CanopyDigi

Synopsis

1. The aim of the programs in this suite is to enable objective quantification of canopy closure, and aggregation of canopy gaps, using flexible digital analysis of tree canopy photographs.

2. Quantification of canopy closure gaps can be effected easily using monochrome photographs taken with a simple digital camera. Once uploaded onto a computer, a threshold level can be applied to each photograph to polarise the potential 256 shades of grey into dark 'canopy' and light 'sky' pixels. Further computer analysis is based upon simple computer counts of the number of pixels in each category.

3. To determine a suitable threshold for a given photograph, false colour images are created with all 'canopy' pixels being coloured blue and all 'sky' pixels being coloured red. In this way, the suitability of any given threshold can be examined in a "determination" stage and canopy then analysed using that threshold in a "quantification" stage. Data are provided on canopy closure (percentage) and aggregation (using Morisita's index – higher figures for increasingly large gaps in the canopy).

4. The programs should work on any Windows XP computer (or later). Testing shows that the programs should also work on Windows 98 and ME, but this is not guaranteed and "Windows VB6 runtimes" may be needed (a search on Google will list sites from which these files may be downloaded, free of charge).

5. Help files are provided for each program and can be viewed by using the F1 key when the program is running (or by clicking on any help file directly from Windows Explorer). There is usually "tool-tip" help too - this shows briefly when the cursor is pointed at a "hot spot" such as a button or input field.

6. All programs have been developed to use a screen size of 800*600, but the program interface should automatically resize to other screen sizes. In addition, because there are now so very many screen sizes in common use, extra small-scale adjustments can be made using the increase and decrease buttons provided in the top left corner, if necessary.

7. The program is designed to handle monochrome BMP photographs at a resolution of 640*480 pixels ONLY. Use of any other size of original photograph, or colour photographs, except where explicitly noted, may result in errors, or at least unpredictable results. Although it is better to take photographs of the "correct" format and size initially if possible, it is possible to convert photographs of other specifications to 640*480 monochrome BMP format using standard software such as Paintshop Pro, or using shareware such as ReaConverter Pro v. 3.2 (www.Reasoft.com).

8. Regrettably, specific support cannot be offered, but the extensive notes provided should resolve any operational or technical problems, while the journal article itself sets out the conceptual ideas.

9. Please note that there is no implied or explicit statement of the programs' fitness for any particular purpose, and that the user is solely responsible for any results obtained or conclusions made therefrom.

Reasons for options

An image resolution of 640*480 pixels was chosen to ensure that analysis, while still being accurate, could be undertaken rapidly. Use of monochrome BMP format files ensures that images have a known and constant files size and number of pixels (images are 921,654 bytes each - this is 640*480 = 307,200 bytes, which must be multiplied by three as three bytes are used to describe each pixel, plus a file header of 54 bytes). This fixed file format ensures that all information is in fixed position, such that it can be analysed easily.

How data are stored and handled

In BMP files, three bytes are used to describe each pixel. For COLOUR BMP files the possible 256 levels of red, green and blue give a palette of 16,777,216 colours. In MONOCHROME BMP files, these three bytes are used to describe the possible 256 shades of grey. Different implementations of BMP "standards" can mean that a photograph that a human sees as obviously monochrome may be regarded as colour by the computer. Accordingly, should this occur, an override option has been provided, which can be used to force analysis to continue. This should ONLY be used when it is certain that the original photograph is monochrome (if a colour photograph is processed as a monochrome one, incorrect results may occur).

Photograph size adjustment

No adjustment facilities are provided. If photographs other than monochrome BMP files at 640*480 resolution need to be processed, these should be pre-processed to these settings using one of the many photo/graphic packages available (see above).

Other comments

The executable programs (but not the source code) are made available in the hope that they will prove useful to others who need to analyse tree canopy (or other situations where percentage cover needs to be determined, including other aspects of vegetation structural complexity such as ground layer coverage).

Loading and Running CanopyDigi

The main folder should be placed in a root directory (e.g. C drive if on a hard disk) or the root directory of a USB stick or other external device. It is suggested that this folder is named CanopyDigi, and this is how it is referred to in this documentation, but it can be renamed if desired. Please note that if CanopyDigi is run from a USB stick, processing time might increase.

The folder structure within the CanopyDigi folder must be maintained (i.e. all folders and files should maintained in this main CanopyDigi folder in the way that they are supplied, otherwise the program may not work). It should be noted that it is not possible to have the main CanopyDigi folder other than directly from a root directory (e.g. if all program files/folders are stored in C:\CanopyDigi, the program should function normally, whereas if all program files/folders are stored in C:\CanopyDigi\CanopyDigi, error messages will be given).

CanopyDigi should always be run using the Command List program (CanopyDigiCommandList.exe) so that parameters are passed correctly. This can be run directly from the main CanopyDigi folder, but the user may wish to create a shortcut to and keep this on the Desktop. Running the individual exe programs directly is not recommended.

It should be noted that, for ease of identification, each computer-generated file is named to retain the path (e.g. C:\CanopyDigi) and name of the original photograph, to which is appended certain information as the programs proceed. This makes for efficient coding but does mean that file names can be very long. For this reason it is suggested that the main folder name (e.g. C:\CanopyDigi) is kept as short as reasonably possible.

CanopyDigi Control List
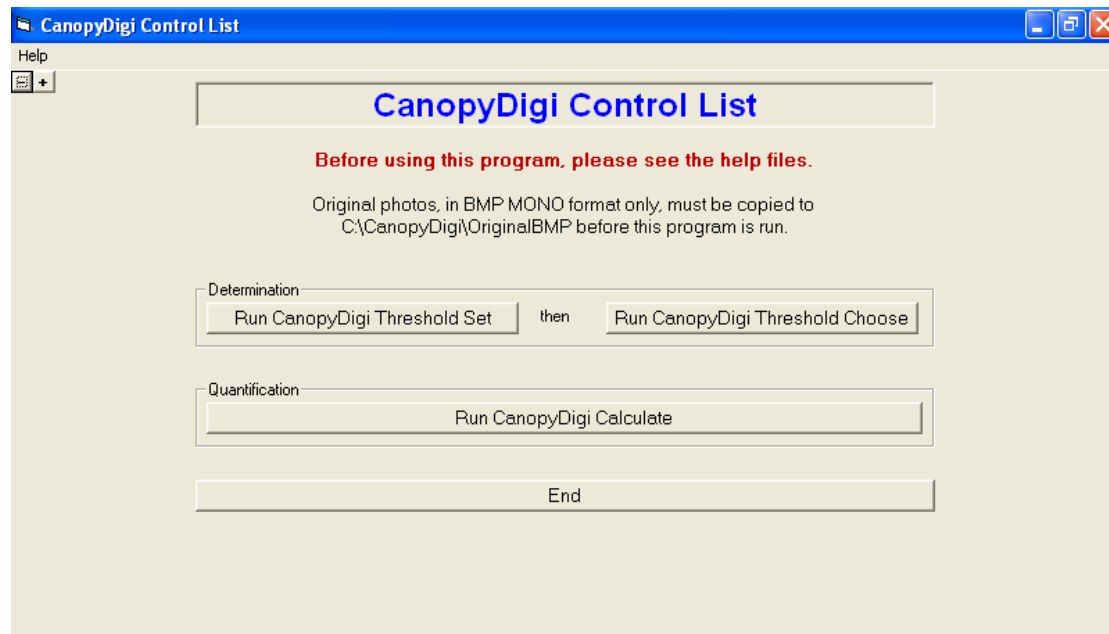
CanopyDigi Control List screen

Program Overview
CanopyDigiControlList.exe exists simply to control the other programs in the suite, and to guide the user through the process of image analysis in a straightforward manner. It can be accessed directly, or, preferably, from a shortcut placed on the Desktop.

Procedure
The program will process all photographs in the OriginalBMP folder, so this folder should not contain any files or photographs other than those to be processed (which, as detailed above, should be in monochrome BMP format at a resolution of 640*480 pixels). The programs will not delete anything from this folder.

There are two sets of programs that can be run through the CanopyDigi Control List and programs from each section (Determination and Quantification) should be used in sequence. These sections are briefly described below, but for a detailed description please see the appropriate help file.

Determination Section
1. CanopyDigiThresholdSet - This option converts photographs into their false colour equivalents at eight different thresholds. No user interaction is needed once the program has started.

2. CanopyDigiThresholdChoose - This option requires user interaction. The program displays each original photograph and its associated eight false colour images, in sequence. This enables the user to select the most appropriate false colour image, which can then be saved (with the click of a button) for further processing.

Quantification Section
This option processes the selected false colour images – no user interaction is needed once the program has started. Initially each false colour image is electronically divided into twelve sub-images. As the program runs, it produces a text file for each group of twelve sub-images giving statistical information. In addition, a single CSV (comma separated variable) file is constructed giving all necessary percentage and aggregation information for every original photograph analysed in a given run of the program. This can be loaded straight into a spreadsheet program (e.g. Microsoft Excel) or statistical software (e.g. SPSS or Minitab) for further analysis.

Buttons
Buttons are provided for each of the options mentioned. In addition there are two small buttons (top left) that can be used to adjust the size of the screen slightly, if required.

Input
As this program merely controls other programs, there is no direct input. However, the user must ensure that all the photographs required for processing, and only those, are copied to the OriginalBMP folder before proceeding further.

Output
There is no direct output from this program, it simply controls the other programs in the suite.

Technical Comments
The structure within C:\CanopyDigi (or equivalent) MUST be as follows:

Folders required	
OriginalBMP	Supplied empty
ProcessedBMP	Supplied empty
CalculateDone	Supplied empty
CalculateHistoric	Supplied empty
Files required	
CANOPYDigiCALCULATE.chm	Help File
CANOPYDigiControllist.chm	Help File
CANOPYDigiThresholdchoose.chm	Help File
CANOPYDigiThresholdSet.chm	Help File
CanopyDigiControlList.exe	Program File
CanopyDigiThresholdChoose.exe	Program File
CanopyDigiThresholdSet.exe	Program File
CanopyDigiCalculate.exe	Program File
ThresholdsDefault.txt	Text File – required
ThresholdsUser.txt	Text File – required
CanopyDigiThresholdChooseInputs.txt	Text File – required
Files- not required, possibly useful	
CanopyDigiThresholdChooseInputs4.txt	Text File
CanopyDigiThresholdChoose4SafetyCopy.txt	Text File – safety copy
CanopyDigiThresholdChoose9SafetyCopy.txt	Text File – safety copy
ThresholdsDefaultSafetyCopy.txt	Text File – safety copy
ThresholdsUserSafetyCopy.txt	Text File – safety copy

CanopyDigi Threshold Set
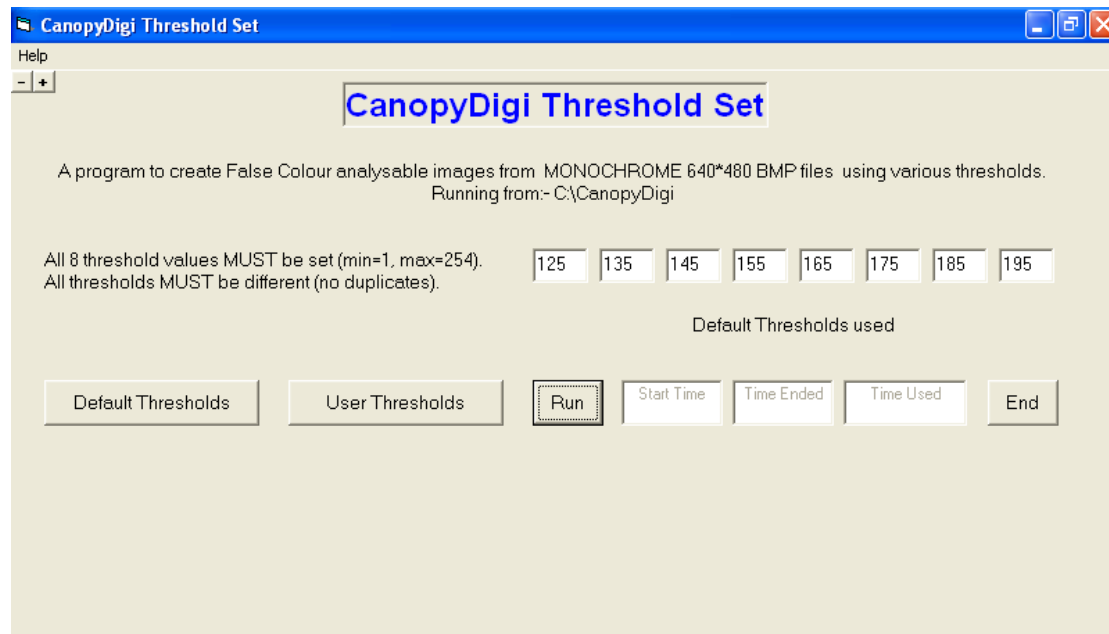
CanopyDigi Threshold Set screen

Program overview
This program takes a copy of a monochrome photograph and converts it into several false colour images, where dark 'canopy' pixels are coloured blue and light 'sky' pixels are coloured red.

Procedure
Eight different false colour images are created simultaneously for each original photograph by setting eight different thresholds (the value at and above which all pixels are regarded as 'canopy'). A set of default thresholds is provided (see below), and it is intended that this is left unaltered. Alternatively, user-supplied thresholds can be set and these are retained automatically from one run to the next. The program will check that all eight thresholds have been set and that they are all different.

Experimentation has shown that thresholds between about 120 and 200 often give reasonable results (155 seems particularly successful) so default thresholds are in this range. It is suggested that if user-supplied thresholds are set, the eight thresholds are entered in ascending order as this displays most intuitively in CanopyThresholdChoose.

As well as regularly-updated progress information during a run, the start time is shown, together with the end time and time used. As a very rough estimate, processing will take around 30 seconds per photograph. Should a run be started in error, the cancel button may be used.

As stated in the synopsis, it is possible – and indeed not uncommon – for the program to consider that a monochrome picture is a colour picture. In such cases, a warning will be displayed. If the user is SURE that the picture in question is indeed a monochrome one, the warning may be ignored.

Buttons
There are several buttons, which do exactly as they say. No further explanation is necessary except to mention that when the "Run" button has been pressed it will disappear (so it cannot be pressed twice) and will be replaced by a "Cancel" button; the "Default Thresholds" and "User Thresholds" buttons will also disappear. A message box will appear when the program completes. After program completion, clicking the "End" button will return the user to the Control List for further action.

Input
Input is from the OriginalBMP folder.

Output
Output is to the ProcessedBMP folder and this is automatic, requiring no user intervention. Output consists of a copy of each photograph processed, together with eight false colour BMP image files (one at each threshold) for each monochrome photograph. Consequently, there will be nine files for every original photograph. These can be viewed using CanopyDigiThresholdChoose.

Technical comments
The file names contain all the necessary information, viz:

Test001-th125blue0226989perc073p890.bmp

The file name was constructed as follows:

The default file folder was used and the original photograph file name was Test001. A threshold of 125 was used, giving 226,989 blue pixels out of a possible (640*480) = 307,200 pixels which equates to 73.890% (note that a "p" is used in the file name instead of a "." as this character should not be used in file names - a programming restriction). The percentage figure shown generally has a leading zero as file names are used on a positional basis - it is possible, if rare, to need to show 100%. Three decimal places are shown as standard. The legend "perc" is used rather than a percentage sign as this (%) sign should not be used in file names – again, a programming restriction.

Thresholds are quite arbitrary, merely being used to distinguish canopy from sky effectively in any particular photograph, thus photographs processed using different thresholds can still be compared correctly.

CanopyDigi Threshold Choose
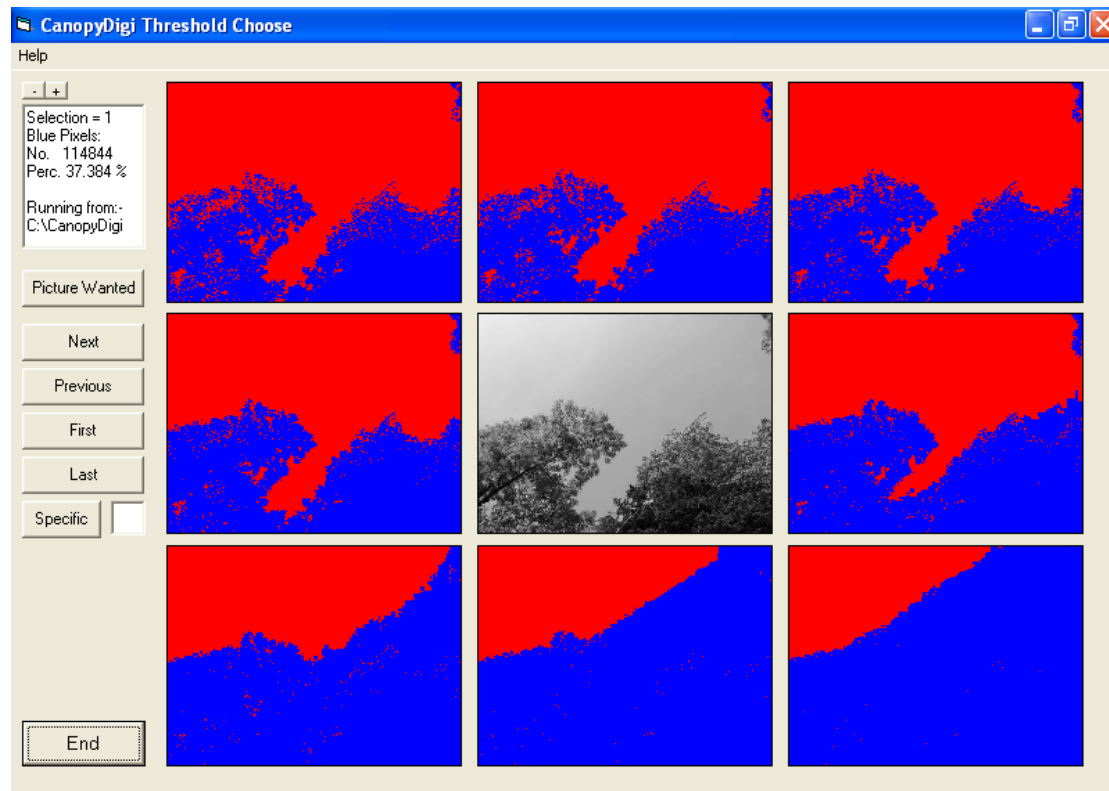
CanopyDigi Threshold Choose screen

Program Overview

This program shows photographs from the ProcessedBMP folder together with eight false colour images. The user can select one of these false colour images (that which is the best fit to the original) for further processing.

Procedure

By default, each original BMP photograph is shown in the middle of a 3*3 matrix, surrounded by the false colour images that relate to it in ascending sequence from top left to bottom right, so that the most appropriate false colour image may be selected easily. The name of the monochrome photograph can be ascertained by clicking on it, when its name will appear in the information box (top left). A false colour image can be selected by clicking on it, and its name will appear, together with the number of blue pixels it contains as an absolute figure and as a percentage. Selection is effected by clicking on the desired false colour image and then on the PictureWanted button, which saves the image selected to a folder for later use. The legend on the PictureWanted button then changes to Picture Saved.

Note that if none of the false colour images is considered a good fit, the user should make a manual note of this and re-run the ThresholdSet program with a new set of thresholds until a suitable false colour image is produced.

Buttons

The buttons provided are, in sequence, "PictureWanted", "Next", "Previous", "First", "Last", "Specific", and "End". These do what they say but, to amplify, the "Specific" button uses the numeric entry entered in the box beside it to jump to a particular picture. For example, typing 25 in the box and clicking "Specific" will display the 25th photograph in the folder(or the last available if there are fewer than 25). Note that this is alphamerically the 25th photograph in the source folder – the actual name is irrelevant.

Input

Input is from the ProcessedBMP folder and this is automatic, requiring no user intervention.

Output

Output is to the CalculateToDo folder and again this is automatic. This program will automatically delete the contents of the CalculateToDo folder as it starts, so that only the current run is processed. If the user wishes to retain these files for any reason, they must be copied elsewhere first.

Technical comments

1. Screen sizes

Because there are so many sizes of screen available, it is possible to amend the screen layout by altering the parameters in the text file containing the picture parameter details (CanopyDigiThresholdsChooseInputs.txt), but this is a somewhat tedious task to be undertaken only if really needed. The order of the input file MUST NOT be changed, just the numeric parameters, and a safety copy of the original file is provided in case of problems, together with an alternative file (CanopyDigiThresholdsChoose**4**Inputs.txt), which forces a 2*2 output, rather than the usual 3*3. (This must be renamed CanopyDigiThresholdsChooseInputs.txt before use - i.e. without the "4".) It should be noted that eight false colour images must be created for each individual photograph in CanopyDigiThresholdSet, even if fewer than eight are displayed (i.e. if the 2*2 layout is used).

2. Erroneous multiple selections

There can be no check on multiple selections for the same photograph; if the PictureWanted button is used to select two *different* thresholds then two records will be stored in the CalculateToDo folder. The erroneous one must be deleted manually.

3. Printing

No print facility has been provided, but printing (should it be required) can be achieved by the use of the PrintScreen option, copying the screen display to a suitable host program (e.g. Microsoft Paint) and printing the result.

CanopyDigi Calculate
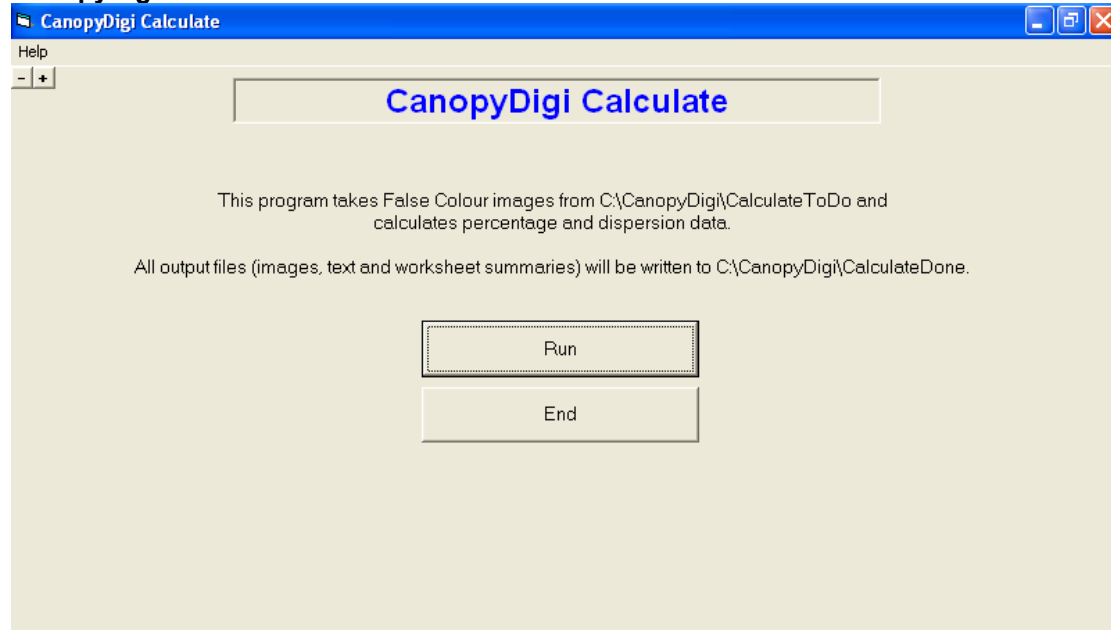
CanopyDigi Calculate screen

Program overview
This program creates 12 sub-images from each false colour image that was chosen in ThresholdChoose to enable the calculation of percentage and dispersion data.

Buttons
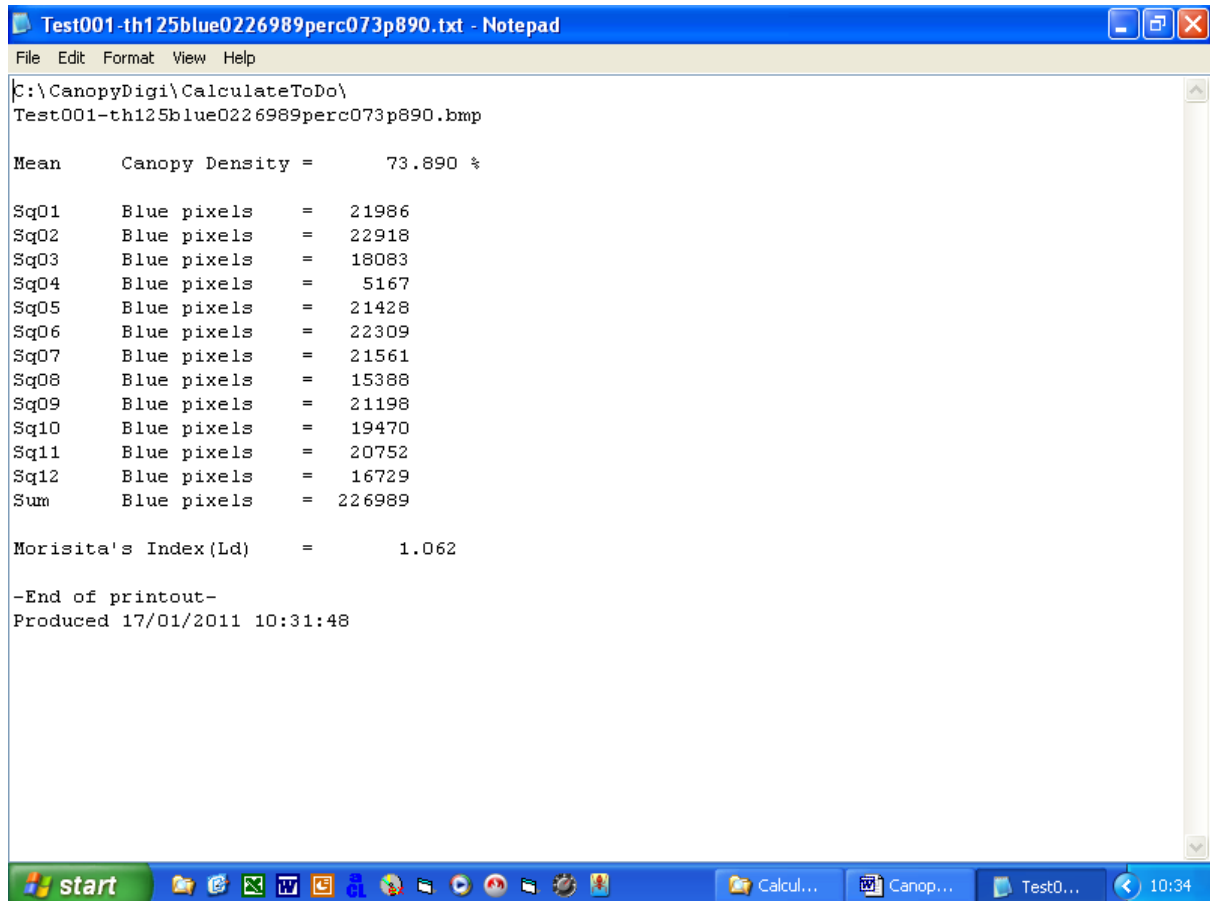Only two buttons are provided, "Start" and "End", which do what they say.

Input
Input is from the CalculateToDo folder and this is automatic, requiring no user intervention.

Output
Output is to the CalculateDone folder and again this is automatic.

This output is twelve sub-images (BMPs) for each original false colour image selected in ThresholdChoose and stored in the CalculateToDo folder. Each new sub-image retains the name of the main false colour image with the sub-image information appended. So, for the main false colour image which was named Test001-th125blue0226989perc073p890.bmp, running CanopyDigi Calculate generates a series of sub-images starting with the existing name of Test001-th125blue0226989perc073p890 (without the .BMP ending) but adding "sq01blue21986perc085p883.bmp" (sq01 refers to the first square of the twelve calculated, blue21986 refers to the number of blue pixels (out of a possible 25,600) in that first square and perc085p883 refers to the percentage (85.883%)).

The information from these twelve sub-images is then combined to calculate the statistical output and is written to a similarly named text file. This will show the following information:

Exemplar text file output

In addition, a single CSV (comma separated variable) file is constructed giving all necessary percentage and aggregation information for every original photograph analysed in a given run of the program. This can be loaded straight into a spreadsheet program (e.g. Microsoft Excel) or statistical software (e.g. SPSS or Minitab) for further analysis. Note that the user may need to effect a small amount of formatting (mainly of column widths), which cannot be done within CanopyDigi.

The text and CSV files are also copied to the CalculateHistoric folder. The computer NEVER deletes anything from this latter file, for safety reasons.

Notes updated 18/01/11 AG