FHAES

Fire History Analysis and Exploration System

By Elaine Kennedy Sutherland, Peter W Brewer and Henri Grissino-Mayer

For FHAES version 2.0.x

Elaine Kennedy Sutherland

Missoula Forestry Sciences Lab
800 Block East Beckwith
Missoula, MT 59801 USA.

✉ esutherland@fs.fed.us

Compiled: September 9, 2014

FHAES

Fire History Analysis and Exploration System

By Elaine Kennedy Sutherland, Peter W Brewer
and Henri Grissino-Mayer

Compiled: September 9, 2014

Contents

Preface

FHAES (Fire History Analysis and Exploration System) is a revision of the original FHX2 program written by Dr. Henri Grissino-Mayer designed for the analysis of chronologies of fire scars developed from tree-ring data (and can be used to analyze chronologies of other disturbance events). The original FHX2 program was written in Pascal and Fortran and uses proprietary graphics software. It provides the means to enter and store fire history data, graph and plot these data, statistically analyze the fire chronologies, and evaluate the relationship between fire occurrence and climate condition. This program has been widely used and considered to be the standard for fire history analysis, but will only run on Microsoft Windows operating systems, XP or earlier, or for higher versions by using a DOS emulator. This revised system, now renamed FHAES (Fire History Analysis and Exploration System), is completely re-written in Java and builds upon a variety of open source libraries. Downloads are available for Windows, Mac OSX and Linux.

FHAES is open source software (see the details of the license on pages 51–56), so you are welcome to inspect and edit the code. Please contact the authors if you'll like to find out how you can contribute.

We wish to acknowledge the contributions of NOAA's Paleoclimatic Division, Boulder, Colorado in early coordination and development of this project. We mention with gratitude the contributions of the late Michael Hartman who set up NOAA's International Multiproxy Paleofire Database, and worked to coordinate this project with it. We also acknowledge the important role of Wendy Gross, who programmed the FHChart module and who also set up the original FHAES website on FRAMES. Also thanks to Evan Larson and Kun Tian who have supervised the development of the FHRecorder module by students at the University of Wisconsin-Platteville.

We hope that you find FHAES useful and look forward to hearing your feedback.

Elaine Kennedy Sutherland
USDA Forest Service
Rocky Mountain Research Station

Peter Brewer
University of Arizona
Laboratory of Tree-Ring Research

Henri Grissino-Mayer
University of Tennessee
Department of Geography

Maria Elena Velásquez
Boise State University
Department of Mathematics

Donald A. Falk
University of Arizona
School of Natural Resources and the Environment
and Laboratory of Tree-Ring Research

Peter Brown
Rocky Mountain Tree-Ring Research, Inc.
Fort Collins, Colorado

Connie Woodhouse
University of Arizona
School of Geography and Development

Part I

User Guide

Chapter 1

Introduction

1.1 What is FHAES?

FHAES (Fire History Analysis and Exploration System) is a software tool to evaluate fire regime properties such as frequency, seasonality, extent, and fire/climate relationships from fire scars (fire-caused injuries on trees). FHAES can also be used to calculate similar properties for other events that create unique signatures, like light rings from insect infestations or frost rings resulting from volcanic eruptions. As input, FHAES requires data in the the Fire History Exchange (FHX) format, similar to FHX2 (Grissino-Mayer, 2001). The techniques of fire history analysis FHAES is built on assumes the user applied dendrochronological cross-dating methods to determine calendar year dates of annual tree rings and the characteristics of fire scars (Stokes and Smiley 1968, Fritts 1976, Holmes 1983, Dieterich and Swetnam 1984, Baisan and Swetnam 1990).

1.2 Comparing FHAES and FHX2

FHX2 (Grissino-Mayer, 2001) has long been the standard for fire history analysis. Copyrighted by Henri D. Grissino-Mayer, it is a mix of Pascal and Fortran, and includes proprietary graphics software (Golden Software, Inc.). It runs on Microsoft Windows operating systems, XP or earlier, and will run on other operating systems by using a DOS emulator.

FHAES is a comprehensive reimplementation of most of FHX2's functions. It is written as an open source, cross-platform, GUI application. FHAES will run on all modern operating systems (including 32 and 64 bit versions) and takes advantage of improvements in memory to analyze larger and longer datasets. In addition to reimplementing functionality provided by FHX2, FHAES also includes additional features that you may find useful.

We hope that those of you familiar with FHX2 will find transitioning to FHAES quite simple. It is, however, important to understand that results produced by FHAES in some cases will not be identical to those produced by FHX2. For instance there are differences in the precision of floating point numbers (especially for provided numbers like π) between Pascal and Java. There are also different—yet equally valid—methods for performing certain calculations. For example, Henri Grissino-Mayer generously provided the source code from FHX2 for us to work from when we were re-coding FHAES. Unfortunately, the code for the Weibull function in FHX2 is a closed source binary (compiled Fortran code) so we had no way to determine its precise implementation. Within FHAES, however, all functions are open source and can be inspected by anyone interested in how the calculations are performed.

We are confident that the results produced by FHAES are identical, equivalent or more precise than those provided by FHX2. If, however, you feel that you have an example dataset which illustrates a degradation in the results produced by FHAES over FHX2, then we urge you to contact the authors so that we can, with your assistance, investigate thoroughly.

Not every facet of FHX2 has been replicated in FHAES. While much of the output has been formatted as text and in spreadsheets, not all the earlier output tables are available at this time. That can change, with user input. There is no test for differences between two time periods or two subsamples of a site ("spatial differences"). If users express that some component of FHX2 was important to their work and is now missing from FHAES, please let us know and we'll do our best to redevelop it in FHAES (`fhaeshelp@gmail.com`).

1.3 Where can I get help?

This manual is the main source for information about FHAES and how to run it. If you can't find the answer to your questions here, you can email the developers at `fhaeshelp@gmail.com` or through the contact form on the FHAES website. Another source is the ITRDB forum mailing list, especially if your question is with regards an academic issue as many of the world's leading dendropyrologists are members. Although right now the manual is more about which buttons to push to make the program work, we will continue to add descriptive information and examples.

Chapter 2

Installation

2.1 Requirements

FHAES will run on any relatively modern operating system, the only requirement being that Java 6 or later is installed. We do, however, highly recommend using Java 7 for FHAES (and for any other Java application) because Java 6 has passed its end-of-life and security updates are no longer released. Only use Java 6 if you have a compelling reason to do so, for example you are running an older versions of OSX that does not readily support Java 7. As with all aspects of FHAES, if you run up against any specific problems installing and running FHAES then please get in touch with the developers for assistance.

2.2 How to install FHAES

Installation packages for the FHAES are available for Windows, MacOSX and Linux. For users of other operating systems FHAES can be run from an executable JAR file.

To install FHAES, download the installation file for your operating system from

- `http://download.fhaes.org/`

The website should provide you with a link to the installer for your current operating system.

Windows – Run the setup.exe and follow the instructions. If you do not have Java installed the installer will direct you to the Java website where you can get the latest version. Once installed, FHAES can be launched via the Start menu. Although FHAES should run on all version of Windows back to Windows 98, testing has been focused on Windows 7 and 8.

Mac OSX – To install FHAES, download then open the zip file and drag the FHAES.app into your applications folder. In theory, FHAES should be able to run on any version of OSX that runs Java 6, however no testing has been done prior to Intel version 10.6 - Snow Leopard.

Ubuntu Linux – A Deb file is available which was designed for use on Ubuntu distributions but should work on any Debian based system. Install using your favorite package management system. On Ubuntu and similar distributions, the package should add a FHAES shortcut to your applications menu. Alternatively you can start FHAES from the command line by typing `fhaes`.

Redhat Linux – An RPM file is available which was designed for use with Redhat but should work on any Linux Standard Base (LSB) distribution such as SUSE, Mandriva, Fedora etc. Install using your favorite package management system. Note that due to the variation in naming conventions for Java between these distributions, the RPM does not include Java as a dependency. You will, however, need to install Java for FHAES to work.

Other operating systems – Make sure you have Java 6 or later installed, then download the FHAES JAR file to your hard disk. You can run FHAES from the command line by typing:

```
java -jar fhaes.jar
```

2.3 How to uninstall FHAES

We understand that FHAES will never suit the requirements of all users, but as an open source product, we would really appreciate feedback as to why it didn't work for you. Without this feedback it is difficult to prioritize future development.

For Windows users, FHAES can be uninstalled using the standard add/remove programs feature in control panel. Mac users should simply delete the application from their applications folder. Linux users should use their prefered package management tool e.g. from the Ubuntu command line:

```
sudo dpkg --remove fhaes
```

Chapter 3

Getting started

If you have not yet done so, please install FHAES using the instructions for your particular operating system on page 7.

3.1 Main screen

Once you launch FHAES you will be greeted by the standard FHAES home screen. Now load[1]. You enter new FHX format data by using the data entry module in FHAES. This is accessed by using the icon on the toolbar, or by using the *File* → *New* menu. Further information about the structure of FHX files and data entry is available in chapter 4.

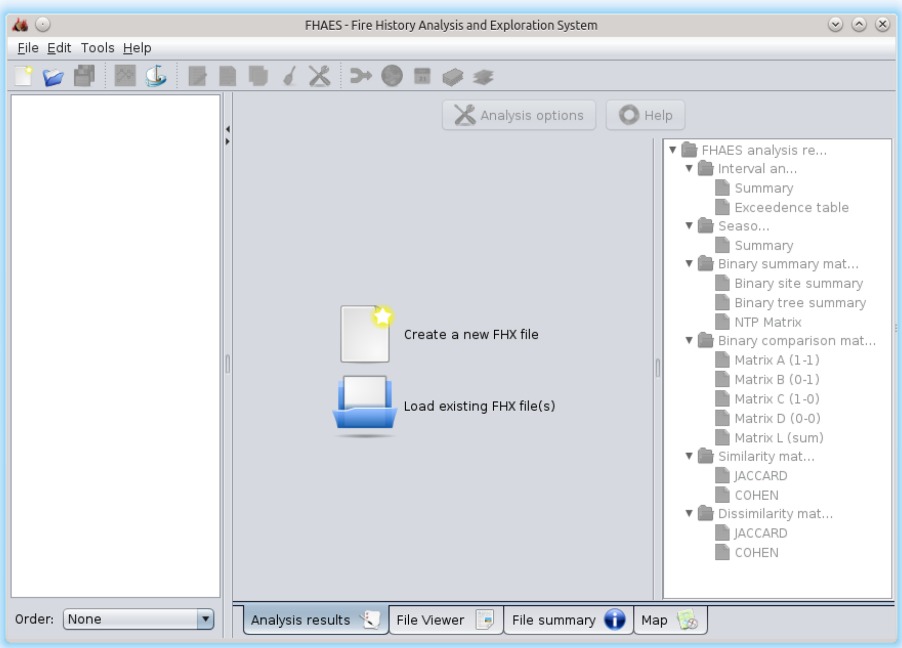


Figure 3.1: The FHAES home screen that it displayed on startup. To begin using FHAES select either ‘Create new FHX file’ or ’Load existing FHX file(s)’.

[1] If you do not have any FHX data files but would like to test FHAES, you can download data from NOAA’s International Multiproxy Paleofire Database `http://www.ncdc.noaa.gov/paleo/impd/` or create one or more new FHX files (figure 3.1). There is also a small sample dataset available from the FHAES software download page.

If you already have FHX files these can be loaded by using the 'open file' icon on the toolbar, through the *File* → *Open* menu, or by dragging and dropping files from your operating system's file manager application onto the file list panel.

3.1.1 Analysis options

Once files are loaded or created you will be presented with the 'Analysis options' dialog. TIP: You should always run the analysis even if you aren't interested in performing it because several of the tools in FHAES cannot function without the analysis results. The dialog is split into three groups of fields: analysis options; filters and years; and seasons. Each of the fields includes a help tip button to provide you with more information after what the parameter means and it's implications for the analysis. This information is also reproduced below:

Event type for analysis – Select whether to perform analyses on:

- only fire events (upper case letters in the input files)
- only other indicators (lower case letters)
- both fire events *and* other indicators

Note that choosing one of the first two options may remove one or more of your input files from the analyses if they do not contain enough of the specified event types.

Label results by – Select how you would like to label the input files in your results tables and charts. Note that FHAES will default to file name if you pick site name or code and a file is missing the relevant header information.

Interval analysis type – Select whether you want to perform analyses based separately upon each sample in your file or by combining samples within a file into a composite. Note if you select 'composite' then you may like to set composite filter options as well.

Include intervals after last event – Indicate whether you'd like to treat the interval from the final event marker until the end of the series as an interval or not during interval analyses.

Alpha value – The alpha value or error is the maximum probability that a given return interval will be significantly short or long. The default alpha value for this two-tailed test is 0.125.

Common years required – Select the number of common years or overlap that must be present between two datasets before comparison matrices can be calculated.

First season combination – Scar positions (in the earlywood, latewood, or between growth rings) are compared for differences based on some hypothesis. A common hypothesis would be that most fires occurred in the typical wildland fire season for the locale (first season combination) and rarely occurred in the second season combination.

Second season combination – The second season combination are scar positions being compared to the first season.

Year range – the default option is that the analyses are calculated across the entire range of years in your input files, or you may specify a more restricted time period.

Composite fire threshold – Specify how the composite of your samples should be filtered during analyses (number or percentage). If you choose 'number of fires' with a value of 1 then all fire events will be used. The 'percentage of fires' value is continuous and ranges from 1 to 99. The larger the filter, the more that extensive events in the record are emphasized.

The analysis options dialog will open automatically each time you load FHX files. If you want to repeat analyses without being asked to confirm options each time you can choose to use the same choices without being asked to confirm for the rest of the session. The next time you load FHAES, although it will remember you preferred analysis options, you will be shown the options dialog and asked to confirm them again. Once you confirm your analysis options FHAES will perform the calculations and populate the tabs on the home screen (see figure 3.2).

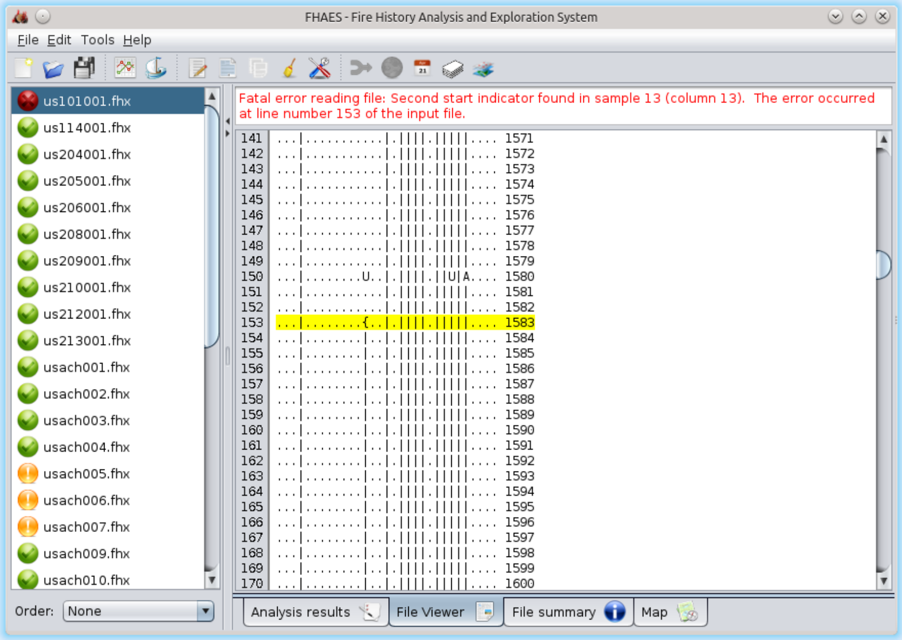


Figure 3.2: The left panel shows the FHX files that are currently loaded and the right tabbed panel contains details about the selected file and results of the fire history analyses. Note that the file list contains one file (us101001.fhx) that has been determined to contain errors, and three that contain no fire events. The 'File viewer' tab is open and contains a view of the erroneous file us101001.fhx. FHAES is highlighting the error in the file and is explaining the error in the message at the top of the screen.

3.1.2 File list

FHAES uses the TRiCYCLE dendro converter library (Brewer et al., 2011) which makes use of the Tree Ring Data Standard (TRiDaS – Jansma et al., 2010) to load files you have chosen and check they are valid. FHX files that are determined to be invalid are indicated by a red cross icon in the file list, while valid files are denoted by a green tick. Files marked with an amber exclamation mark are technically valid FHX files but contain no valid event data (FHX demography files for instance) and are therefore excluded from analyses. Erroneous files can be corrected by double clicking the appropriate file in the list and then using the FHAES data entry screen (see pages 15–20).

The file list can be sorted using the drop down menu at the bottom of the screen. This can be helpful as the order of the files in the list will also be reflected in the order the analysis results will be presented.

The following sections describe the contents of the various tabs in the right hand panel of the main screen.

3.1.3 File viewer tab

The 'File viewer' tab displays the contents of the currently selected file in the file list (see figure 3.2). If this file has been determined to be invalid (i.e. it is marked by red cross symbol) then a message is shown at the top of the screen. Where possible, FHAES will also highlight the line where the error exists. You can edit existing files by right clicking and choosing edit, or by using the equivalent toolbar or menu options.

3.1.4 Summary tab

The 'File summary' tab contains a report summarising the contents of the file currently selected in the file list. The summary includes details about how many samples there are in the file, dates for the start and end of each sample, number of events; average number of years for each fire event etc.

3.1.5 Map tab

The 'Map' tab contains an interactive map displaying the location of the sites described by the latitude and longitude of currently loaded files. You can choose between a variety of background styles, zoom to the current map pins, and also turn the pin labels on or off using the buttons at the top of the page.

Please note that the latitude and longitude fields in FHX files are free-text and can therefore be in a wide variety of formats. FHAES will do its best to parse these fields to ascertain the coordinates, however, this may fail in which case you will be warned. Please also note that in addition to lat/long fields FHX format files also contain location information in UTM and township/range fields. Because there is no field in FHX files for recording the UTM zone which is essential for the eastings and northings to make sense, UTM information is disregarded by FHAES. Due to the huge potential variability of townshop/range data and the very limited use of these fields in FHX, they are also disregarded by FHAES. We strongly recommend using standardized WGS84 decimal latitude and longitude in your FHX files.

FHAES uses the latitude and longitude fields in all spatial analyses. For further information see sections 3.2.4 and 3.2.5.

3.1.6 Analysis results tab

The 'Analysis results' tab contains the results of all the analyses performed by FHAES. A categorized list shows all the available results on the right, while the table on the left shows the currently selected result. A full description of each of the analyses is provided in chapter 5 as well as through the online help system accessed by pressing the help button.

To view the results of the analyses simply select the analysis type from the categorical list on the right and it will be shown in the table on the left. You can copy and paste values from this table into your preferred spreadsheet or statistical package using the edit menu, toolbar buttons or right click popup menu. You can also save single tables by right clicking the required table in the results tree on the right. Certain tables may also be saved in other formats. For example the popup menu for 'Binary site summary' will allow you to save as a GIS Shapefile (see page 13 for more information).

To save all the analysis results at once, you can go to *File* → *Save* → *Save analysis results* or use the save button on the toolbar. You have the option of specifying ZIP or XLSX format, the former will give you a ZIP file containing each table as a CSV text file, the latter will give you a single Microsoft Excel workbook with each table as a separate worksheet.

3.2 Tools

FHAES includes a number of tools for manipulating and processing your fire history data. These are available from the buttons on the toolbar or from the 'Tools' menu on the main screen. Because of their complexity, the Sample Size Analysis, Superposed Epoch Analysis and Chart tools are described in their own chapters (chapters 6, 7 and 8 respectively). Descriptions and instructions for all other tools are provided below:

3.2.1 Merge selected files

The 'merge selected files' tool enables you to combine the data from two or more FHX files into a single file. It maintains all the samples from each input file as separate series within the output file. Note that because the tool requires two or more files, it will only be enabled once you select two or more files from the file list. When you launch the tool you will be asked whether to merge all years or just a subset of years. Once you have made your choice you will then be asked where you'd like to save the resulting FHX file, and whether you'd like to immediately add it to your existing project.

3.2.2 Create composite file

The 'create composite file' tool is similar to the merge tool, with the exception that all samples from a file are combined into a single series in the output. The output file therefore contains the same number of series as input files. Like the merge tool, a dialog will open asking whether the output file should be restricted to specified years, or whether all years should be included. However, you will also be asked to specify how the composite should be calculated. When creating a composite it is often desirable to ignore events that are not widely represented in your datasets. The composite filter enables you to specify a threshold of absolute number of events, or to specify a percentage of series which must share the event for it to be included.

Note that events in composite files are always recorded as having an unknown seasonality because FHX files cannot represent events without multiple seasons within a single year.

3.2.3 Create event file

The 'create event file' tool produces a simple single column text file containing a list of years recording events. The file is typically used as an input to Superposed Epoch Analysis (see chapter 7) but may also be of use for other analyses. The tool is run on one or more selected files from the file list, and like the composite tool, it also asks the user to specify a year range, and options for how to filter the input files into a composite.

3.2.4 Spatial join on selected files

The 'spatial join' tool provides a method for creating event, composite and merge files based on location. It is only available when two or more files are selected in the file list. The tool works by clustering together files based upon the lat/long location fields provided in the FHX file header. It gives you the option to specify a threshold in kilometres lower than which sites are combined together. This is useful when doing regional analyses when you have multiple sites located close to each other recording similar fire histories. By combining these together you can simply the comparison between these sites and those located further away.

When you specify your distance threshold, the tool will automatically create groups of sites list on the left of the dialog. You can click on each in turn to examine which sites have been included in each group. Files with no location information (or whose location information has not been successfully parsed) are located in a final miscellaneous group. By double clicking on the group names you can rename them to suit your needs. The tool also includes a separate map tab to show the spatial relationship between the groups. Each group is given a unique color.

The other parameter that needs to be set before continuing is what sort of output file you'd like to create: event; composite; or merge files. Once you've chosen your output file type and selected save you will be asked to chosen an output folder location. The files will be named according to the names you gave each group.

3.2.5 Create site summary shapefile

The 'create site summary shapefile' tool enables you to save the results of the 'binary site summary' table in Shapefile format for further visualization and analysis in GIS applications such as ArcGIS and QGIS. The resulting shapefile is typically viewed inconjunction with a temporal GIS plugin such as the Time Slider facility in ArcGIS or the Time Manager plugin to QGIS.

The export to shapefile dialog (figure 3.3) asks the user to provide an export filename, to specify the style of attribute table to use and to select the years you'd like to include. There are two attribute table styles, which you will find most convenient will depend on the GIS tool you are using.

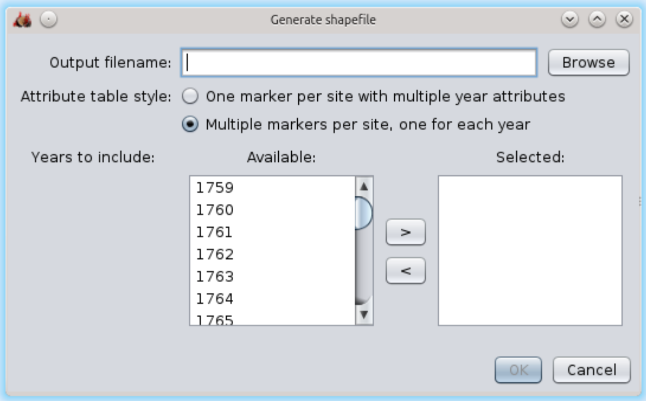


Figure 3.3: The screenshot of the export to shapefile dialog.

The first creates a shapefile with just one map marker pin (row) per site but the associated attribute table contains multiple fields, one for each year requested. Because the shapefile format only supports a limited number of fields you can only include data for 255 years in your file. An example of the associated attribute table as displayed by QGIS is shown on the left in figure 3.4.

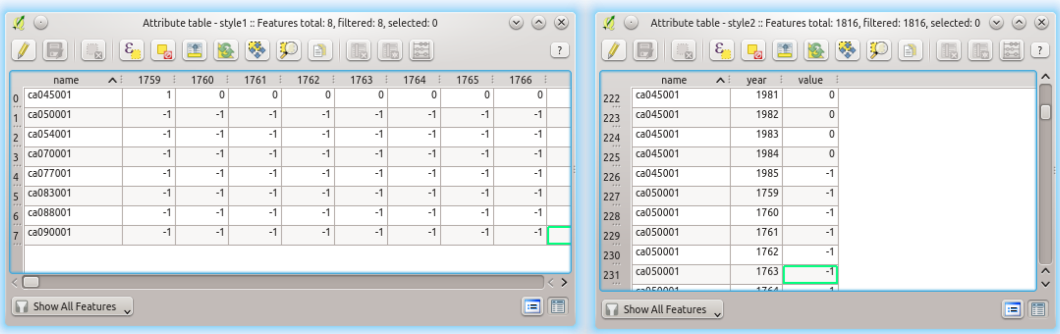


Figure 3.4: Examples of the attribute tables associated with the shapefiles exported by FHAES. On the left is the table produced when the output style was set to 'one marker per site with multiple year attributes', whereas the right shows the output style when set to 'multiple markers per site, one for each year'.

The second style creates multiple map markers (rows) for each site, one for each requested year. So if you select 200 years you will end up with a shapefile containing 200 markers in the same location for each site in your dataset. The associated attribute table will have just two fields, one containing the year and the other the data value. An illustration of this is shown on the right in figure 3.4. There are no hard coded limits to the number of sites or years you can include using this style. However, if you do select a very large dataset you may find that your GIS becomes sluggish. In this case you would be best to import your data into a spatial database and ensure the relevant indexes have been configured.

Chapter 4

Data entry

4.1 Introduction to FHX (Fire History Exchange) data files

The FHX data format is the data standard used to archive fire-scar based fire history data in the International Multiproxy Paleofire Database hosted by NOAA[1]. Although the file extensions are .fhx, they are actually text files formatted specifically for storing fire history information. While we recommend using the data entry tool in FHAES, with a good understanding of the format it is also possible to edit FHX files using standard text editing software.

The information recorded with FHX files includes an optional (yet highly recommended) header for storing metadata about the site and the samples, followed by the data (see figure 4.1 for an example data file). The data include the sample identification code and information regarding the beginning and ending year, years when the sample was and was not fire scar susceptible, and years when a fire scar or other indicator was recorded. The sample data are not numeric as is typical in dendrochronological data files, they are categorical and describe the status of each tree ring for the entire series. There are different characters for the beginning year depending on whether the sample included the pith (the true inside year). There are also different characters for the last year of the series, indicating whether the sample still had bark, or if it had bare wood that could potentially have eroded. The position of a fire scar or other indicator in an annual ring relative to its earlywood or latewood can be recorded. This provides evidence of wildfire season. A complete list of the characters used for recording all these conditions is shown in table 4.1.

The data for each sample are arranged by column, with each row corresponding to a year–beginning with the earliest year of any sample in the entire data set and ending with the latest year in the entire data set. This may seem unusual, but the nature of the data drives it. Fire scar data series can be several centuries or even millennia long. If the data format were reversed – that is, each year was represented by a column rather than a row, then there could be many hundreds of columns in a file. Viewing and managing many columns of data is far more unwieldy in most software compared to viewing and managing many rows of data.

Further information about the FHX file format can be found on the NOAA Paleoclimate website[2]

4.2 Fire History Recorder

The purpose of the data entry module (FHRecorder) in FHAES is to create and edit FHX files. Please note that it is designed for editing standard data series files recording information about individual trees (as outlined above) and not for the very similarly formatted 'composite' files (see section 3.2.2) that represent data for multiple trees and/or sites. There should be no need for you to manually edit composite files and FHRecorder will warn you of this.

When creating a file we strongly advise you to record the metadata as fully as possible. If all the information is not available at first, fill out as much as possible and plan to obtain it and revise the file later. Because the

[1] `http://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/fire-history`
[2] `http://www.ncdc.noaa.gov/paleo/impd/tree_event_info.html`

Header / Metadata

```
  1 Name of site   : Mesic mainland sites around Lake Duparquet
  2 Site code      : DMM
  3 Collection date: Summer 1985 and 1986
  4 Collectors     : Y. Bergeron, J. Brisson, D. Lemieux, F. Tetrault
  5 Crossdaters    : Y. Bergeron, J. Brisson, D. Lemieux, F. Tetrault, B. Suran
  6 Number samples : 45
  7 Species name   : Thuja occidentalis, Pinus banksiana, Pinus resinosa
  8 Common name    : Eastern white cedar, jack pine, red pine
  9 Habitat type   : Mesic shoreline
 10 Country        : Canada
 11 State          : Quebec
 12 County         : Abitibi-Temiscamingue
 13 Park/Monument  : L.Duparquet Research and Teaching Forest
 14 National Forest:
 15 Ranger district:
 16 Township       :
 17 Range          :
 18 Section        :
 19 Quarter section:
 20 UTM easting    : 630000m
 21 UTM northing   : 5370000m
 22 Latitude       : 48 28 N
 23 Longitude      : 79 17 W
 24 Topographic map: Rouyn-Noranda (32 D) 1:250 000
 25 Lowest elev    : 270m
 26 Highest elev   :
 27 Slope          :
 28 Aspect         :
 29 Area sampled   :
 30 Substrate type : Till, sandy clay, and silty sand
 31 Begin comments BELOW this line:
 32 Principal Investigator(s) Yves Bergeron, Jacques Brisson;
 33 End comments ABOVE this line.
 34
```

Data

```
 35 FHX2 FORMAT
 36 1573 45 3
 37 676382883011400066669996777758882299996366662
 38 026305112911677733332224877642225564455055559
 39 776076659523823145894561823989784518904367894
 40
 41 ...{......................................... 1573
 42 ............................................. 1574

291 ...............|...|.........{.....||||...... 1818
292 ...............|...|...............||||...... 1819
293 ...............|...|...............||||...... 1820
294 ...............|...|...............||||...... 1821
295 .....U.........|...|...E...U.......||||E..... 1822
296 .....|.........|...|...|...|.......|||||..... 1823
297 .....|...{.....|...|...|...|.......|||||..... 1824
298 .....|.........|...|...|U..|.......|||||..... 1825
299 .....|.........|...|...||..|.......|||||..... 1826
300 .....|.........|...|.E.||..|.......|||||..... 1827
301 .....|.........|...|.|.||..|.......|||||..... 1828
302 .....|.........|...|.|.||..|.......|||||..... 1829
303 .....|.........|...|.|.||..|.......|||||..... 1830
304 .....|.........|...|.|.||..|.......|||||..... 1831
305 .....|........[|...|.|.||..|.......|||||..... 1832
306 .....|.........|{..|.|.||..|.......|||||..... 1833
307 .....|.........|...|.|.||..|.......|||||..... 1834
308 .....|.........|...|.|.||..|.......|||||..... 1835
309 .....|.........|...|.|E||..|.......|||||..... 1836
310 .....|.........|...|.||||..|.......|||||..... 1837
311 .....|.........|...|.||||..|.......|||||..... 1838
312 .....|.........|...|.||||..|.......|||||..... 1839
313 .....|.........|...|.||||..|.......|||||..... 1840
314 .....|.........|...|.||||..|.......|||||..... 1841
315 .....|.........|...|.||||..|.......|||||..... 1842
316 .....|.........|...|.||||..|.......|||||..... 1843
317 .....|.........|...|.||||..|.......|||||..... 1844
318 .....|.........|...|.||||..|.......|||||..... 1845
319 .....|.........|...|.||||..|.......|||||...{. 1846
320 .....|.........|..E|.||||EU|.......|||||EEEE. 1847
321 .....|.........|..||.|||||||.......|||||||||. 1848
322 ...u.|..E......|..||.|||||||.......|||||||||. 1849
```

Figure 4.1: An example FHX data file with header/metadata at top followed by data section. Note the file has been split and truncated (indicated by the line numbers on the left) to show the detail of the most interesting part of the file.

Symbol	Described as	Interpreted as
.	Period or dot	Can indicate two things: Space holder in data matrix before sample starts or after sample ends Dated tree rings if sample is not recording for some period (typically before the first event in a series)
{	Left curly bracket	Beginning of sample's tree-ring series, if pith is not present
}	Right curly bracket	End of sample's tree-ring series, if no bark is present
[	Right bracket	Pith date of a sample; not always present
]	Left bracket	Bark date of a sample; not always present
|	Bar or Pipe	Recorder year, starts the year after the first fire event
D,d	Dormant season	The injury occurred between after cambial growth ceased or before it began; during the cambial "dormant" season
E,e	Early earlywood	The injury occurred during the first third of tree ring growth.
M,m	Middle earlywood	The injury occurred in the middle third of the tree ring growth.
L,l	Late earlywood	Cambium was injured late in earlywood development.
A,a	Latewood	The injury was apparent in the latest stage of cambial growth that year.
U,u	Undetermined	The position of the injury either was not or could not be determined.

Table 4.1: Symbols that indicate the status of each tree ring in a sample series. Brackets indicate beginning and ending years but are different depending on whether the pith or bark are present. Upper case letters designate years with fire scars, while lower case letters show years when indicators of fire other than scars–like resin ducts and growth releases–were present. Periods (dots) are used to fill the years before the tree was first scarred, or during periods when it is uncertain that the tree was recording fires (for example, a pocket of rot has obscured some rings).

original FHX metadata format did not provide a field to record UTM zone, if you have the UTM coordinates, record the zone used in the comment field and fill out the latitude and longitude field. For strongly recommend that you use the latitude and longitude fields as the primary means for recording locality information.

To create a new file you can click the icon on the toolbar, or by going to *File* → *New*. If you'd like to edit an existing file open it in FHAES as normal, then double click the entry in the file list, or select the file and click the edit button on the toolbar. The main data entry screen has four tabs: data; metadata (see figure 4.2); summary; and graphs.

4.3 Metadata

The metadata tab provides a straightforward method for filling out the fields that make up the FHX header and at the bottom of the tab is space to enter comments. Next to each field is a help tip button which gives you a short description of the field and the sort of data you should be entering. This information is also provided below:

Township, Range, Section, Quarter Section – Township, range, section and quarter section fields have been used historically in the USA to record the locations using the Public Land Survey System. If used, the township and range fields are required at a minimum, with the section and quarter section values optionally used depending on the precision and size of area being defined. These fields are not used by FHAES in spatial analysis, the latitude and longitude fields should be used instead.

Site name – Human readable name for the site. To be compatible with FHX2 this field should be no more than 70 characters long.

Site code – Short code used to identify the site. By convention and for use in FHX2, this should be 3 characters long, but can be longer if you only intend to use the file in FHAES.

Collection date – Date or dates when the samples included in this file were collected. It is best to use the ISO 8601 standard so that dates are recorded YYYY-MM-DD e.g. 2000-12-25.

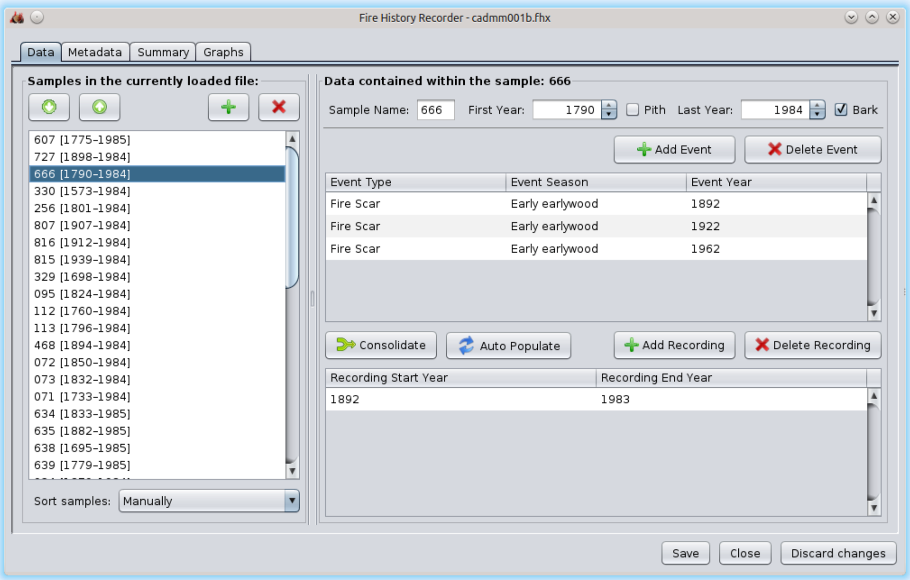


Figure 4.2: The main data entry dialog showing a file containing multiple series. The details of the selected series (666) are shown on the right. We can see it contains fire scars in the early earlywood portion of the 1892, 1922 and 1962 rings.

Collector(s) name(s) – The name or names of those in the field that collected the samples represented in this file.

Dater(s) name(s) – Name or names of those who provided the dendrochronological placement for these samples.

Latin name(s) – Latin names of the trees from which these samples were taken. If more than one species is included in this file separate them with commas and then provide further information in the comments field.

Common name(s) – Common/vernacular names for the species in this file. As for latin names if more than one species is included then separate with commas.

Habitat type – Habitat type at this site. Please use standardized naming systems applicable to the region wherever possible.

Country – Country where this site is located.

State – State where this sample is located.

County – County where this sample is located.

Park – Park (e.g. National Park) where this site is located.

Forest – Name of forest where this site is located.

Ranger district – The Ranger district that covers this site.

UTM easting –*Warning Deprecated* – UTM easting value for the site. The FHX specification does not provide a facility for recording the UTM zone so UTM data is ignored by FHAES. The latitude and longitude fields should be used instead.

UTM northing –*Warning Deprecated* – UTM northing value for the site. The FHX specification does not provide a facility for recording the UTM zone so UTM data is ignored by FHAES. The latitude and longitude fields should be used instead.

Latitude – Latitude value for the location of this site. Although this is a free text field and any formatting is valid, we strongly recommend using decimal degrees. Existing free text values can be parsed and converted using the convert button.

Longitude – Longitude value for the location of this site. Although this is a free text field and any formatting is valid, we strongly recommend using decimal degrees. Existing free text values can be parsed and converted using the convert button.

Topographic map – Reference to the topographic map covering the site.

Highest elevation – Highest elevation of the site. Please also specify units.

Lowest elevation – Lowest elevation of the site. Please also specify units.

Slope angle – Angle of the slope of the site either as a description, or as a value in degrees.

Slope aspect – General aspect of the site, typically recorded as compass direction.

Area sampled – Total area sampled. Please also specify units. Should be 10 characters or less to remain compatible with FHX2.

Substrate – Description of the substrate at this site.

Sample count – This field is automatically set by FHAES depending on the number of samples entered in the data screen.

Note that all fields are free-text with no formatting restrictions (see section 4.7) but it is best to be consistent and standardize wherever possible . For example, we strongly suggest for the latitude and longitude fields you restrict yourself to using standard WGS84 decimal degrees. If you do have coordinates in other styles you may like to try the conversion buttons to standardize your data. It will successfully convert many commonly used styles of coordinates those in degrees, minutes and seconds.

The metadata tab includes a checkbox to enforce original FHX2 field length requirements. The original FHX2 program included limits for the length of each field. Although FHAES does not have these same limitations (see section 4.6), if you intend to use the file in FHX2 as well as FHAES you should tick the checkbox here. Fields that do not meet the FHX2 specification are highlighted in red and a warning appears at the top of the screen. Note this checkbox enforces a length limit on sample names too.

4.4 Data

The main data tab is where you enter details about your samples and events. The panel on the left shows a list of series within the file. Series can be added and removed using the plus and cross buttons respectively. The order of the series can also be changed, either automatically by choosing sort criteria, or manually by using the up and down buttons. The order of the series in this list will be reflected in the order they appear in the FHX file, and therefore the order they will appear in analysis outputs and charts.

When you add a new series, you will be asked: to give the series a name; to specify the start and end years for the sequence; and to indicate whether the sample has pith and/or bark (see section 4.7 for an explanation of cases where pith/bark information is disregarded). In FHAES, the series name can be as long as the user wishes unless the 'Force FHX2 requirements' checkbox has been selected on the metadata page. In this case you will be restricted to eight characters to ensure the file can be successfully read in the original FHX2 program. See section 4.6 for more information.

4.4.1 Events

To add **events** to the series, first select the sample in the list. The panels on the right will show the details about the selected series and list any existing events currently associated with it. The series name, year range, pith and bark information are displayed and can be edited at the top of the screen. You can add events by clicking the add event button. In the event table you can then specify: whether the event is a fire or other injury; the year the event was recorded and what season it was recorded in. Note that events will automatically be ordered into chronological sequence.

Once the recording years table (described below) has been populated also note that you will not be able to add events that fall outside of the year range(s) that describe when the tree was 'recording'. For instance if you need to add an event prior to your first defined event you will need to extend the recording years backwards in time before the event table will accept the earlier year.

4.4.2 Recorder years

Once you have entered the events for your sample, you can then specify the **recorder years** i.e. the years in which the tree was susceptible to fire (*sensu* Romme, 1980). Typically this will be from the first event until the end of the sample. If the recording years are not correct you can automatically re-populate the table using the button above the table. This option allows you to override the recording years to: from first event to the end of the sample; or from beginning to the end of the sample. The second case is used occasionally by some researchers when working with certain ecosystems and species where it has been determined that trees record fires regardless of whether they have already sustained an injury or not. [clarification and citation required]

In some samples there may be periods when the sample reverts to 'non-recording' status in the middle of the series. For instance a tree that has been injured by fire and therefore considered to be in 'recording' status may grow over and around the scar until it is completely covered. At this point the tree would be considered to be in 'non-recording' status again until another cambium-damaging fire was to occur. In such cases you can add multiple ranges for 'recording' with gaps covering the 'non-recording' years to reflect this.

4.5 Summary and Graphs

The remaining two tabs in the FHRecorder window provide an overview of the data file which can be helpful to verify that the data entry has been done correctly. The summary tab (figure 4.3) provides a table summarising the samples on a year-by-year basis. For each year the number of events, the number of samples and the percentage scarred samples are shown, along with the distribution of events by season. The final column of the table includes a colour bar summarising the seasonality of the events recorded. The colour bar can be customised with the button at the top of the screen. This enables the user to change colours as well as merge together seasons into a single colour bar. This is done by dragging and dropping the seasons together into a single group.

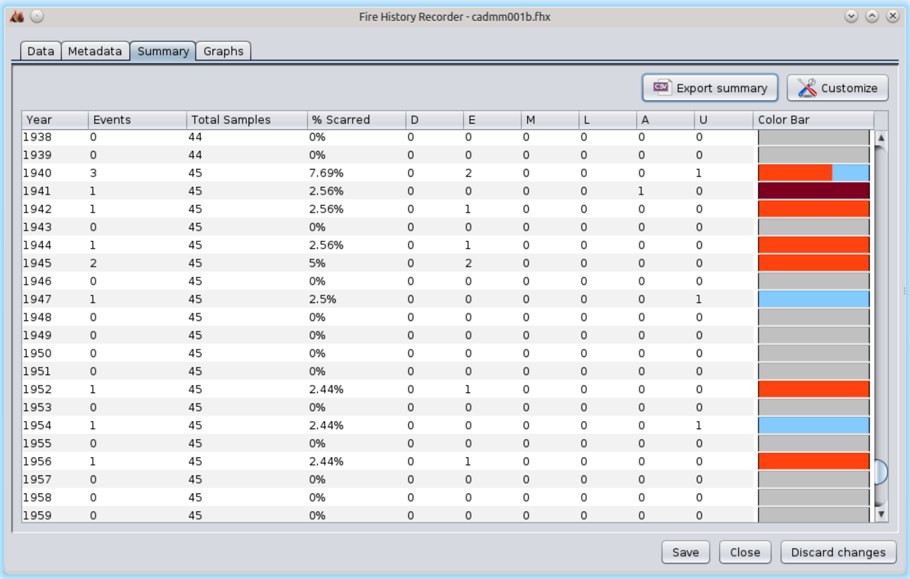
The summary table can be exported to a CSV file using the relevant button at the top of the screen. It can also be copy and pasted into various spreadsheet applications.

The graph tab (figure 4.4) shows similar information in a graphical form. The colour bar is replicated horizontally at the top of the screen, with the number of events and samples shown at the bottom. One good use for the bottom graph is to check for single events located immediately before or after a large number of events. This may be an indication that an event has been added a year too early or late.

4.6 FHX2 restrictions

The original FHX2 application enforces a number of limitations on field sizes and amount of data. This was in response to the relatively limited computer resources available at the time the program was originally written. With the ever increasing speed and amounts of memory in modern computers such limitations were not necessary when developing FHAES. FHAES can therefore read and edit all data files produced by the original FHX2 application, however, a little care must be taken if you intend to use files created by FHAES in FHX2.

On the metadata page of FHRecorder there is a checkbox that instructs FHAES to enforce the original FHX2 format requirements. With this checked, the FHX2 field length limits are displayed and any fields exceeding these limits highlighted. Any fields not meeting the restrictions must be truncated before the file can be saved.



Year	Events	Total Samples	% Scarred	D	E	M	L	A	U	Color Bar
1938	0	44	0%	0	0	0	0	0	0	
1939	0	44	0%	0	0	0	0	0	0	
1940	3	45	7.69%	0	2	0	0	0	1	
1941	1	45	2.56%	0	0	0	0	1	0	
1942	1	45	2.56%	0	1	0	0	0	0	
1943	0	45	0%	0	0	0	0	0	0	
1944	1	45	2.56%	0	1	0	0	0	0	
1945	2	45	5%	0	2	0	0	0	0	
1946	0	45	0%	0	0	0	0	0	0	
1947	1	45	2.5%	0	0	0	0	0	1	
1948	0	45	0%	0	0	0	0	0	0	
1949	0	45	0%	0	0	0	0	0	0	
1950	0	45	0%	0	0	0	0	0	0	
1951	0	45	0%	0	0	0	0	0	0	
1952	1	45	2.44%	0	1	0	0	0	0	
1953	0	45	0%	0	0	0	0	0	0	
1954	1	45	2.44%	0	0	0	0	0	1	
1955	0	45	0%	0	0	0	0	0	0	
1956	1	45	2.44%	0	1	0	0	0	0	
1957	0	45	0%	0	0	0	0	0	0	
1958	0	45	0%	0	0	0	0	0	0	
1959	0	45	0%	0	0	0	0	0	0	

Figure 4.3: The FHRecorder summary tab summarises the information recorded in a data file on a year-by-year basis.

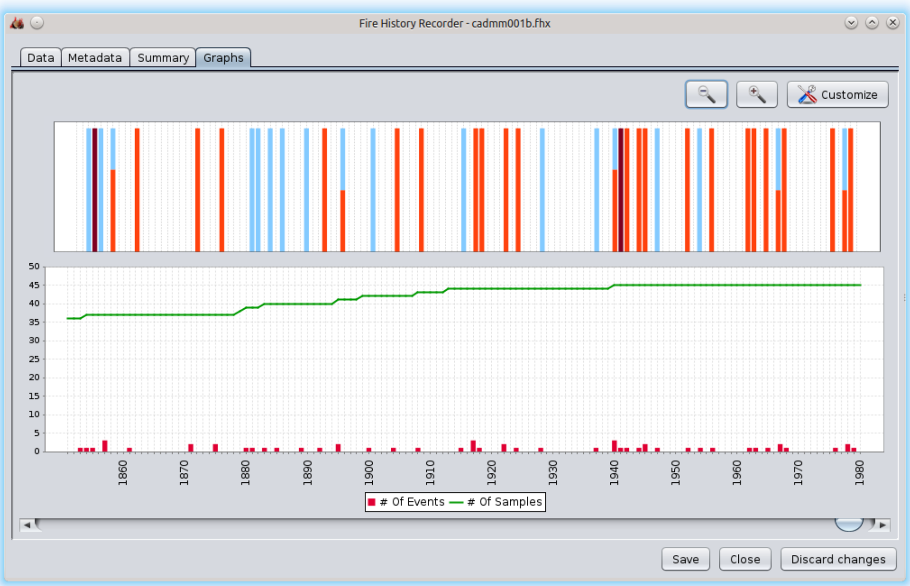


Figure 4.4: The FHRecorder graph tab illustrates similar information to that provided in the summary table (see figure 4.3) but in a graphical form.

Additional limitations in FHX2 that are not present in FHAES include: the length of series names (limited to 8 characters); the number of series in a file (up to 254); and range of years (501BC-2020AD although earlier releases were 501BC-2006AD). It is also worth noting the difference in handling of BC dates in FHAES and FHX2. FHX2 uses the astronomical dating system which includes the year zero. This means that all year numbers prior to 1AD are offset by one e.g. 1AD=1; 1BC=0; 2BC=1 etc. FHAES on the other hand uses Gregorian year numbering, thus skipping the non-existent year 0. Care should therefore be taken when moving datasets containing BC data between the two programs.

4.7 Limitations of the FHX format

Even though the field and data length restrictions of FHX2 outlined in section 4.6 have been removed in FHAES, the FHX format still has a number of fundamental limitations for the accurate description of fire history data. The primary issues are outlined below:

- **No standardisation of metadata** – The metadata fields that are present in FHX files are all free text with no restrictions on how information should be added or formatted. The clearest example of this is the latitude and longitude fields. They can be written in a wide number of formats and styles: either decimal degrees; degrees minutes and seconds; degrees and decimal minutes; direction characters variably as +,-,N,S,E or W; space delimited; apostrophe delimited. The list is almost endless. To make use of this information in FHAES or in any other software, the coordinates, and other metadata fields must be interpretable without manual user intervention.
- **Single data point per sample per year** – The format only allows for a single data point to be recorded for each sample in each year. This causes problems, for instance when a tree begins or ends with an event as it means the pith/bark status cannot also be included[3]. Perhaps more importantly, it means that fire scars and other injuries cannot be coded in the same years which provides significant problems for those attempting to do analysis comparing say fire and insect outbreaks in the same stand.
- **Metadata applies to all series in the file** – The metadata header is limited by the fact that it applies to all series within the file. If the file contains data from different species, although the user can list the species in the header, there is no mechanism for defining which species applies to which series. There is a similar issue with coordinates as it's routine now to record each tree location with a GPS rather than more general coordinates for entire sites. Likewise for slope, aspect, collection date, substrate type etc, users may prefer to record these on a tree-by-tree rather than site-by-site basis. Having access to this data would be extremely useful especially for charting purposes.
- **Pre-defined categories of events with no flexibility** – The analytical routines within FHAES are agnostic with regards the type of events being processed. However, the pre-defined nature of the event categories defined in the FHX format means that users may have difficulties in adapting their data when using FHAES for novel analyses. As indicated elsewhere in this manual, the analyses performed in FHAES are not limited to fire histories but could be used for a wide variety of similar event types. These pre-defined event categories also do not allow for the recording of more general (textual) observations about particular rings.
- **Separation of dendro and fire history data** – Fire history research is often conducted alongside traditional dendrochronological research. The separation of ring-width and fire event data into different data files means duplicatation of effort with regards metadata management. Combining all this data into a single file would be more efficient and would also facilitate analyses that combine ring-width and event data, for instance growth releases following fire events.
- **Dated and undated series** – Although fire history research is conducted overwhelmingly on trees that are absolutely dated via standard dendrochronological methods, it is conceivable that researchers may want to use FHAES on samples for which this is not the case. For example research may be carried out on wood sourced from archaeological or palaeoecological contexts. In these cases the samples may be dated within a relative dating framework; dated with uncertainty (e.g. via radiocarbon analysis); or not-dated at all. It would be preferable if this information was included alongside the fire history data.

[3] In cases like this the event information supersedes the pith/bark status so data series may in some circumstances begin and/or end with events rather than brackets. When this happens we must assume pith and/or bark are absent.

To overcome these issues, the long-term aim is to support the Tree Ring Data Standard (TRiDaS – Jansma et al., 2010) within FHAES while maintaining the ability to read existing FHX data files. In the mean time we recommend you maintain extensive notes to go with your FHX files. These can then be used to upgrade your existing FHX files in future once TRiDaS is fully supported.

Chapter 5

Analyses

5.1 Interval analysis

The Interval analysis tables shows the results of a variety of analyses for each data file. A description and formula for each is shown below.

5.1.1 *Coefficient of Variation*

5.1.2 *Skewness*

5.1.3 *Kurtosis*

$$\gamma 2 = \frac{-6\Gamma_1^4 + 12\Gamma_1^2\Gamma_2 - 3\Gamma_2^2 - 4\Gamma_1\Gamma_3 + \Gamma_4}{[\Gamma_2 - \Gamma_1^2]^2} \tag{5.1}$$

where: $\Gamma_i = \Gamma(1 + \frac{i}{k})$

5.1.4 *Weibull Scale Parameter*

$$\lambda \epsilon (0, \infty) \tag{5.2}$$

5.1.5 *Weibull Shape Parameter*

$$k \epsilon (0, \infty) \tag{5.3}$$

5.1.6 *Weibull Mean*

$$\lambda \mathit{\Gamma}(1 + \frac{1}{k}) \tag{5.4}$$

5.1.7 *Weibull Median*

$$\lambda(\ln(2))^{\frac{1}{k}} \tag{5.5}$$

5.1.8 *Weibull Modal*

$$\begin{cases} \lambda(\frac{k-1}{k})^{\frac{1}{k}} & k > 1 \\ 0 & k = 1 \end{cases} \tag{5.6}$$

5.1.9 Weibull Standard Deviation

5.1.10 Weibull Fire Frequency

5.1.11 Weibull Skewness

$$\frac{\Gamma(1+\frac{3}{k})\lambda^3 - 3\mu\sigma^2 - \mu^3}{\sigma^3} \tag{5.7}$$

5.1.12 Exceedance Intervals

5.2 Seasonality

5.3 Binary summary matrices

The binary summary matrices provide summaries of presence or absence of events, be they fire, other injuries, or both. If an event is recorded then the matrix includes a value of 1, whereas if the event is not recorded despite the fact the trees were capable of recording then the matrix includes a value of 0. If there is no data for that particular year (perhaps the tree-ring record doesn't extend to that particular year) then a value of -1 is recorded in the matrix.

There are three types of binary summary matrices produced by FHAES:

Binary site summary – this provides a summary on a site-by-site basis, therefore the matrix has one column per file.

Binary tree summary – this provides a similar summary but divided into individual trees. In addition to the normal header row containing the site name, code or filename, the matrix has a second header row containing the tree code.

NTP matrix – the NTP matrix contains three columns per file: one for the number of fires; one for the number of trees; and a third for the percentage of trees that were scarred.

5.4 Binary comparison matrices

5.5 Similarity and dissimilarity matrices

The general form for a probability-corrected similarity index is:

$$Sp = \frac{P(z) - P(e)}{1 - P(e)} \tag{5.8}$$

Where Sp is the pth index, $P(z)$ is the probability of agreement between two pairs, and $P(e)$ is the expected probability of agreement based on chance.

		Site j	
	Outcomes	1	0
Site i	1	a (1,1)	b (1,0)
	0	c (0,1)	d (0,0)

This method can be illustrated with Cohen's index (S_{COH}), in which both (1,1) and (0,0) cases a and d are considered 'agreement', $P(a) = \frac{a+d}{N}$, where $N = a + b + c + d$. $P(e)$ is computed as the joint probability of sites i and j having a '1'; hence,

$$P(1i) = \frac{a+b}{N}, \tag{5.9}$$

$$P(1j) = \frac{a+c}{N} \tag{5.10}$$

$$P(e) = P(1i) \times P(1j) \tag{5.11}$$

Consider a comparison between a pair of sampling units with the following outcome:

		Site j	
	Outcomes	1	0
Site i	1	8 (1,1)	4 (1,0)
	0	5 (0,1)	83 (0,0)

Hence $a = 8$, $b = 4$, $c = 5$, $d = 83$, and $N = 100$. Then:

$$P(z) = \frac{8+83}{100} = 0.920$$
$$P(1i) = \frac{8+4}{100} = 0.120$$
$$P(1j) = \frac{8+5}{100} = 0.130$$
$$P(e) = 0.12 \times 0.13 = 0.016$$
$$S_{COH} = \frac{0.920 - 0.016}{1 - 0.016} = 0.919$$

Note that similarity in this case is dominated by the d (0,0) case. This represents a common outcome for rare events where d $>>$ a.

In the previous example, when both the a and d cases are considered 'agreement', the index can be dominated by d case when events (a) are rare. An alternative approach for rare events is to calculate similarity based on the positive outcomes only, e.g. in our context, event years, the a (1,1), b(1,0), and c (0,1) cases. Let $R = (a + b + c)$, the union of event years; then pairwise similarity is calculated as:

$$Sp = \frac{P(a) - P(e*)}{1 - P(e*)} \tag{5.12}$$

Where $P(a) = \frac{a}{L}$, the probability of the a case given a fire in either site, $P(1*_i) = \frac{a+b}{R}$, $P(1*_j) = \frac{a+c}{R}$, and $P(e*) = P(1*_i) \times P(1*_j)$, the probability of joint 1s occurring by chance in an event year. In the example given:

$$L = a + b + c = 8 + 4 + 5 = 17$$
$$P(a) = \frac{8}{17} = 0.471$$
$$P(1*_i) = \frac{8+4}{17} = 0.706$$

$$P(1*_j) = \frac{8+5}{17} = 0.765$$

$$P(e) = 0.706 \times 0.765 = 0.540$$

$$S* = \frac{0.471 - 0.540}{1 - 0.540} = -0.15$$

This index reflects only the distribution of the event cases a, b, and c. The outcome is negative if $(b+c) > a$, and positive if $a > (b+c)$, which complicates interpretation. To avoid this outcome the index can be expressed as $1 + S$, which occurs on 0,1; in this case, $S* = 0.85$.

Chapter 6

Sample Size Analysis

6.1 Introduction

Like all areas of paleoecological research, fire history relies on analysis of remnant evidence. While such evidence can provide a long time perspective on ecological processes, individual remnant evidence generally represents an incomplete picture of the events and conditions at the time of its creation. In the case of fire history, fire scar formation and retention reflect a combination of deterministic and stochastic processes. Fire does not cause the cambial damage that leads to lesion formation in every tree in a stand exposed to fire; fire intensity (heat output per unit area) can be highly variable within stands due to variation in fuel mass and continuity, as well as fine-scale variation in winds, humidity, and topography. Tree characteristics (such as diameter, bark thickness and rooting depth) can also vary within stands, making some trees more susceptible to scarring than others. Once scarred, a variety of contingent factors affect the retention and preservation of lesions, including subsequent burning, mechanical damage, wood decomposition, and mobilization of resin into xylem cells in a zone from the heartwood to the injured surface. The net result of these factors is that individual trees provide an incomplete record of fire occurrence, even at the stand scale.

To counteract the limitations of records provided by individual trees, fire historians and ecologists typically create composite records comprised of the recorded fires from multiple trees in a stand or other scale of interest. In most fire regimes, the records from individual trees overlap to some extent; i.e., there are some fires in common between trees, whereas other events may be detected on some trees but not others. Thus, as the number of trees sampled increases, additional fire dates are usually detected, but at a decreasing rate (Falk, 2004). This pattern is formally analogous to the "collector's curve" in estimating species richness from a number of sample plots. For a given area, the number of species detected (s) is a function of the number of samples (trees or plots). As n increases, s generally increases at a decreasing rate, causing the collector's curve to flatten out with additional samples.

The sample size analysis tool is designed to ask the same question for characterization of fire history in a study area. Have we sampled enough trees to capture the main fire dates, and to characterize properties of the fire regime (frequency, interval distribution, etc.)? If our sample size is too small, can we estimate how many more samples would be required to provide a reliable estimate of the site fire history?

Although sample size analysis tool is designed to explore the effect of sample size on the observation of fire frequency, it is equally capable of exploring other event data such as insect infestations. The tool calculates the mean number of events per century observed in an ever decreasing sub-sample of series within a data file. Multiple simulations are run by randomly picking series from the file to simulate the reduction in tree sample size.

The sample size analysis tool in FHAES is a reimplementation of the original SSIZ tool written by Richard Holmes under the direction of Tom Swetnam at the Laboratory of Tree Ring Research, University of Arizona. The FHAES implementation of SSIZ removes the limitations in simulation number, sample size, and time span imposed by the original SSIZ program while dramatically speeding up analyses. FHAES also extends the the original SSIZ analysis to include the calculation of asymptotes as described by Falk (2004). This provides an indication of the number of samples required in a particular study region to ensure the fire history regime has been accurately characterised.

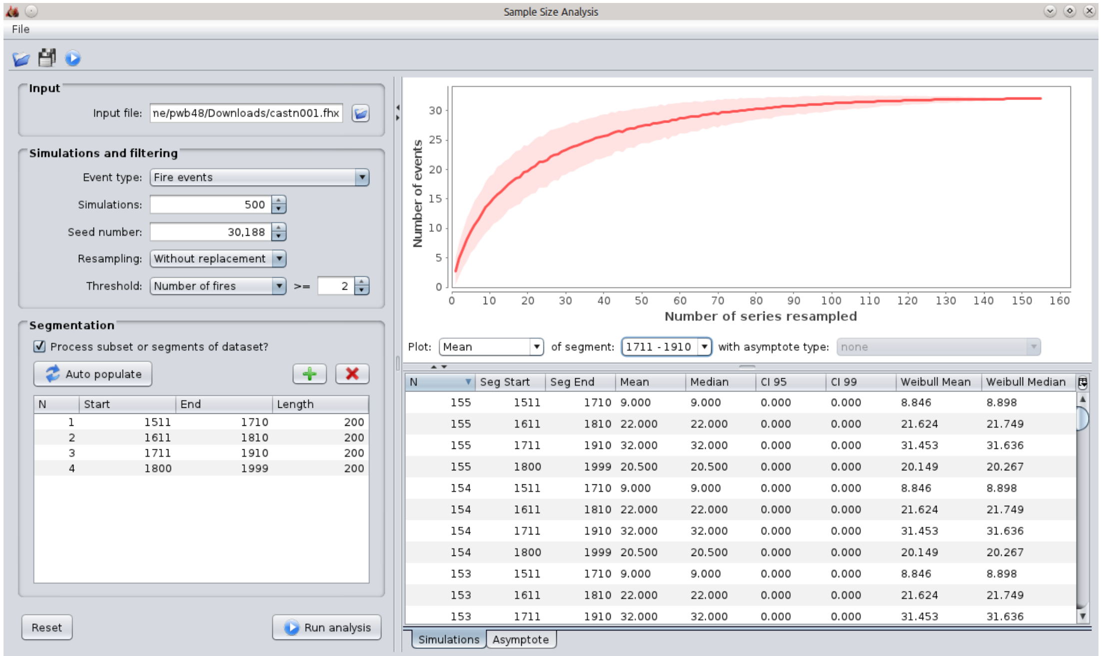


Figure 6.1: The screenshot of the sample size analysis tool. The screen includes the analysis parameters on the left and the results on the right.

6.2 Performing analysis

The sample size analysis tool is launched from the tools menu or via the equivalent button on the FHAES toolbar. The screen (figure 6.1) is split into two halves: the left containing the analysis parameters; and the right the analysis results. The parameters required by the tool are outlined below:

Input file – provide an FHX format file containing the data you would like to analyse. If you would like to analyse data across multiple files you will need to use the 'Merge files' tool in FHAES first (see page 12).

Event type – you can choose to analyse: just fire events (in which case all lower case events are ignored in the FHX data file); just injuries (in which case upper case events are ignored); or fires and injuries together.

Simulations – here you specify the number of simulations or repetitions on the analysis you'd like to run for each stage of the analysis. The more simulations you run the small the confidence intervals, however the longer the analysis will take.

Seed number – the random selection of series is in fact pseudo-random. This means that when an analysis is done with the sample parameters and seed number the results will be identical[1]. The seed number should be a large integer and can be left as the default value unless you specifically want to generate results from a different randomised pool of series.

Resampling – FHAES supports resample both with and without replacement. When sample with replacement is chosen, each random selection of a series is done from the entire dataset which means that one series can be included multiple times. Conversely when sampling without replacement, each series can only appear in the random pool once.

Threshold – the threshold parameters determine how many times an event must be recorded in the file to be considered a true event for sample size analysis. The threshold can be determined either as an absolute number, or as a percentage within the dataset. If the threshold is set to ¿1 fire then all events within the dataset are used including those that are only represented by a single series. Often researchers prefer to exclude events recorded by just one tree as they can be indicative of very localised fires that have not played a significant role in the region.

[1]This should be the case when run on different computers running the same major version number of Java, however it can only be guaranteed when run on exactly the same system.

Common years – this option enables users to limit the analysis to only the years in common to all series within the file. This can be useful, for example, when a single series in the file extends way beyond the temporal coverage of all the remaining series in the file. If all years are considered in such an analysis, then the events recorded by the long series will skew the analysis.

Include series with no events – this option enables the user to choose whether to include or exclude series which don't include events. By excluding series with no events the user should interpret the result of the asymptote analysis as indicating the number of samples *with evidence of fires* required to adequately characterise the fire history of the study region. If series are included, then the asymptote is indicative of the number of trees required to characterise the regime of the study region, regardless of whether the trees have any visible signs of fire damage. This could be useful for instance if you are studying insect oubreaks where trees are sampled without any visible damage. Note that if you are running analyses on a subset of a series (either due to the common years option being enabled, or through segmentation) then a series will be excluded if there are no events within the time period being analysed, regardless of whether it has events elsewhere in the dataset.

Segmentation – the segmentation parameters enable you to run the sample size analysis on one or more time periods in the file. You can manually specify the start and end years for each segment by click the 'add' button and typing the values in the table. Alternatively you can use the 'auto populate' button to generate equally sized segments. The dialog asked you for the first year you'd like analysed, the length of each segment and the lag between the start of each segment. For instance with a start year of 1600, a length of 100 and a lag of 50, the segments would run: 1600–1699; 1650–1749; 1700–1799 etc.

Once you have entered your parameters you can press the 'run analysis' button at the bottom of the screen or on the toolbar. Note that if you have chosen a very large number of simulations and have many series in your data file, the analysis may take several minutes to run.

6.3 Analysis results

The results of the analysis are shown in the tables and graph on the right hand side of the screen.

The options on the chart enable you to visualise the the different measures calculated during the analysis. If you ran the analysis on multiple segments you can choose which segment to view. The shaded area on the chart shows the confidence interval. This chart can be exported to in both PNG and PDF formats by right clicking and it can also be copied and pasted into other applications. Some basic properties of the chart can be altered through the right click properties option.

> 💡 Once you have run your analysis you may prefer to hide the parameters panel by clicking the collapse button on the vertical divider in the middle of the screen. Likewise the amount of space given to the chart and tables can be altered by dragging the horizontal divider.

Below the chart, the raw data produced by the analysis are shown in tables. These tables can be copy and pasted into other applications such as spreadsheet programs for further analysis. They can also be exported to tab delimited text files. Both options are accessed via a right click menu. Alternatively you can use the option in the file menu or the equivalent button on the toolbar to save the results to disk.

6.4 Interpreting results

Function	Family	pdf	Asymptotic term
Logistic	Sigmoidal	$\dfrac{a}{1+be^{-cx}}$	a
Michaelis-Menten	Growth/saturation	$\dfrac{ax}{b+x}$	a
Modified exponential	Exponential	$ae^{\frac{b}{x}}$	a
Modified Michaelis-Menten	Growth/saturation	$\dfrac{ab+cx^d}{b+x^d}$	c
Weibull	Sigmoidal	$a-be^{-cx^d}$	a

Table 6.1: Description of the different curve fitting functions used to calculate the asymptote.

Chapter 7

Superposed Epoch Analysis

Chapter 8

Fire History Charts

FHAES includes the tools necessary to produce publication quality fire history charts. These charts provide a powerful method for illustrasting the fire regime of a site or region.

To produce a chart, simply select the file of interest in your file list on the left panel in FHAES, then either click the chart button on the toolbar, select *View* → *Fire History Chart*, or right click and select 'Fire history chart' from the popup menu. Figure 8.1 shows a typical chart produced by FHAES.

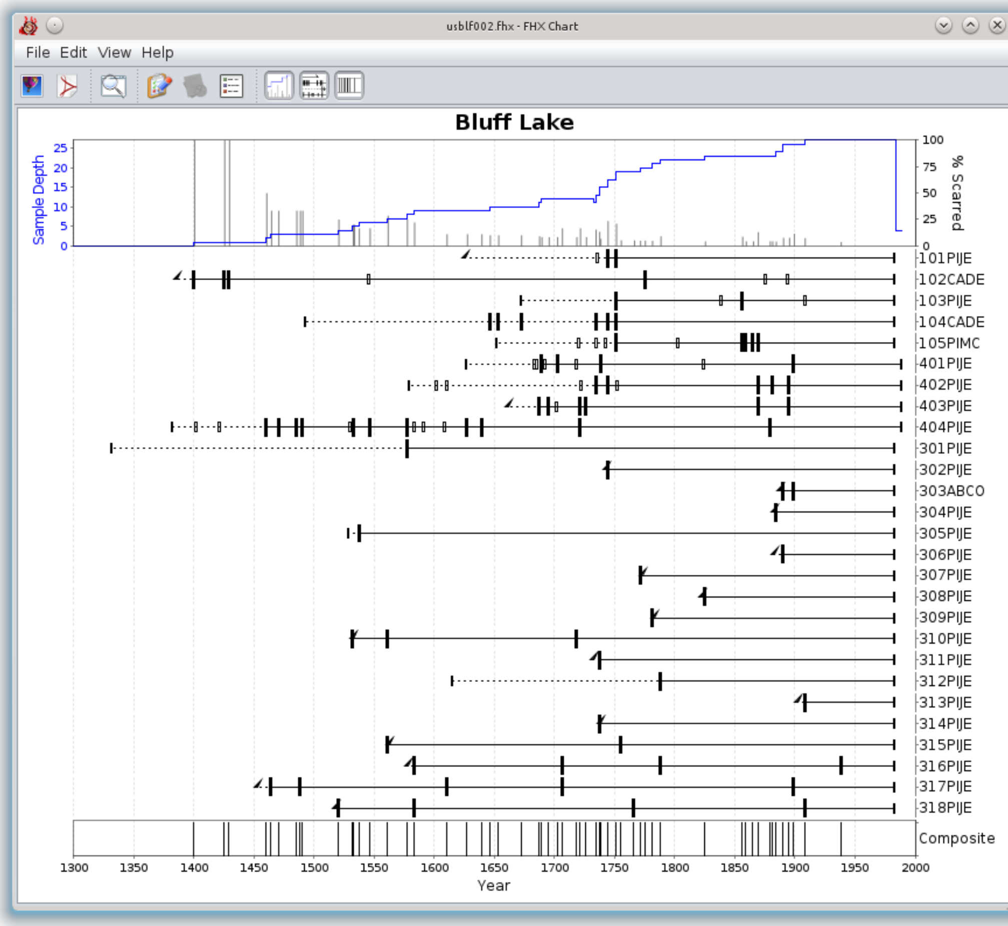


Figure 8.1: A typical fire history chart produced by FHAES. The chart has three optional components: fire index plot (top); fire chronology plot (middle); and fire composite plot (bottom).

⚠ *Please note that in this release of FHAES the chart module only supports the plotting of standard FHX files with series that begin and end with bracket characters. If you try to plot composite files, or files which begin or end with an event,*

8.1 Chart components

There are three components to a fire history chart, each or which can be included or removed as desired. The first (shown at the top of figure 8.1) is the **fire index plot**. This includes a histogram showing the sample depth for each year (i.e. how many trees are recording the fire history in each year) and a bar chart illustrating what percentage of these trees record a scar event.

The second component is the **fire chronology plot**. This shows a bar for each sample in the file illustrating the timeline for the tree e.g. the start and end year for each sample and all fire events. Through the use of various symbols the plot illustrates whether the tree is recording fire histories or not; when a tree records a fire scar or injury; and whether the sample starts and ends with pith and bark or not. Figure 8.2 shows the symbols used by this plot for each feature.

The third and final component is the **fire composite plot**. This shows whether the samples in the site or region as a whole record a fire event depending on certain threshold criteria set in the plot preferences. When the criteria are met, a line is marked on the plot for that year. The criteria can be set so that only years where greater than a specified percentage of trees record an event are marked. It is also possible to require a minimum number of samples so that events recorded by small number of trees when the sample depth is very low are not shown. These criteria are set by going to *Edit* → *Filter Options* → *Composite Axis Filters*.

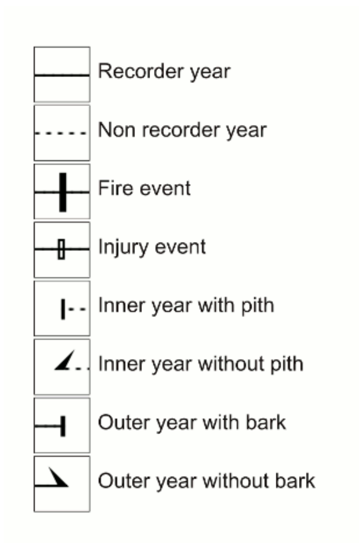


Figure 8.2: Legend for fire chronology plots.

Each of the chart components can be displayed or hidden by toggling them on and off using the toolbar buttons or the options in the view menu.

8.2 Modifying the chart

The main features of the chart can be altered through the chart properties dialog. This can be access through the toolbar, menu or by right-click popup menu. Options such as fonts, colors, ticks, grids, titles, labels etc can all be altered here.

It is possible to restrict the temporal scope of the chart to a certain year range by clicking and dragging on the chart. To return the chart to the full extent, simply click the 'zoom to full extent' button on the toolbar.

The contents of the chart (i.e. exactly what is plotted) can be altered in a couple of ways. First through the use of the *Edit* ➔ *Filter Options* ➔ *Select Series to be Plotted* menu. Here you can choose to hide one or more series from the file and you can also alter the order that they appear in the fire chronology plot. The contents of the composite plot can be altered using the *Edit* ➔ *Filter Options* ➔ *Composite axis filters* dialog. This works in a similar way as the composite filter dialogs elsewhere in FHAES whereby a threshold of number or percentage of samples recording an event can be specified.

8.3 Exporting charts

Once you are happy with your chart you have two options for exporting it for use in publications and reports. The chart can either be saved as a PNG image or as a PDF file. Both of these options can be accessed through the toolbar or the file menu. Which format you choose depends on how you will use the chart. The PNG image file can easily be embedded in word processing documents but because it is a raster file format the quality of the output will degrade if enlarged too much. The PDF format is written as a vector file so can be enlarged to any size with no loss in quality. The PDF format should therefore be used when publication quality output is required.

Part II

Developers guide

Chapter 9

Developing FHAES

FHAES is open source software and we actively encourage collaboration and assistance from others in the community. There is always lots to do, even for people with little or no programming experience. Please get in touch with the development team as we'd love to hear from you.

9.1 Source code

This section describes how to access the FHAES source code, but as you are no doubt aware it is normal (if not essential) to use a integrated development environment for developing any more than the most simplistic applications. If you plan to do any development work, it is probably best to skip this section and move straight on to the 'Development environment' section which includes instructions for accessing the source code directly from your IDE. If, however, you just want to browse the source code please continue reading.

The FHAES source code is maintained in a Subversion repository at Sourceforge.net. The simplest way to see the source code is via the web viewer on the Sourceforge website: `http://sourceforge.net/p/fhaes/code/HEAD/tree/trunk/`.

If you have Subversion installed you can do an anonymous checkout of the code as follows:

```
svn checkout svn://svn.code.sf.net/p/fhaes/code/ fhaes-code
```

An overview of the development can be seen through the FHAES Open Hub pages at `https://www.openhub.net/p/fhaes/`. Open Hub provides graphics summarizing the code over time, including timelines of commits by user.

9.2 Development environment

The IDE of choice of the main FHAES developers is Eclipse (`http://www.eclipse.org`). There are many other IDEs around and there is no reason you can't use them instead. Either way, the following instructions will hopefully be of use.

We have successfully developed FHAES on Mac, Windows and Linux computers. The methods for setting up are almost identical.

The first step is to install Eclipse, Java 6 or 7 JDK, Subversion, Maven, RPM and NSIS[1]. These are all readily available from their respective websites. On Ubuntu they can be install from the command line easily as follows:

```
sudo apt-get install eclipse subversion default-jdk maven2 nsis rpm
```

[1] If you do not have NSIS and/or RPM installed you will get an error when packaging FHAES, however, all other aspects of the development environment should work fine if you comment out the NSIS and/or RPM sections in the pom.xml file. Remember not to commit this change to the repository though!

Once installed, you can then launch Eclipse. To access the FHAES source code you will need to install the Subversive plugin to Eclipse. As of Eclipse v3.5 this can be done by going to *Help* ➔ *Install new software*. Select the main Update site in the 'Work with' box, then locate the 'Subversive SVN Team Provider' plugin under 'Collaboration'. If you are using an earlier version of Eclipse you may need to add a specific Subversive update site. See the Subversive website (`http://www.eclipse.org/subversive/`) for more details. Once installed you will need to restart Eclipse.

Next you will need to install the m2e Maven plugin to Eclipse. This can also be installed by going to *Help* ➔ *Install new software*, however, you may need to add the Maven update site as this plugin is not currently available in the main Eclipse repository. You can do this by click the 'Add' button and using the URL `http://m2eclipse.sonatype.org/sites/m2e`. Once again you will need to restart Eclipse before continuing.

Next you need to get the FHAES source code. Go to File *New* ➔ *Project*, then in the dialog select *SVN* ➔ *Project from SVN*. There are two methods of accessing the FHAES repository: anonymously (in which case you will have read only access); or with a username provided by the FHAES development team. Anonymous users will need to add a repository in the form: `http://svn.code.sf.net/p/fhaes/code/` and full users will need to use `svn+ssh://svn.code.sf.net/p/fhaes/code/`.

FHAES is comprised of a number of projects which are stored as seperate folders within the 'trunk' folder in in Sourceforge. This enables us to work and package different aspects of the system separately. For instance the graphics module can be built and run separately from the main stats modules. You will need to set up separate projects in Eclipse for each of these modules:

- FHUtil
- FHRecorder
- FHChart
- FHSampleSize
- FHAES

The FHAES project is the main application that most users use to access the functionality of the other modules. Although FHAES depends upon the other modules mentioned above, the Maven configuration should retrieve these modules from our Maven repository if you don't intend to work with them. This means you shouldn't need to configure all modules in Eclipse to get up and running.

To launch FHAES from within Eclipse you will need to go to *Run* ➔ *Run Java application*. Create a new run configuration with the main class set to 'org.fhaes.gui.MainWindow'.

9.3 Dependencies

FHAES is built with Maven. One of the main benefits of Maven is that it handles dependencies efficiently. All the libraries that FHAES relies upon are configured within the Maven pom.xml file and installed seamlessly as part of the build process. Maven handles transient dependencies (i.e. dependencies of dependencies) automatically. Therefore if a developer knows he needs the functions within a particular library, he simply needs to supply the details of this library without having to worry about the other libraries that this new library is in turn dependent on. Maven also manages versions efficiently. If a library is dependent on a particular version of another library this is specified within the Maven build mechanism. This means it is much easier to keep dependencies up-to-date without having to worry about the cascading issues that upgrades often have. In short, Maven is intended to save developers from 'JAR hell'.

For the record, FHAES currently depends upon the libraries listed in table 9.1. The table also specifies the licenses that these libraries are made available under.

Library	License
Apache commons lang	Apache 2.0
TridasJLib	Apache 2.0
JFreeChart	LGPL
JMapViewer	GPL
Log4J	Apache 2.0
iText	GAPL
DendroFileIO	Apache 2.0
Java Simple MVC	MIT
SLF4J	MIT
MigLayout	BSD
SwingX	LGPL

Table 9.1: FHAES primary and major first order dependencies along with the licenses under which they are used.

Library	License
Apache commons lang	Apache 2.0
Launch4J	BSD/MIT
NSIS	zlib/libpng
Ant	Apache 2.0
Eclipse	Eclipse Public License - v1.0
M2Eclipse	Eclipse Public License - v1.0
Subversive	Eclipse Public License - v1.0

Table 9.2: Additional tools/libraries typically used in the development of FHAES.

9.4 Multimedia resources

FHAES includes infrastructure for multimedia resources such as icons and images within the Maven resource folder 'src/main/resources' of the FHUtil module. The icons are accessed via the static Builder class. This has various accessor functions which take the filename and return the icon itself or a URI of the icon from within the Jar.

9.5 Logging

Logging in FHAES is handled by the SLF4J and Log4J packages. Rather than write debug notes directly to System.out, Log4J handles logging in a more intelligent way. First of all, each log message is assigned a log level which are (in order of severity) fatal, error, warn, info, debug and trace. Through a log4j.xml configuration file contained within the FHUtil resources folder, we can control the level at which messages are displayed. For instance while we develop we would likely show all messages up to and including 'trace', but when we deploy we might only want to show messages up to and including 'warn'.

Log4J also enables us to log to several places (known as appenders), e.g. console, log file or a component within our application. It is also possible to change the level of logging depending on the log type, so minimal messages can be sent to the console but verbose messages to the log file. FHAES has the following appenders configured:

- Standard log file (fhaes.log) that rolls over up to 2mb of messages
- Console – standard messages to the console when launched from command line
- Help console – simple console component available from the FHAES application menu *Help* → *Error log viewer*

To alter the way these appenders are configured you need to edit the log4j.xml file. See the Log4J documentation for further information.

Using the logging framework is very simple. Just define a Logger as a static variable in your class like this:

```
private final static Logger log = LoggerFactory.getLogger(MyClass.class);
```

where MyClass is the name of the current class. Then you can log messages simply by calling log.warn('My message'), log.debug('My message') etc.

Before managed logging was introduced to FHAES, debugging was often handled through the use of System.out and System.err messages. To ensure that these messages are not lost we use another package called SysOutOverSLF4J. This redirects messages sent to System.out and System.err to the logging system. This is a temporary solution so when working on older classes, please take the time to transition these older calls to the proper logging calls. We can then remove the need for SysOutOverSLF4J.

9.6 Preferences

It is helpful to remember certain user preferences e.g. last folder opened etc so that they don't have to do tasks repeatedly. This is achieved through the use of the FHAESPreferences class. This stores preferences in a specific place on the users computer depending on the operating system they are using. For instance in Windows preferences are stored in the registry and in Linux they are stored in a hidden file within the users home folder.

The preferences are accessed from the static member as follows:

```
FHAESPreferences.setPref(PrefKey.PREFKEY, "value");
```

where PrefKey.PREFKEY is an enum containing a unique string to identify the preference, and the second value is the string value to set.

To retrieve a preference, you use a similar syntax:

```
FHAESPreferences.getPref(PrefKey.PREFKEY, "default value");
```

When you get a preference the second parameter contains the default value to return if no preference is found. There are a number of variations on the setPref and getPref functions which ensure the data type of the preference you are saving/retrieving e.g. setIntPref, setBooleanPref etc.

9.7 Build script

FHAES is built using Maven and is controlled through the pom.xml file stored in the base of the FHAES source code. It would be possible to distribute FHAES as an executable JAR file, however, we we have chosen to also produce native installers for the major platforms. This gives us the opportunity to tightly integrate FHAES into the users operating system making it behave more like the native applications they are used to using. For instance, it means that we can associate the .FHX file extension in Windows with FHAES enabling users to double click on files and have them open automatically. It also means the application has its own icon rather than the generic Java coffee icon. In MacOSX it also means the menu bar is placed at the top of the screen rather than in the window.

While you develop, Maven should automatically build FHAES for you in the background. Specific build commands are only required as you approach a release. We use the standard Maven 'life cycle' for building, packaging and deploying FHAES. The method for doing this in Eclipse is by right clicking on the pom.xml file and selecting *Run as* ➔ *Maven package* etc. If the option you want is not displayed, you will need to create an entry in the build menu by going to *Run* ➔ *Run configurations*, then create a new Maven Build with the required 'goal'. The main goals are as follows:

clean - This deletes any previously compiled classes and packages in the target folder. It should only be necessary to run this occassionally if Maven has got a bit confused. If this is the case you may also need to force Eclipse to clean too by going to *Project* → *Clean...*

package - This compiles FHAES and builds a single executable JAR containing all dependencies (thanks to the maven-shade-plugin) along with native Windows, MacOSX and Linux packages. These are all placed in structured folders within 'target
Binaries' ready for deploying on the website.

deploy - This uploads the compiled jar into the maven.tridas.org repository. Note that you will need to either run this phase from the command line or by setting up a customer run configuration in Eclipse.

9.7.1 Windows installer

Maven generates the Windows executable for the Tellervo application through the 'launch4j' plugin. Windows users, however, expect an installer that will create menu entries and add uninstall options to the control panel. An installer is also required to install the user manual.

The best open source tool for creating Windows installer scripts is NSIS (see `http://nsis.sourceforge.net`). This is an extremely flexible scripting system that does all we need. If you have NSIS installed the Maven package goal should create the Windows installer automatically. We use the Maven antrun plugin to run the makensis executable. This script is stored in Native/BuildResources/WinBuild. The Maven resource plugin moves it into the target folder and replaces the version numbering for use in filenames etc.

9.7.2 Mac package

The Maven osxappbundle plugin is able to produce both .app and .dmg files. Unfortunately, the libraries for producing .dmg files are proprietary to Apple. When Maven is run on Windows or Linux, it is therefore only able to produce a zipped .app file, and not .dmg. Note an antrun plugin is used to remove duplicate libraries from the final package.

9.7.3 Linux Deb package

A Linux Debian package is produced using the JDeb Maven plugin. If Maven does its job properly, it should all 'just work' as part of the standard maven package phase. In addition to the configuration in the pom.xml, there are three files that are used to configure the final deb file. In src/deb/control/ there is a control file which describes the runtime dependencies, maintainer of the package, description etc. In Native/BuildResources/LinBuild are two files, one a simple bash script that is used to launch FHAES on the users computer and the other a .desktop file for configuring how it appears in the users menus. All three of these files are automatically updated with the current version number, so hopefully you shouldn't need to change anything.

9.8 Code signing

From Windows Vista and MacOSX 10.7 (Lion) onwards code signing has become important. Windows applications that are not signed result in terrifying warning messages, and in OSX by default they cannot even be run. The idea behind code signing is that it provides some level of security for the user as code signing certificates can be revoked if an application is deemed to be malicious.

To sign an application you first need a code signing certificate. In fact you need two: one for Windows and Java; and another for OSX as Apple only support certificates issued by themselves. A generic Windows and Java certificate can be purchased from a variety of suppliers (e.g. Verisign etc) the Apple certificate must be purchased through the Apple Developer Connection.

Code signing the Java jars and Windows installers is handled within Maven. The current set up in the Maven pom.xml file is configured for Ubuntu Linux. If you are developing on another platform you will need to make changes.

9.8.1 *Signing Java jars*

The Java jars are signed using a Java utility called jarsigner that comes with your JDK so there is nothing to install. The pom.xml is currently hard coded to access the certificate and key files stored on the lead FHAES development machine. You will need to alter these settings accordingly.

9.8.2 *Signing Windows executables*

Windows executables are typically signed using the Windows-only Microsoft utility signcode. On Linux and OSX there is an open source equivalent called osslsigncode which can be downloaded from Sourceforge and compiled. You may also be able to find third-party binaries for your operating system.

The FHAES pom.xml file has been configured to run osslsigncode with the location and naming of the certificate and key files hard coded. Change these to match the certificate you are using. If you are using signcode instead of osslsigncode you should find that the parameters are very similar. You should hopefully be able to modify them without too much difficulty.

Please note that both signcode and osslsigncode need the certificate in a different format to jarsigner. You can use openssl to do this conversion and there are many tutorials online which describe how.

9.8.3 *Signing OSX executables*

With the inclusion of the GateKeeper technology in OSX 10.7, code signing has become almost essential in OSX. The jar wrapped in native apps will fail to load under default security settings and the OS reports the file as 'damaged' because the JavaApplicationStub used has an existing signature and the contents of the package has changed. This signature must be removed or replaced with another before the application can be launched. If a self-signed or third party certificate is used then the GateKeeper will block the application saying that it isn't from a trusted developer. It is possible for users to go to the *System Properties* → *Security and Privacy* and set the application security level to 'any developer' but this is long and involved for novice users and results in a lot of warnings. Please note that all signing of Mac application must be done on a recent Mac. There are no cross-platform tools currently available.

The best way to fix the issue is to sign the application using an Apple certified Developer ID certificate and GateKeeper will allow the application to launch with the default security settings. Obtaining this certificate is a fairly involved process and requires an annual subscription to Apple Developer Connection. Note that your certificate must begin with 'Developer ID' to work. Other Apple-provided certificates are used for distributing your application through the Mac App store and will not work.

Once you have your Developer ID certificate installed on your Mac, you can sign your application using the command:

```
codesign -f -s "Developer ID" FHAES.app
```

You can then verify that the signing worked by doing:

```
codesign --display --verbose=4 FHAES.app
```

9.9 Developing graphical interfaces

The graphical interfaces in FHAES have mostly been designed using the Google WindowBuilder Pro tool with Eclipse. Unlike other graphical design tools WindowBuilder has the benefit of being able to parse (most) hand written layout code, so it is possible to manually edit the layouts if you prefer. However, most of the interfaces are built using the MigLayout layout manager which can be a little tricky to code by hand.

9.10 Writing documentation

The documentation in FHAES is written in the well established typesetting language LaTeX 2_ε. LaTeX is a great tool for producing high quality documentation with a good structure and style. Unlike standard WYSIWYG (what you see is what you get) word processing applications like Microsoft Word, LaTeX uses simple plain text code to layout a document so that it is often described as WYSIWYM (what you see is what you mean)! The style of a LaTeX document is handled separated enabling the author to concentrate on content. By removing the possibility for authors to tinker with font sizes etc, LaTeX forces you to create clear, well structured documents. For further details see `http://en.wikibooks.org/wiki/LaTeX/`.

LaTeX has fantastic cross-referencing and citation functionality built in. Please follow the lead of the existing documentation!

9.11 Making a new release

Making a new release should be a relatively quick and simply process, but there are still a few things to remember:

- Make sure this documentation is up-to-date.
- Update the logging appenders to an appropriate level so that the user is not swamped by debug messages.
- Increment the build version number(s) in the pom.xml of FHAES and any of the other modules as applicable.
- Check the code in Eclipse and eliminate as many warnings as possible.
- Make sure the developers metadata is correct in the pom.xml. Add any new developers that have joined the project since the last release.
- Run Maven deploy on the secondary packages.
- Run Maven package on the FHAES project itself.
- *Test*! Make sure all packages are working on the major operating systems being supported.
- Copy the packages to the website and change the most recent build number on the website. This will inform users of the new release the next time they load FHAES.

Part III

Appendices

Appendix A

GNU General Public License

FHAES is released under the GNU General Public License (GPL) version 3.

A.1 Preamble

The GNU General Public License is a free, copyleft license for software and other kinds of works.

The licenses for most software and other practical works are designed to take away your freedom to share and change the works. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change all versions of a program–to make sure it remains free software for all its users. We, the Free Software Foundation, use the GNU General Public License for most of our software; it applies also to any other work released this way by its authors. You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for them if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs, and that you know you can do these things.

To protect your rights, we need to prevent others from denying you these rights or asking you to surrender the rights. Therefore, you have certain responsibilities if you distribute copies of the software, or if you modify it: responsibilities to respect the freedom of others.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must pass on to the recipients the same freedoms that you received. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

Developers that use the GNU GPL protect your rights with two steps: (1) assert copyright on the software, and (2) offer you this License giving you legal permission to copy, distribute and/or modify it.

For the developers' and authors' protection, the GPL clearly explains that there is no warranty for this free software. For both users' and authors' sake, the GPL requires that modified versions be marked as changed, so that their problems will not be attributed erroneously to authors of previous versions.

Some devices are designed to deny users access to install or run modified versions of the software inside them, although the manufacturer can do so. This is fundamentally incompatible with the aim of protecting users' freedom to change the software. The systematic pattern of such abuse occurs in the area of products for individuals to use, which is precisely where it is most unacceptable. Therefore, we have designed this version of the GPL to prohibit the practice for those products. If such problems arise substantially in other domains, we stand ready to extend this provision to those domains in future versions of the GPL, as needed to protect the freedom of users.

Finally, every program is threatened constantly by software patents. States should not allow patents to restrict development and use of software on general-purpose computers, but in those that do, we wish to avoid the special danger that patents applied to a free program could make it effectively proprietary. To prevent this, the GPL assures that patents cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification follow.

A.2 Terms and Conditions

0. Definitions.

   "This License" refers to version 3 of the GNU General Public License.

   "Copyright" also means copyright-like laws that apply to other kinds of works, such as semiconductor masks.

   "The Program" refers to any copyrightable work licensed under this License. Each licensee is addressed as "you". "Licensees" and "recipients" may be individuals or organizations.

   To "modify" a work means to copy from or adapt all or part of the work in a fashion requiring copyright permission, other than the making of an exact copy. The resulting work is called a "modified version" of the earlier work or a work "based on" the earlier work.

   A "covered work" means either the unmodified Program or a work based on the Program.

   To "propagate" a work means to do anything with it that, without permission, would make you directly or secondarily liable for infringement under applicable copyright law, except executing it on a computer or modifying a private copy. Propagation includes copying, distribution (with or without modification), making available to the public, and in some countries other activities as well.

   To "convey" a work means any kind of propagation that enables other parties to make or receive copies. Mere interaction with a user through a computer network, with no transfer of a copy, is not conveying.

   An interactive user interface displays "Appropriate Legal Notices" to the extent that it includes a convenient and prominently visible feature that (1) displays an appropriate copyright notice, and (2) tells the user that there is no warranty for the work (except to the extent that warranties are provided), that licensees may convey the work under this License, and how to view a copy of this License. If the interface presents a list of user commands or options, such as a menu, a prominent item in the list meets this criterion.

1. Source Code.

   The "source code" for a work means the preferred form of the work for making modifications to it. "Object code" means any non-source form of a work.

   A "Standard Interface" means an interface that either is an official standard defined by a recognized standards body, or, in the case of interfaces specified for a particular programming language, one that is widely used among developers working in that language.

   The "System Libraries" of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A "Major Component", in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it.

   The "Corresponding Source" for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work's System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work.

   The Corresponding Source need not include anything that users can regenerate automatically from other parts of the Corresponding Source.

   The Corresponding Source for a work in source code form is that same work.

2. Basic Permissions.

   All rights granted under this License are granted for the term of copyright on the Program, and are irrevocable provided the stated conditions are met. This License explicitly affirms your unlimited permission to run the unmodified Program. The output from running a covered work is covered by this License only if the output, given its content, constitutes a covered work. This License acknowledges your rights of fair use or other equivalent, as provided by copyright law.

   You may make, run and propagate covered works that you do not convey, without conditions so long as your license otherwise remains in force. You may convey covered works to others for the sole purpose of having them make modifications exclusively for you, or provide you with facilities for running those works, provided that you comply with the terms of this License in conveying all material for which you do not control copyright. Those thus making or running the covered works for you must do so exclusively on your behalf, under your direction and control, on terms that prohibit them from making any copies of your copyrighted material outside their relationship with you.

   Conveying under any other circumstances is permitted solely under the conditions stated below. Sublicensing is not allowed; section 10 makes it unnecessary.

3. Protecting Users' Legal Rights From Anti-Circumvention Law.

   No covered work shall be deemed part of an effective technological measure under any applicable law fulfilling obligations under article 11 of the WIPO copyright treaty adopted on 20 December 1996, or similar laws prohibiting or restricting circumvention of such measures.

   When you convey a covered work, you waive any legal power to forbid circumvention of technological measures to the extent such circumvention is effected by exercising rights under this License with respect to the covered work, and you disclaim any intention to limit operation or modification of the work as a means of enforcing, against the work's users, your or third parties' legal rights to forbid circumvention of technological measures.

4. Conveying Verbatim Copies.

   You may convey verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice; keep intact all notices stating that this License and any non-permissive terms added in accord with section 7 apply to the code; keep intact all notices of the absence of any warranty; and give all recipients a copy of this License along with the Program.

   You may charge any price or no price for each copy that you convey, and you may offer support or warranty protection for a fee.

5. Conveying Modified Source Versions.

   You may convey a work based on the Program, or the modifications to produce it from the Program, in the form of source code under the terms of section 4, provided that you also meet all of these conditions:

   (a) The work must carry prominent notices stating that you modified it, and giving a relevant date.
   (b) The work must carry prominent notices stating that it is released under this License and any conditions added under section 7. This requirement modifies the requirement in section 4 to "keep intact all notices".
   (c) You must license the entire work, as a whole, under this License to anyone who comes into possession of a copy. This License will therefore apply, along with any applicable section 7 additional terms, to the whole of the work, and all its parts, regardless of how they are packaged. This License gives no permission to license the work in any other way, but it does not invalidate such permission if you have separately received it.
   (d) If the work has interactive user interfaces, each must display Appropriate Legal Notices; however, if the Program has interactive interfaces that do not display Appropriate Legal Notices, your work need not make them do so.

   A compilation of a covered work with other separate and independent works, which are not by their nature extensions of the covered work, and which are not combined with it such as to form a larger program, in or on a volume of a storage or distribution medium, is called an "aggregate" if the compilation and its resulting copyright are not used to limit the access or legal rights of the compilation's users beyond what the individual works permit. Inclusion of a covered work in an aggregate does not cause this License to apply to the other parts of the aggregate.

6. Conveying Non-Source Forms.

   You may convey a covered work in object code form under the terms of sections 4 and 5, provided that you also convey the machine-readable Corresponding Source under the terms of this License, in one of these ways:

   (a) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by the Corresponding Source fixed on a durable physical medium customarily used for software interchange.
   (b) Convey the object code in, or embodied in, a physical product (including a physical distribution medium), accompanied by a written offer, valid for at least three years and valid for as long as you offer spare parts or customer support for that product model, to give anyone who possesses the object code either (1) a copy of the Corresponding Source for all the software in the product that is covered by this License, on a durable physical medium customarily used for software interchange, for a price no more than your reasonable cost of physically performing this conveying of source, or (2) access to copy the Corresponding Source from a network server at no charge.
   (c) Convey individual copies of the object code with a copy of the written offer to provide the Corresponding Source. This alternative is allowed only occasionally and noncommercially, and only if you received the object code with such an offer, in accord with subsection 6b.
   (d) Convey the object code by offering access from a designated place (gratis or for a charge), and offer equivalent access to the Corresponding Source in the same way through the same place at no further charge. You need not require recipients to copy the Corresponding Source along with the object code. If the place to copy the object code is a network server, the Corresponding Source may be on a different server (operated by you or a third party) that supports equivalent copying facilities, provided you maintain clear directions next to the object code saying where to find the Corresponding Source. Regardless of what server hosts the Corresponding Source, you remain obligated to ensure that it is available for as long as needed to satisfy these requirements.
   (e) Convey the object code using peer-to-peer transmission, provided you inform other peers where the object code and Corresponding Source of the work are being offered to the general public at no charge under subsection 6d.

   A separable portion of the object code, whose source code is excluded from the Corresponding Source as a System Library, need not be included in conveying the object code work.

   A "User Product" is either (1) a "consumer product", which means any tangible personal property which is normally used for personal, family, or household purposes, or (2) anything designed or sold for incorporation into a dwelling. In determining whether a product is a consumer product, doubtful cases shall be resolved in favor of coverage. For a particular product received by a particular user, "normally used" refers to a typical or common use of that class of product, regardless of the status of the particular user or of the way in which the particular user actually uses, or expects or is expected to use, the product. A product is a consumer product regardless of whether the product has substantial commercial, industrial or non-consumer uses, unless such uses represent the only significant mode of use of the product.

   "Installation Information" for a User Product means any methods, procedures, authorization keys, or other information required to install and execute modified versions of a covered work in that User Product from a modified version of its

Corresponding Source. The information must suffice to ensure that the continued functioning of the modified object code is in no case prevented or interfered with solely because modification has been made.

If you convey an object code work under this section in, or with, or specifically for use in, a User Product, and the conveying occurs as part of a transaction in which the right of possession and use of the User Product is transferred to the recipient in perpetuity or for a fixed term (regardless of how the transaction is characterized), the Corresponding Source conveyed under this section must be accompanied by the Installation Information. But this requirement does not apply if neither you nor any third party retains the ability to install modified object code on the User Product (for example, the work has been installed in ROM).

The requirement to provide Installation Information does not include a requirement to continue to provide support service, warranty, or updates for a work that has been modified or installed by the recipient, or for the User Product in which it has been modified or installed. Access to a network may be denied when the modification itself materially and adversely affects the operation of the network or violates the rules and protocols for communication across the network.

Corresponding Source conveyed, and Installation Information provided, in accord with this section must be in a format that is publicly documented (and with an implementation available to the public in source code form), and must require no special password or key for unpacking, reading or copying.

7. Additional Terms.

   "Additional permissions" are terms that supplement the terms of this License by making exceptions from one or more of its conditions. Additional permissions that are applicable to the entire Program shall be treated as though they were included in this License, to the extent that they are valid under applicable law. If additional permissions apply only to part of the Program, that part may be used separately under those permissions, but the entire Program remains governed by this License without regard to the additional permissions.

   When you convey a copy of a covered work, you may at your option remove any additional permissions from that copy, or from any part of it. (Additional permissions may be written to require their own removal in certain cases when you modify the work.) You may place additional permissions on material, added by you to a covered work, for which you have or can give appropriate copyright permission.

   Notwithstanding any other provision of this License, for material you add to a covered work, you may (if authorized by the copyright holders of that material) supplement the terms of this License with terms:

   (a) Disclaiming warranty or limiting liability differently from the terms of sections 15 and 16 of this License; or
   (b) Requiring preservation of specified reasonable legal notices or author attributions in that material or in the Appropriate Legal Notices displayed by works containing it; or
   (c) Prohibiting misrepresentation of the origin of that material, or requiring that modified versions of such material be marked in reasonable ways as different from the original version; or
   (d) Limiting the use for publicity purposes of names of licensors or authors of the material; or
   (e) Declining to grant rights under trademark law for use of some trade names, trademarks, or service marks; or
   (f) Requiring indemnification of licensors and authors of that material by anyone who conveys the material (or modified versions of it) with contractual assumptions of liability to the recipient, for any liability that these contractual assumptions directly impose on those licensors and authors.

   All other non-permissive additional terms are considered "further restrictions" within the meaning of section 10. If the Program as you received it, or any part of it, contains a notice stating that it is governed by this License along with a term that is a further restriction, you may remove that term. If a license document contains a further restriction but permits relicensing or conveying under this License, you may add to a covered work material governed by the terms of that license document, provided that the further restriction does not survive such relicensing or conveying.

   If you add terms to a covered work in accord with this section, you must place, in the relevant source files, a statement of the additional terms that apply to those files, or a notice indicating where to find the applicable terms.

   Additional terms, permissive or non-permissive, may be stated in the form of a separately written license, or stated as exceptions; the above requirements apply either way.

8. Termination.

   You may not propagate or modify a covered work except as expressly provided under this License. Any attempt otherwise to propagate or modify it is void, and will automatically terminate your rights under this License (including any patent licenses granted under the third paragraph of section 11).

   However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

   Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

   Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, you do not qualify to receive new licenses for the same material under section 10.

9. Acceptance Not Required for Having Copies.

   You are not required to accept this License in order to receive or run a copy of the Program. Ancillary propagation of a covered work occurring solely as a consequence of using peer-to-peer transmission to receive a copy likewise does not require acceptance. However, nothing other than this License grants you permission to propagate or modify any covered work. These actions infringe copyright if you do not accept this License. Therefore, by modifying or propagating a covered work, you indicate your acceptance of this License to do so.

10. Automatic Licensing of Downstream Recipients.

    Each time you convey a covered work, the recipient automatically receives a license from the original licensors, to run, modify and propagate that work, subject to this License. You are not responsible for enforcing compliance by third parties with this License.

    An "entity transaction" is a transaction transferring control of an organization, or substantially all assets of one, or subdividing an organization, or merging organizations. If propagation of a covered work results from an entity transaction, each party to that transaction who receives a copy of the work also receives whatever licenses to the work the party's predecessor in interest had or could give under the previous paragraph, plus a right to possession of the Corresponding Source of the work from the predecessor in interest, if the predecessor has it or can get it with reasonable efforts.

    You may not impose any further restrictions on the exercise of the rights granted or affirmed under this License. For example, you may not impose a license fee, royalty, or other charge for exercise of rights granted under this License, and you may not initiate litigation (including a cross-claim or counterclaim in a lawsuit) alleging that any patent claim is infringed by making, using, selling, offering for sale, or importing the Program or any portion of it.

11. Patents.

    A "contributor" is a copyright holder who authorizes use under this License of the Program or a work on which the Program is based. The work thus licensed is called the contributor's "contributor version".

    A contributor's "essential patent claims" are all patent claims owned or controlled by the contributor, whether already acquired or hereafter acquired, that would be infringed by some manner, permitted by this License, of making, using, or selling its contributor version, but do not include claims that would be infringed only as a consequence of further modification of the contributor version. For purposes of this definition, "control" includes the right to grant patent sublicenses in a manner consistent with the requirements of this License.

    Each contributor grants you a non-exclusive, worldwide, royalty-free patent license under the contributor's essential patent claims, to make, use, sell, offer for sale, import and otherwise run, modify and propagate the contents of its contributor version.

    In the following three paragraphs, a "patent license" is any express agreement or commitment, however denominated, not to enforce a patent (such as an express permission to practice a patent or covenant not to sue for patent infringement). To "grant" such a patent license to a party means to make such an agreement or commitment not to enforce a patent against the party.

    If you convey a covered work, knowingly relying on a patent license, and the Corresponding Source of the work is not available for anyone to copy, free of charge and under the terms of this License, through a publicly available network server or other readily accessible means, then you must either (1) cause the Corresponding Source to be so available, or (2) arrange to deprive yourself of the benefit of the patent license for this particular work, or (3) arrange, in a manner consistent with the requirements of this License, to extend the patent license to downstream recipients. "Knowingly relying" means you have actual knowledge that, but for the patent license, your conveying the covered work in a country, or your recipient's use of the covered work in a country, would infringe one or more identifiable patents in that country that you have reason to believe are valid.

    If, pursuant to or in connection with a single transaction or arrangement, you convey, or propagate by procuring conveyance of, a covered work, and grant a patent license to some of the parties receiving the covered work authorizing them to use, propagate, modify or convey a specific copy of the covered work, then the patent license you grant is automatically extended to all recipients of the covered work and works based on it.

    A patent license is "discriminatory" if it does not include within the scope of its coverage, prohibits the exercise of, or is conditioned on the non-exercise of one or more of the rights that are specifically granted under this License. You may not convey a covered work if you are a party to an arrangement with a third party that is in the business of distributing software, under which you make payment to the third party based on the extent of your activity of conveying the work, and under which the third party grants, to any of the parties who would receive the covered work from you, a discriminatory patent license (a) in connection with copies of the covered work conveyed by you (or copies made from those copies), or (b) primarily for and in connection with specific products or compilations that contain the covered work, unless you entered into that arrangement, or that patent license was granted, prior to 28 March 2007.

    Nothing in this License shall be construed as excluding or limiting any implied license or other defenses to infringement that may otherwise be available to you under applicable patent law.

12. No Surrender of Others' Freedom.

    If conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot convey a covered work so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not convey it at all. For example, if you agree to terms that obligate you to collect a royalty for further conveying from those to whom you convey the Program, the only way you could satisfy both those terms and this License would be to refrain entirely from conveying the Program.

13. Use with the GNU Affero General Public License.

    Notwithstanding any other provision of this License, you have permission to link or combine any covered work with a work licensed under version 3 of the GNU Affero General Public License into a single combined work, and to convey the resulting work. The terms of this License will continue to apply to the part which is the covered work, but the special requirements of the GNU Affero General Public License, section 13, concerning interaction through a network will apply to the combination as such.

14. Revised Versions of this License.

    The Free Software Foundation may publish revised and/or new versions of the GNU General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Appendix B

GNU Free Documentation License

This manual is released inder the GNU Free Documentation License (FDL) v1.3.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.3 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts.

B.1 Preamble

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

B.2 Terms and conditions

1. Applicability and definitions

   This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "**Document**", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "**you**". You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

   A "**Modified Version**" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

   A "**Secondary Section**" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

   The "**Invariant Sections**" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
D. Preserve all the copyright notices of the Document.
E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
H. Include an unaltered copy of this License.
I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. Combining documents

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements".

6. Collections of documents

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. Aggregation with independent works

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within

References

Brewer, P., Murphy, D., Jansma, E., 2011. TRiCYCLE: a universal conversion tool for digital tree-ring data. Tree-Ring Research 67, 135–144.

Falk, D.A., 2004. Scaling rules for fire regimes. Ph.D. thesis. University of Arizona. Tucson, Arizona.

Grissino-Mayer, H., 2001. FHX2 - software for analyzing temporal and spatial patterns in fire regimes from tree rings. Tree-Ring Research 57, 115–124.

Jansma, E., Brewer, P., Zandhuis, I., 2010. TRiDaS 1.1: The tree-ring data standard. Dendrochronologia 28, 99–130.

Romme, W., 1980. Fire history terminology: Report of the ad hoc committee., in: Stokes, M., JH, D. (Eds.), Proceedings of the Fire History Workshop, October 20-24, 1980, Tucson, Arizona, US Department of Agriculture General Technical Report RM -81. pp. 135–137.

For FHAES version 2.0.x
Compiled September 9, 2014