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Application of repeat photography in landscape change analysis in the region of Bragança, Portugal

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Abstract

Nowadays, landscape change analysis is occupying a prominent place among ecological studies, as it reflects the crucial role landscapes play in the dynamics of populations. This change can be assessed via a multitude of means, at different scales, depending on the nature of the study areas, the aimed objective of the research and the user's level of expertise.

One of the techniques that stands out in this field of study is repeat photography (RP), as it provides an exhaustive follow-up of the occurring changes through time. Yet, in order to accomplish a deeper image analysis, tools are required to extract qualitative and quantitative information and process the photographs.

The aim of the present work is to select and assess methods of visualization, description and comparison of chronological series of aerial oblique photographs to landscape change analysis in the Bragança region of Northeastern Portugal. The two main presented tools in this study are the Image Analysis Toolkit (IAT), by the Mountain Legacy Project (MLP), and the WSL Monoplotting Tool by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Bellinzona, Switzerland. IAT allows users to display and analyze single or multiple images (up to three images side by side). The editing is rudimentary, as it allows creating segmentation masks on the platform, that can be saved to the users own offline file system. The WSL tool , allows to analyze photographs by allowing extraction of spatially referenced vector data from oblique photographs.

Such tools require georeferenced images taken repeatedly from the same spot over the years in order to ensure the repeat aspect of the process. Their outputs may vary from GIS maps to freehand sketches, depending on how advanced the study is. The selection and assessment of these computer tools was based on criteria such as accessibleness, data formats, friendliness, and others.

Keywords : **Repeat photography**, **Landscape Change**, **Mountain Legacy Project**, **WSL Monoplotting Tool**

Resumo

Hoje em dia, a análise da mudança de paisagem ocupa um lugar proeminente entre os estudos ecológicos, pois reflete o papel crucial que as paisagens desempenham na dinâmica das populações. Esta mudança pode ser avaliada através de uma multiplicidade de meios, em diferentes escalas, dependendo da natureza das áreas de estudo, o objetivo objetivo da pesquisa e o nível de conhecimento do usuário.

Uma das técnicas que se destaca neste campo de estudo é a fotografia repetida (RP), pois fornece um acompanhamento exaustivo das mudanças ocorridas ao longo do tempo. No entanto, para realizar uma análise de imagem mais profunda, as ferramentas são necessárias para extrair informações qualitativas e quantitativas para processar fotografias.

O objetivo do presente trabalho é selecionar e avaliar métodos de visualização, descrição e comparação de séries cronológicas de fotografias aéreas oblíquas e análises de mudanças de paisagem na região de Bragança no nordeste de Portugal. As duas principais ferramentas apresentadas neste estudo são o Image Analysis Toolkit (IAT), pelo Mountain Legacy Project (MLP) e a WSL Monoplotting Tool pelo Instituto Federal Suíço de Pesquisa Floresta, Neve e Paisagem WSL, Bellinzona, Suíça . O IAT permite aos usuários exibir e analisar imagens únicas ou múltiplas (até três imagens lado a lado). A edição é rudimentar, pois permite criar máscaras de segmentação na plataforma, que podem ser salvas no próprio sistema de arquivos offline dos usuários. A ferramenta WSL abre a porta para analisar fotografias, permitindo a extração de dados vetoriais referenciados espacialmente a partir de fotografias oblíquas. Ele permite extrair informações ecológicas a partir de fotografias angulares oblíquas.

Essas ferramentas requerem imagens georreferenciadas tomadas repetidamente do mesmo local ao longo dos anos, a fim de garantir o aspecto de repetição do processo. Suas saídas podem variar de mapas de GIS para esboços de mão-direita, dependendo de quão avançado o estudo é.

A seleção e uso de ferramentas de computador baseou-se em critérios como acessibilidade, formatos de dados, simpatia e outros.

Palavras-chave : **Repetição de fotografia**, **Mudança de paisagem**, **Projeto Legacy Mountain**, **WSL Monoplotting Tool**

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1 Introduction

In a context of socio-economic changes that modern societies are going through, of a growing interest in climate change and its repercussions on resources sustainability, but also of technologies development for ecological studies, landscape change is occupying a prominent place, as it reflects the crucial role they –landscapes- play in the dynamic of populations.

In response to this interest, researches have proven, through the years, that landscape change can be assessed via a multitude of means, on different scales, depending on the nature of the studies areas, the aimed objective of the research and the user's level of expertise.

One of the techniques that seems to stand out in this field of study is repeat photography (RP), as it provides an exhaustive follow-up of the occurring changes through time. Yet, in order to accomplish a deeper image analysis, ad hoc tools are required to extract qualitative and quantitative information from the photographs and process them.

The aim of the present work is to select and assess methods of visualization, description and comparison of chronological series of aerial oblique photographs to landscape change analysis in the Bragança region of Northeastern Portugal.

Such tools require georeferenced images taken repeatedly from the same spot over the years in order to ensure the repeat aspect of the process. Their outputs may vary from GIS maps to freehand sketches, depending on how advanced the study is.

The selection and use of computer software tools was based on criteria such as accessibleness, data formats, friendliness, and others.

1.1 Problem

Landscapes, especially natural ones, are very complex and contain several components, which occupy different areas through time, depending on how intensively resources are exploited, and whether people value agriculture, livestock farming, or both simultaneously. In addition to this, landscapes are subject to many disturbances such as forest fires, especially in Portuguese forests, storms and floods. Therefore, it is highly requested to find tools, online or desktop applications that help extract information about the occupied areas for the mentioned landscape components and quantify the changes in the landscape. And, in both cases, make the outputs available for further analyses. Repeat photography is one of the options to assess landscape changes, and it requires specific tools to extract information from the photographs.

1.2 Objectives

The aim of this work was to select and assess methods of visualization, description and comparison of chronological series of oblique photographs, to lead a landscape change analysis in the landscapes of the Northeastern region of Portugal, including the Montesinho Natural Park. The tool should be:

- Efficient, and meet the intended purpose from its use, which is to provide reliable quantitative and qualitative outputs for a landscape change analysis
- Friendly for all kinds of users, with different levels of knowledge
- Graphically pleasant and does not hinder the user experience

Therefore, this work will have two main steps :

- The selection of the tools to work on in this report, that match perfectly with the objectives of this study
- The assessment of the chosen tools and the way they operate, followed by their comparison, based on different criteria such as accessibleness, data formats, friendliness, and others.

1.3 Approach

For this project, the approach can be broken down as follows:

- Literature review of the repeat photography approach and practices;
- Choice, evaluation and comparison of tools and methods of image analysis;
- Critical review of the tools and applicability to the region of Bragança;

1.4 Document organization

This document is organized into four chapters:

- The first chapter consists of an introduction presenting the objectives and the methodology followed in this thesis;
- The second chapter is dedicated to examine literature about repeat photography, and display an overview of the related work;
- The third chapter presents the adopted methods to select and assess repeat photography analysis tools in details;
- The fourth chapter includes a description of the chosen tools and the results of their comparison, followed by a critical review and their applicability to the landscapes of the region of Bragança;

2 Literature review

2.1 Oblique photography

Oblique photography is a term that refers to images “taken with the camera axis intentionally directed between the horizontal and the vertical” (Wolf, 1983). It is another form of generation of data to communicate the change of the landscape at the local scale, using a huge collection of pictures of aerial photographs (Chandler et al., 2002; Corripio, 2004)

An interesting example of application of oblique photos is a study based on a collection of oblique images covering all parts of Denmark recorded between 1930 and 1990 illustrated the changes that have taken place in the rural landscape at the local scale (Svenningsen et al., 2015).

2.2 Repeat Photography

Several studies used repeat photography as a scientific tool to assess many aspects of changes over widely differing landscapes. The scientists demonstrate the use of this technique to record the effects of climate change on the landscapes (Chen et al., 2011), to track changes in land use (Bass 2006; Webb et al., 2010; White and Hart, 2007; Zier and Baker, 2006), and to assess erosion (Graf, 1978). The interpretation of changes can be simplistic, and repeat photography can reveal the causes and the effects that may be indicative for future changes in the landscape (Webb et al., 2010). Repeat photography was helpful to answer many question about fluvial dynamics, erosion and deposition (Butler, 1994; Osterkamp et al., 1995; Cluer, 1995). For instance, the effect of plants on the resistance of erosion (Graf, 1978), and the response of the channel alteration to mining (Graf, 1979).

Repeat photography can help make decisions concerning the environment, to increase public awareness, to understand changes and the likely consequences of the decisions of land use, to document the damage caused by using old landscape where a new manager cannot intervene or take action for rehabilitation (Bullock et al. 2004). Monitoring the landscapes after natural disasters is another area of wide application of repeat photography.

The strengths of repeat photography lies in the length of time that covers (can reach more than 100 years), another very significant lies in the relative cost / effective- ness, especially in developing countries where climate change, and also the evolution of land use methods that contributes to change the landscape at a large scale (Webb et al., 2010).

Repeat photography was underestimated in the assessment of landscape changes due to the evolution of technology that tracks the landscape with several methods, but it was clear that combining images with the results of other tools can provide a broad overview of the changes that could not be reached otherwise (Moore et al. 2016).

2.3 Application of repeat photography

2.3.1 Using repeat photography to explore change in mountain landscapes

Repeat photography typically works with land-based oblique images, those taken looking out from a mountaintop or promontory and thereby rendering the landscape as continuously variable across the image plane.

These are images taken from a human-eye viewpoint rather than the bird's-eye view of aerial photography and remotely sensed satellite imagery. Vast numbers of oblique images exist for mountainous regions of the world because climbers and enthusiasts have been inspired to document ascents and remarkable mountain landscapes almost since the invention of practical photography in the mid-19th century. Indeed, the first use of repeat photography as a scientific tool was in 1888 by Bavarian mathematician Sebastian Finsterwalker studying mountain glaciers in the Tyrolean Alps (Webb 1996: 30).

Today repeat photography is used extensively to document change in a wide variety of ecological, geological, fluvial, and human phenomena. White and Hart's (2007) repeat photography in the Canadian Rockies touches on all of these phenomena. Collection types vary significantly, from one-off images gathered in archives to large, systematic collections such as those collected to track changes in desert plant communities near Tucson, Arizona (Hastings and Turner,1965; Webb et al., 2007) and the MLP (Delaney,2008; Trant et al., 2015).

2.3.2 Challenges in using repeat photography image pairs

Apart from the issues of working with the continuously variable representation of landscapes within oblique photographs, there is the challenge of finding image collections that are both comprehensive and systematic.

Systematic collections are those taken with similar or consistent imaging techniques according to consistent rules (eg triangulated views from mountain summits), and are sufficiently comprehensive across a landscape to be useful. Finding historical images to repeat, especially in isolated areas, can be challenging.

Moseley (2006), looking at historical landscape change in remote northwestern Yunnan province, China, collected photos from a wide range of sources, including National Geographic Magazine. Kull (2005), in examining regional land use change in the Madagascar Highlands, describes issues around obtaining spatially representative images, noting that collections often include many images taken from the same place— usually a place that is easily accessed. Neusser (2000) used repeat photography to look at sustainability, land use, and landscape change in the Nanga Parbat region of Pakistan. He notes the valuable role it can play when combined with other analysis techniques (eg. historical reviews, in situ interviews, and ground truth analysis). Repeat photographers are sometimes asked, "Why not just use remotely sensed data, such as aerial photographs and satellite imagery?" **Depth of time and increased subject detail are 2 reasons to consider repeat photography of landscapes**.

In the Canadian mountain west, for example, by 1945 only one quarter of Canada had air photo coverage. Only in 1957 was the entire country covered (Harris, 1990). Thus, many of these early air photos go back only 60 years, and they do not provide the detail found in historic glass-plate images taken by earlier mountain surveyors. If we rephotograph the oblique survey images used in creating maps of the Canadian cordillera, in some cases we can look 125 years into the past. In writing about the history and processes behind the use of photography in the creation of early Canadian maps, Dyce (2013: 74) says, **"Both maps and photographs represent reality through the rules of perspective—they are reduced-scale versions of what they portray, where the relative distances in the smaller versions correspond to the larger distances found in reality."**

Thus, the oblique image gives us a perspective view—a representation of reality close to what the human eye sees.

In their closing chapter, Webb et al (2010 : 310) suggest that repeat photography, a decidedly low-tech tool in the evolving high-tech world of remote image capture, has a compatible and complementary role to play in acquiring spatial data alongside that of the most sophisticated remote systems, "in fact, far exceeding those systems if site-specific information or a long-term perspective is desired." Another key challenge is the ability to align images.

2.4 Repeat photography analysis

Several researchers have shown interest in studying landscape change through repeat photography:

Applied historical ecology is the use of historical knowledge in the management of ecosystems. Our understanding of the dynamic nature of landscapes is increased thanks to historical perspectives, which also provide a frame of reference for assessing modern patterns and processes (Swetnam et al., 1999). However, some challenges come alongside with the historical records: they are often too brief or fragmentary to be useful, or they are not obtainable for the process or structure of interest, which makes the selection of appropriate reference conditions a little complicated. These complications, however, do not lessen the value of history; rather they underscore the need for multiple, comparative histories from many locations for evaluating both cultural and natural causes of variability, as well as for characterizing the overall dynamical properties of ecosystems. With the increasingly severe wildfires, historical knowledge may not simplify the task of setting management goals and making decisions, but disregarding it can be perilous.

Swetnam et al (1999) describe a montane grassland restoration project in northern New Mexico that was justified and guided by an historical sequence of aerial photographs showing progressive tree invasion during the 20th century. They combine repeat photography with dendrochronology in order to restore landscape history. Using fire scar chronologies, it was possible to justify natural fire in forests. Combining these results with those of historical time series, and aggregating them across spatial scales points to the key role of interannual lags in responses of fuels and fire regimes to the El Niño–Southern Oscillation (wet/dry cycles), with important implications for long-range fire hazard forecasting. Therefore, the detection and explanation of historical trends and variability in such examples of applied historical ecology are necessary to informed management (Swetnam et al., 1999).

Repeat Photography: Methods and Applications in the Natural Sciences Webb (2010) is a book that provides the reader with solid, up-to-date information about how to take repeat photographs, how to catalog and archive them, and how to effectively present them. It include information about how computer-aided technologies, such as GIS, virtual repeat photography and electronic overlays, can help expand the range and potential of repeat photography. It provides the basic information needed to develop a purposeful rephotography project and strongly suggests that repeat photography can be used to quantitatively and qualitatively assess changes in vegetation. Only to show how repeat photography can be very useful for monitoring changes in vegetation and landscape in general. In addition, using fixed-pointed photography, field surveys and GIS can help add precision about the locations and quantify the change during a 10 years period.

The WSL Monoplotting Tool, which is a new piece of software that allows analyzing photographs by allowing for extraction of spatially referenced vector data from oblique photographs. It allows to extract ecological information from oblique angle landscape photographs (Stockdale et al., 2015). A very large repeat photography collection based on the world's largest systematic collection of historical mountain topographic survey images, the Mountain Legacy Project that provided the previous tool, contains 6000 high resolution oblique image pairs showing landscape changes in the Rocky Mountains of Alberta between 1900 - today. A subset of photographs from this collection was used to assess the accuracy and utility of the WSL Monoplotting Tool for georeferencing oblique photographs and measuring landscape change (Stockdale et al., 2015). The accuracy aspects will be explored in the next chapter.

The Image Analysis Toolkit. It is a browser based JavaScript program. It allows users to display and analyze single or multiple images (up to three images side by side). The editing is described by the creators as rudimentary, as it allows creating segmentation masks on the platform, that can be saved to the users own offline file system. Since 1996, The Mountain Legacy Project (MLP) interdisciplinary mountain researchers have been in the peaks of western Canada rephotographing historic mountain landscape images (Sanseverino et al., 2016). With an ever-deepening collection of historic and modern image pairs available for comparison, MLP researchers asked this one question that gave birth to the heart tool of the project: What tools do mountain study researchers and community practitioners from diverse disciplines need to help them better access, explore, and analyze image pairs (Sanseverino et al., 2016).

3 Material and methods

In order to recommend the most suitable programs to assess the landscape change in the region of Bragança, Northern Portugal, we went through the following steps:

- Selection of the tools to work on in this report, from the ones presented above
- Assessment of the chosen tools, and the way they operate, including a comparison that values the user experience

3.1 Selection of tools

Working on oblique photographs has the advantages of providing a tridimensional description of the landscape as they give us a perspective view—a representation of reality close to what the human eye sees, therefore more details are brought about. Dyce (2013: 74) says, “Both maps and photographs represent reality through the rules of perspective—they are reduced-scale versions of what they portray, where the relative distances in the smaller versions correspond to the larger distances found in reality.”

The selection will be based on how effective the tools are in terms of working directly on aerial or terrestrial oblique photographs, even though they operate differently. Which means that, first of all, they should match with objectives of this study. It is preferable if they can be used by people with different levels of knowledge about Geographic Information Systems, whether they are beginners or researchers from other fields of study who happen to show interest in repeat photography analysis. It is also preferable if these tools come with a user guide, and offer a friendly working platform that doesn’t hinder the experience.

3.2 Assessment of tools

The assessment of the selected tools will include a detailed description of their platforms, and the way they operate, followed by a comparison that takes into account both their usability and the user experience.

The user’s willingness to use a program is highly conditioned by the user experience UX, which became a buzzword in the field of human – computer interaction (HCI) and interaction design (Hassenzahl and Tractinsky, 2006). User Experience (UX) refers to a person's emotions and attitudes about using a particular product, system or service. It includes the practical, experiential, affective, meaningful and valuable aspects of human–computer interaction.

The term usability pre-dates the term user experience. Part of the reason the terms are often used interchangeably is that, as a practical matter, a user will at minimum require sufficient usability to accomplish a task, while the feelings of the user may be less important, even to the user herself.

The user experience is fairly valued in this study. A user needs his tasks to be done, and we're talking here about the program's usability. After a presentation of the chosen tools that helps the user discover them, the input is the first criteria to describe the usability. It gives a hint about what the user should expect by having a look at the available material he has got. In the present study, it gives an idea about the possible starting points with each application. The second criteria is the output types of files. It will help him compare his output expectations with the ones available, and judge by himself which program is worthier of use, depending on his study objectives. The third criteria for usability is the level of complexity to expect while using the programs. Meanwhile, the user experience criteria, which are more subjective, will be explored through: the friendliness of the interfaces, or how the buttons are disposed and whether or not keyboard shortcuts are available, the using mode –online or offline- and the aesthetics of the interfaces as it is an aspect that cannot be ignore, and can either help or hinder the experience.

4 Results and discussion

The following two studies ones are the most recent and the most effective in terms of working directly on aerial or terrestrial oblique photographs, even though they operate differently. They match better with the objectives of this study.

The next part will introduce the Canadian Analysis application, the Image Analysis toolkit. It is chosen to be presented first because it shows a minor complexity when used, therefore targeting landscape researchers that do not necessarily have deep knowledge in Geography Information Systems, but still need to conduct a study using a rich photographs database. It will be followed by a presentation of the WSL Monoplotting Tool, which comes off as more sophisticated, yet easy to use, for researchers with deeper knowledge in GIS, and who have more diverse entry files to conduct the study.

A detailed comparison of the two programs will be carried out, in order to evaluate their usability, through input and output types of files, and level of complexity, but also evaluate the user experience, through their friendliness, using mode and aesthetics. The last paragraph of this chapter is a critical review.

4.1 Description of the tools

4.1.1 MLP Image Analysis Toolkit

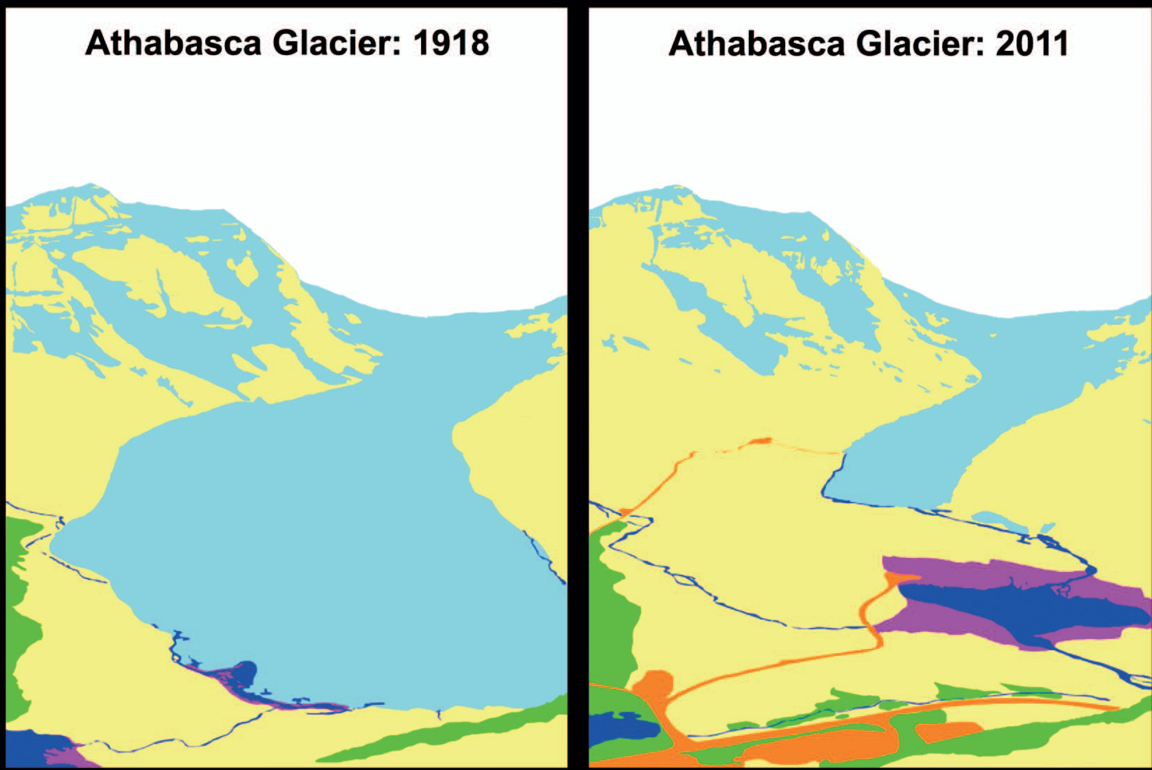
The first program is the Image Analysis Toolkit .It is a browser based JavaScript program which allows users to display and analyze single or multiple images (up to three images side by side). The editing is rudimentary, as it allows creating segmentation masks on the platform, that can be saved to the users own offline file system.

The article about the tool above was published in November 2016 by Mary Ellen Sanseverino of the Department of Computer Science, University of Victoria in Canada, Michael James Whitney and Eric Stowe Higgs, both of the School of Environmental Studies belonging to the same university. The article gives a sampling of the wide range of studies from many different disciplines that have successfully used repeat photography methodology in scholarly inquiry (Sanseverino et al, 2016).

The canvases form the heart of the IAT program. Within a canvas you can drag-and-drop files, and display photos and other images, including segmentations/masks. IAT is usually used with two canvases, aligned side by side or sometimes top and bottom, so that two images of identical size can be visually compared. However, it is also possible to view only one canvas at a time, or even three in certain cases (figure 2) and (figure 3).

The following figure (figure 1) shows an example of two IAT output classification masks, that allow to compare two photographs taken 93 years apart in The Athabasca Glacier, one of the six principal 'toes' of the Columbia Icefield, located in Alberta, Canada. The study could identify six different categories in the landscape: Roads/Buildings, Water, Upland Herbaceous, Snow/Ice, Rock/Scree (broken rock fragments) and Fluvial. It is therefore possible to compare the number of pixels of each class, and the ration pixels of the class/gross pixels of the photo. Then calculate the number of pixels that are in common between the two masks, and measure each category's growth/ diminishment between 1918 and 2011.

These calculations are independent from any georeferencing tool, and only rely on the visual side of the landscape's components, which explains there simplicity.



1918 image

Classifications	# of pixels in class	% of class in image
Roads/Buildings	0	0 %
Water	136,845	1.3 %
Upland Herbaceous	256,451	2.5 %
Snow / Ice	5,675,373	57.1 %
Rock / Scree	3,796,190	38.2 %
Fluvial	48,749	0.5 %

2011 image

Classifications	# of pixels in class	% of class in image
Roads/Buildings	459,029	4.6 %
Water	392,688	3.9 %
Upland Herbaceous	611,749	6.1 %
Snow / Ice	1,650,114	16.7 %
Rock / Scree	6,419,385	64.8 %
Fluvial	351,430	3.6 %

Intersection of 1918 and 2011 images

Classifications	# of pixels in common in class	% of class in common in both images
Roads/Buildings	0	0 %
Water	18,373	0.1 %
Upland Herbaceous	207,597	2.0 %
Snow / Ice	1,592,319	16.0 %
Rock / Scree	3,034,304	30.5 %
Fluvial	0	0 %

Fig. 1: Study of the evolution of the At habasca glacier bassin capacity using the IAT

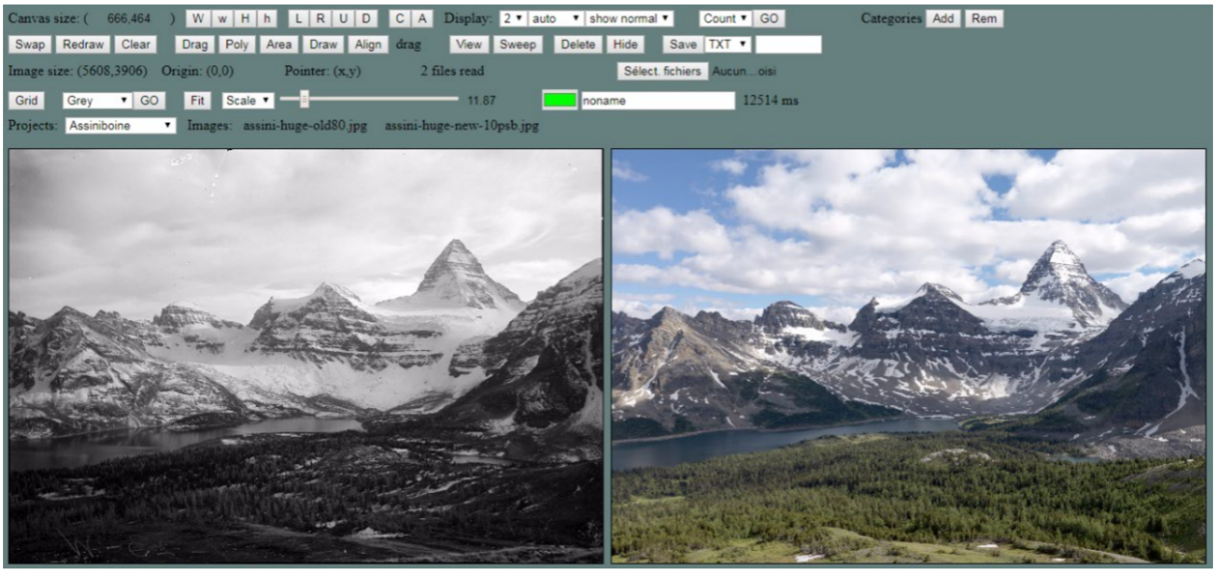


Fig. 2: IAT platform with two canvases

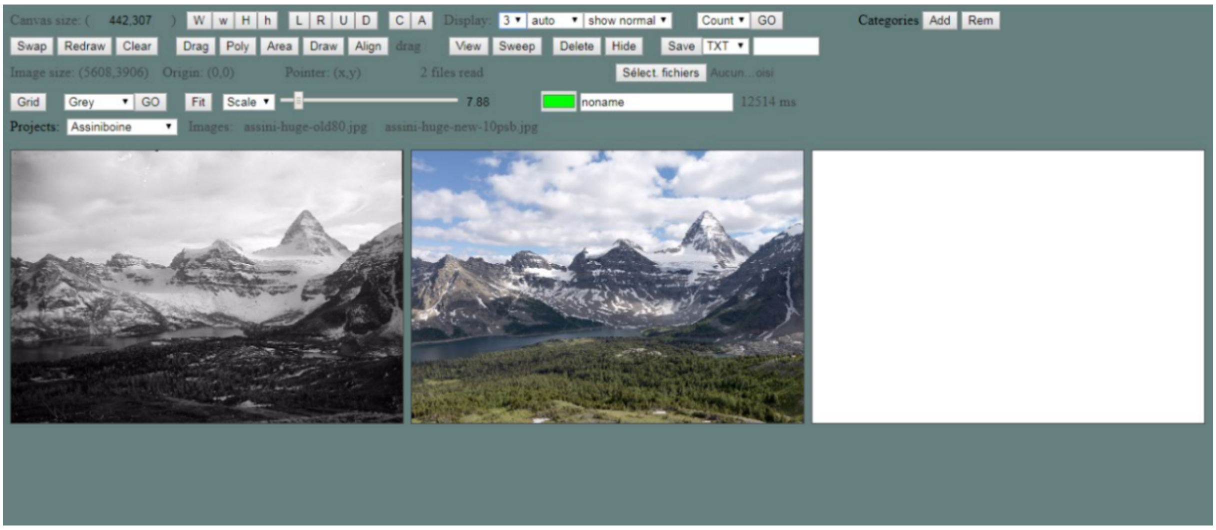


Fig. 3: IAT platform with three canvases

4.1.1.1 Main controls

In an effort to conserve screen real estate, most of the various buttons are usually hidden. Functionally related sets of them can be exposed with the main controls, horizontally arranged from the top left much like pulldown menus in other programs. Click once to show a row of controls, click elsewhere to replace that row with another. Use "All" to show/hide all available controls, but note how little room is then left for the canvas area!

- **File** Load and save local files; select projects (demos);
- **View** Adjust canvas number, dimensions, and view modes;
- **Edit** Draw and edit regions and objects to make masks;
- **Tools** Image transformations, counting operations, etc;
- **Prefs** User preferences ("advanced");
- **All** Show/hide all the available rows of controls;

- **Help** Show the help file, that explains the key controls;

4.1.1.2 Modes

Most of these roughly correspond to the **Edit** controls.

- **Drag** the default mode, allows mouse to drag image;
- **Pick** used to select among objects;
- **Poly** draw a polygon (hit poly again to finish);
- **Area** draw an enclosed area of arbitrary shape;
- **Draw** draw a simple curved line, to show a river for example;
- **View** draw a rectangular viewer;
- **Sweep** sweep/wipe left and right to show two images;
- **Align** choose 3 pairs of control points to try an image alignment;

4.1.1.3 Mouse

What the mouse does depends very much on what particular mode or situation IAT is currently in.

- **Click** select a canvas, an object, a viewer, start a new viewer ...;
- **Double-click** choose color at cursor;
- **Drag** move image, viewer, or selected object about;
- **Wheel** zoom in/out about cursor;

4.1.1.4 Functions and tools

This is an ever-changing (mostly growing) aspect of IAT. Most of these controls are hidden behind pulldowns to conserve space.

- **Grid** show/hide crosshairs grid centered on the image(s) ;

4.1.1.5 Transformations

These are all organized in one selection control. Choose one, then press GO to see it in action on one or two canvases. Some functions only write a message.

- **Grey** convert image in current canvas to greyscale;
- **Clean** resolve antialiasing problems due to overlapping objects;
- **Colors** count number of distinct colors;
- **Compare** count number of differing pixels between canvases;
- **Invert** flip each pixel according to XOR bits - speed test;

- **Flip** flip about horizontal axis - speed test;
- **Mirror** flip about vertical axis - speed test;
- **Reduce** reduce number of colors in image by n bits per channel (use JPG control) – experimental;
- **(revert)** reload original image/mask (ALT-GO works too);

The reduce function is a first attempt to incorporate segmentation help in IAT.

4.1.1.6 Slider Widget

This control originated primarily for the cross-fade function.

- **Scale** images are scaled about their origin (upper left);
- **Fade** two images cross-faded against each other;
- **Mask** image cross-faded against corresponding mask (work in progress);
- **Alpha** opacity level of objects drawn on images;
- **JPG** set JPG output quality on 0-100 scale (overloaded);

4.1.1.7 Count

This control is intended for masks and/or object collections, and will cause each and every pixel (one mask) or pixel pair (two masks) to be stepped through and compared with each other. A number of categories must be defined. Counts for each category/color are accumulated, and if a 3rd canvas is present, a new image is drawn there. Select a counting function.

4.1.1.8 Categories

Segmentations based on masks and/or drawn objects use categories, defined by the user or (more frequently) saved in the past and loaded into the program. Each category has a distinct name and color. There can be any number of categories, although generally there are less than 20.

There are some categories built in to IAT. They can be edited with the buttons below, or replaced in their entirety by loading a "project file" containing saved categories. When objects are drawn, their color is taken from the current category.

- **Categories** press to remove from main window and make sub window;
- **Add** append new category to end of; categories menu
- **Rem** remove the current category from the menu;
- **Color widget and input field** current category and name

4.1.1.9 Files

Many different types of files can be loaded into and saved from IAT. The easiest way to load files is to simply drag them from your own local filesystem onto any canvas. Most users grab a couple images at once from their desktop and drop them in. You can also use the Load button, in the File set of controls.

- **Images** usually photos, usually .jpg and .bmp and .gif files;
- **Masks** aka segmentations, limited color range, must be .png for now;
- **Data** these are .txt files containing IAT data: image and mask names, objects, and categories;
- **XML** these are .ilt and .ilp files containing ImageLabeler data, for direct upload to IAT;

Files can also be saved, using the Save button in the **File** set of controls. Save images in JPG format (use the slider control to set quality level), masks in PNG format, and IAT data in TXT files. These files can be loaded into a later IAT session.

4.1.1.10 Keyboard Shortcuts

Click in a canvas (ie. Give the canvas focus) first.

- **1** one canvas;
- **2** two canvases (default);
- **3** three canvases (use to show a Count);
- **a** area mode - prepare to draw a new area;
- **c** center images within their canvases;
- **f** full screen (use ESC to exit);
- **g** draw/erase grid;
- **h** hide (or show) tools;
- **m** maximize - canvases fill available space;
- **s** swap images;
- **t** toolbars (ie. all controls) hide/show;
- **w** wiper - enter/exit wiper mode;
- **0** zoom to 100%;
- **-** zoom out;
- **+** zoom in;
- **ESC** exit full screen;

4.1.1.11 Preferences

These references can be exploited for extra customization of the experience.

- **Path** show entire path name if images/masks;
- **CORS** ask for images with cross-origin permissions;
- **Chrome** set up program to work with Chrome -allow-file-access-from-files;
- **Constrain** try to keep images from creeping away from the canvas edges;
- **Smooth** use smooth rather than pixelated drawing for over scale zooms;

4.1.2 WSL Monoplotting Tool

The WSL Monoplotting Tool is a new piece of software that allows analyzing such photographs by allowing for extraction of spatially referenced vector data from oblique photographs.

The creators determined that the tool georeferenced objects to within less than 15 m of their real world 3D spatial location, and the displacement of the geographic center of over 121 control points was less than 3 m from the real world spatial location. Most of the error in individual object placement was due to the angle of viewing incidence with the ground (i.e., low angle/highly oblique angles resulted in greater horizontal error). Simple rules of control point selection were proposed to reduce georeferencing errors (Stockdale et al, 2015).

The article about this tool was published in September 2015 by Christopher A. Stockdale and S. Ellen Macdonald of the Department of Renewable Resources, Faculty of Agriculture, Life and Environmental Science, University of Alberta in Canada, Claudio Bozzini of the Insubric Ecosystem Research Group, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Bellinzona, Switzerland and Eric Higgs of the School of Environmental Studies, University of Victoria, Victoria, British Columbia, Canada (Stockdale et al, 2015).

4.1.2.1 Basic idea

Photographs are currently little used for quantitative analysis of landscape evolution because they can hardly be reproduced in a three-dimensional space. The purpose of the monophotogrammetry and the insertion of single terrestrial photos into the real physical landscape. It automatically calculates the actual coordinates of each point of the photo using the digital model of the earth and a mathematical model that simulates the geometry of the photographic applet: **the collinearity condition**.

The camera (at XcYcZc), a point on the photograph (at xaya), and the actual point in the real world (at XAYAZA) all lie in a straight line. The collinearity condition equation solves the relationship between these points. The values r11 - r33 are functions of the rotation angles of the camera about the X, Y and Z axes. The value x0y0 is the 2D coordinate of the line drawn from the projection center of the camera through the center of the image, and f is the focal length of the camera. (Figure 4)

$$x_a - x_0 = -f \frac{r_{11}(X_A - X_C) + r_{21}(Y_A - Y_C) + r_{31}(Z_A - Z_C)}{r_{13}(X_A - X_C) + r_{23}(Y_A - Y_C) + r_{33}(Z_A - Z_C)}$$

The collinearity equation is solved by using the "Matrix Camera Calibration" tool. Once a suitable solution has been found by minimizing the "mean angle error" field, the image can be analyzed either by drawing polygons around features of interest, or importing a spatial grid for a raster-based analysis.

Several different metrics were calculated to assess the accuracy of the WSL Monoplotting Tool intrinsic camera parameters computed for each image. Computed values for each image and its best-, worst- and random-dispersed internal camera solutions are as follows:

- Error vector length (per point): The distance between the projected Test Point (P0) and actual Control Point (P) location was measured by creating new line features in ArcGIS, and computing the length of the line.
- 'Mean error vector length (per image camera combination): for all test points in each image-intrinsic camera solution, the mean error vector length was calculated (arithmetic mean of all D per image-camera combination).
- Angle of viewing incidence (per point): using a ray from the camera location to each control point the angle between the viewing vector and the mean slope/aspect of a 10 m segment of the line running from the camera through the control point and fixed to the ground.
- Displacement error (per image-camera combination): the geometric center (centroid) of all Test Points (P0) and Control Points (P) for each image-camera combination was computed, and the difference between these centroids is the Displacement Error for each image camera combination. Additionally, the geometric center for all Test Points (P0) and Control Points (P) was calculated for each camera solution (all images combined) to determine the total landscape displacement error(Stockdale et al, 2015).

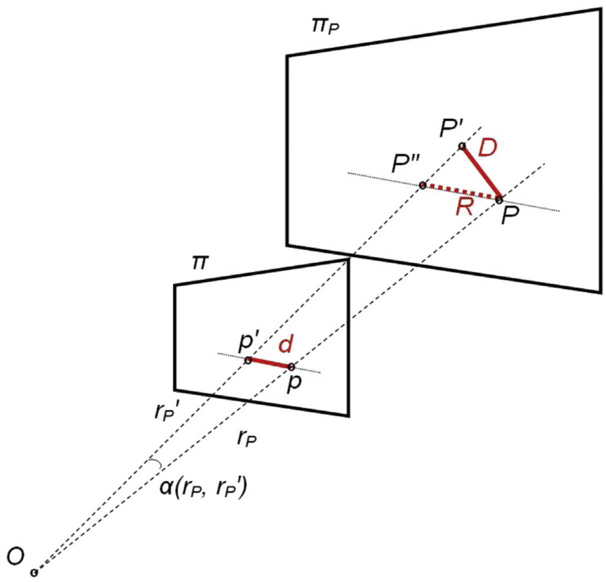


Fig. 4: The difference between the modeled relationship and the real relationship between objects in the real world (3D) and the photographic plane (2D).

Ray OpP (rP) aligns the camera, the image point p, and the real world object P. Ray Op0P0 shows the computed line due to errors arising from control point placement, lens distortion, sensor/film distortion, DEM inaccuracies, or any combination of these factors.

If image point p is misplaced by the user at p0, the real world point P is then projected to P0. Conversely, if the real world point P is displaced at P0, then image point p gets projected at p0. Errors in the placement of both p and P compound the displacement.

Stockdale, Bozzini, Macdonald and Higgs (2015) determined that the tool georeferenced objects to within less than 15 m of their real world 3D spatial location, and the displacement of the geographic center of over 121 control points was less than 3 m from the real world spatial location. Most of the error in individual object placement was due to the angle of viewing incidence with the ground (i.e., low angle/highly oblique angles resulted in greater horizontal error). Simple rules of control point selection are proposed to reduce georeferencing errors.

4.1.2.2 Advantages of terrestrial photographs

The terrestrial photographs can be very similar to aerial oblique photographs if they are taken from a certain altitude, or in some cases, from a point that allows the photograph to be very descriptive and panoramic .Therefore, they are satisfyingly representative and intuitive, as it relates exactly what is out there in the physical world.

They are also distinguished by their richness of details. Because not only do they describe how the landscape components occupy the space, like the orthophotographs, but also give information about their precise tridimensional arrangement the aesthetics of the landscape. (Figure 5)

4.1.2.3 Applications

Different applications can be conducted using this tool, for different analysis purposes. The following examples are amongst the most remarkable.

Just like the IAT, the WSL Monoplotting Tool allows, as a first form of application, to run a quantitative analysis using the number of pixels. The ratio the number of pixels of a new photo/ that of an old one, relative to a specific landscape pattern, can give an idea about the evolution of its area through time. In (figure 6), it is relative to the spread of vineyard in Loco, which can give an idea about the interest shown by the inhabitants of the region to this agricultural activity, after 119 years.

It is also possible with the WSL Monoplotting Tool to merge an ancient terrestrial panoramic photograph of the region of Loco (1885) and a tridimensional elevation model, in order to add more details to the former, and obtain a photograph that shows at which exact altitude every landscape component lays (Figure 7).

Furthermore, a reconstruction of the channels for timber exhumation can be conducted, in this case only by using a postal card from 1930, and transferring the information to a map. For the record, an exhumed channel is a ridge of sandstone that remains when the softer flood plain mudstone is eroded away (Figure 8).

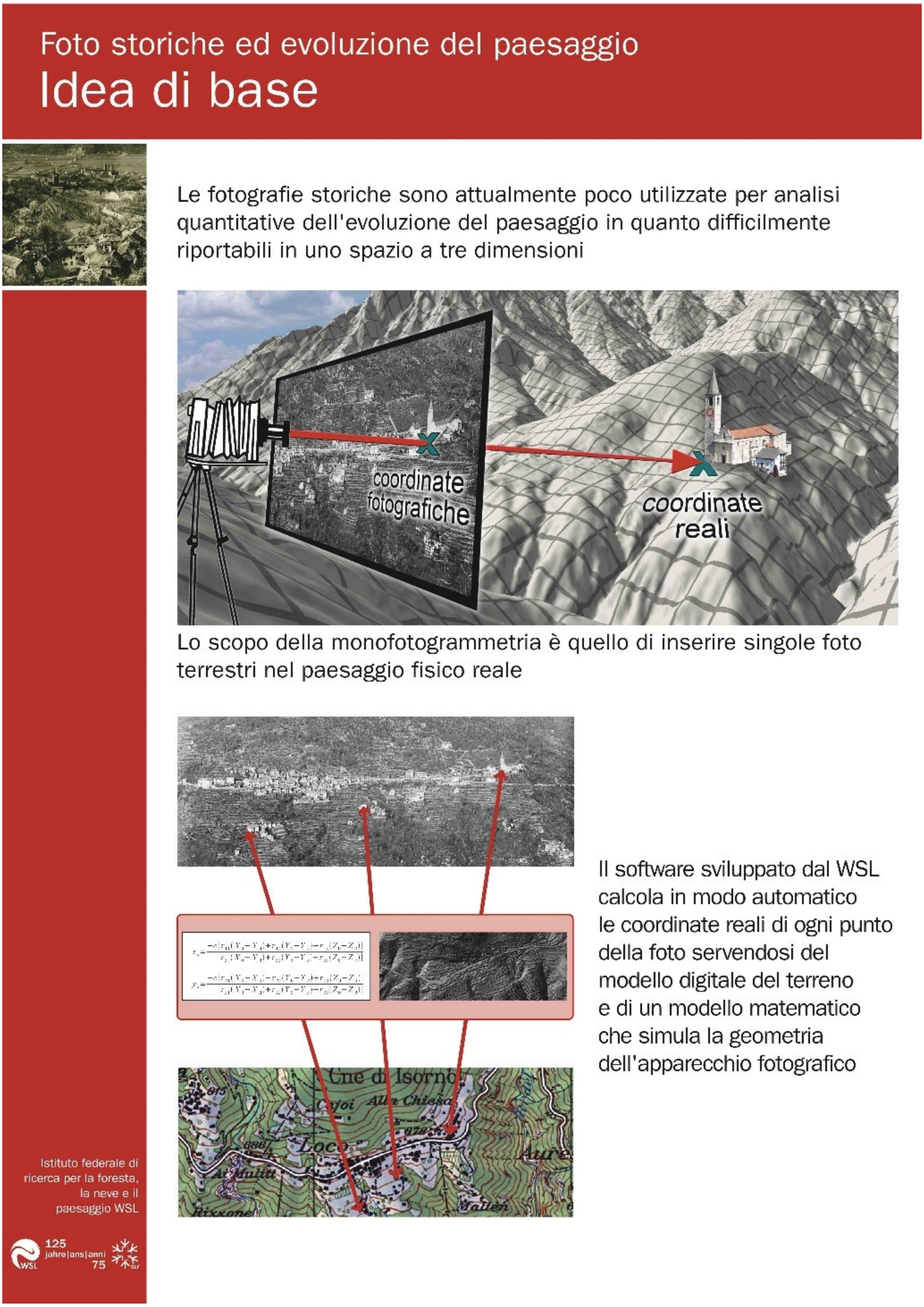
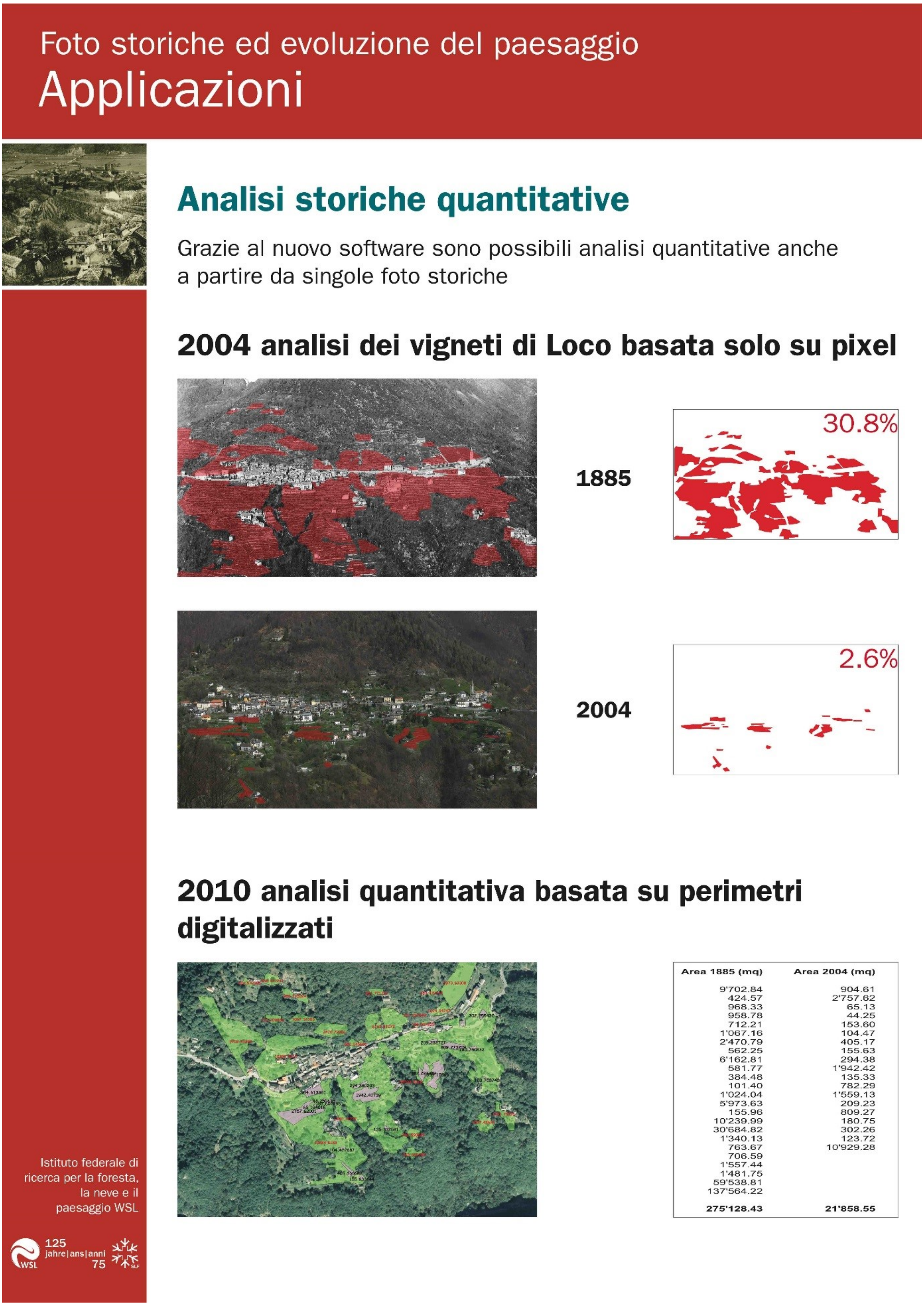


Fig. 5: WSL Monoplotting Tool: Basic idea

Fig. 6: WSL Monoplotting Tool: Advantages of terrestrial photography



Area 1885 (mq)	Area 2004 (mq)
9'702.84	904.61
424.57	2'757.62
968.33	65.13
958.78	44.25
712.21	153.60
1'067.16	104.47
2'470.79	405.17
562.25	155.63
6'162.81	294.38
581.77	1'942.42
384.48	135.33
101.40	782.29
1'024.04	1'559.13
5'973.63	209.23
155.96	809.27
10'239.99	180.75
30'684.82	302.26
1'340.13	123.72
763.67	10'929.28
706.59	
1'557.44	
1'481.75	
59'538.81	
137'564.22	
275'128.43	**21'858.55**

Fig. 7: WSL Monoplotting Tool applications: Quantitative analysis

Fig. 8: WSL Monoplotting Tool applications: Tridimensional detailed vision

Fig. 9: WSL Monoplotting Tool applications: Reconstruction of the channel for timber exhumation

4.1.2.4 WSL Monoplotting Tool platforms for different input file types

The software features different platforms for different entry files:

- Platform for toponimi, ie. Files maps with only place names (in Italian, considering that the Software was created in Switzerland, and Italian is one of its official languages).

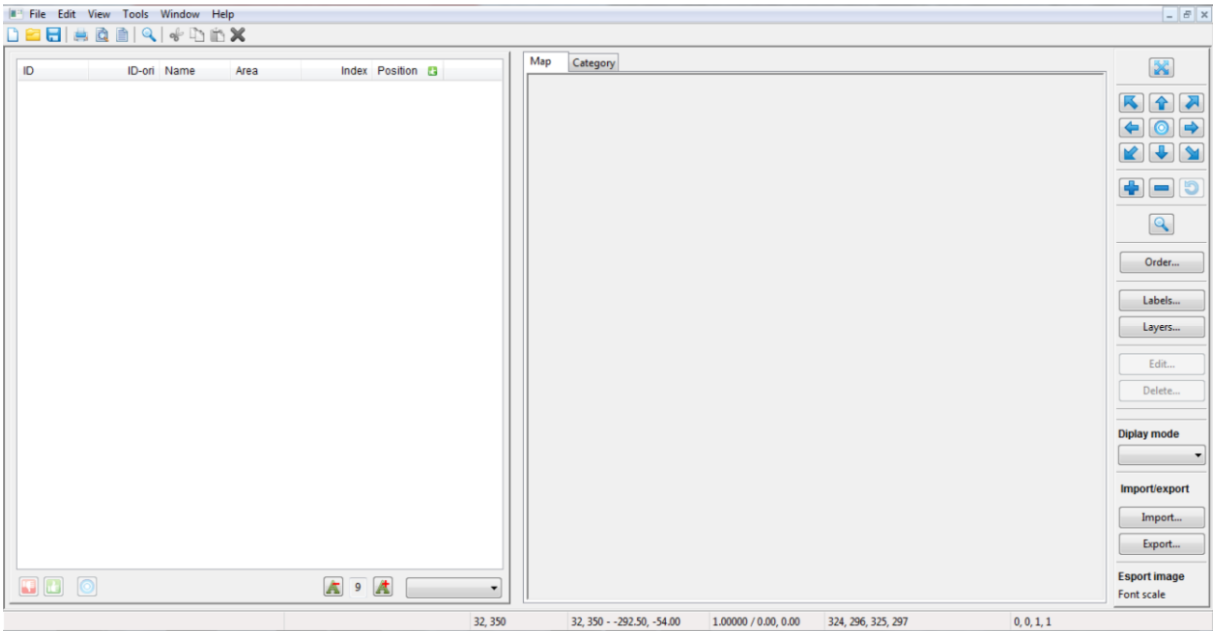


Fig. 10: WSL Monoplotting Tool platform for toponimi files

- For Google Earth maps as entry data, the platform is the same as the previous one

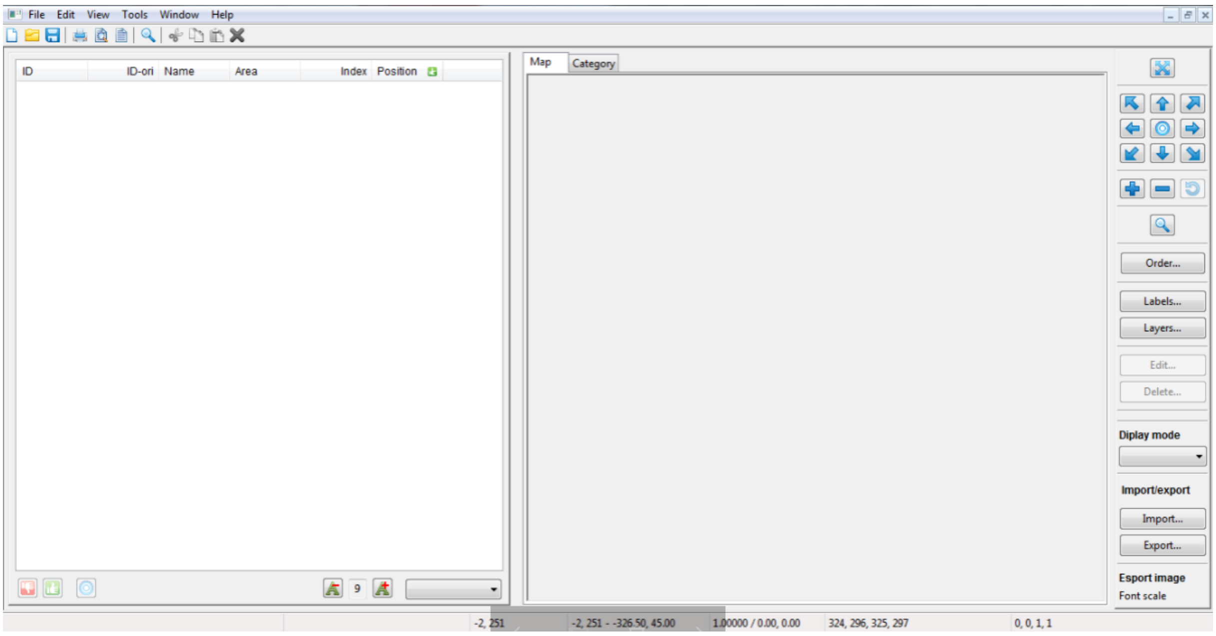


Fig. 11: WSL Monoplotting Tool platform for Google Earth Maps

- For GPX

GPX, or GPS Exchange Format, is an XML schema designed as a common GPS data format for software applications. It can be used to describe waypoints, tracks, and routes.

The format is open and can be used without the need to pay license fees. Location data (and optionally elevation, time, and other information) is stored in tags and can be interchanged between GPS devices and software. Common software applications for the data include viewing tracks projected onto various map sources, annotating maps, and geotagging photographs based on the time they were taken.

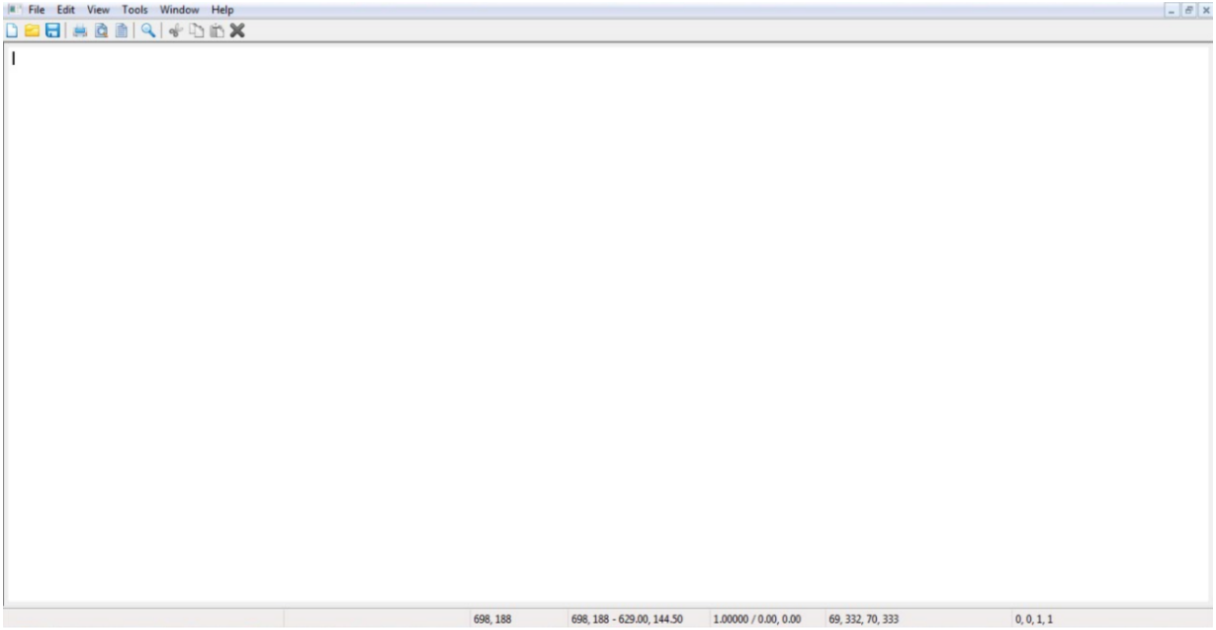


Fig. 12: WSL Monoplotting Tool platform for GPX files

- For image

A georeferenced aerial oblique photograph, or a terrestrial photograph taken from a certain altitude point in order to shower 3D landscape details, or a terrestrial photograph taken from a not so high altitude point but that shows enough landscape details can be inserted in this platform.

Fig. 13: WSL Monoplotting Tool platform for images

- For GIS

Fig. 14: WSL Monoplotting Tool platform for GIS files

This platform allows to connect an image to a map from the same year, and create GIS layers containing polygons for comparison over the years.

- Upload photo;
- Upload map right below it;
- Find the center of the image;
- Apply the center to the map;
- Look for the point from where the picture was taken on Google Map;
- Point editor, selecting 5 points on the picture (once pointed on the picture, they're automatically selected on the map);
- Matric camera calibration and computing (which considers the position, the rotation and the focal length) (figures 15 and 16);
- Create a polygon on the map that will define a region for comparison (the previously created points are only for camera calibration);
- ArcGIS export;
- Export the selection;
- Polygon layer available on ArcGIS for use;

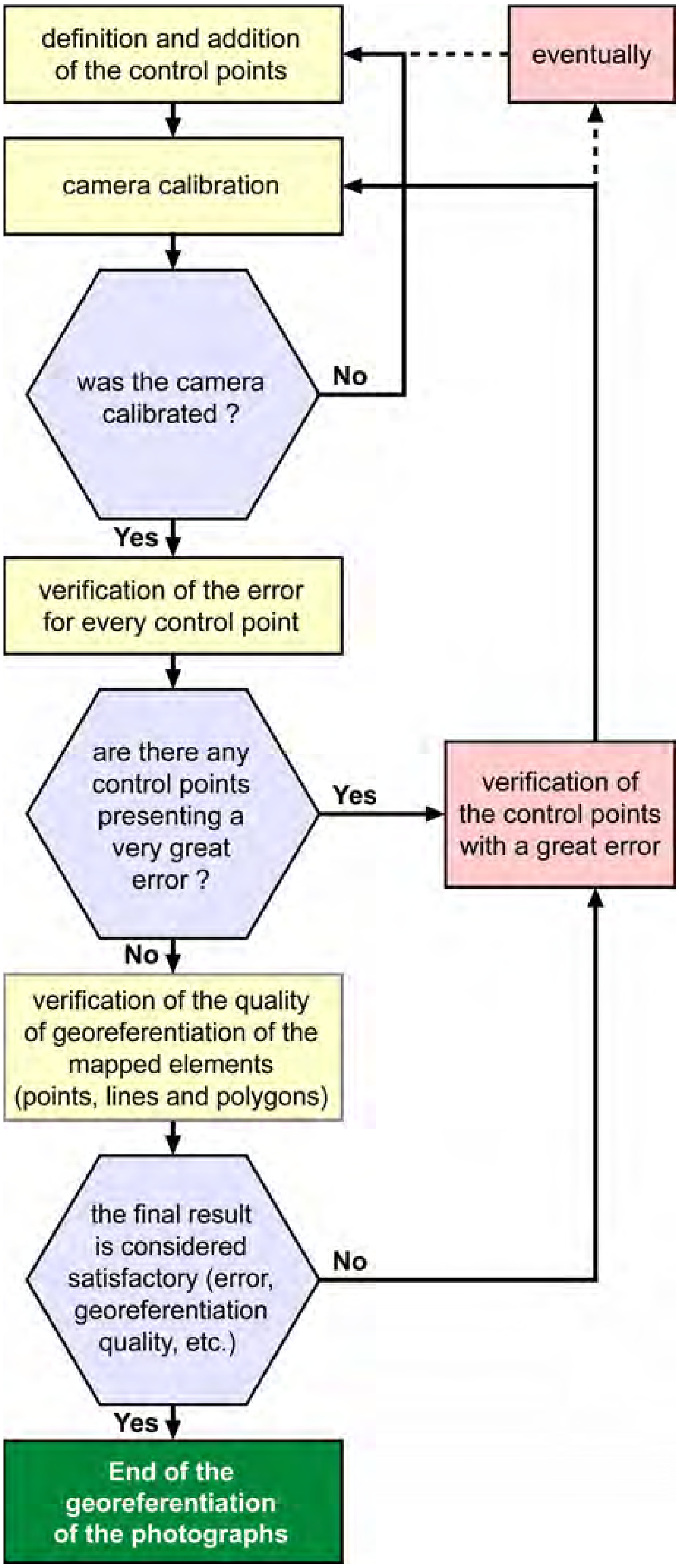


Fig. 15: Camera calibration diagram in the WSL Monoplotting Tool

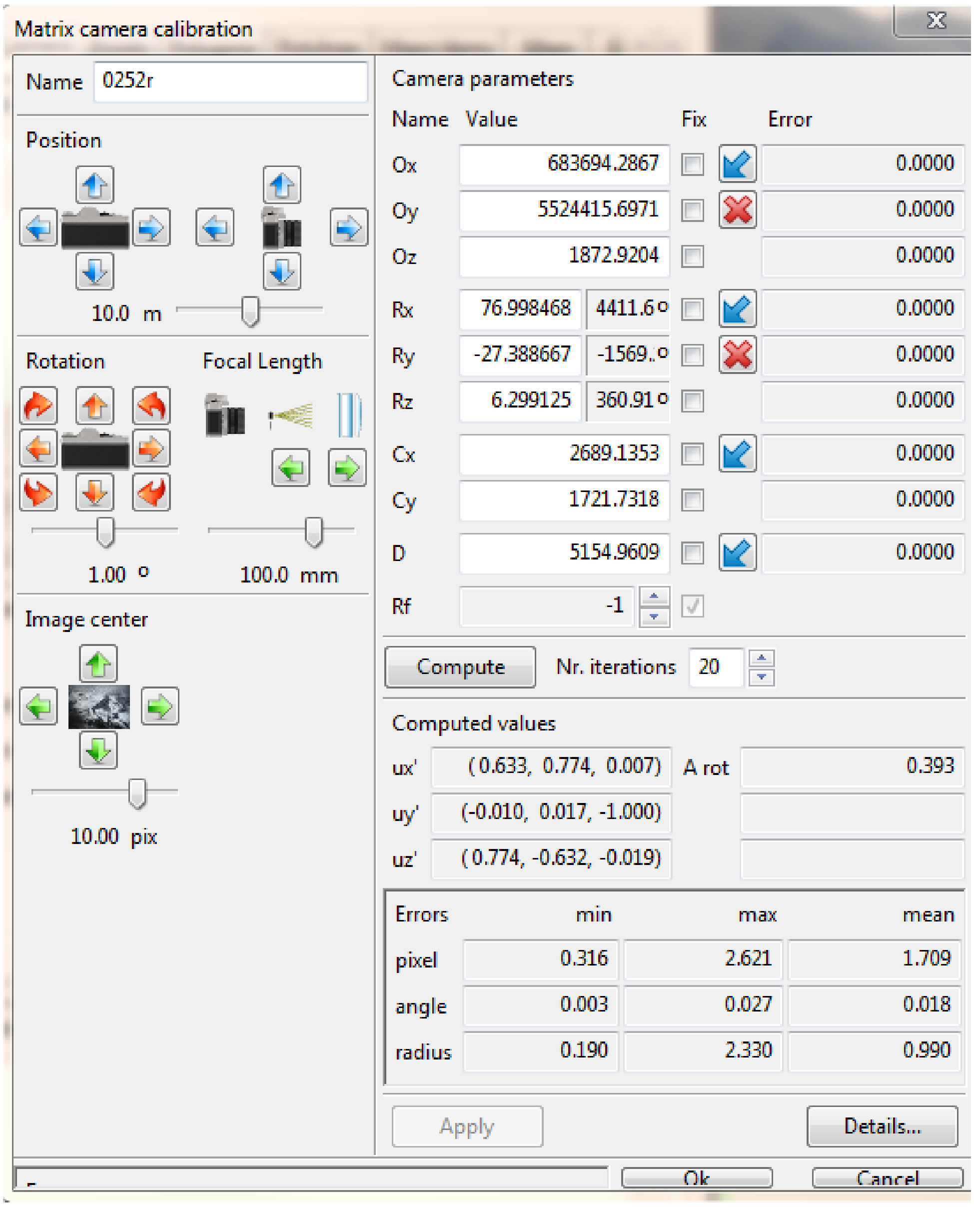


Fig. 16: Camera calibration window in the WSL Monoplotting Tool

4.2 Comparison between MLP IAT and WSL MT

Table 1: Table of comparison between the MLP Image Analysis Toolkit and the WSL Monoplotting Tool

	MLP Image Analysis Toolkit	**WSL Monoplotting Tool**
Presentation	Basic image manipulation and file management tools, advanced classification and categorization, visualization, and analysis tools. Previously used for assessing forest fires	Monoplotting interface with the aim of offering an intuitive platform for georeferencing and orthorectifying ordinary individual photographs in order to produce georeferenced vector data by drawing them directly on the pictures and exchanging them with traditional GIS-Systems. Resulting polygons may be visualized both on terrestrial pictures or orthophotos and maps. Raster data can be rapidly extracted from an image pair to measure changes in vegetation cover over time. This new process permits the rapid evaluation of a large number of images to facilitate landscape scale analysis of oblique imagery.
Input	**-Images** usually photos .jpg and .bmp and .gif files **-Masks** aka segmentations, limited color range, must be .png for now **-Data** these are .txt files containing IAT data: image and mask names, objects, and categories **-XML** these are .ilt and .ilp	**-Toponimi** Files maps with only place names **-Google Earth Maps** **-GPX** GPX, or GPS Exchange Format, is an XML schema designed as a common GPS data format for software applications. It can be used to describe waypoints, tracks, and routes **-Images** **-GIS**: A georeferenced aerial oblique photograph, or a terrestrial photograph taken from a certain altitude point in order to shower 3D landscape details or a terrestrial photograph taken from a not so high altitude point but that shows enough landscape details can be inserted in this platform. This platform allows to connect an image to a map from the same year, and create GIS layers containing polygons for comparison over the years.

Output	Patches classes described by their number of pixels and percentage of the class in the image.	Patches can be featured in GIS layers. Information like actual superficies, perimeters, elevation river canals and can be extracted from them. It is possible to reconstruct elements of the landscape and draw the historical change.
Level of complexity	Low, as it allows users who do not master GIS to compare historical photographs.	Middle to high, as it allows different types of input files to finally have a GIS one as an output. It depends on the user's knowledge about GIS.
Friendliness	Keyboard shortcuts availability, but shows a bit of slowness when used	No keyboard shortcuts availability, but very explicit options, and very fast to use.
Using mode	Browser used, but it can be saved and ran offline.	Freely downloadable for desktop usage.
Aesthetics	Neutral font with all the buttons displayed on the top, the images canvas right below.	Basic software icon (on the windows tool bar)Neutral grey font, the software window resembles to a windows vista window.

4.3 Critical review

After a detailed comparison of the two recently available tools cited above, it is worth mentioning the following:

The Image Analysis Toolkit is a tool that was crafted in order to bring help to landscape researchers, or as called by the creators 'mountain studies practitioners' who do not master GIS softwares (Arcgis, Qgis) so they still can elaborate a study based on repeat photographs of a certain region. Furthermore, this tool was created while taking into consideration the existence of an exhaustive database of photographs taken every year from the same spot, and that for several spots in the Canadian State of Alberta. Consequently, with the availability of a rich and a rigorously organized database of photographs, and without deep knowledge of Geographic Information System softwares, it is possible to assess landscape change through a general yet undetailed –in terms of numeric output- comparison and by having segmentation masks as an output. These masks can be saved offline and used later. The program is still subject to changes, as an updated version is being worked on.

While the IAT is designed for rudimentary use, the WSL Monoplotting Tool comes off as a more sophisticated mean to lead a landscape study.

First, it allows several types of input files, from maps to images. For images, it is effective when it comes to providing quite precise georeferencing by connecting an ensemble of points from the image with their equivalents from a map -for example-, using their coordinates. This step is very manual and required a lot of concentration as well as back and forth checking from the map to the image.

Second, after having a group of points that are well defined on the image, it is possible to distinguish polygons of common subjects, that in natural landscapes, can represent patches of a certain vegetation, patches of visible water resources on the surface (a lake, a river that have a certain level of water), patches of housing areas, patches of snow, or patches showing the effect of a natural disaster like forest fires. At this moment, what we get is a sort of GIS layer with different patches. Therefore, the layer of patches relative to a landscape pictured from a certain point of view in year n can be compared to that of year n+1 and so and forth.

In order to see how effective the Monoplotting Tool is, the creators chose to work on the same database of photographs as the first tool, which is that of the State of Alberta, in Canada.

What we can conclude is that, thanks to a solid and consistent database as that of Alberta, it is possible with both programs to have good representation of the landscape change, clearly at two different levels of proficiency. Which brings us to talk about the real challenge: realizing a landscape change analysis with fewer available photographs that are not necessarily taken from the same spot through constant intervals of time (every year, every other year, etc.), or aerial oblique photographs taken with highly performing cameras.

Will these softwares succeed to provide enough information for a landscape analysis so as to be able to consider it as such? (While waiting for a database to be gathered)

To be of value in management applications, imagery showing change is most useful when:

- It can be described and quantified
- It's intuitive and accurate
- It can go through rapid assessment procedures to facilitate landscape-scale analysis.

5 Conclusion

Landscape analysis is an ever-evolving methodology that has as a major aim the assessment of changes in the natural landscapes for management purposes. It may rely on satellite, aerial or terrestrial imagery. Using satellites is viewed as most sophisticated, but it only provides two dimensional data. Meanwhile it is mostly common to use aerial and terrestrial repeat photographs thanks to the tridimensional information they give.

In this document, the main purpose was to find programs that helps analyze these photographs, extract information and use them for landscape change assessment.

For this aim, two programs where selected and assessed in details, which are the Image Analysis Toolkit by the Canadian Mountain Legacy Project, and The Monoplotting Tool by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. They were also compared in terms of their operating mode, friendliness, and accuracy of the outputs.

These two tools require very different levels of familiarity with Geographic Information Systems as they show different levels of complexity: While the Image Analysis Toolkit allows to assess landscape change by having segmentation masks as an output from oblique photographs, and providing numeric information via the numbers of pixels of each landscape component in each picture, the WSL Monoplotting Tool provides GIS layers as output from different input formats like oblique photographs and maps among others.

Therefore, if the difference of their operating modes is taken into consideration, these tools are both effective because it is guaranteed to get successful in producing the desired or intended result at two different levels of complexity. Thus, by considering these two tools as a set that gives the researcher more choice, it is recommended to define the intended level of complexity first before launching a landscape change study, in order to spend the right amount of effort and time for the right results.

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