only shown when the bin contains some elements.</p>
 Settings	<p>Settings</p> <p>Settings let you update the covariates and data model of a conservation area.</p>
 Close	<p>Close icon</p> <p>This option closes SMART Spatial Analysis.</p>

Quick Start

SMART Spatial Analysis requires the users to follow an essential workflow to complete an analysis (see Figure X). The remaining subsections of the user guide provide more illustrations, hints and tips how to run some analyses.

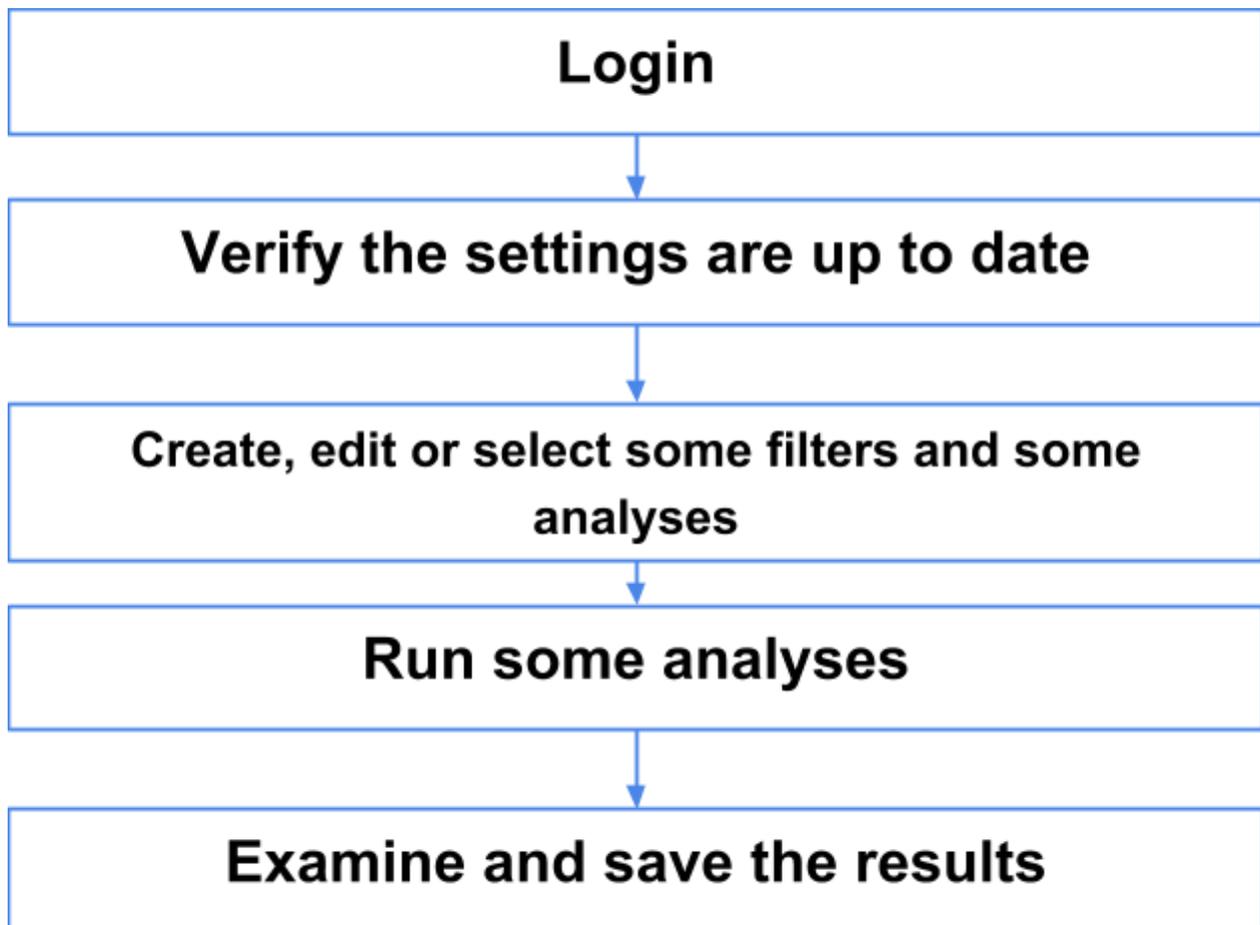
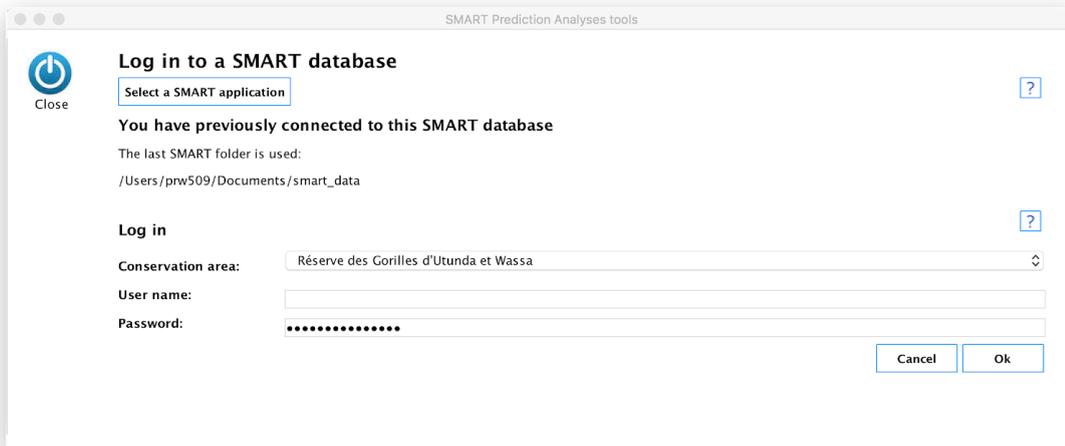


Figure X: Workflow to run an analysis with SMART Spatial Analysis

Login

Users can log in if [Step 3 of the installation and setting up guides](#) have been completed.

The users can type their SMART username and password for a specific conservation area. The information is verified; if it is valid then the users are logged on. Otherwise, the users can try again to logging on. The users can have many attempts.



Conservation area:

All the conservation areas with some valid boundaries are listed. Users must select one from the list.

User name:

A valid SMART username needs to be typed. Otherwise no access to the data stored in a SMART database can be granted.

Password:

The valid password for the user name must be entered.

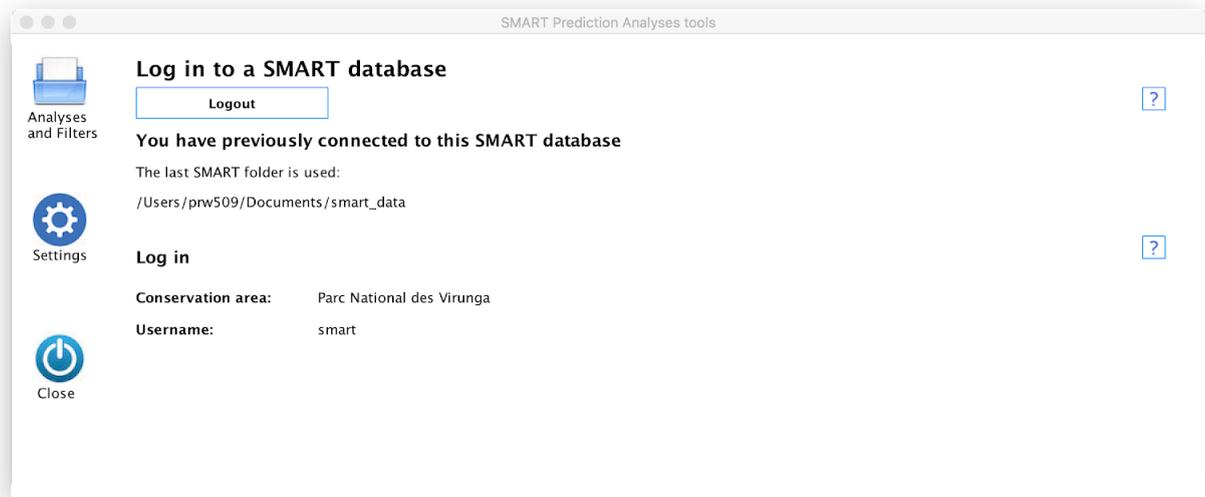


Managing user name and password in SMART Application

Generally the manager of a conservation area give the users access to their conservation area. When many conservation areas have been centralised, a SMART administrator accomplishes this duty. Therefore, if you are experiencing some difficulties, contact this person and they will help you with this first step.

Log out

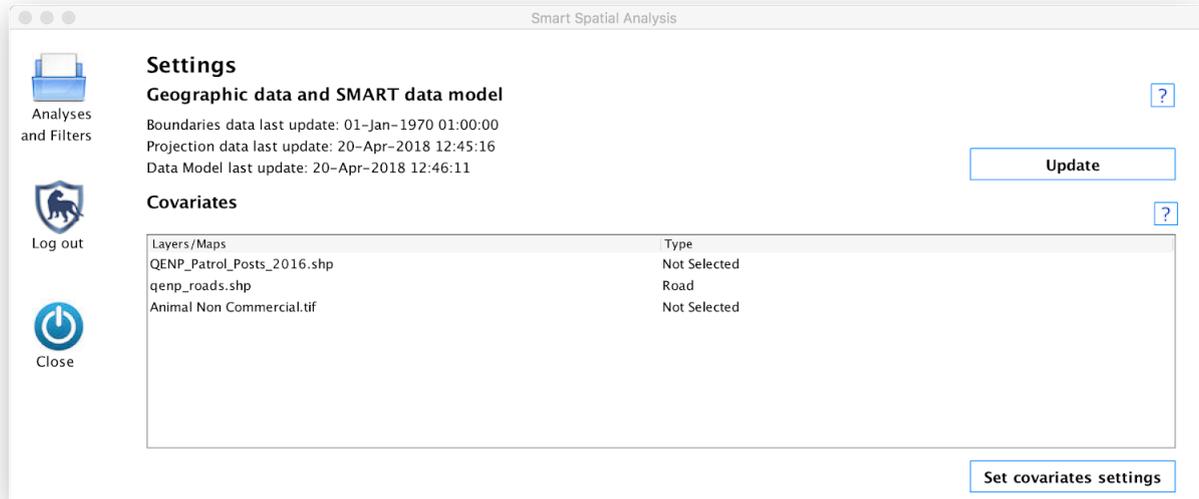
Users can log out of a SMART database; by clicking on logout option. Once the user has logged out, then a user can log in again and another SMART database can be selected to be analysed in SMART Spatial Analysis (see [Login subsection](#)).



Verifying the settings are up to date

Users need to open the *Settings* screen, so that the users can do the following:

1. Update geographic data (see [the geographical data sub-section](#))
2. Update SMART data model (see [the data model entries sub-section](#))
3. Set the covariates (see [the covariate sub-section](#))



Update:

This feature imports the up-to-date boundaries covariate, the projection covariate and an complete data model. This update can run automatically if some geographic data or the data model is incomplete. This process may take a few minutes, as the data to extract can be quite large. A timer will appear while this process is running.

Set covariates settings:

A drop-down list provides the following options. Each of these options has been introduced in the [Covariates sub-section](#).

- ❖ Not selected
- ❖ Road
- ❖ Water
- ❖ Other classified
- ❖ Other numeric



Frequency of update

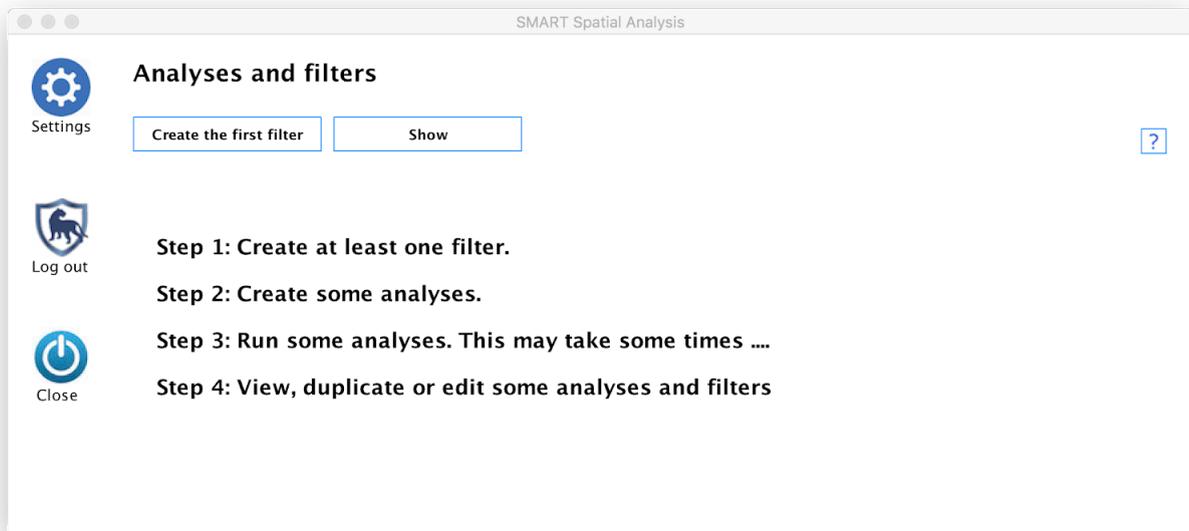
It is recommend to update this data each time you create some filters and analyses are created, edited or executed. Otherwise, the latest information attached to the observations may not be shown. Your results may not be as accurate as you are expecting them.

Create, edit and view some filters and some analyses

Some filters and analyses can be created and viewed from the *Analyses and filters* screen.

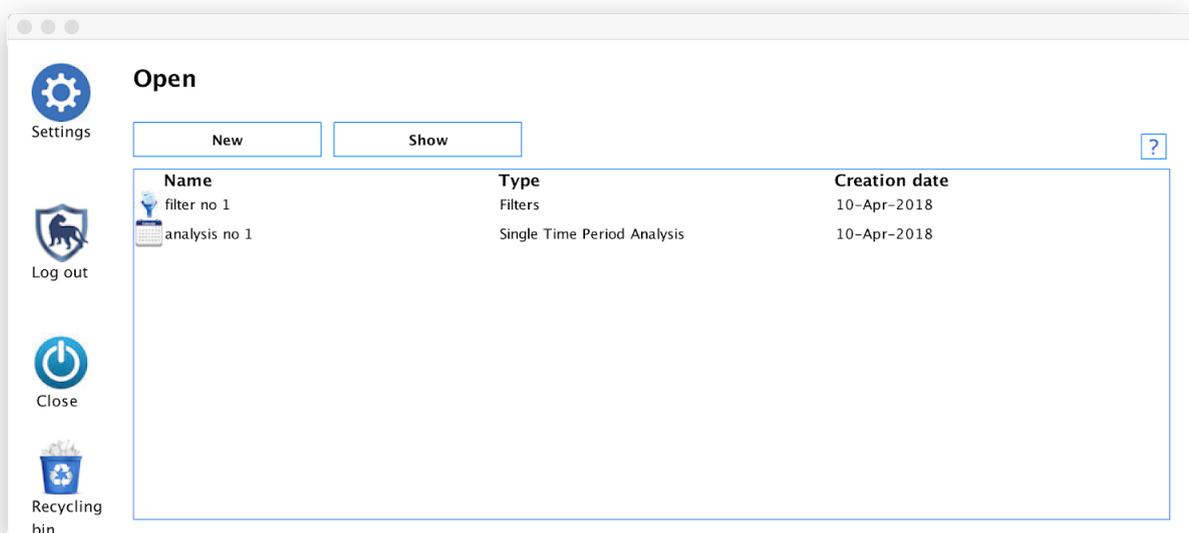
Using the first time SMART Spatial Analysis

When no filter and no analysis has yet to be created for a conservation area, users can only create their first filters.



Using again SMART Spatial Analysis

Otherwise, all the filters and analyses are shown. Both screen are shown below.



Create the first filter button:

This button shows a form to create the first filter.

New button:

This button provides the functionality to create new filters or analyses. Some analyses may only be shown, when enough observations have been recorded in a SMART database.

Show button:

This button “refreshes” the content of the screen. It is necessary to include any newly added filters and analyses. Unlike a Google drive, this is not automatically scanned to maximise the performance of SMART Spatial Analysis; a lot of data can be held in a SMART database slowing down the retrieval of the information.

The show button has the following features:

- **All** : show every filter and analysis.
- **More recent elements**: the most recent analyses or filters are shown. It is useful to identify any newly created filters and analyses.
- **Filters only**: only the filters are shown
- **Analyses**: show every analysis or a specific type

**Naming analyses and filters with a meaningful name**

We would recommend any analyses and filters to be named with a meaningful name. This type of names helps the users identify suitably the content of a filter or an analysis. For the purpose of demonstration, we have used “*Filter no 1*”. It is better to use instead some names related to the data model; for examples “*Fire arms and carcasses*”.

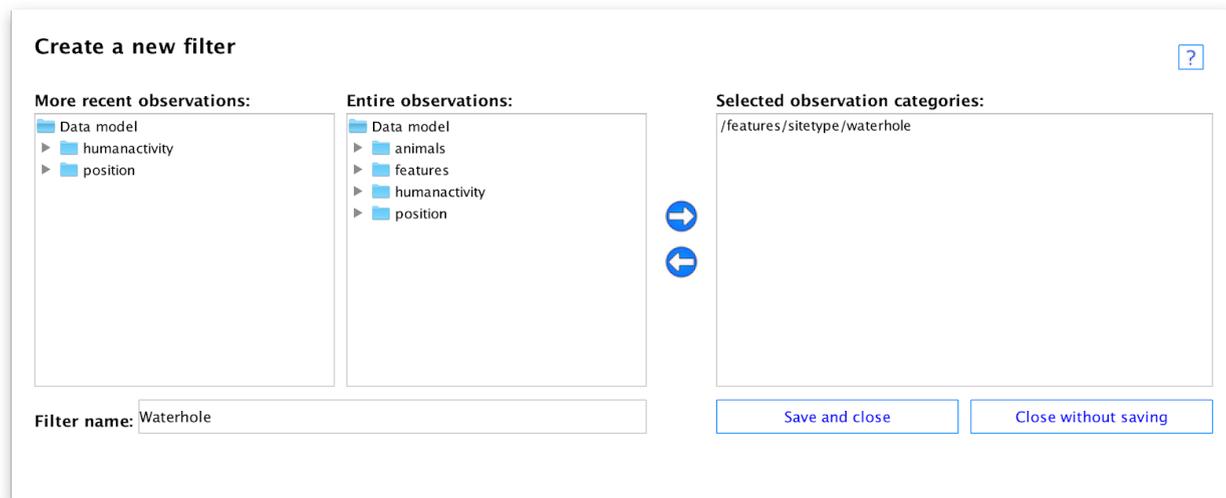
If two analyses or two filters share the same names, then each element can be identified by their creation dates.

Create a new filter

New filters need to be considered carefully and may need to be refined several times. The user needs to select some observations categories and verify first the number of observations (click the *Verify no of observations* button). When the number of observations exceeds 50, then the new filter can be saved (see .

**Concept of filters**

The [concept of filtering](#) was introduced in the [Concepts section](#). The same filter can be used again for several analyses. Therefore, it is feasible that only a small number of filters may be created.



Arrows left and right:

The *right* arrow adds any selected folders in the *more recent* and *entire observations* sections.

The *left* arrow removes one selected category from the list referred as *Selected observation categories*.

Verify number of entries (not shown on the screen):

This features counts the number of observations that matches the selected observation categories. If it exceeds the minimum requirement of 50, then it lets the users saving the new filter.

Save and close:

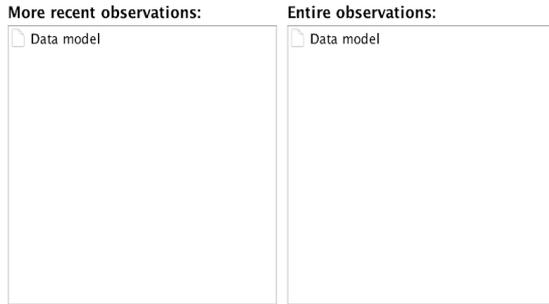
Save the filter and close the form. This can only occurs if some observation categories have been selected and a filter name has been entered. It is worth noting, this button is only shown once the threshold has been reached.

Close without saving:

The users can close without saving. All her/his work is likely to be lost. She/he needs to confirm their choice of leaving without saving or continuing to edit.

Troubleshooting

The observations are unlikely to be empty. However, (1) when the predictions data have not been updated or (2) no observation has been input in SMART Application, this can occur.



Predictions have not been updated:

Follow the information from [Verifying the settings are up-to-date](#)

No observation has been input

Using SMART Application, enter some observations for at least one year. Then follow the information from [Verifying the settings are up-to-date](#).

View an existing filter

By clicking on a filter’s name, a quick view screen is shown (see below). We recommend the users to view existing filters when planning some analyses.



Move to the recycling bin:

A filter can only be move to the recycling bin, if it is not selected in any analyses. Once clicked, the filter is not show in the a list. To restore it see XXXXX to do

Duplicate and edit:

A copy of the filter is created. Then some categories can be added and/or removed using the same screen used during the creation process. (see [Create a new filter](#)).

Close:

Close the screen to return to the previous screen.



Installation And Setup Guide

SMART Spatial Analysis can be downloaded from **ADD HERE URL**. The installation program can be copied to any data storage, including USB flash drive, hard disk, and writeable DVD or CD-ROMs.

System requirements

The following are the basic requirements for installing SMART Spatial Analysis:

- ❖ **Minimum Operating system:**
 - Windows 7 (extended support is planned to stops in 01/2020)
 - El-Capitan (support is planned until 2025)
- ❖ **Available space on hard disk:** 3 GB. If less is available the whole performance of the personal computer may be degraded.
- ❖ **Minimum RAM:** 4 GB. More would be recommended.
- ❖ **Minimum access right:** Administrator rights on the computer for the installation.
 - A user that is a member of the Administrators group (Windows)
 - The Administrator user (any operating system)
- ❖ **SMART application:** A version of SMART Application with at least one year of observations recorded.

Installation overview

The installation program installs SMART Spatial Analysis application on a single computer at a time. The installation program automatically creates two folders an *application* and a *setting folder*. A shortcut to the default and preferred method to launch applications is also created. In Windows, this shortcut icon is located in the Start Menu and in MacOS the launch pad.

- ❖ **Application folder:**
 - **Purpose:** A version of R programming language, some SQL files and a suitable Java Virtual machine.
 - **Windows:** [Drive]:\Program files\smart_predictions
 - **MacOs:** \Applications\smart_predictions
- ❖ **Setting folder:**
 - **Purpose:** Stores some small setup files.
 - **Windows:** [Drive]:\Users\llll[to do]
 - **MacOs:** \Users\Shared\smart_predictions

Installation process

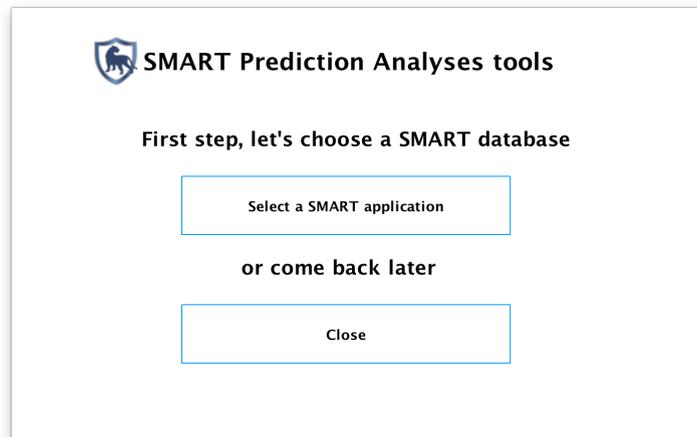
TO DO - INFORMATION SERVICES HAS YET TO GET BACK TO P. SHE IS ACTIVELY CHASING THEM....

Setup overview

Once SMART Spatial Analysis has been installed, a SMART database must be identified and setup.

Step 1

Launch for the first time the SMART Spatial Analysis. The following screen will provide only two choices:

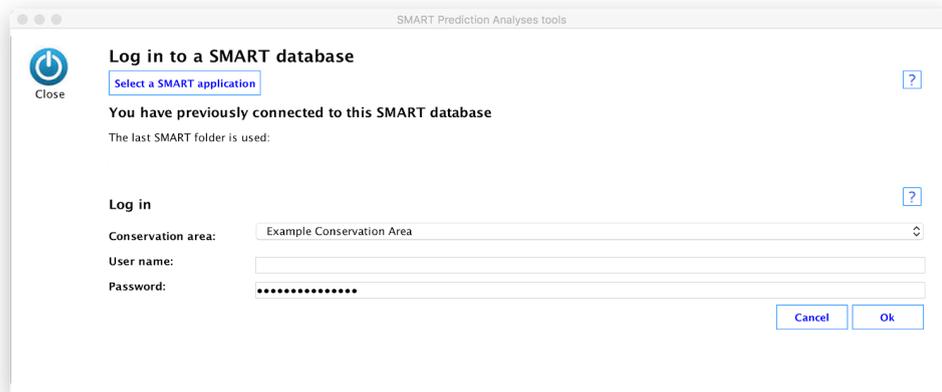


Step 2

Click on the *Select a SMART application* button. You will be able to navigate through the file structure of the computer. If a valid SMART application is selected, then you will be able to continue. Otherwise an error message is displayed and you cannot continue to step 3.

Step 3

We would advise to log on to any conservation areas with your SMART password. The user name and password are the same the ones defined in the selected SMART application.



employees in SMART application

Further information on how to setup employees and the System information can be found in *Module 1: Setting up of a Conservation area of the SMART Training manual*.

Step 4

Before you can create any analyses, we are recommending to retrieve some conservation-area-specific geographical data. You will need need to complete this step each time you first log on in a conservation area. Once logged on a step by step process guides you to setup the following elements:

Boundaries and projection information:

This spatial information is retrieved from the SMART database. If any boundaries or projection have yet to be uploaded for the conservation area, then the setup process needs to be stopped.



Uploading some Boundaries and projection information

Module 1: Setting up of a Conservation area and *Module 2: Map Navigation and GIS* of the *Training manual* provide all the information how to upload this information.

The [Graphical data and Graphical information systems](#) section provides more information about the nature of this type of information.

Setting up covariates

Boundaries and projection covariates must be kept updated. Some messages will remind you to upload these geographical information for the first time. It is strongly encouraged to upload these non-optional covariates, when you requested. Otherwise, you can update them anytimes from the Settings option.

Predictions data ?

Boundaries data last update: 04-Apr-2018 12:07:14

Projection data last update: 04-Apr-2018 11:42:49

Data Model last update: 23-Feb-2018 12:12:06

Update

Spatial information (e.g. habitat,, water, roads) may have been uploaded for each conservation area. Consequently, some files may be listed and some suitable labels can be set for each of them. For each entry in the *Covariates* table, you can set a suitable label; each label are described in the [covariates](#) section of the Concept chapter. Once you have complete the labelling, click on *Set covariates settings* button to save choices.

Covariates ?

Layers/Maps	Type
KSP.shp	Not Selected ⇅
Patrol_roads.shp	Road

Set covariates settings



Uploading some covariates in SMART application

If no covariates have yet to be setup, then we would recommend you to upload some to the SMART Application to provide more accurate results. *Map Navigation and GIS* of the *Training manual* provide all the details on how to upload this data.

Geographical data and data model:

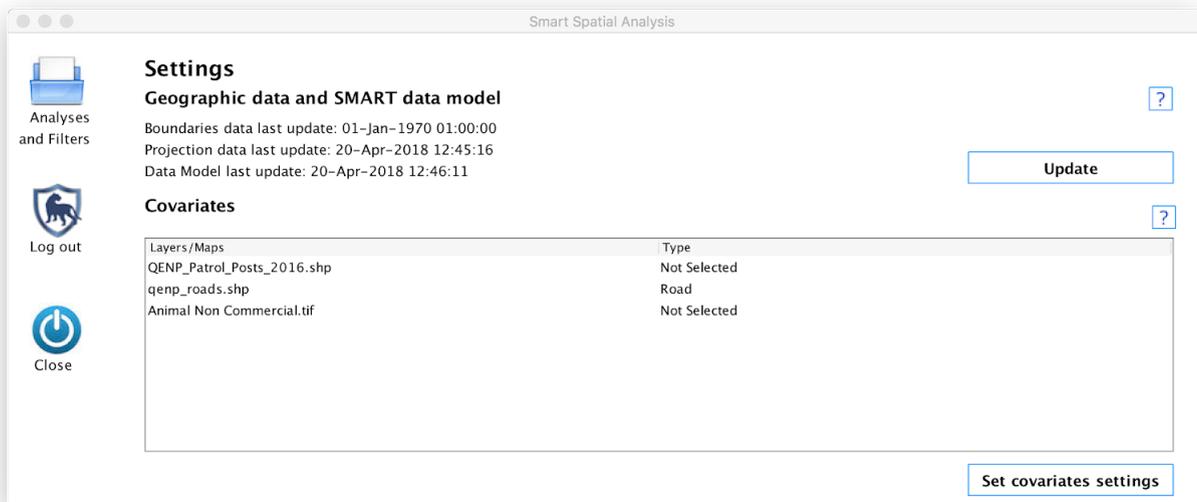
The data model recorded in the observations of the selected conversation area is extracted. If no observation has yet to be recorded in the selected conservation area, then the data model cannot be constructed and analyses cannot be created. *Module 3: Patrol* and *Module 7: Data model management* of the *Training manual* explains how to record these information.

Importing and setting up information from SMART Application

Some dialogues boxes suggests the workflow to import this required information. We would strongly recommend the reader important this data when requested. If they prefer to complete this at a later stage, then they can use the following screen:

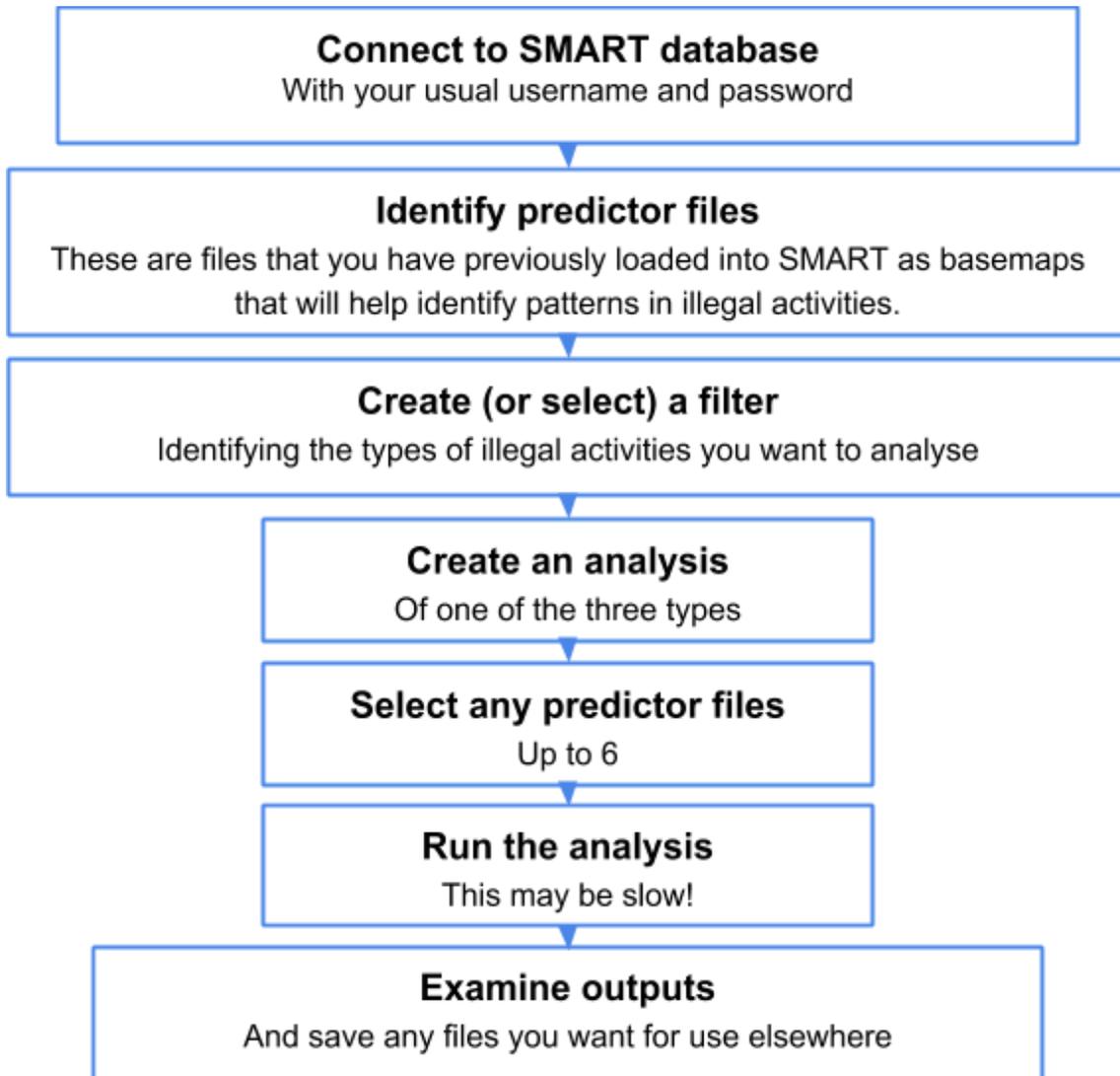
Create prediction data button imports the boundaries, projection and data model from a SMART file storage and database.

Set covariates settings: Save the covariates settings currently displayed.



QUICK START

SMART Spatial Analysis uses the following essential workflow for an analysis:



Each screen of SMART Spatial Analysis has been designed to be intuitive to the following types of users: (1) users who can use the basic features of Windows, (2) users who can browse the web, and (3) users who can install applications. The users should find the interface intuitive. However, we understand that sometimes some assistance may be needed. Therefore, some hints and useful information is provided in several ways. Firstly, we provide an overview of each screen of SMART Spatial Analysis; new users will find them useful. Secondly, if the users needs assistance to complete a task, some hints will be displayed to help them moving forward. Finally, some features will appear as soon as it is suitable to use them.



We would recommend you to read the remainder of the manual; it will help you understanding some of the concepts you may not yet familiarised.

Connect to SMART Database - to be made much more accessible

The first stage in running an analysis is to identify and select an appropriate SMART application which already needs to be installed in your machine. If several SMART databases are managed on one machine, then the users can identify and select one of them before starting the analysis process (see first step of the diagram 1).

You will need to log in to the database using your usual SMART username and password details.

Identify predictor files

Once you have connected to a database you should see a list of the maps that have been uploaded to SMART via the basemap facility (see SMART Manual pages XXXX for details, and <http://gisgeography.com/spatial-data-types-vector-raster/> for basic GIS file formats) that can be used to help identify patterns in illegal activities: we call these predictor maps. (If you have no basemaps loaded in SMART this will be blank and this can be ignored!)

To make use of covariate maps in analyses, you will first need to tell the SMART Spatial Analysis what type of information is in each of the files. We identify four different types of files that we use in different ways to predict illegal activities:

1. Roads - if you have shapefiles that identify a road network, this often helps identify ease of travel for rangers and poachers alike. For example, illegal activities might occur closer to roads and tracks as the areas are more easily accessible. SMART Spatial Analysis takes these files and calculates the distance to the nearest road for use in analysis. Road shapefiles should be as spatial lines.
2. Water - Areas close to water are also likely to be hotspots of illegal activities (particularly poaching). If you have shapefiles containing spatial lines of rivers or spatial polygons identifying lakes and waterholes, these shapefiles as water and the program will calculate the distance to the nearest water for analysis.
3. Other numeric - other types of files must be provided in raster format. Other numeric (often referred to as continuous rasters) are maps like altitude, or slope from digital elevation models where each grid cell contains a gradually changing variable (you could download many types of numeric data free from the NASA website if you want: <https://search.earthdata.nasa.gov/search>). If other raster variables are provided, they do not need to be in the same projection or cell size structure as the other variables; this process is included as part of SMART Spatial Analysis.
4. Other class - Other class maps must also be provided in raster format. Other class (sometimes referred to as discrete rasters) are maps like habitat or land use where each grid cell contains a number that identifies how the cell relates to a class of values. For

example, in a vegetation map, '1' may be used to indicate grasslands, '2' indicates woodlands and '3' indicates forest, but intermediate values make no sense. Some habitat maps are also available from the MODIS website (https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1). These variables are useful if there are major differences in habitat within your conservation area, but must not be finely classified: the analysis will only work with 3 or 4 different classes identified, so use these very sparingly!

Create or select a filter

Filters define classes of illegal activities that you want to analyse together as one class. They allow you to group different elements of the SMART *data model* (see **page XXX** of the SMART user manual) for analysis. For example, the data model may separate records of carcasses by species such as carcass:kob, carcass:wildebeest, etc. For meaningful analysis we need as much similar data as possible and unless carcasses are really common, we'd be better off grouping all carcasses of animals hunted using the same method (say, by snaring) into a single analysis of carcasses. We might even want to lump carcasses and snares themselves to make a single group of that we could call something like 'snaring of wildlife'. But we would be wise to treat that sort of illegal activity as different from, say, timber harvesting and wood cutting, NTFPs (Non Timber Forest Products), or commercial hunting of elephant and rhino.

Essentially, here you can access elements in the SMART data model in the right hand side of **figure X**, and anything you add to the list on the right hand side will be grouped for later analysis with the name you give it. We call this grouping process a filter.

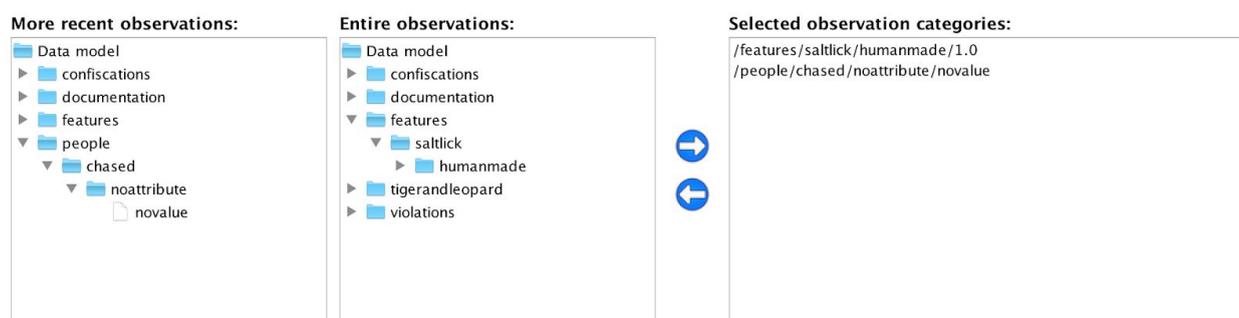


Figure X: A filtering tool based on the data model entries recorded against some observations.

Once you've created a filter or two you are ready to build the actual analysis.

Create an analysis

There are three types of analysis you can run using the SMART Spatial Analysis program:

- (1) A single time-period analysis.
- (2) An analysis of a management intervention.
- (3) A multiple time-period analysis.

WARNING: All analyses run in SMART Analyses require a reasonable amount of data to make sense: very rare events are not reliably predicted. Ideally, you'd pick a time period and a set of illegal activities to analyse that resulted in at least 50 detections within the time period specified.

Single time-period analysis:

This is the simplest analysis you might want to run and allows you to identify the places within a conservation area where a particular set of illegal activities happened most frequently during a specified time period. Output from this analysis looks like [Fig 1](#).

Test management intervention analysis:

This analysis allows you to run two single time-period analyses before and after a particular change in management. For example, from the 1st March 2017 you may have increased the number of ranger patrols in one area and want to know whether this has resulted in a decrease in illegal activities. To test this, you will need to identify two time periods, one before and one after the intervention and you need to compare the two. Ideally, these will be the same length of time and otherwise matched. In the example of an increase in ranger activities, it might be sensible to pick a six month period from 1st March 2016 as the baseline conditions and compare that with the 6th month period from 1st March 2017 when the new management was in place. Both time periods should have a suitable number of observations for analyses (at least 50 data entries). The analysis will run two single time-period analyses for the two time periods and will automatically identify changes between the two.

Trend analysis:

This analysis allows you to identify how numbers and distribution of illegal activities are changing over time (remembering that all analyses require at least 50 data entries). You need to specify an end date, the length of each time period (e.g. one year) and the number of time periods you want. The program will use this information to identify time periods and will analyse each time period separately, before summarising the patterns of change over time and geographically. At the end of the analysis you will be given maps of occurrence of illegal activities within each time-period, as well as the trend in activities over time and space (for example, some areas of the conservation area may have increasing levels of illegal activity, while others are decreasing) and the overall trend in time. This sort of analysis might be useful to run once a year on annual time steps for annual reports, identifying how the past year fits into changes over recent years.

Once you've decided what type of analysis you want to run, click on open and select the analysis type you want to create.

Select predictor variables

Including predictor variables (covariates) will improve the accuracy of results. Up to 6 covariates can be included in each analysis, for example if the following covariates are included in the SMART database they can all be used: distance to roads, distance to boundary, distance to water, habitat, elevation, human population density. The more covariates that are selected will increase the length of analysis time.

If no covariates are selected, the analysis will run using the distance to the conservation area boundary as a default covariate.

Run an analysis

Once you understand what the analysis does, running any analysis is pretty similar: identify the filter you want to use, select the time period(s) you want, identify the grid size you want to use, identify any of the predictor files that you want to use (up to 6) and press run!

The grid size you chose identifies the grain of the analysis: a large value (say 5km²) will group all data into 5km² boxes to give a broad overview of patterns (and a relatively quick analysis, ideal when you have relatively few detections to analyse). A finer scale (say 1km²) would take more time to run (especially if you have a very large conservation area) but if you have sufficient data to run at this fine scale will give you a more precise location of illegal activities.

If you have no basemaps in your SMART database the analysis will run with the distance to the boundary of the conservation area as the sole predictor map. Distance to conservation area boundary is always available for analysis and is often very useful. Once you have selected the minimum required options, the 'save and run' button will be enabled and you can go. If you have run the model before you will just see a button to retrieve previous results: the analysis will be saved for you to come back to later if you want.

Single time-period analysis

This is the simplest analysis and is run exactly as described above.

Test management intervention analysis

For this analysis the only difference is that you must specify two time periods (perhaps with a gap between them to allow changes to take place). Ideally these time periods will be of similar length and, if illegal activities are at all seasonal, cover the same periods of the calendar year.

Trend analysis

This analysis simply runs several single time-period analyses one after the other, then processes the results to identify trends. Time periods are specified by specifying first the end date, then the interval of each time-period and the number of time periods required. The program automatically sets the start date that meets these requirements: e.g. if I select 31/12/2017 as my start date, set each interval at one year and ask for four time periods the start date is 1/1/2014.

WARNING: running a large number of time periods will take some time: you might want to run this overnight, or before a lunch break!

Once you have set up an analysis you can either save and run, or save to run later. If you return to the analysis later you will see the same options if you have not run the analysis before, or an option to simply view the results again if the analysis has been run before.

Examine outputs

Once you have run an analysis (or if you return to a saved analysis after previously running it and select 'view results') if all has gone well you should be presented with a window showing the main analysis results. Exactly what this consists of depends on the type of analysis chosen, but each analysis will return at least one map and both the intervention analysis and the multiple time-period analysis will show a graph of overall results. The window presented is simply an overview of the full results. Your options at this stage are to save a high-quality version of the images (as a .pdf file that you can view and save elsewhere) and/or to save the maps as raster files that could be imported into GIS software for further analysis. The different analyses provide results as follows:

Single time-period analysis

For this analysis you are simply provided with a map of the occurrence of illegal activities across the conservation area (e.g. see **Figure X**). Compare this map with maps of where rangers are going to identify areas to patrol more regularly! You can save this map as an image or as a raster file for GIS analysis.

Test management intervention analysis

Following this analysis you will see four figures: two are maps of occurrence of illegal activities during the two time-periods, a third maps the changes in occurrence between the two periods and the final graph shows the overall occurrence in the two time periods: if your management intervention has been successful you should see lower values on the right than on the left (assuming you have used equal length time slots in both periods). This figure, a boxplot, shows the variation in occurrence across the entire conservation area: the box contains the values in half of the cells across the conservation area (the black line in the box identifies the middle (median) value across the entire area), while the lines show where most values fall and the dots are the outlier points at either extreme. If the two boxes and the middle line are not overlapping, it is reasonable to assume there are significant differences in occurrence between the two time periods.

Trend analysis

Following this analysis you will see two figures: the map is the trend over time in each cell: negative values indicate places where there has been a general tendency across all the time periods for illegal activities to reduce, positive values indicate where there has been an overall increase. Note that this does not mean that in every time-period there has necessarily been an increase in cells with a positive trend, just that overall the trend is upwards, and similarly for negative trends. The second figure is a boxplot that shows the overall occurrence of illegal activities in each time period. Interpretation of changes in these are as above for the management intervention analysis. If you save the .pdf file for these you will have a multi-page .pdf file that includes each separate map for each time-period on a separate page (not accessible through this simple format).

Don't forget that you can access high resolution (.pdf) images of each of these results and also save the raw GIS files using the save options.

FAQs

How much data do I need to run an analysis?

This is hard to answer: the more data you have, the more accurately the plugin will identify patterns. As a rule of thumb, we suggest you aim at analyses that have at least 50 detections within each time period selected. Below this, results will be very uncertain.

Why can't I just summarise raw data from SMART?

This is a very good question: rangers in the field are usually the experts when it comes to knowing where illegal activities of different types occur. However, our research has shown that sometimes rangers miss some of the hotspots that our program can identify, and that often rangers spend more time than required in some areas with relatively lower rates of illegal activity: knowing where illegal activities are more likely to happen can dramatically improve detections. In practice, rangers know some of the hotspots but not all of them. Poachers also change their activities over time to avoid the areas rangers most often go.

How can I plan ranger patrols using this program?

Currently we do not have a module that specifically plans individual patrol routes, though this work is in planning stage. For now the best way to use the program to help plan patrols is to compare the map of illegal activities produced by any of the analyses with the patterns of where rangers go: where you see a hotspot that isn't covered very well should be a target for future patrols.

How do I request a new feature?

We have a number of ideas for how this program can be developed in the future, but we're keen to know what is most useful to people in the field. If you have a particular idea, please let Colin Beale know by email: colin.beale@york.ac.uk. If time and funds allow we'll see how this can be incorporated into future releases!

My SMART database records activities outside the conservation area boundary as well as within. What should I do?

Currently all analyses are based on the boundary of the conservation area; only ranger patrols and records of illegal activity that occur within the conservation area (which is used as a base map in SMART or is imported as a covariable) are included as part of analyse. If many of the ranger patrol records fall outside the the existing conservation area boundary, it may be sensible to create a new boundary shapefile (a spatialpolygons shapefile in GIS software) and import this as a covariate as a predictor file.

How can I find out more about the methods?

We're glad you asked! We have published the methods in detail in two scientific papers:

References

Critchlow, R., Plumptre, A. J., Alidria, B., Nsubuga, M., Driciru, M., Rwetsiba, A., & Beale, C. M. (2017). Improving Law-Enforcement Effectiveness and Efficiency in conservation areas Using Ranger-collected Monitoring Data. *Conservation Letters*, 10, 572-580.

Critchlow, R., Plumptre, A. J., Driciru, M., Rwetsiba, A., Stokes, E. J., Tumwesigye, C., & Beale, C. M. (2015). Spatiotemporal trends of illegal activities from ranger-collected data in a Ugandan national park. *Conservation Biology*, 29, 1458-1470.

If you're publishing scientific papers based on analyses using this program, we'd be grateful if you could cite these papers: thanks!

