The ITC Suite Manual

A Semi-Automatic Individual Tree Crown (ITC) Approach to Forest Inventories

Dr. François A. Gougeon

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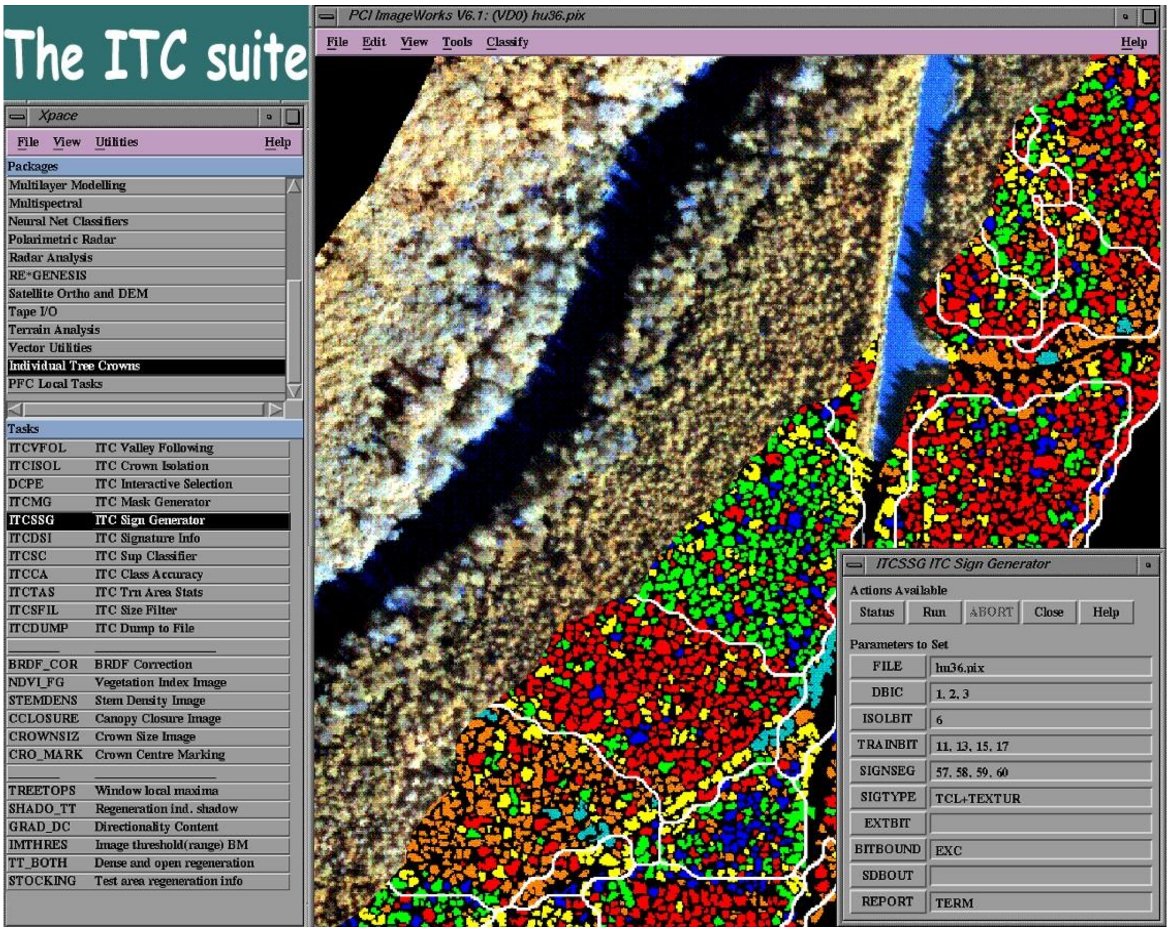

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The ITC Suite Manual : A Semi-Automatic Individual Tree Crown (ITC) Approach to Forest Inventories
François Gougeon (2010)

This is a fully revised version of the ITC Manuals previously known as:

Gougeon, F.A. 2005
The Individual Tree Crown (ITC) Suite Manual
Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada.
Victoria. B.C. Canada. 51p.

Dawson A. and F. Gougeon. 2000.
Procedure for Individual Tree Crown (ITC) Analysis of an Image.
Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada.
Victoria. B.C. Canada. December 2000. 25 p.

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Important note:

In its present version, the ITC Suite runs under the EASI / Xpace Image Analysis System of PCI Geomatics Inc., as if it was one of their packages. At the time of this writing, it runs under PCI Geomatica v6 to v10.2, on both Unix and Windows systems.

Acknowledgements:

The ITC Suite is closely linked with the research endeavours of NRCan/CFS/Pacific Forestry Centre's researchers: François A. Gougeon and Donald G. Leckie.

It has been put through its pace by the dozens of students and young professionals that have made their way through PFC's Digital Remote Sensing Group in recent years.

Thanks to all of them, and thank you Don,

François Gougeon

Introduction

Most foresters would agree that there is a pressing need to improve the precision, accuracy, timeliness, completeness and cost-effectiveness of forest information. Such improvements could come about gradually via incremental changes to existing methods (e.g., softcopy interpretation, more detailed plots, more field visits, or different sampling schemes), but not without serious cost considerations. Budgetary constraints might force us to opt for more innovative methods and even possibly **a major shift in paradigm**: a transition from mapping relatively homogeneous forest stands and interpreting their content from medium-scale aerial photographs to the semi-automatic computer analysis of high spatial resolution (10-100 cm/pixel) multispectral aerial or satellite images in order to produce individual tree crown (ITC) based forest inventories.

This manual describes some of the tools for ITC-based information extraction that have been developed by the Canadian Forest Service over the last twenty years. Together, they form a software package known as the ITC Suite, which at this point in time, runs within the Canadian-made PCI image analysis system. Within the ITC Suite, you will find techniques to separate forested from non-forested areas, delineate individual tree crowns, identify their species and regroup them into newly generated forest stands. The tree-top (i.e., local maxima) technique, an ITC approach more appropriate to regeneration assessments or to the detection of mature trees in cruder resolution images, is also included, as well as, its locally adaptive variation (LATTOPS), useful for combinations of dense and more open regenerating areas. Finally, the task ITCPCD reports on the species composition within the semi-automatically generated forest stand (or other) polygons.

The recent availability of high spatial resolution satellites (e.g., IKONOS, QuickBird, GeoEye, .etc.) delivering good quality images of map sheet size could make the production of ITC-based inventories very efficient. Although initially developed for the analysis of higher resolution multispectral aerial images, the ITC Suite has been successfully applied to such satellite images. However, it should be noted that because of the cruder resolution of these sensors, especially the multispectral bands, the analysis of this type of data is departing slightly from the concept of "true" individual tree inventories. Indeed, with such media, larger quantities of the isolated objects may actually be tree clusters rather than individual trees. Nevertheless, when reporting the results by forest stands some of the information (e.g., species composition) is generally superior to that of the conventional inventory process.

As satellite and airborne sensors, analysis techniques and computing power improve, forest managers will probably forego static regroupings into forest stands and keep all the information at individual tree level (e.g., position, species, crown area). Regroupings may then be done on demand for each specific application (e.g., ecosystem units, biodiversity, wildlife management), if it is done at all. From such detailed information, numerous parameters in addition to those found in conventional inventories can be easily extracted (e.g., snag locations, forest gaps, health status). The ITC approach is also ideal for specialized inventories, such as those targeting a single, yet commercially important species. An ITC paradigm may lead to more precise volume and biomass estimates, and foster the use of individual tree growth models. The ITC Suite is a first step in the realization of this new ITC-based forest inventory paradigm.

Using the ITC Suite: caveats and helpful hints

In this fast pace world, people don't have time to read all of the research material behind the ITC Suite before putting it to use. In addition, technology transfer does not always take place under ideal circumstances (i.e., with comprehensive training sessions). Consequently, hoping to increase the knowledge of any existing or potential user, I've written these few pages of caveats and helpful hints. All I ask is that you seriously ponder these caveats before starting any significant project. Hopefully, this section will provide a good source supplemental information to the ITC Suite Manual (and to the scientific literature) in guiding you through the ITC analysis process. As a researcher, this document also gives me the occasion to put down on paper heuristics (i.e., rules of thumb) and "tricks of the trade" that are difficult, if not impossible, to convey in scientific publications.

- The **main assumption** behind the crown delineation software of the ITC Suite is the presence of shade between tree crowns. This means that the ITC Suite works best in medium to dense forests (fortunately the majority of forest areas in many regions of Canada). The analysis of other forested areas (e.g., open stands, prairie fringe, urban forests) may simply require more pre-processing, post-processing, or may not produce acceptable results.

- It is vitally important to **mask-out** all regions of the image that do not conform to this assumption (e.g., roads, man-made areas, agriculture/pasture areas, even open forests). Failure to do so may results in unexpected software crashes. For example, neglecting to remove roads (or low lying vegetation along roads) may result in the software trying to create one extremely long tree crown and literally blowing its stack (i.e., computer memory stack). Leaving grassy areas may result in the detection of multitudes of tree crowns where none is present.

- Software other than the main crown delineation programs (ITCVFOL and ITCISOL) can sometimes be used for forest situations not conforming to the main assumption. For example, SHADOW_TT (now imbedded in LATTOPS) can be used in open areas when trees have specific shadows (as opposed to being surrounded by shade). LATTOPS (Locally Adaptive Tree Top) allows for adaptation from dense to open forested areas, but does not provide full crowns (only a dot for crown location).

- LATTOPS (and TREETOPS) is most useful when trees are small (regenerating areas) or when the spatial resolution is cruder (with mature trees). TREETOPS, LATTOPS, and STOCKING are a somehow distinct part of the ITC Suite that is particularly good for regenerating areas and very young plantations.

- Of course, the available spatial resolution affects the results one can expect. The delineation programs (ITCVFOL and ITCISOL) need a minimum crown area of 2x2 pixels to operate. However, they also need shade between the tree crowns, such that an area of 3x3 pixels may be considered a minimum detection area.

LATTOPS can detect a “tree top” (local maximum) of one pixel, but that pixel needs to be surrounded by pixels of lower values. Forested areas covered by "out of control" natural regeneration (stem that you couldn’t walk through) fair very poorly. For these situations, texture-based segmentation or pixel-based classification may be worth considering, but decent results will be very difficult to obtain by any technique.

- The ITC Suite essentially deals with tree crowns as distinct objects and was developed initially for high spatial resolution airborne sensors. It is possible, and often very desirable, to use it with cruder resolution satellite sensors such as IKONOS or QuickBird. In such cases, the isolated objects are often clusters of trees rather than individual tree crowns, but species classification and the generation of forest stands (or alternative regroupings) are still possible. Species composition information within these stands is generally good. However, take note that this is **getting further away from a "true" individual tree inventory** (i.e., lots of objects are tree clusters rather than individuals) and thus, results should be judged accordingly.

- With satellites like IKONOS or QuickBird, the lower spatial resolution of the multispectral data undoubtedly affects tree species and health classification results (i.e., material around tree crowns has a corrupting influence). All crown boundary pixels (or even all crown pixels) are "mixels" containing spectral reflectances from the tree crown, the surrounding shadow, the understorey or other trees. Even pure stands of the same species with different stand densities can be perceived as different.

- Even if satellite images could at this point in time provide the proper spatial resolution for a "true" individual tree inventory, present “run-of-the-mill” computer technology could hardly handle all of these tree crowns as individual polygons (with attributes) for a typical IKONOS area of 11x11km^2 (16.5x16.5km^2 for QuickBird). At this point in time, this information can only be kept as bitmaps or images.

- Applying the ITC approach, interesting information can often be extracted from digitized aerial photos, even panchromatic ones (even at scales like 1:30,000).

- Trade-offs between using airborne or satellite sensors are beyond the scope of these brief notes. Please consult research papers or talk to François Gougeon or Don Leckie (fgougeon@nrcan.gc.ca and dleckie@nrcan.gc.ca).

- After the pre-processing is done (i.e., generating non-forest masks, filtering and possibly resampling of images, generating a pan-sharpen image (for satellite images)), and auxiliary information (GIS, base maps, photos) is gathered, the ITC Suite can be run in a fairly straightforward manner. Very often, only one or two variables (parameters) need to be defined from one program to the next. However, variables for special operations or research-related function are also present. They can usually be ignored for more operational uses.

- Smoothing your illumination image at least once using a 3x3 window kernel is highly recommended (e.g., PCI's FAV), unless your image is already the product of various manipulations that had a smoothing effect.

- Although the ITC delineation software is based on following valleys of shade between tree crowns and was developed with the goal of getting the fullest crowns possible (i.e., better crown areas should produce better volume calculations), having both the shaded sides and the lit sides of tree crowns is counter productive when it comes to ITC species classification (i.e., the classification may be more influenced by the proportion of lit to shaded pixels than by the intrinsic reflectance of a given species). For this reason, the classification is generally based on the spectral information from the lit side only. This is accomplished by running ITCMG (mask generator) to get a LIT side mask, which is then used in the signature generation and classification processes.

- Because of the pixels assigned to the valleys of shade, one should always expect an underestimation of crown areas. The optimization of certain parameters to improve the separation of individual crowns (e.g., in ITCVFOL) may lead to further underestimation of crown areas. However, the presence of numerous tree clusters can lead to the opposite result when summarizing at the stand level.

- For typical Canadian forests, the ITC Suite works better around a 50 cm/pixel spatial resolution. For various reasons, it is often useful to resample 1 m/pixel data (e.g., IKONOS) to 50 cm/pixel. Very high spatial resolution data (say 10 cm/pixel) may also fare better when degraded to 50 cm/pixel. On the other hand, the very large crowns of tropical forests may be analysed better at 1 m/pixel, although the ITC Suite may not be well suited for tropical forest analysis. Research is ongoing.

- The present version of the software **favours crown separation**, thus bigger crowns (e.g., deciduous trees, white pine) can often be overbroken. A solution has been to smooth even more (PCI's FAV 7x7) areas with big tree crowns. Until an adaptive smoothing program is created (AFAV), this implies apriori information to separate stands with big trees from stands with small trees. If the size separation is along deciduous vs coniferous trees, a pixel classification of a degraded resolution image (say IKONOS 4 m/pixel MSS) may prove useful. Otherwise, a texture segmentation of the image (HOMOG, PCI’s TEX, or eCognition) will usually work. Of course, forest stands with a mixture of tree sizes will be difficult to optimize for.

- Of course, the ITC Suite (and optical remote sensing in general) can only get "directly" at what is seen in the image (i.e., mostly the dominant and co-dominant trees). Everything else about a stand has to be inferred.

- Even though the smallest crown delineated may be as small as 2x2 pixels, for classification purposes crowns need to have a significant number of pixels within them to create viable "ITC signatures". More so if only the LIT sides of the crowns are considered (as usually recommended). You may loose a lot of small trees (i.e., unclassified cause unused) if too many multispectral bands and other features are used in the classification process. ITCSSBD can help find the most significant bands and features for species separation.

- There is no point in using ITC texture and structure signatures at resolutions poorer than 30 cm/pixel (in addition to the above concern).

- There will always be crowns that are hard to separate from each other. For example, trees in exposed rows that are aligned at 90 degrees to the sun illumination and have little or no shade between them.

- The ITC Suite (for delineation and/or classification) needs **a continuous radiometric space** (i.e., a continuum of grey levels in each band or feature). Any discontinuity will create artefacts. Always verify that the data you are using was not subjected to radiometric stretches. For example, the use of Digital Globe or Space Imaging pan-sharpen images is not recommended as they often use piece-wise linear stretches to make their products more appealing for human consumption (i.e., the press and television media).

- The "true" radiometric capabilities of the sensor will influence species separation. Poor sensor radiometry may limit species separation to 3-5 coniferous species and 3-5 deciduous species. Better sensor radiometry and attention to details may permit the separation of more species. (N.B.: A sensor may be quoted as having 12 or 16 bits of radiometric resolution, but its commercial products may be delivered with a much lower radiometric range.)

- **Not all species are separable** from one another. Species with similar characteristics will exhibit more confusion among each other. Sometime, it may be better to group such species into a single class; other times, it is more appropriate to classify them separately, take note of the confusion, and regroup them for reporting and accuracy assessment purposes

- For certain species, the natural variability within the species can be more sizeable than its difference from the next closest species. In such cases, it may be useful to create two different narrow signatures (classes) for the classification and combine them as a single class later.

- Health will affect intra-species variability and thus, inter-species separability. Health and various other factors (e.g., illumination, site quality, ...) may need to be considered along with species when creating classes.

- Trees in open areas or close to open areas, trees taller than surrounding trees, or exceptionally large trees often have different signatures than other trees of the same species.

- A given species on south-facing slopes may have to be treated separately (i.e., as a different class) from the same species on north-facing slopes. The ITC classification may proceed better with these as separate classes, to be regrouped at the end of the analysis process. Thus, in mountainous areas, introducing a digital elevation model as a feature in the classification process could help (i.e., it typically helps in Landsat analyses). However, so far, very little work has been done in that regard.

- Cloud cover is a big concern in the acquisition, selection and processing of imagery. It is both the clouds themselves and the cloud shadows that are important. For tree classification of airborne imagery, clear sky conditions are recommended. With satellite images, clouds can compromised any well-planned acquisition window (or even a full acquisition season). They can tempt you to settle for a not so desirable archive image, from a less useful part of the year or with a large acquisition angle. On the other hand, if you can afford the loss of coverage, fairly distinct clouds and their shadows are typically easy to deal with (BTW, never rely on cloud cover percentages from the image supplier, most of them don't make any sense to me).

- Haze is a much more threatuous affair. It will typically be invisible on the crude "quick-look" images used for ordering satellite images and may still be invisible when you get the real images. An extreme stretch of the blue band may reveal its presence.

- With aerial imagery, whether from digitized photos, digital frame cameras or from linear arrays, one should generally restrict the computer analysis to a zone of ±15 degrees off-nadir.

- Because of the "pointable" nature of these satellites, IKONOS and QuickBird images can be purchased with a sizeable off-nadir view angle. Large acquisition angles should be avoided.

- When analysing (tree crown delineation or classification) imagery from different satellite acquisitions or airborne missions or even different flight lines, **caution** should be used. Often, a radiometric normalization between images is needed in order to apply the same classification or isolation parameters. However, even under the best of circumstances (good radiometric normalization), mosaics of aerial (or satellite) images may have serious deleterious effects on species classification.

- The ITC Suite can also be used to delineate tree crowns in Lidar-generated canopy models given a proper spatial resolution. This can lead to individual tree crown volume estimations and other synergistic effects (see research papers). For example, the difficulties in delineating tree crowns in well-lit open areas can be aleviated by using a simple height threshold to mask the surrounding or understorey material.

- Every effort has been made to keep consistency between running the ITC Suite in the PCI's Xpace environment and in the PCI's EASI environment. The first is the user-friendly version of the ITC Suite depicted in this manual. The ITC Suite appears like just any other PCI package in the Xpace environment. The latter is typically used by more experienced users and facilitates the creation of production scripts or batch files (e.g., MY_RUN.EAS)

- At this point in time, the ITC Suite has not been integrated into PCI's Geomatica Focus' library of modules.

Additional Information

- For more information, please consult the following Web pages:
  http://cfs.nrcan.gc.ca/directory/fgougeon

- More importantly, the scientific underpinnings of the ITC Suite can be found in numerous scientific publications under:
  http://cfs.nrcan.gc.ca/index/gougeon-publications/4

- The following publication is **highly recommended** as an introduction to the ITC Suite techniques and applications:

  Gougeon, F.A.; Leckie, D.G. 2003. Forest information extraction from high spatial resolution images using an individual tree crown approach. PFC Information Report BC-X-396 (et **en français** BC-X-396-F). Natural Resources Canada, Canadian Forest Service, Victoria, B.C., Canada. 26 p.

  http://www.pfc.cfs.nrcan.gc.ca/cgi-bin/bstore/catalog_e.pl?catalog=21272

This software suite is the fruit of over 20 years of dedicated work. I sincerely hope that you enjoy using the ITC Suite and revel in thoughts of what this approach might do to the future of forestry in Canada and around the world.

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Victoria, BC

Methodology for Individual Tree Crown Analysis

The following two flowcharts outline the methodology for individual tree crown delineation, classification and regrouping that is typically used to produce forest stand polygons for which detailed information will be available. The methodology is described in details in the BC-X-396 report mentioned above.

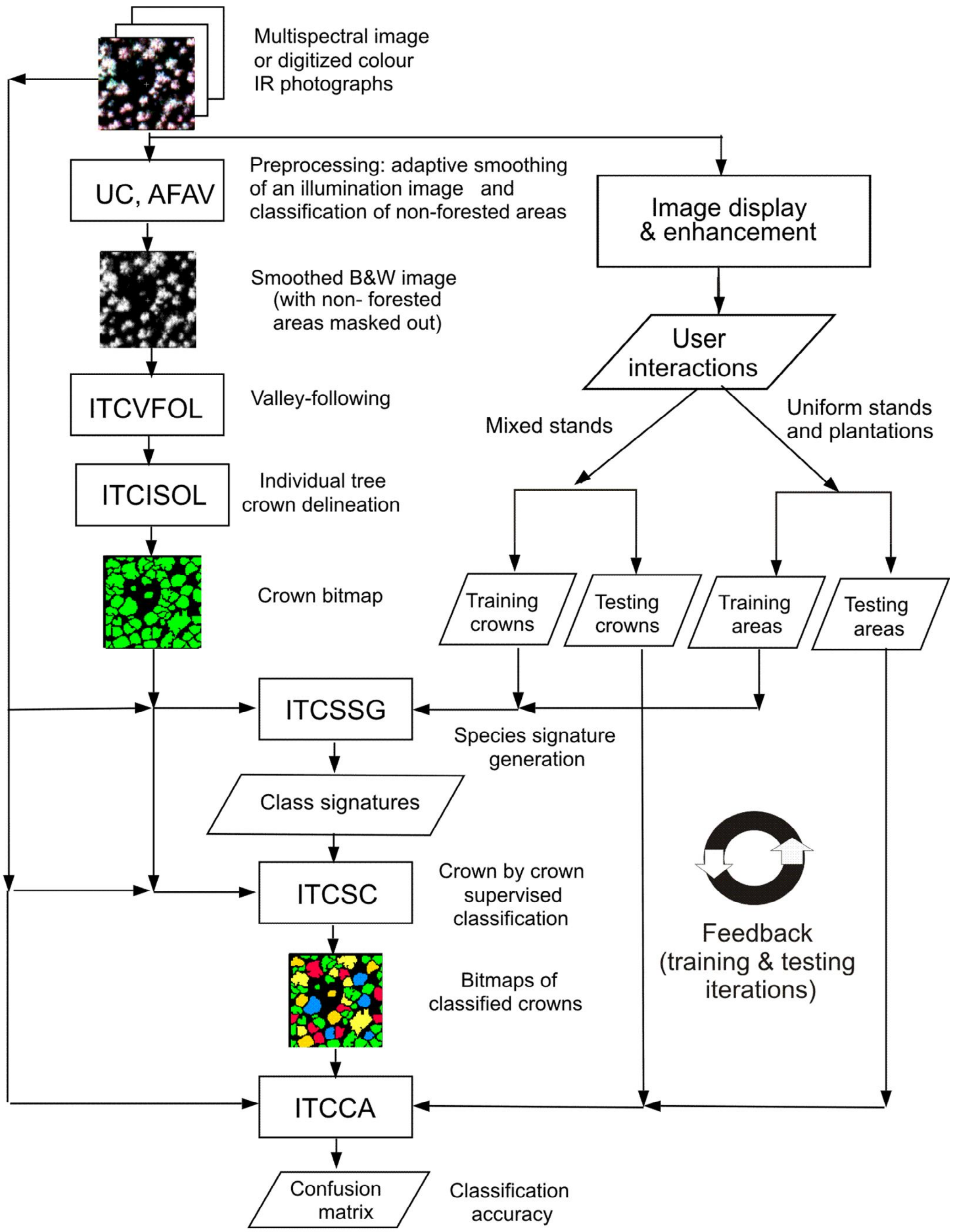


Figure 1 - Methodology for individual tree crown delineation and supervised classification from high spatial resolution (~50 cm/pixel) multispectral images

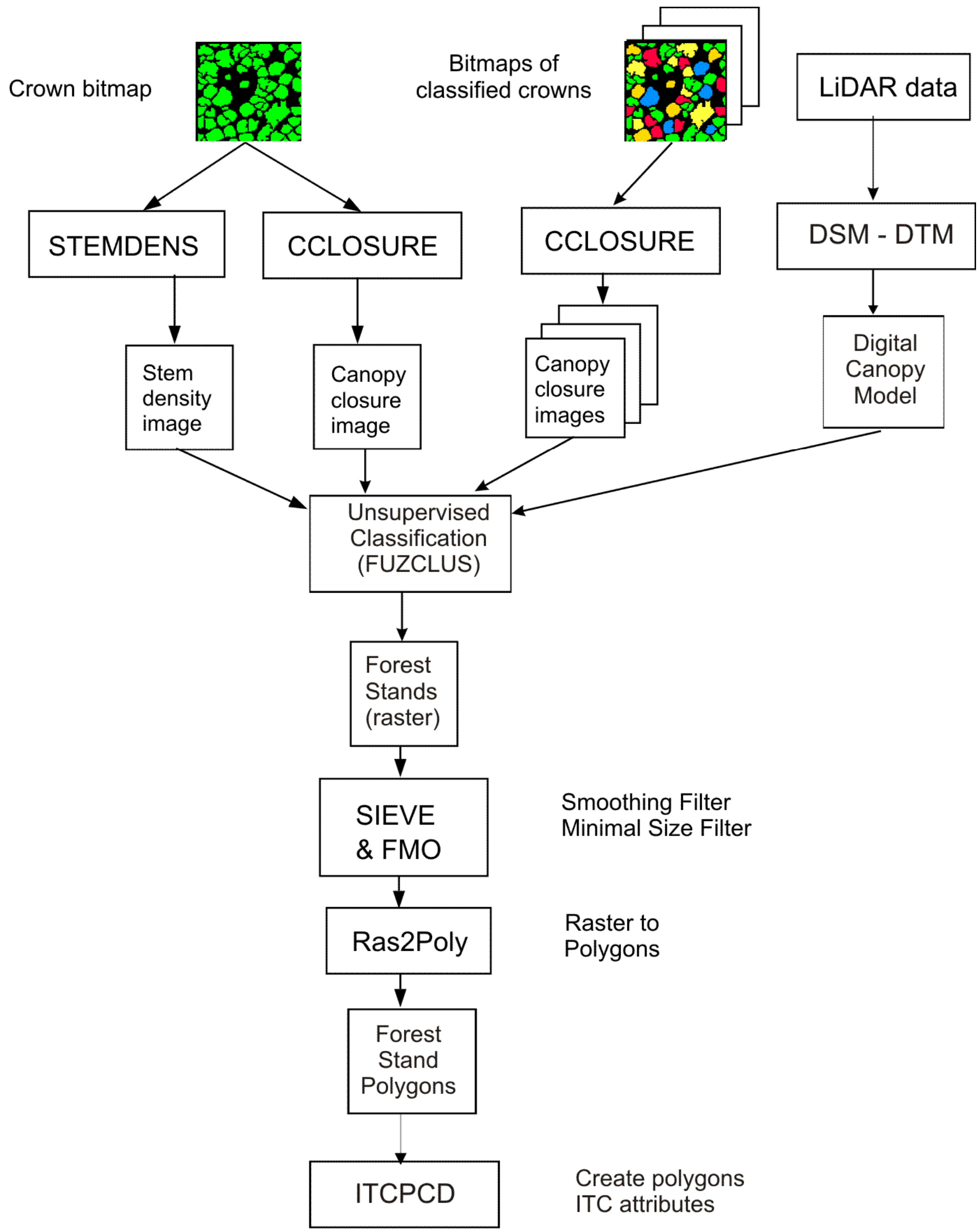


Figure 2 - Methodology for generating forest stand polygons from ITC information

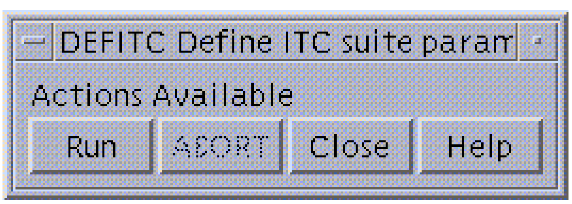
Using the ITC Suite in the PCI EASI/Xpace environment

Assuming the software has been installed properly (see ITC-Suite_xxx_Installation.txt) such that both PCI and ITC programs can be run from the system prompt level.

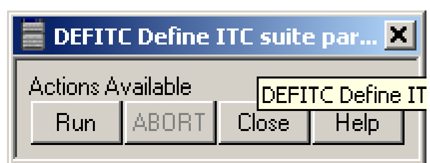
1. Open a command (terminal) window from the operating system (Windows or Unix)
2. Change to the directory where the project images reside (i.e., we encourage the use of one directory per project)
3. If this is a new project, make sure there is a PRM.PRM file (that keeps track of PCI environment variables, including the ITC Suite variables). If not, at the EASI prompt,
   EASI> **Run COPPRM**
   EASI> quit

Note : Files PRM.PRM from PCI v10 and above are incompatible with previous versions of PCI. Programs compiled for say, PCI v9.n, will not operate if a PRM.PRM from PCI v10 and above is present. Always make sure to have the proper PRM.PRM file in your directory. PRM.PRM from PCI v10 are roughly 715KB. Older versions are roughly hald that size (~ 350KB).

4. At system prompt, type “Imageworks”
5. Load your images using “...file/ Load Image” in Imageworks
6. At system prompt, type “Xpace”
7. Under packages, select **Individual Tree Crowns**. A list of tasks will appear. These tasks are the tools for tree crown delineation and species identification.
8. Under tasks, select **DEFITC**



Unix look of DEFITC control panel



Windows look of DEFITC control panel

- This procedure initializes parameters (in PRM.PRM) in order to be able to run the Individual Tree Crown (ITC) image analysis Suite. It is typically run ONCE at the beginning of a project after COPPRM and/or when using a new directory.

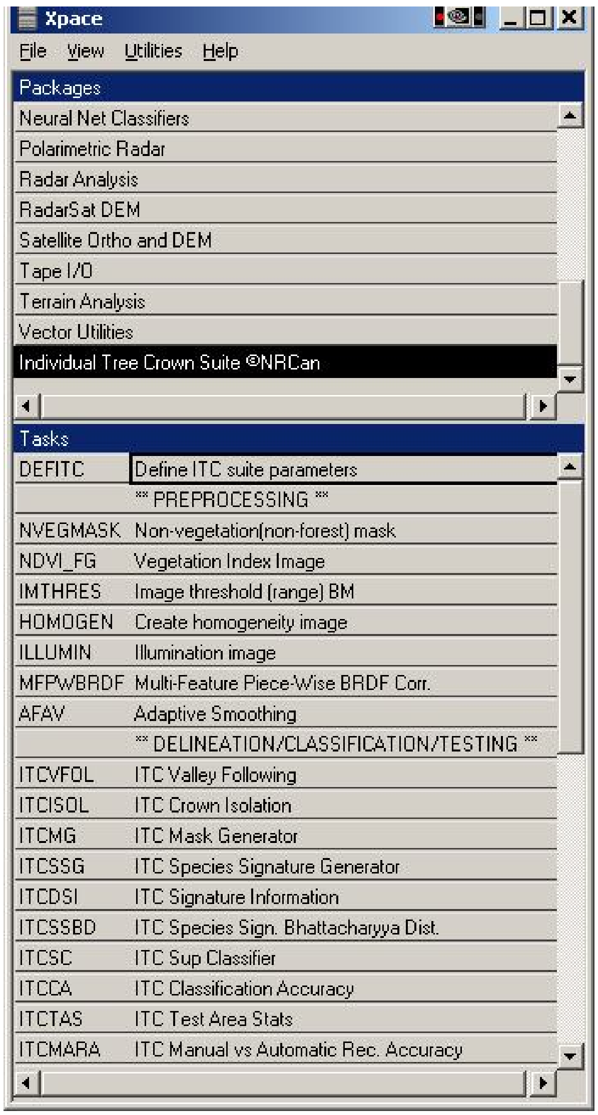
- Select RUN

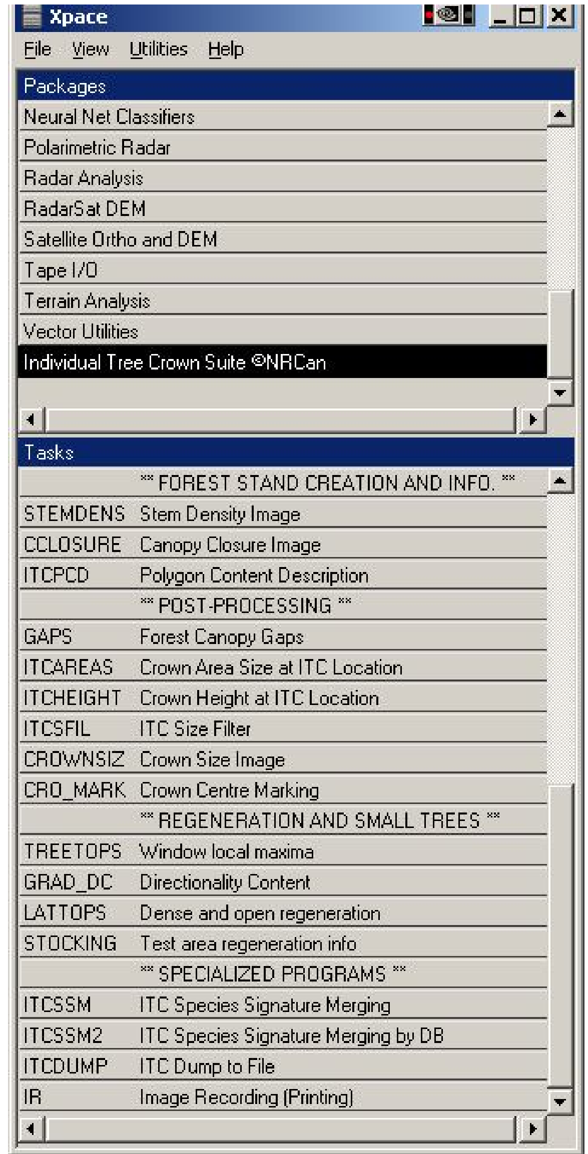
Note: Like all other ITC Suite programs, DEFITC can also be run at the EASI prompt:

EASI> **run DEFITC**

Running ITC Suite programs from the EASI prompt is generally the preferred (and fastest) way for image analyst already familiar with the ITC Suite.

The following figures show the ITC Suite tasks as seen from the PCI Xpace environment in PCI Geomatica v9.1.8:





Note that the tasks are organized in different groups that more or less correspond to the main headings in this manual: pre-processing programs, core ITC programs, ITC utility programs, forest stand generation programs, regeneration-related programs, aerial images related programs, generic utility programs.

Pre-processing

As with most computer image analysis projects, there is generally a need for some pre-processing before attempting to delineate and classify the individual tree crowns (ITCs) of an image. As stated in the "caveats and hints" section, there is a primary need to mask-out non-forested areas, thus removing them from the ITC analysis. However, there are also numerous other pre-processing tasks that are required or useful to get better results.

A first concern, after you have a good handle of all your image files and auxiliary data, a well organized directory/subdirectory structure, and some means of backup, is to make sure you are using an appropriate spatial resolution. As stated above, for the typically Canadian forests, the ITC Suite generally works well around 50 cm/pixel. That is a good place to start. Later, you may decide that you want to analyse your typically smaller crown coniferous trees at 30 cm/pixel while analysing your bigger crown deciduous trees at 60 cm/pixel. Thus, as an initial stage, images should be resampled to 50 cm/pixel and/or pan-sharpened images created at that spatial resolution.

Another concern may be the radiometric resolution. The ITC Suite is capable of dealing with image channels that are stored in 8bit or 16bit PCIDSK channels and, combination thereof. However, when dealing with big images and/or little computer memory, it is worth considering doing the initial work with 8bit images. In any case, a lot of sensors have only a few bands for which it is worth considering using more than 8bit of radiometric resolution (e.g., the panchromatic and the near infrared bands).

As stated above, for a preliminary analysis, it may not be warranted to do completely separate analyses of hardwood (broad leaves deciduous) and softwood (conifers) trees. However, within a single analysis, it is possible to deal with those two situations slightly differently. For example, the program AFAV is meant to deliver more smoothing to the hardwood areas in an attempt to prevent a typical over-segmentation of these crowns. To control this process, we need to generate masks that will direct the software to the areas that need more or less smoothing. This can be accomplished in numerous ways.

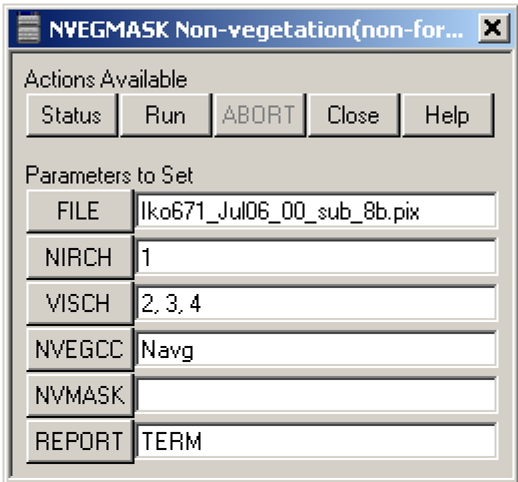
One simple way to separate hardwood from softwood areas is to create a cruder resolution image (say 2 m/pixel) and use a standard pixel-based classifier (à la Landsat), possibly unsupervised, to separate those regions and thus create the required masks. This may also be a useful way to create various other masks such as: sandy, rocky, or man-made areas; water and lake areas; generally non-vegetated areas; non-image areas; etc. These are useful to eventually create the much desired non-forest mask, but will come-in handy for various operations throughout the ITC image analysis process.

Also note that generally, lots of these masks can be generated by using simple thresholds on specific bands (e.g, nIR, blue) and that, ITC Suite programs such as NVEGMASK or, NDVI_FG followed by some thresholding, are also meant to help in that regard.

Another way to separate hardwood from softwood areas is to rely on texture measures at our preferred 50 cm/pixel, as these forested areas should be significantly different that texture-wise. This is what a program like HOMOGEN is meant to do. Of course, other texture programs such as PCI's TEX or Definiens' eCognition can be used just as successfully for that purpose. Texture can also be used to separate vegetated, yet shrubby areas, from forested areas.

Finally, if a LiDAR-generated or stereo-disparity-generated Digital Canopy Model is available (even at a crude resolution such as 1 m/pixel), a simple height threshold can be used to mask-out well lit, yet shrubby openings within the forest, often isolating individual trees within them in the process. Of course, such DCM will be very useful in the semi-automatically process that generates ITC-based forest stands (Figure 2) and later, in reporting on forest stand heights (via ITCPCD).

NVEGMASK could be useful to create a much needed non-forest mask. Information extracted from a base map and simple image thresholds can also be very useful. A non-forest mask is needed for the ITC Suite to concentrate on medium to dense forested areas in the image.



NVEGMASK (non-vegetation mask) produces a bitmap of the brightly illuminated non-vegetated (non-forested) areas (man-made features, slash, snags, senescing vegetation) by comparing (normalised or not) the nIR and the visible image values. The resulting bitmap (NIR < visible) is typically used with the ITC-suite (e.g., ITCVFOL, TREETOPS) as non-forest mask (NFMASK). However, note that the mask may eliminate unhealthy or partially defoliated trees. These would no longer be available for ITC delineation and classification. Conversely, it can thus be used to detect snags in forested areas. Also note that artefacts can also appear in the image's dark areas where visible to NIR return comparisons are less meaningful. These areas can be removed apriori by thresholding.

NVEGMASK is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	PCI Database File Name (for in/output)	64	Char
NIRCH	Input nIR channel	1	Int
VISCH	Input visible channels	1-8	Int
NVEGCC	Compare criteria(Raw/Navg/Nmax/Nmo/Nra)	64	Char
NVMASK	Output bitmap of non-vegetated areas	1	Int
REPORT	Reporting device	64	Char

<u>FILE</u> PCI Database File Name

Specifies the name of the PCIDSK file containing the input and output channels (images), bitmaps (themes), vector layers, and additional segments. The selected file will now be the default for the rest of the ITC analysis and for other PCI programs. Please verify that you are always pointing to the proper file (**N.B.:** This filename is usually the same as that of ImageWorks, but they are actually independent).

```
EASI>FILE="filename"
```

NIRCH   Input nIR channel

Specifies the channel number of the nIR channel (band).

```
EASI>NIRCH=n
```

VISCH   Input visible channels

Specifies the channel numbers of the visible bands.

```
EASI>VISCH=n,n,n...     Can handle up to 8 channels
```

NVEGCC   Comparison criteria (Raw/Navg/Nmax/Nmo/Nra)

NVEG Comparison criteria selects the type of normalization (or not) used in comparing the nIR and visible chanels on a pixel basis

```
Raw    no normalization on channel data
Navg   channel data normalized by the channel average grey level
Nmax   channel data normalized by the channel maximum grey level
Nmode  channel data normalized by the channel mode grey level
Nrange channel data normalized by the channel useful range of
       grey level
```

```
EASI>NVEGCC="type"
```

NVMASK   Output bitmap of non-vegetated areas

Specifies an output bitmap number in which to write the non-vegetation (non-forest) areas mask. As per other PCI program, a bitmap number need only be specified if one wants to overwrite a particular bitmap. Otherwise, a new bitmap is created automatically with a description and a history of how it came about.

```
EASI>NVMASK=n
```

REPORT   Reporting device

Progress reports can be sent to the terminal(TERM) or to an optional file to collect the reported information.

```
EASI> REPORT =                generates reports on your terminal
EASI> REPORT = "filename"     generates reports in "filename"
```

Note: The following names have special meaning:

```
EASI> REPORT = "TERM"   | generates reports on your terminal
EASI> REPORT = "DISK"   | generates reports on file "IMPRPT.LST"
EASI> REPORT = "OFF"    | (may) switch off report generation
```

NDVI_FG - Creates an NDVI image

From two input channels assumed nIR and RED, this program writes in an ouput channel an NDVI image using the standard formula:

$$\frac{nIR - red}{nIR + red}$$

PARAMETERS

NDVI_FG is controlled by the following global parameters:

Name	Prompt		Count	Type
FILE	Database File Name		64	Char
DBIC	Input channels (nIR and Red)	2	Int	***
DBOC	Output channel (NDVI image)		1	Int
REPORT	Reporting device		64	Char

FILE

Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

```
EASI>FILE="filename"
```

DBIC

Specifies the channel numbers of the nIR and red bands.

```
EASI>DBIC=n,n
```

DBOC

Specifies an output channel number in which to write the NDVI image.

```
EASI>DBOC=n
```

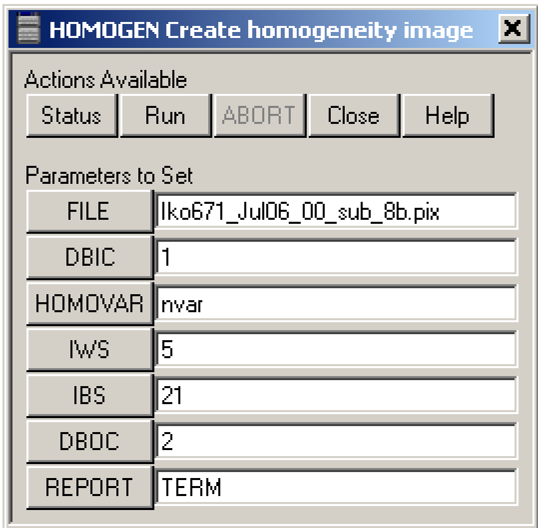
REPORT

Specifies the file to append generated report to:

```
EASI> REPORT = "filename"

EASI> REPORT =               generates reports on your terminal
EASI> REPORT = "OFF"         (may) switch off report generation
```

HOMOGEN produces an output image relating the "homogeneity" (a texture measure) of the input image based on a specific variable (HOMOVAR). It essentially conveys a measure of, for example, the normalized variance (NVARS) for a pixel, as calculated within a window of IWS*IWS pixels around the pixel of interest, and summarize by bigger blocks IBS*IBS to produce a smoother image. Such an image can later be thresholded to separate regions with different greylevels or textures.



HOMOGEN is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	PCI Database file name (for in/output)	64	Char
DBIC	Input Illumination (B&W) Channel	1	Int
HOMOVAR	Homogeneity basis (MEAN/VARI/...)	64	Char
IWS	Size of moving window (e.g.,3,5,7)	1	Int
IBS	Size of block to summarize info	1	Int
DBOC	Channel for resulting variance image	1	Int
REPORT	Reporting device	64	Char

<u>FILE</u>

Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

<u>DBIC</u>

Specifies the input channel containning the image to analyse. Image data can be 8 or 16 bits/pixel.

HOMOVAR

Variable to use in judging homogeneity

HOMOVAR="MEAN || VARI || NVAR || STDEV || COVAR || MIN || MAX

MEAN: Multispectral mean within the IWSxIWS area
VARI: Variance within the IWSxIWS area
NVAR: Normalized Variance within the IWSxIWS area
STDEV: Standard deviation within the IWSxIWS area
COVAR: Coeficient of Variation within the IWSxIWS area
MIN: Minimum within the IWSxIWS area
MAX: Maximum within the IWSxIWS area

IWS

Size of the moving window (e.g., 3, 5, ...) from which Normalized Variance
will be calculated (IWS*IWS) (if unspecified, 3x3 is default).

EASI>IWS=n

IBS

Size of block (e.g., 11, 21, 31 ...) to use to summarize normalized variance info. (if unspecified, 21x21 is default).

EASI>IBS=n

DBOC

Specifies the ouput channel (8 bit)to contain the resulting variance image.

REPORT

Progress reports can be sent to the terminal(TERM) or to an optional file to collect the reported information.

EASI> REPORT = "filename"

Note: The following names have special meaning:

EASI> REPORT = "TERM" | generates reports on your terminal
EASI> REPORT = "DISK" | generates reports on file "IMPRPT.LST"
EASI> REPORT = "OFF" | (may) switch off report generation

AFAV - Adaptive Smoothing Filter

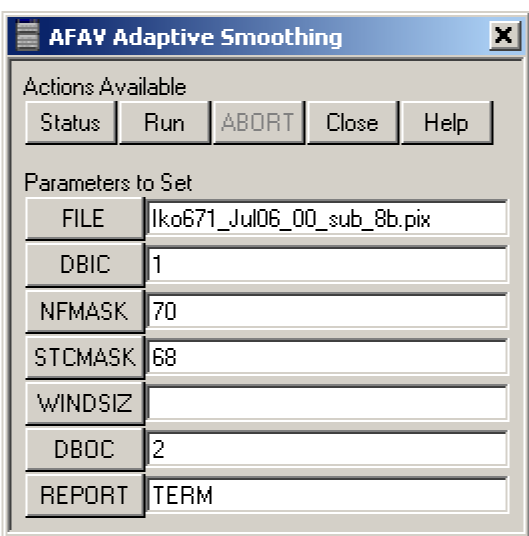
AFAV smoothes various image areas "more or less" depending on needs. The process is guided by the small tree crown mask (STCMASK) and the non-forest mask (NFMASK). Typically, it smoothed the small tree areas with a 3x3 average filter, and the big tree areas with a 5x5 filter on top of the 3x3 smoothing. The default of 3x3 and 5x5 can be changed using parameter WINDSIZ. When finished, it writes the image to the output channel.

The non-forested area mask (NFMASK) is used to point to areas considered non-forested. Internally, the NFMASK and STCMASK are used together as a surogate for a BTCMASK (big tree crown mask). NFMASK could have been obtained in various ways : from a GIS coverage or from pre-processing, either from a cruder resolution image pixel-based classification or a texture analysis of the image (e.g., HOMOGEN).

The small tree crown area mask (STCMASK) can be gathered by texture analysis of the image (eCognition, PCI/TEX) or with the ITC-Suite own HOMOGEN, typically set to produce a Normalized variance image (HOMOVAR="NVAR) and then, thresholded; or, with a pixel-based classifier used on a cruder resolution version of the image (i.e., to separate conifers from hardwoods, making the assumption that conifer trees are typically smaller trees).

TREETOPS is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	PCI database file name (for in/output)	64	Char
DBIC	Input Image Channel	1	Int
NFMASK	Bitmap to mask out non-forested area	1	Int
STCMASK	Bitmap to indicate small tree areas	1	Int
WINDSIZ	Sizes of moving windows (def.:3&5)	1	Int
DBOC	Output image channel	1	Int
REPORT	Reporting device	64	Char



FILE

Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes) (EASI>FILE="filename")

DBIC

Specifies the input illumination image channel, typically a nIR band, or a panchromatic channel, an intensity channel (e.g., IHS transform), or a vegetation index channel, etc., the smoothed version of which (DBOC) will be used to delineate ITCs using ITCVFOL folowed by ITCISOL.

Note: A nIR image may not be ideal to fing snags and dead or defoliated trees.

EASI>DBIC=n Only one channel is allowed

NFMASK

Bitmap to mask out the non-forested areas.

EASI>NFMASK=n

STCMASK

Bitmap to indicate the areas containing small tree crowns (STC). Other forested areas are assumed to contain bigger trees that require more smoothing in order for crowns not to get over broken.

NOTE: For this program, it would have been more logical to ask the user to supply a BTCMASK as these are the areas requiring additional smoothing, on top of the regular 3x3 smoothing of the rest of the forested areas. However, it is generally easier to produce a small tree crown mask, as these areas have a more distinct texture. Large crown areas often have a texture similar to that of open or non-forested areas (flatter texture).

WINDSIZ

Sizes of moving windows(e.g.: n,m). The first number refers to the size n x n of the moving window to be used to smooth the areas of small trees. The second number refers to the size m x m of the moving window to be used to smooth crowns in areas of large tree crowns.

EASI>WINDSIZ=n,m Defaults are: 3,5

DBOC

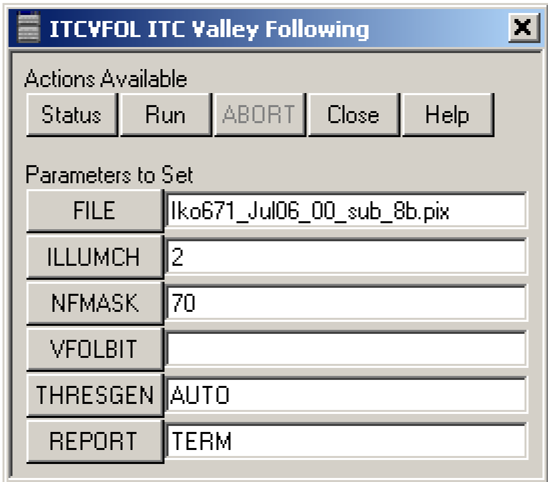
Specifies the output image channel number in which to write the adaptively smoothed image.

REPORT

Specifies an optional file to collected the reported information rather than simply displaying it on the screen (TERM)

Individual Tree Crown Delineation

1) To start the crown delineation phase, select **ITCVFOL**



ITCVFOL (Individual Tree Crown Valley Following) produces an output bitmap representing lines and areas of shaded material between tree crowns. This is done by following the valleys of shaded material (dark) between brighter tree crowns.

ITCVFOL is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	PCI database file name (for in/output)	1-64	Char
ILLUMCH	Input Illumination (control) B&W Channel	1	Int
NFMASK	Non-forested Area Input Bitmap (a mask)	1	Int
VFOLBIT	Resulting VFOL Bitmap	0-1	Int
THRESGEN	Threshold generation (AUTO/MANUAL/PRESET)	1-64	Char
REPORT	Report Mode: TERM/OFF/filename	1-64	Char

FILE

Use the default file(typically)

ILLUMCH

Specifies the input illumination channel, typically a smoothed nIR band. Alternatively, a panchromatic band, an intensity channel (from HIS, or ILLUMIN), a vegetation index channel, or a principal component channel can be used. Generally, it is recommended to smooth (PCI-FAV) the input image unless it has already gone through transformations that are smoothing by nature.

Note: A nIR image may not be ideal to find snags or defoliated trees.

NFMASK

Specifies an optional input bitmap (non forested mask) to be used as mask eliminating certain areas from processing. For example: to eliminate roads, pastures, open areas, ...

VFOLBIT

Specifies the output segment number for the output bitmap containing the results of the valley following. If no segment number is given, a new segment will be created.

THRESGEN

The user can let ITCVFOL decide on three delineation-related thresholds (in AUTOmatic mode). However, in MANUAL mode, one can input the thresholds manually when prompted or, input them into a variable (VFOL_THR) before running the program (PRESET mode). Even in the automatic mode, if ITCVFOL considers itself to have calculated bad thresholds, it may ask the user for manual inputs. These thresholds are:

lower_thres : Pixels with values lower than this threshold will be designated as shade (irrelevant of anything else). This typically gets rid of large shaded areas. Hint: Pick a grey-level at the boundary between shade and shaded crown material.

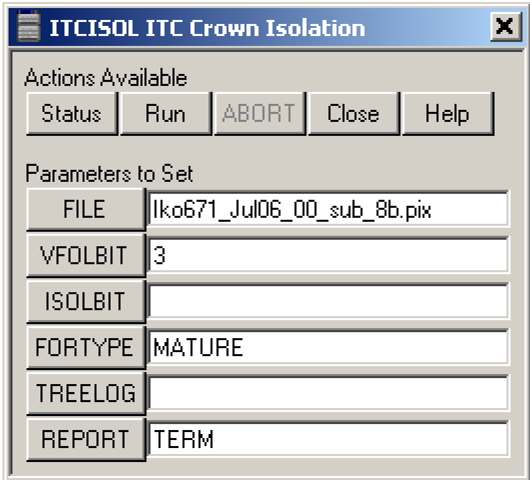
upper_thres : Pixels with values higher than this threshold will be ignored by the valley following algorithm. This is a crude way to prevent the algorithm from climbing up a tree crown and possibly over splitting big tree crowns (especially hardwoods) or to deal with brite sunny forest openings. The preferred approach for the later is to mask these areas using NFMASK. Such masks can be generated by a crude a priori pixel-based unsupervised classification or with tools like NVEGMASK or AHOMOGEN.

plusminus : acceptable range of pixel values for pixels to be considered part of a "relatively" flat valley floor. This is sometimes referred to as the “valley noise” threshold. It can also be though of as a radiometric noise level. In practice, it is often set to 1 with 8-bit images and, 2 or 3 with 16-bit images. Higher levels permit valleys to grow forwards more easily, but create wider valleys as a side effect.

REPORT

Specifies an optional file to collected the reported information rather than simply displaying it on the screen (TERM)

2) Next, to continue the crown delineation phase, select **ITCISOL**



ITCISOL (Individual Tree Crown Isolation) produces an output bitmap showing distinct individual tree crowns (ITC). ITCISOL uses a rule-based approach to continue and formalise the outlines of tree crowns and tree clusters partially delineated by ITCVFOL (valley-following approach).

ITCISOL is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	PCI database file name (for in/output)	1-64	Char
VFOLBIT	Input Bitmap from ITCVFOL	1	Int
ISOLBIT	Output Bitmap to contain ITCs	0-1	Int
FORTYPE	Forest type (MATURE/REGEN/TROPIC/PROMPT	64	Char
TREELOG	Log file for individual results	64	Char
REPORT	Report Mode: TERM/OFF/filename	64	Char

FILE:

Use the default file (typically)

VFOLBIT

Specifies the input segment number of the bitmap produced by ITCVFOL with tree crowns partially separated.

ISOLBIT

Specifies the output segment number to contain the bitmap of individual tree crowns (ITC’s). If ISOLBIT is specified, then that bitmap segment is overwritten. If ISOLBIT is not specified, then a new bitmap segment is created.

FORTYPE

Specifies the type of forest in an image. Possible values are ***MATURE, REGEN,*** and ***PROMPT.*** Software defaults to MATURE. If MATURE or REGEN are specified, the maximum pixel 'bridge' length will be calculated from the pixel size as 1 meter and 0.5 meter, respectively. If PROMPT is specified, the user will be prompted for a maximum jump distance, in pixels.

TREELOG

Specifies a "log" file to hold some individual tree information. When use on a full image, this can generate **LOTS OF OUTPUT**, thus

***** ITS USE IS NOT RECOMMENDED *****

It thus defaults to "/dev/null" on Unix or "NUL:" on PC's (from DEFITC.EAS). It is suitable for debugging purposes or to transfer crown information to statistical analysis packages, etc.

REPORT

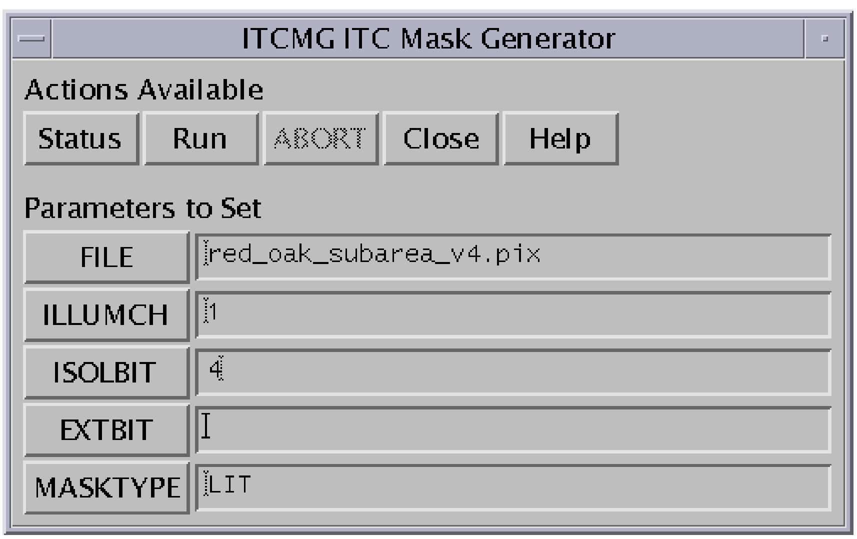
Specifies an optional file to collected the reported information rather than simply displaying it on the screen (TERM)

- Click **STATUS** and check the resulting output in order to verify that none of the **essential** parameter values are reported as missing.
- Select **RUN**

Methodology for ITC classification

1) The methodology for the classification into species of the individual tree crowns (or tree clusters) delineated with ITCVFOL and ITCISOL is shown in **Figure 1**. It does not convey the following pre-processing stage, which is often useful with the higher spatial resolution images. Indeed, our crown delineation process based on following valleys of shade between tree crowns was conceived to capture, as much as possible, the full extent of the crowns of trees (i.e., to be paired with height for potential volume assessments). When successful, the delineation process captures the lit, as well as, the shaded sides of tree crowns. This is less desirable for classification purposes, as the classification runs the risk of being based more on the ratio of the number of lit to shaded pixels in the tree crowns rather than on the intrinsic radiances of that species of trees. For this reason, it is desirable to isolate the well-lit portions of crowns and gather spectral statistics only from that part (at least to generate the "spectral" signatures, the full crown may be more desirable for a "structure" signature).

Thus, as a pre-processing step to the classification of the individual tree crowns just delineated, select **ITCMG** and create a LIT side mask that will be used to generate the spectral signatures and will also be used in the classification of the tree crowns into their proper species.



ITCMG (ITC Mask Generator) - generates LIT / SHADED / TT masks. This is a program that takes the bitmap generated by ITCISOL and an illumination channel (same as used in ITCVFOL) to generate a bitmap assumed representative of the lit side, shaded side or top of tree crowns. This bitmap may be used as Extra mask (EXTBIT) in ITCSSG and ITCSC to create signatures and classify trees based only on that part of the crown. As an option for research purposes or manual signature generation, the bitmap of automatically delineated crowns (ISOLBIT) can be replaced by a vector layer of manually delineated crowns.

Some information that may be required to run ITCMG

- FILE: Use the default

- ILLUMCH: Specifies which channel is the illumination channel. This is the channel which is used by the Mask Generator program in order to generate the bitmap mask and **should be the same** as used in ITCVFOL

- ISOLBIT: Specifies a bitmap produced by the ITCISOL (Individual Tree Crown Isolation) program to be used as a mask of the image. This bitmap is scanned to determine the locations of the individual trees, and thereby build up the specified mask type.

- EXTBIT: Specifies a segment to which the generated bitmap mask will be written to. If a segment is not specified, or if a segment is not valid, a new segment will be created to contain the information.

- MASKTYPE: Specifies which type of mask should be generated. Possible values are: LIT/SHADE/TOP.

  - ***LIT*** creates a mask of the "lit" side of tree crowns. Actually, bits are set for the pixels of the tree crown which have values in the illumination channel above the mean value of the crown for that channel.
  - ***SHADE*** creates a mask of the "dark" side of the tree. That is, parts of the tree crown which have values in the illumination channel below the mean value of the crown for that channel.
  - ***TOP*** creates a mask of what may be the tree top (highest point in the tree). For each tree crown, the most brilliant pixel in the illumination channel is used to mark the location of the treetop.

2) The present ITC classification (or species recognition) process within the ITC Suite is based on a supervised classification approach (**Figure 1**). To prepare for this classification process (i.e., to train the classifier), one needs to create **a training areas (as bitmaps or vector polygons) for each species (or class) of interest** using the image and auxiliary information about the forested area (e.g. aerial photos, old inventory). This is the least automatic part of the whole ITC image analysis process. Here, we show how to do this via bitmaps created in PCI ImageWorks. Of course, creating polygons training areas (vector outlines) can also be done in a geographic information system or a softcopy interpretation system and later ported to the PCI environment.

1) In PCI ImageWorks, under Edit, select Graphic.

2) Select a graphic plane that is not currently being used by another bitmap or clear an existing one.

3) Under Operation, select a tool that will allow you to draw a closed shape over a specific area on the image. For example, “Trace&Close” works very well.

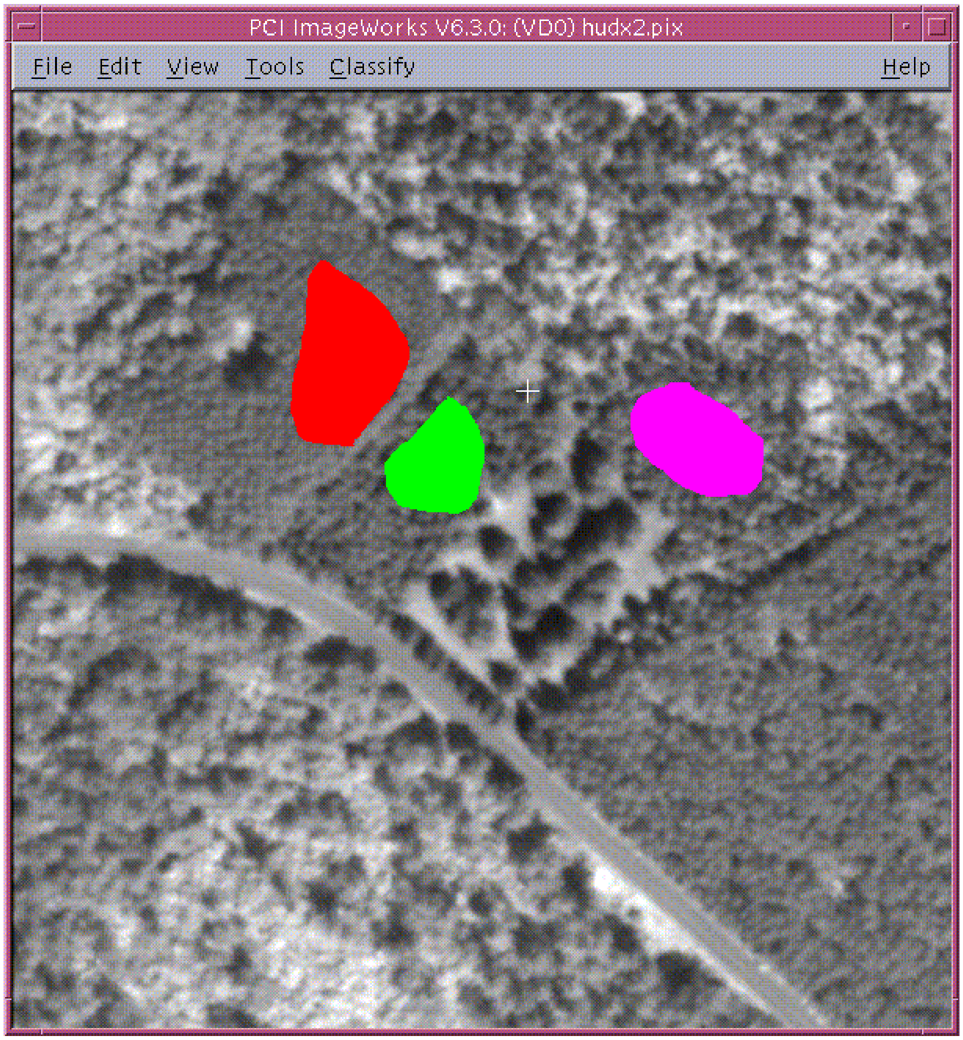
4) Draw a training area over a homogeneous stand of trees. The training area allows the ITC software to analyse the characteristics of the trees in the selected area (i.e., create tree signatures) and later, while classifying, find trees of the same characteristics in the image. When a homogeneous forest area representative of a given species has been decided upon, draw a closed shape capturing that area.

5) With the graphic editor, select Flood Fill under operation. Use this tool to fill in the closed shape. What should be left is a solid blob. You may repeat the above steps (3-5) to gather other areas representative of the same species (class) to be stored in the same bitmap.

6) Go to FILE, and select SAVE GRAPHICS. Save the graphic from the chosen graphic plane, giving it a description and name (e.g., Black Spruce, BS). After the graphic has been saved, it will be given a bitmap number in the PCI image (.pix) file.

7) Do this process again for the other species (or class, or situations) that are to be identified. The minimum number of training bitmaps depends on how many tree species one wishes to identify. For example, if there are four species to be identified, then a minimum of four training bitmaps are needed. However, each of those bitmaps may contain one or more training areas corresponding to several homogeneous stands of that species.

An example of three training areas delineated for three different species is shown below.

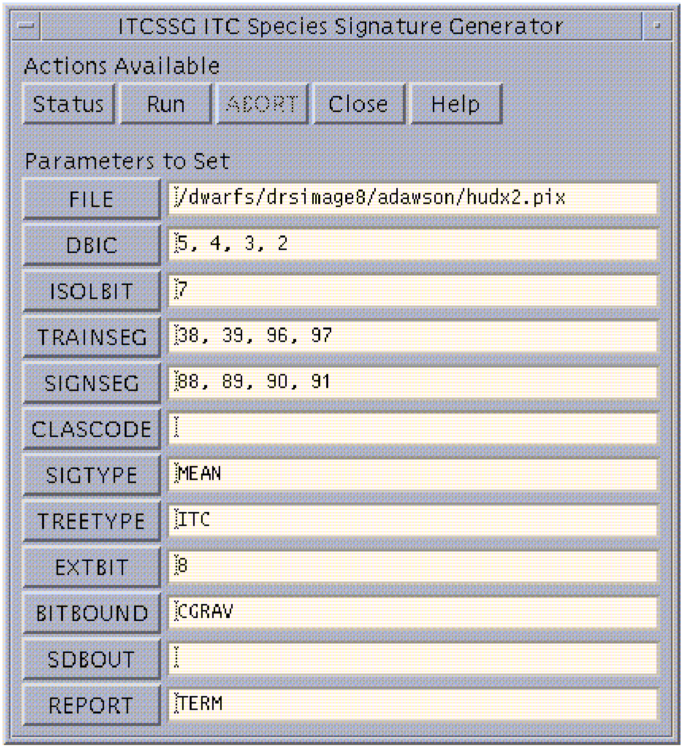


Note: It is typical to delineate several independent training areas for each species (or situation) one wants to parameterize, as long as they are stored in the same bitmap. This may also be a good time to create independent test areas (in different bitmaps, one bitmap for each species) to be used later with ITCCA to verify the classification accuracy.

NOTES:

- An alternative way to generate species training information is to select individual trees in the isolation bitmap (ISOLBIT). This is much more demanding and is only done for species where individuals are never found as clusters.
- For such situations, it is better to forgo creating such training bitmaps and delineate individual tree crowns in a vector layer.

3) To create the ITC species signatures, select **ITCSSG**



ITCSSG (Individual Tree Crown (ITC) Species Signatures Generation) generates ITC-based signatures for different species of trees. From a set of multispectral channels, it typically uses an ITC bitmap generated by ITCVFOL&ITCISOL and a series of training bitmaps (generated as per above) to generate ITC-based signatures for different species (class) of trees.

Some information that may be required to run ITCSSG

- <u>FILE</u>: Use the default PCI database file (.pix).

- <u>DBIC</u>: Specifies the file channel(s) holding the input MSS image. A list of up to 8 channels may be specified.

- <u>ISOLBIT</u>: Typically specifies a bitmap of individual tree crowns (ITC's) produced by the ITCISOL program. Exceptionally, when TREETYPE= Slayer, ISOLBIT may point to a single vector layer containing all of the training tree crowns for all of the species.

- <u>TRAINSEG</u>: Typically specifies a list of Training Segments (bitmaps or vectors) to be used, one for each species (class) signature to be created. For uniform forest stands, these bitmaps typically contain filled training areas, whereas vector layers contain outlines of training areas (i.e., polygons).

- SIGNSEG: Specifies an optional list of segments to which the generated signatures will be output. If a full segment list is not specified, or if a segment is not valid, new segments will be created. These signatures are presently stored as PCI "Text Segments" in order for the segments to show up when ImageWorks File Utility is used (i.e., segments of type unknown to PCI don't show up with this utility). However because of this subterfuge, they do not copy well from one PCI file to another (i.e., it is actually binary data). Please use ITCSSM in "single signature mode" if you need to copy ITC- based signatures. Signatures calculated for one type of processor will not work with another type of processor (SUN vs SGI vs Intel vs Motorolla).

- CLASCODE: This an optional parameter for specialized operations. This parameter allows the user to enter a specific class code (e.g., 183) for each class to be considered when in single layer mode (TREETYPE=SLayer). In this mode, ISOLBIT points to a single vector layer containing numerous manual tree crowns (vector polygons), some of which will be used to generate the species signatures. In this mode, the number of classes specified by CLASCODE will generally govern the number of signatures that will be generated.

- SIGTYPE: Specifies which type of signature is to be generated. Possible types include: MEAN/TCL/TCL2/TEXTUR/STRUCT.

  - ***MEAN***: The multispectral means of each ITC are averaged to create species signature. MEAN can be used with EXTBIT to create LIT-side MEAN or TT, to create treetop-type signatures. **For typical ITC analyses, the MEAN-LIT signatures are generally recommended.**
  - ***TCL***: First eigen vector & corresponding intercept of each ITC are averaged to create the species signature.
  - ***TCL2***: First eigen vector & corresponding intercept & eigenvalues are averaged to create species signature.
  - ***TEXTUR***: Multispectral variances of each ITC (a simple texture parameter) are averaged to create species textural signature.
  - ***STRUCT***: 3D moments (now Kurtosis) of each ITC are averaged to create species structural signature.

- TREETYPE: Specifies whether signature generation (SSG) and classification (SC) are to be done based on a full crown per tree (type = ITC) or only one pixel per tree crown (type = TT), the so-called "tree tops" type of ITCMG (local maximum *within* an ITC). **The default is ITC**. Note that TT can only be used with SIGTYPE=MEAN and an Extra bitmap (EXTBIT) of treetops. The LIT (or SHADE) Extra bitmap is typically used with TREETYPE=ITC. Other, more research-oriented modes exist:

When TREETYPE=ManBM, the training bitmaps are made of individual tree crowns that were (typically) delineated manually and filled on the screen by an interpreter. The ISOLBIT and the BITBOUND parameter are disregarded. This is a research mode to see if purer signatures are generated by human interpretation.

When TREETYPE=ManVec, the training layers are made of individual tree crowns that were delineated manually on the screen by an interpreter, but the manually delineated tree crowns exist in vector form as close polygons (PCI shapes). The different species prototype crowns are stored in different PCI vector layer segments. The ISOLBIT and the BITBOUND parameter are disregarded. This is a research mode to see if purer signatures are generated by human interpretation.

TREETYPE=SLayer permits the generation of multiple signatures from manually delineated tree crown (vector polygons) by specifying a single input layer in ISOLBIT and a field of that layer (TRAINF) that identifies the class code of each tree crown. The parameter CLASCODE selects which classes are of interest for a given run of ITCSSG and thus, how many signatures will be generated.

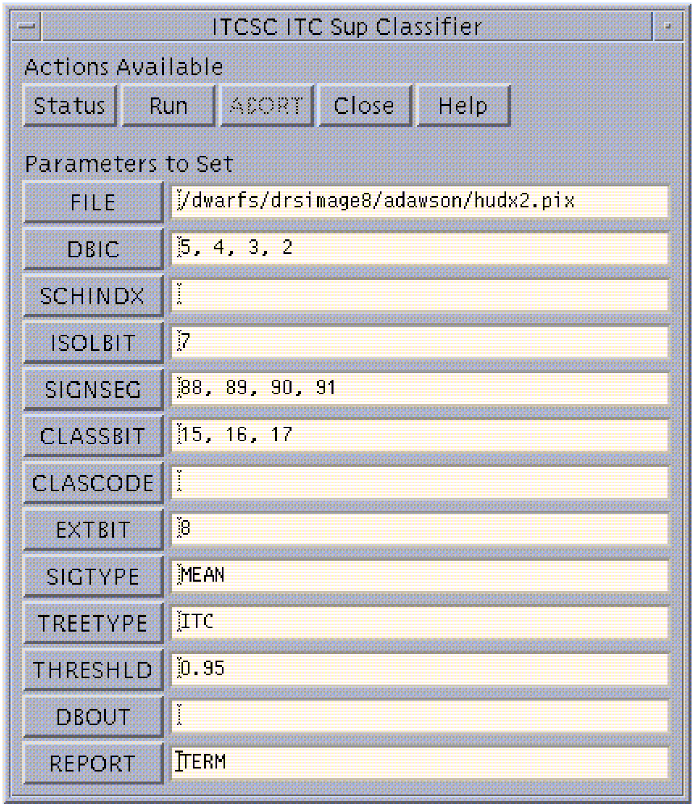
- EXTBIT: Specifies a segment, which contains an Extra Bitmap Mask. This is an additional bitmap which is used to mask which parts of the ISOLBIT should be used to generate the signature. Generally this is a bitmap from the ITCMG program. In BITBOUND = POINTS mode, the EXTBIT bitmap points to the tree crowns that should be considered.

- BITBOUND: Possible values: INC / EXC /AUTO / CGRAV / POINTS (Inclusive or Exclusive or Automatic or Centre of gravity or Pointers). Specifies whether tree crowns that fall on the boundary of training areas (TRAINSEG) should be included (INC) or excluded (EXC), or have their insertion decided upon automatically (AUTO) based on having 50% of their crown area inside the area, or based on their "centre of gravity" (stem?) being inside (CGRAV) the training area. POINTS is a separate case in which the EXTBIT bitmap contains pointers to the tree crowns to consider.

- SDBOUT: Specifies the name of an optional Signature output file. If a filename is specified, the signature information for each ITC and the species signatures will be written to a plain text file, making possible more detailed analyses later (e.g., SAS, Splus, Excel).

- REPORT: Use same default as before

4) When all of the species (and species in specific situations) signatures have been generated, run the ITC classifier by selecting **ITCSC**



ITCSC (Individual Tree Crown Supervised Classifier) classifies the individual tree crowns (ITCs) of an image into different species using a Maximum-Likelihood decision rule. The classification is based on comparing the signature of each ITC, one by one, with the ITC-based signatures of the various species. These species signatures must have been produced by the ITCSSG program. A series of bitmaps is produced showing the results of the classification. One bitmap per species is generated showing the ITCs classified to that species.

Some information that may be required to run ITCS

- FILE: Use the default

- DBIC: Specifies the channels holding the input images.

- SCHINDX: Optional index (1-8) to select by their order which channels in the species signatures match the DBIC channels (i.e., which channels are spectrally compatible). Useful when signatures were ported from another image (typically a sub-area) with different channel ordering.

- ISOLBIT: Typically specifies a bitmap of individual tree crowns (ITC's) produced by the ITCISOL program.

- SIGNSEG: Specifies a list of segments containing each a species signature typically generated from the ITC bitmap and training areas by ITCSSG. These ITC-based species signatures are used by the maximum-likelihood classifier to classify the individual trees.

- CLASSBIT: Specifies a list of segments to which the bitmaps resulting from the classification will be written. Need only be entered to overwrite specific existing bitmaps. If an output segment is not valid, a new segment will be created to contain the information.

- CLASCODE: This optional parameter allows the user (if desired) to enter a specific class code (e.g., 183) for each class to improve reporting of classification results in output layer (when ITCSC is used in vector mode). Otherwise, classes are reported with just an index code corresponding to their order (0-15) in SIGNSEG.

- EXTBIT: Specifies a segment, which contains an Extra Bitmap Mask. This is an additional bitmap, which is used to indicate which subparts of the crowns should be used to generate the signature (e.g., LIT side). Generally, this is a bitmap generated by the ITCMG program.

- SIGTYPE: specifies which type of signature is to be used. Possible types include: MEAN/TCL/TCL2/TEXTUR/STRUCT. Refer to ITCSSG for a complete explanation.

- TREETYPE: Specifies whether signature generation (SSG) and classification (SC) are to be done based on a full crown per tree (type = ITC) or only one pixel per tree crown (type = TT), the so-called "tree tops" type of ITCMG (local maximum *within* an ITC). The default is ITC. TT can only be used with SIGTYPE=MEAN and an Extra bitmap (EXTBIT) of treetops. LIT and SHADE extra bitmaps are used with TREETYPE=ITC.

- TRESHLD: Specifies a classification threshold level for the maximum-likelihood classifier. Values may be between 0 and 1 (typical values are 0.95 and 0.99). Trees that are outside the confidence interval (e.g., 0.95, 0.99) of the class they are "the closest to" are left unclassified. For NOW, leaving this value empty is equivalent to entering a value of 0.99. A value of 1 indicates that all trees should be classified (i.e., a tree is assigned to the closest class independent to how far from its cluster it may be). This is not appropriate when some significant classes are known to be missing. For example, having no hardwood class when hardwoods are known to be present.

- DBOUT : Specifies an optional Output Text Filename. If a filename is specified, the individual signature information for **each** tree crown is written out to a text file. Species signature information is also written to the file. If no filename is specified, then no database is created. This is mostly used for debugging and in depth analysis. Its use is **not recommended,** as the file **COULD BE HUGE!!!** for anything but a very small image.

- REPORT: Use same default as before

5) One way of verifying a classification's accuracy is to use test areas (or test trees), similar, yet distinct, from the training areas. Given such test areas in separate bitmaps (or vector layers), one bitmap for each species or class of interest, use **ITCCA** to obtain a classification confusion matrix.

ITCCA (Individual Tree Crown (ITC) Classification Accuracy) determines the classification accuracy of an ITC classification. A confusion matrix is generated, based on the testing bitmaps that the user specifies and the bitmaps produced from ITCSC, as a result of the classification. The result is a table (matrix) showing both counts of trees and percentages, plus the average accuracy and the overall accuracy. As well, the counts for unclassified trees are included (percentages and accuracy reflect the presence of the unclassified trees). The Kappa Coefficient and Kappa Variance are also calculated (not including the unclassified trees in the classifications). The average crown area of the correctly classified tree crowns is displayed.

```
ITCCA is controlled by the following global parameters:

 Name     Prompt                                   Count   Type

 FILE     PCI Database File Name                   64      Char
 ISOLBIT  ITC Bitmap from ITCISOL                  1       Int
 TESTSEG  Testing Area Bitmaps/polygons            16      Int
 CLASSBIT Classification Bitmaps                   16      Int
 POSBIT   Pointer Bitmap  (Tree positions)         1       Int
 BITBOUND Boundary ITCs:INC/EXC/AUTO/CGRAV/POINTS 64      Char
 REPORT   Report Mode: TERM/OFF/filename           64      Char
```

Some information that may be required to run ITCCA

- FILE: Use the default

- ISOLBIT: Typically specifies a bitmap of individual tree crowns (ITC's) produced by the ITCISOL program.

- TESTSEG: Specifies the list of Testing Bitmaps (or vector layers) to be used. These bitmaps generally contain filled areas covering parts of homogeneous stands of known species. One testing bitmap is used per species (class) and compared against the classification results for that species (class), thus building up the confusion matrix leading to the estimation of classification accuracy. Species order must be the same as the classification bitmaps (CLASSBIT).

- CLASSBIT: Specifies a list of Classification Bitmaps. These are bitmaps that were generated by the ITCSC program and are the result of an ITC classification. One bitmap is specified per species, showing the ITC's classified into that species. This is compared against the Testing Bitmaps

(TESTBIT) in order to generate the confusion matrix leading to the estimation of classification accuracy. Test areas and test trees are usually independent (distinct, no overlap) from training areas and trees.

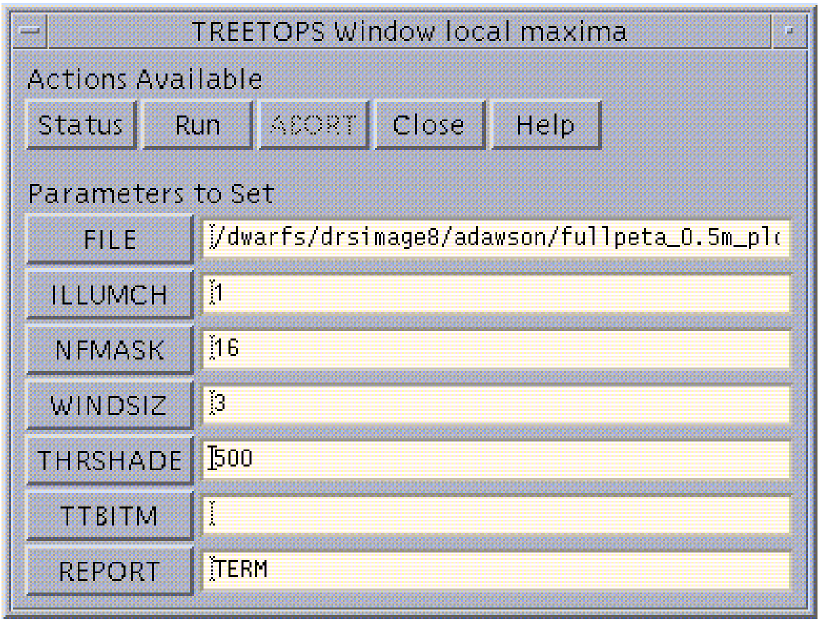
- POSBIT: Here, only used in BITBOUND = POINTS mode. The POINTS mode is a separate case in which the EXTBIT bitmap contains pointers to the tree crowns to consider.

- BITBOUND: Possible values: INC / EXC /AUTO / CGRAV / POINTS (see ITCSSG for explanation)

- REPORT: Use same default as before

Regeneration Assessments

a) The crown delineation processes (ITCVFOL&ITCISOL) may have difficulties with small trees (e.g., regeneration); or mature, yet small diameter crown trees (e.g., black spruce); or, large mature trees but on images of poorer spatial resolution. To detect these small, yet apparently visible trees, in medium to densely populated areas, select **TREETOPS**



TREETOPS (Program to create a "tree top" bitmap) This program moves a window of a given size on an input image and detects the local “centered” grey-level maximum of each window's instance. When finished, it writes the "tree tops" to an output bitmap.

TREETOPS is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	Database file name (for input/output	64	Char
ILLUMCH	Input Illumination (B&W) Channel	1	Int
NFMASK	Bitmap to mask out non-forested area	1	Int
WINDSIZ	Size of moving window (e.g.,3,5,7)	1	Int
THRSHADE	Threshold to removed shaded areas	1	Int
TTBITM	Output bitmap of tree tops	1	Int
REPORT	Reporting device	64	Char

- FILE: Use the default

- ILLUMCH: Specifies the input illumination channel. See ITCVFOL for explanation.

- NFMASK: Bitmap to mask out non-forested area. Use this parameter to prevent tree tops from being found in non-forested (or any undesired) areas.

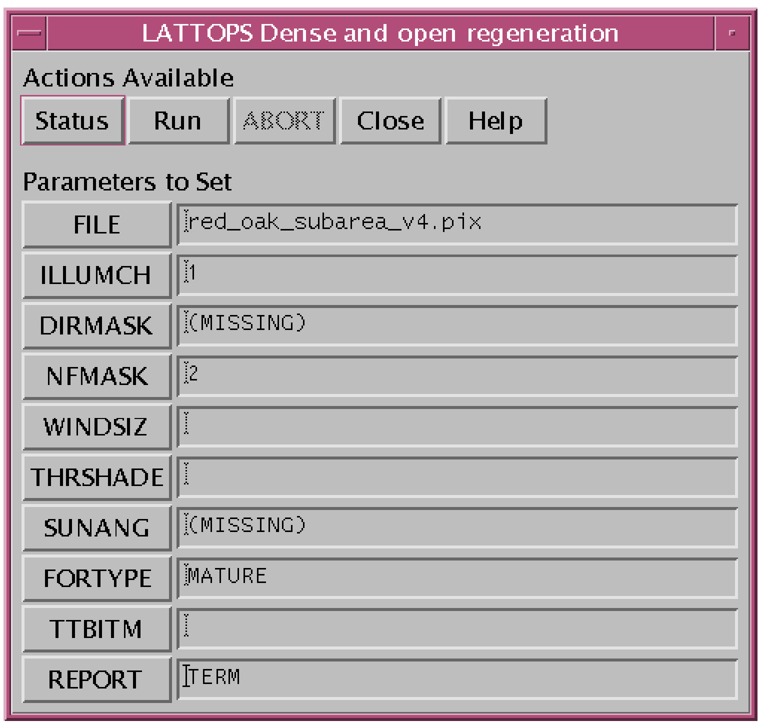
- WINDSIZ: Size of moving window (e.g.: 3, 5, or 7) Local maxima will be gathered from centre of window of size WINDSIZ*WINDSIZ. (If unspecified, 3x3 is default)

- THRSHADE: Threshold to remove shaded areas. Use this parameter to prevent tree tops from being found in purely shaded areas. HINT: Use the typical value found at interface between crown material and shaded background area.

- TTBITM: Specifies an optional output bitmap number in which to write the treetops. (If none specified, a new bitmap is created)

- REPORT: Use same default as before

b) For the trees mentioned above (in (a)), but that are located in dense as well as open areas, select **LATTOPS**. It finds treetops surrounded by shade in dense areas and treetops with specific shadows in more open areas, as designated by the directionality mask (DIRMASK).



LATTOPS finds treetops in densely forested areas and treetops with specific shadows in more open areas, as designated by the directionality mask (DIRMASK).

This program moves a window of a given size on an input image and detects the local centered grey-level maximum of each window's instance. For the areas covered by an input mask (DIRMASK) (i.e., directionality mask), it keeps only those max. with a significant low grey level area (i.e., a shadow) in the direction commensurate with SUNANG (180^o + SUNANG). (N.B.: The angle assumes North at top of the image)

Optionally: Operation under the directionality mask (open areas) are done on a smoothed version of the image, if supplied as b in ILLUMCH = a,b. This may improve results.

Optionally: If DIRMASK=1, trees from the whole image (except under NFMASK) are considered to have discrete shadows (used to be done with program SHADOW_TT)

Some information that may be required to run LATTOPS

- FILE: Use the default

- ILLUMCH: Specifies the input illumination channel. See ITCVFOL for explanation.
- Optionally: Operation under the directionality mask (open areas) are done on a smoothed version of the image, if supplied as b in ILLUMCH = a,b. This may improve results

- DIRMASK: Input mask (a bitmap) with bits set for areas of high directionality due to shadows on the ground (typically from GRAD_DC, followed by THR). (i.e., densely treed areas don't have specific shadows, they exibit shade in between somewhat round tree crowns and thus, exhibit omnidirectionality or no specific directionality)

  ****Special cases****

  a) DIRMASK = 1, for which the whole image is considered to have directionality (i.e., trees generally have individual shadows everywhere in the image). This is equivalent to the old program SHADOW_TT.
  (Programming note : "1" can be used for this special case situation since segment 1 in a PCI file is the georeferencing segment and as such, could never be used to store a mask, thus no confusion here)
  b) When "DIRMASK =   ", the regular tree top (local maxima) algorithm is run throughout the image (except non-forest areas (NFMASK)). In this case, of course, SUNANG is disregarded.

- NFMASK: Bitmap to mask out non-forested area. Use this parameter to prevent tree tops from being found in non-forested (or any undesired) areas.

- WINDSIZ: Size of moving window (e.g., 3, 5, or 7). Local maxima will be gathered from the centres of window of size WINDSIZ*WINDSIZ. (If unspecified, 3x3 is the default)

- THRSHADE, THRSHADOW: Threshold to remove shaded areas from the analysis. Use this parameter to prevent tree tops from being found in purely shaded areas. When finding tree shadows, four pixels lower than THRSHADOW must be found in a 3x3 window at suspected shadow location (based on SUNANG) (i.e., shadows are assumed brighter than the deep shade between trees in dense forest)

  HINT: For THRSHADE, use the typical value found at interface between crown material and shaded area in a DENSE forest. For THRSHADOW, use the typical value found at interface between the crowns (or the lit background) and their shadow, specially if only interested in trees with shadows (DIRMASK=1).

  EASI>THRSHADE=n,m

  If a second value is not specified, THRSHADOW is calculated as follows:
  THRSHADOW = 1.3 * THRSHADE

- SUNANG: (Angle of sun relative to image) Specifies the sun illumination angle (in degrees) relative to image. N.B.: This is not always the sun azimuth (relative to true North). This is the angle of sun illumination relative to the image, as if North was atop the image. It is sun azimuth only if the image was geometrically corrected. Also, this is not the angle of the shadows, but that of the sun's illumination (180o more).

- FORTYPE: Forest type (MATURE/REGEN/BIG/PROMPT) Specifies the type of forest to analyse. Possible values are MATURE, REGEN, BIG and PROMPT, defaults to MATURE. Depending on this parameter, LATTOPS looks at different distances for a shadow area (in the direction opposite to SUNANG). If REGEN, MATURE, or BIG is specified, distances of 2, 4 and 6metres will be calculated from the pixel size. Think of it this way: shadows seen from above have to start at a distance that is as a bit more than the typical crown diameter. If PROMPT is specified (or anything else), the user will be prompted for a distance, in pixels.

- TTBITM: Specifies an optional output bitmap number in which to write the treetops. (If none specified, a new bitmap is created)

- REPORT: Use same default as before

c) **GRAD_DC** (Gradient directionality content)

Program that produces an output image related to the amount of gradient directionality found in small areas (blocks) of the input image in a direction commensurate with the sun illumination angle (SUNANG). It is typically used to produce the DIRMASK needed by LATTOPS by thresholding the resulting image.

GRAD_DC is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	1-64	Char
DBIC	Database Input Channel	1	Int
DBOC	Database Output Channel	1	Int
IBS	Size of blocks used (IBS*IBS)	1	Int
SUNANG	Angle of sun relative to the image	1	Int
REPORT	Specifies the file to append report	1-64	Char

Some information that may be required to run GRAD_DC :

- FILE: Specifies name of PCIDSK database file from which image channels are
    - read and written.

- DBIC: Specifies the input channel (database channel) Note: Only one channel

- DBOC: Specifies the output channel (database channel) Note: Only one channel

- IBS: Block size (or window size) A window (IBS*IBS) that is used to accumulate directions and calculated a directionality factor (or index) Typically, IBS is 20 or 30, for 20x20 or 30x30 directionality summarization

    - **NOTE**: Gradient magnitudes and directions are calculated using a 7x7 window (IWS) independently of the reporting block size (IBS).

- SUNANG: Specifies the sun angle (in degrees) relative to image. NOTES: This is not always the sun azimuth (relative to true North). This is the angle of sun illumination relative to the image, as if North was atop the image. It is sun azimuth only if the image was geometrically corrected.

- REPORT: Specifies the file to append generated report to:

d) **STOCKING**

From a bitmap showing individual (distinct) tree crowns (TYPE=ITC) OR for one showing only a pixel per tree (TYPE=TT) OR for a bitmap containing both types (TYPE=BOTH) AND from bitmaps representing test areas, this program generates information about: stems/hectare, average crown area, average tree distances, stocking, ... for each of the testing areas.

This program optionally (GAPFL=”YES) generates a bitmap where sub-areas of the test areas that are devoid of trees (i.e. unstocked openings) are shown (if above a certain minimum size and other criteria based on the stand original prescriptions (PRESCRIP) or the apparent prescription).

STOCKING is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	64	Char
ITCBM	Bitmap of tree crowns or tree tops	1	Int
TREETYPE	Tree Type: TT/ITC/BOTH	64	Char
TESTBM	Bitmaps of test areas	16	Int
PRESCRIP	Original prescription for test areas	16	Real
GAPFL	Is a GAP bitmap desired (YES/NO)?	64	Char
GAPBM	Bitmap of unstocked areas	1	Int
REPORT	Reporting device	64	Char

- FILE: Specifies the name of the PCIDSK file containing the input and output bitmaps (themes).

- ITCBM: Specifies a bitmap, showing individual (distinct) tree crowns (TYPE=ITC) (such as the one generated by program ITCISOL) or for one showing only a pixel per tree (TYPE=TT) (such as produced by programs such as TREETOP or TT_BOTH or SHADO_TT, or ITCMG (TYPE=TT)) to be used as reference in evaluating

- TREETYPE: Specifies the type of information we have about the tree crowns in the input bitmap (ITCBM). Either a full crown per tree (type = ITC) or only one pixel set per tree crown (type = TT), the so called "tree tops" type, or a combination of both (best of both worlds)

- TESTBM: Specifies the input bitmaps showing the testing areas for which we want to know stems/hectare, stocking, etc. figures.

- PRESCRIP: Original prescription for above test areas if known (i.e., density that the stand was supposed to have been planted with). This parameter permit better precision on detection of gaps and estimation of proper stocking. If unknow, it will be estimated from current stem density assuming it is spread evenly on the test area (stand).

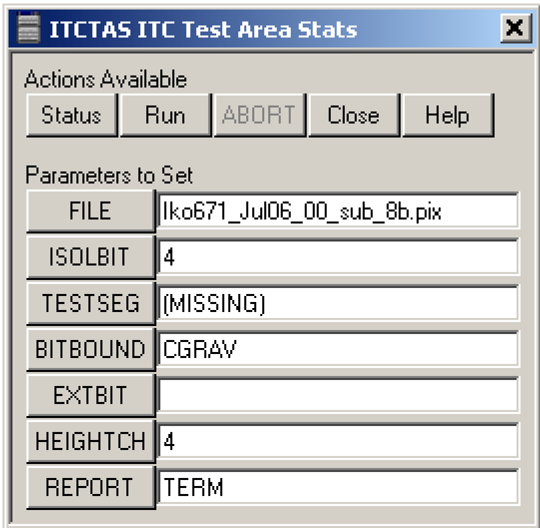
- GAPFL: Specifies whether an output bitmap of unstocked areas (or canopy openings), areas devoid of trees, is required (YES or NO)

- GAPBM: Specifies the output bitmap where the unstocked areas (devoid of trees) will be written (if GAPFL=YES)

- REPORT: Specifies the file to which the generated report should be appended.

Other Useful ITC Programs

A simple way to get basic forestry information for a few given test areas represented each by a bitmap or a polygon (in a vector layer) is to use **ITCTAS :**



ITCTAS (ITC Test Area Statistics) outputs a number of statistics based on the crowns found in testing areas and can optionally dump to a file individual tree information such as: location, crown area, height, ... (N.B.: Not to be confused with ITCDUMP, which dumps individual tree signatures)

The following information is generated:

o Segment number
o Number of Crowns
o Average Crown Area (in pixels and square meters)
o Total Testing Area (in pixels and square meters)
o Stems Per Hectare
o Crown Closure.
o Uncounted ITC (cause of BITBOUND)
o Average ITC height

Some information that may be required to run ITCTAS

- FILE: Use the default

- ISOLBIT: Specifies a bitmap of ITCs typically produced by the ITCISOL program, to be used as the basis of the tree crown information generated for the given testing areas.

- <u>TESTSEG</u>: Specifies a list of testing area bitmaps or vector layers of polygons to be used. These bitmaps contain filled areas, typically delineated by the user on the screen. These test areas are often different from the training areas used in ITCSSG and from the testing areas used in ITCCA. They maybe areas of interest for which the above information is required.

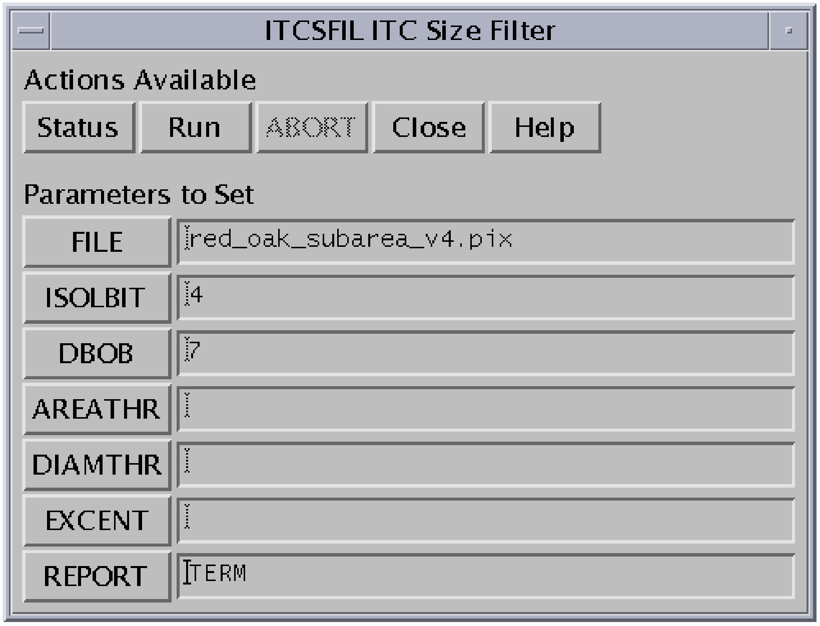
- <u>BITBOUND</u>: Possible values are:
  INC / EXC /AUTO / CGRAV / POINTS
  (please see ITCSSG for explanation).

- <u>EXTBIT</u>: Here, only used in BITBOUND = POINTS mode, POINTS is a separate case in which the EXTBIT bitmap contains pointers to the tree crown to consider.

- <u>HEIGHTCH</u> Optional height channel (i.e., DCM). A channel (8 or 16 bit) containning a height-related image, like a Digital Canopy Model (DCM) from Lidar first returns (DCM=DSM-DTM). If specified, height information will be reported using the maximum height within each tree crowns (ITC).

- <u>REPORT</u>: Use same default as before

ITCSFIL can be used to filter tree crowns by size (and even excentricity):



ITCSFIL (ITC Size Filter)
From a bitmap showing individual tree crowns (ITCs) (such as the one generated by program ITCISOL), this program generates a bitmap containing only the crowns within a certain range of crown sizes (using lower and upper thresholds (in pixels)), or a certain range of diameters (using lower and upper thresholds (in meters) of crown diameters). It can also filter for crown "good shape" based on a **very crude** excentricity criteria (ratio of X direction diameter vs Y diameter).

Some information that may be required to run ITCSFIL

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

- ISOLBIT: Specifies a bitmap showing tree crowns, typically produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as input.

- DBOB: Specifies an output bitmap to contain only the crowns of a certain size found from ISOLBIT. If not specified, a new bitmap is created.

- AREATHR : Range of crown sizes (in pixels) to keep in output bitmap. Only one of AREATHR or DIAMTHR can be used. If both AREATHR and DIAMTHR are left blank then a default size range of 4 to 999 pixels is used.

  EASI>AREATHR=n,m | keeps crowns with size between n and m pixels
  EASI>AREATHR=n | keeps crowns with size above n pixels

- DIAMTHR : Range of crown diameters (in meters) to keep in output bitmap. Only one of AREATHR or DIAMTHR can be used. If both AREATHR and DIAMTHR are left blank then a default size range of 4 to 999 pixels is used.

  EASI>DIAMTHR=n,m | keeps crowns with diameter between n and m meters
  EASI>DIAMTHR=n | keeps crowns with diameter above n meters

- EXCENT : Max. excentricity to be tolerated. This is a form factor for good shape based on excentricity, a ratio of one diameter versus the other.

  For example, you may want to only tolerate up to a 2:1 form factor (i.e., one diameter is at max twice the size of the other), then use EXCENT=2.0 (or EXCENT=2)
  NOTE: The diameter are taken purely in the line and pixel directions (i.e., elongated tree crown at a 45o angle to the image will not be considered excentric).

- REPORT: Progress reports can be sent to terminal (TERM) or to a file

Generating forest stand polygons

ITC-based forest stands can be generated semi-automatically by using the procedure outlined in **Figure 2** (reproduced next page). It involves generating crude images representing important stand features such as stem density, crown closure and species composition; feeding them to an unsupervised classifier; filtering the results and rendering them in vector format. If forest/tree height is available via a Digital Canopy Model, this can also be taken into consideration by this process.

The forest stands created following this methodology are thus based on species composition, crown closure, stem density and height, essentially the same factors used by photo-interpreters. The same methodology could be used to introduce additional factors such as elevation, slopes or aspects, if a Digital Terrain Model is available.

The concept of species composition is a difficult one to convey directly to a computer and thus, this methodology relies on a surrogate approach. To effectively convey species composition, images of crown closure (or stem density) of each species (in addition to the overall ITC stem density and crown closure) are fed to the system.

All these crude (smoothed) images are fed to a standard pixel-based unsupervised classifier (e.g., FUZCLUS), the user asking for a certain quantity of classes (e.g., 10). The user should do a few iterations asking for a different quantity of resulting classes, until he/she is satisfied that it leads to a breakdown into decent forest stands, always keeping in mind that classes can easily be aggregated to create a more desirable breakdown. The pseudo-color look-up table is a good tool to look at these classes and practice with combining some of them, remembering that the final aggregation will need to be burned into a final 8bit channel.

Once the user is satisfied that the breakdown achieved would create decent forest stands, PCI's SIEVE can be used to remove areas smaller than the minimum prescribed by the authorities (e.g., no stand < 4ha.). These areas will be merged into the dominating class surrounding them. A filter like PCI's FMO should also be used to smooth the boundaries such that the final polygons to be produced will not have lines that are unnecessarily jagged.

Finally, PCI's RAS2POLY can be used to produce the vector layer that will have the forest stands polygons. Once such stands have been created (or for any other polygons), the task ITCPCD can be used to summarize the detailed ITC content of each polygons, producing information similar to that a forest inventory maps. If forest/tree height is available via a Digital Canopy Model layer, height statistics can also be included in such report (see ITCPCD).

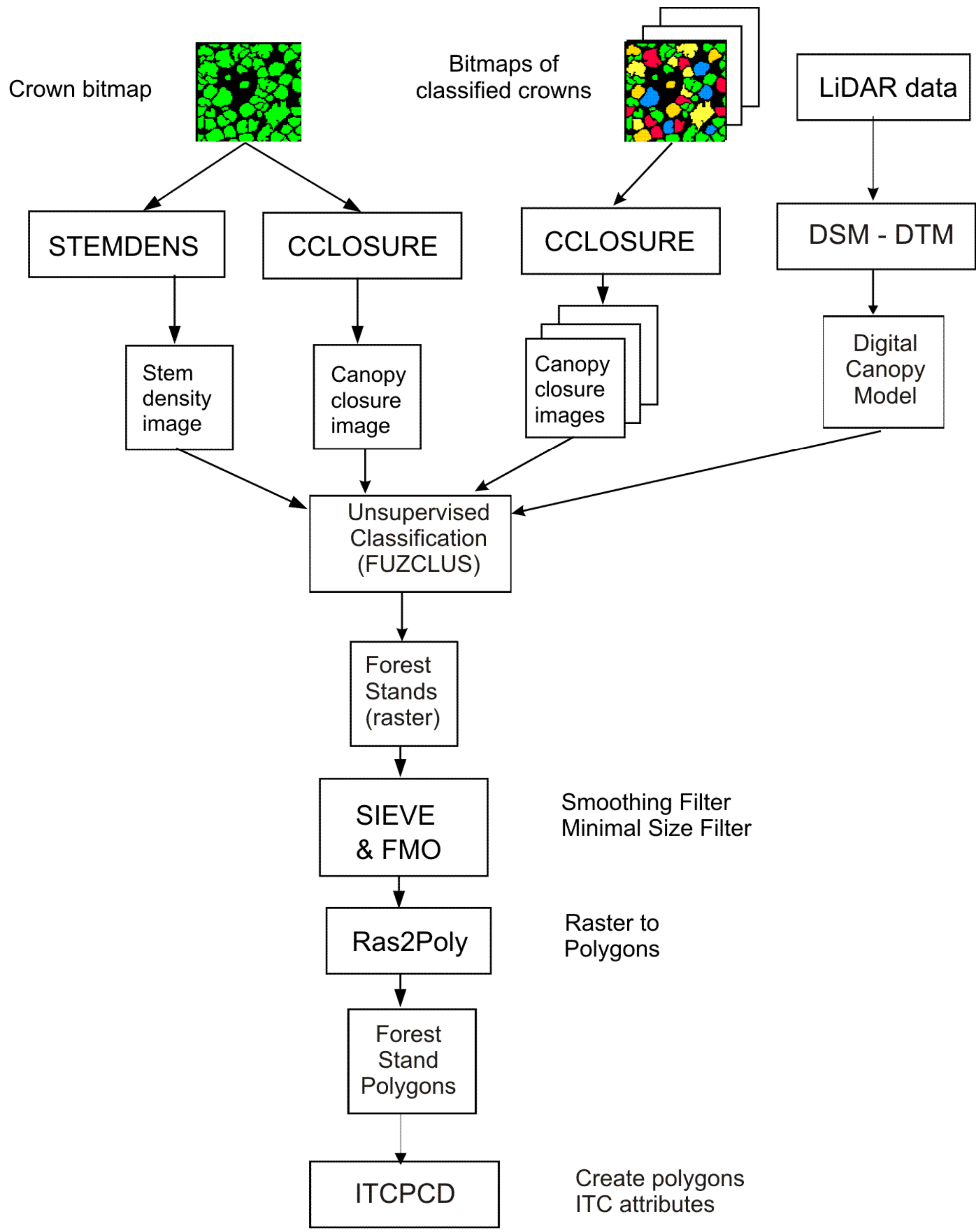


Figure 2 - Methodology for generating forest stand polygons from ITC information

Here are a few practical aspects:

- Since numerous intermediate images are produced using this methodology, it is useful to create an independent PCI image (in a separate directory) to work at stand creation. It is generally sufficient to move the ITC bitmap, the class bitmaps and a few non-forest, non-vegetation, and non-image bitmaps to such a file, while creating numerous empty 8bit channels before proceeding.

- The program SIEVE is limited as to the size of area (in pixels) it can filter. It may be desirable at that point to move to a cruder resolution image with a spatial resolution of 1m or 2m, to be able to run SIEVE properly. This should also facilitate the job of border filtering with FMO.

- In complex species situations, where the process generates too much detail, and the user finds it hard to control by simply asking for less classes from the unsupervised classifier or by simply aggregating classes, one may decide to use only hardwood and softwood as species.

The following tasks, often used to produce forest stands, can also be of interest on their own. The **STEMDENS** program generates a raster image where each pixel value is relative to the number of stem/hectare in a given neighbourhood. The **CCLOSURE** program generates a raster image where each pixel value is relative to the canopy closure in a given neighbourhood. **CROWNSIZ** is a similar program producing a crude image where grey levels are proportional to crown sizes. They mostly use the same variables.

STEMDENS : From a bitmap showing individual tree crowns (ITCs), such as the one generated by program ITCISOL, or for one showing only a pixel per tree (TTs) such as produced by programs such as TREETOP or LATTOPS, this program generates a raster image where each pixel value is relative to the number of stem/hectare in its neighbourhood.

CCLOSURE (Canopy (or crown) closure): From a bitmap showing individual tree crowns such as the one generated by program ITCISOL, this program generates a raster image where each pixel value is relative to the canopy closure in a given neighbourhood.

CROWNSIZ : From a bitmap showing individual tree crowns such as the one generated by program ITCISOL, this program generates a raster image where each pixel value is relative to the size of crowns in a given neighbourhood.

Some information that may be required to run these software tools

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

- DBIB: Specifies a bitmap, generally produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as input data in evaluating the required feature

- DBOC: Specifies the output image to contain the results

- TREETYPE : Specifies whether the input bitmap contains ITC's or TTs (used only with STEMDENS)

- NFMASK: Specifies an optional input bitmap (non forested mask) to be used as mask eliminating certain areas from processing. For exemple: to eliminate roads, pastures, open areas, etc. It also ensures that stem density (crown closure) falls immediately to zero at these locations. It also ensure that stem density (crown closure) does not decrease slowly as it approaches these areas.

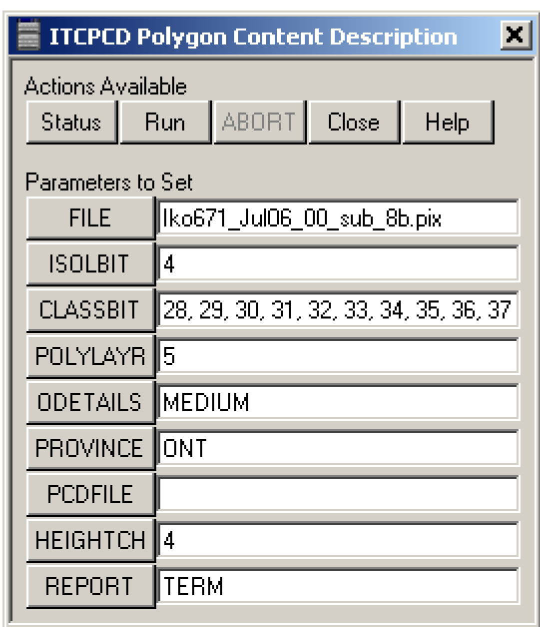
- REPORT: Progress reports can be sent to terminal (TERM) or to a file.

To summarize the ITC information within forest stand polygons

ITCPCD (Individual Tree Crown Polygon Content Description) is the main task to report on ITC information within forest stand polygons (or any other set of polygons). The forest stand polygons may have recently been generated from an ITC analysis with the methodology outlined in Figure 2 or maybe come from an existing conventional forest inventory (useful for comparisons). Attributes (fields) describing the ITC content of a given polygon will be appended to the existing attributes or, the ITC content of the polygons can be printed to a text file (PCDFILE).

The following information is generated for each polygon:

- o Polygon area
- o Number of crowns, total and for each class
- o Crown Closure percentage, total and for each class
- o Stems/Hectare, total and for each class
- o Class percentage of total stem density
- o Average ITC diameter, total and for each class
- o Average ITC height, total and for each class
- o Standard deviation on ITC height, for each class



ITCPCD is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	PCI Database File Name	64	Char
ISOLBIT	Bitmap of ITCs (from ITCISOL)	1	Int
CCLASSBIT	Class Bitmaps	16	Int
POLYLAYR	Input Vector Layer containing polygons	1	Int
ODETAILS	Output level of detail required in PCDFILE	64	Char
PROVINCE	Prov. jurisdiction of interest (affects CC%)	64	Char
PCDFILE	Optional text file to get ITC info. by stand	64	Char
HEIGHTCH	Optional height channel (i.e., DCM)	1	Int
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILE: PCI Database File Name. Use the default .pix file for the project.

- ISOLBIT: Specifies an Individual Tree Crown (ITC) bitmap (typically produced by the ITCISOL).

- CLASSBIT: Specifies a list of Class bitmaps to be used. These bitmaps typically contain ITCs classified by ITCSC, each bitmap representing a single class (or species).

- POLYLAYR: The input/output layer which holds the inventory polygons and to which additional fields will be appended (unless PCDFILE is used).

- ODETAILS: Output detail level.

When asking for a printed output (via PCDFILE) :

LOW	Polygon area (pixels and hectare) and ITC counts
MEDIUM	Same as HIGH
HIGH	Reports on all of the species in the polygon (same order as bitmaps)

When adding attributes to a vector layer (POLYLAYR):

LOW	Polygon area (pixels and hectare) and ITC counts
MEDIUM	Reports on the five most important (by closure) species in the polygon
HIGH	Reports on all of the species in the polygon (same order as bitmaps)

To get more control over the species ordering when adding attributes to a vector layer, variations of the above parameters were introduced. They are:

HIGHSP	All of the species in the same order as that of thebitmaps.
HIGHCC	All of the species ordered by crown closure.
HIGHITC	All of the species ordered by ITC counts.
MEDIUMCC	The five (5) main species as ordered by crown closure.
MEDIUMITC	The five (5) main species as ordered by ITC counts.

- PROVINCE: Specifies the provincial jurisdiction of interest (QUE, ONT, BC, NB, AB, …). As this point in time, it only affects the way crown closure (CC) is reported. For example, provinces may have a different crown closure definition:
  1. Québec species CCs sum up to stand CC (say 66%)
  2. Ontario species CCs sum up to 100%
  3. Other provinces, species CCs sum up to 100%

- PCDFILE: Specifies an optional output file (plain text) in which to write the polygon (forest stand) ITC content information.
  N.B.: If this parameter is used, the generated information is NOT appended to the vector layer. Information for all species (not just the most dominant one) will be reported in the same order as that of the classification bitmaps (CLASSBIT) order, whether a MEDIUM or HIGH level of detail was requested.

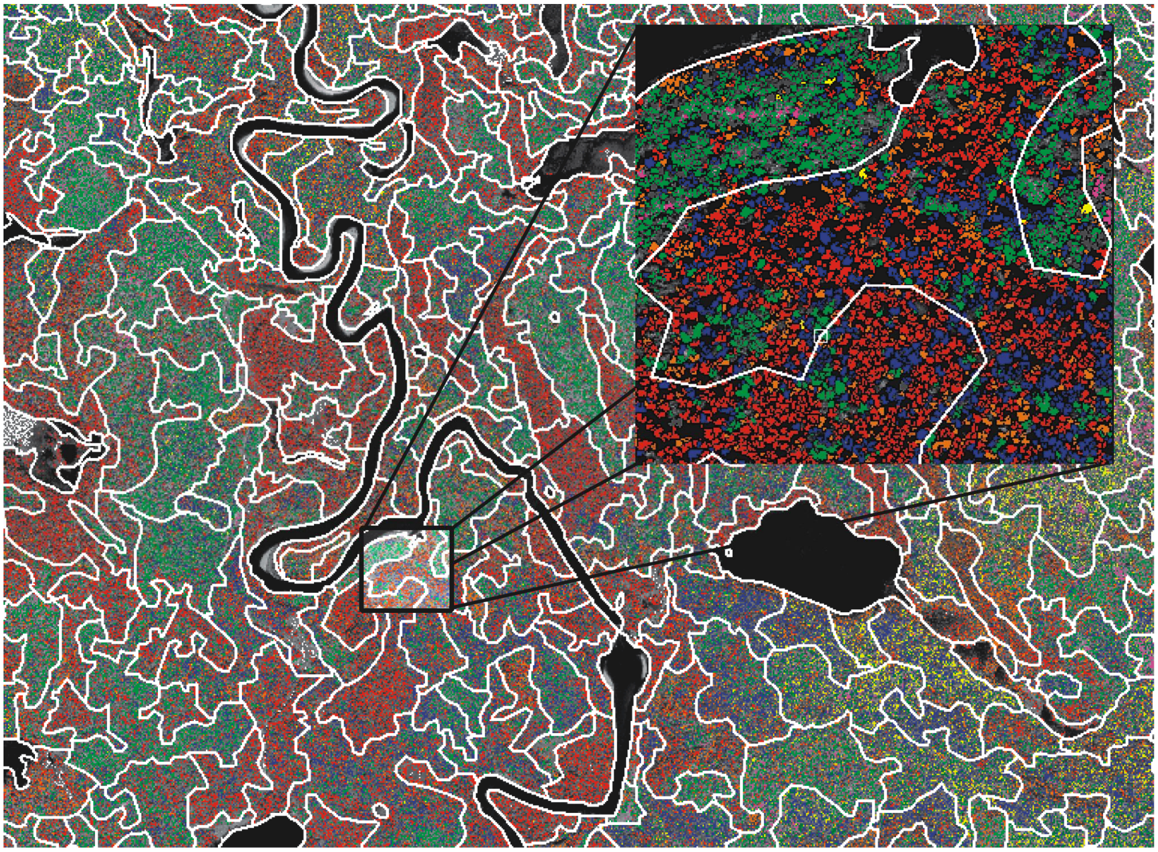
  HEIGHTCH: A channel (8 or 16 bit) containing a height-related image, like a Digital Canopy Model (DCM) from Lidar returns (DCM = DSM - DTM). If specified, height information will be reported using the maximum height within each tree crowns (ITC). HINT: If low memory availability, make sure to use an 8bit image for HEIHTCH as 16bit images typically load as 32bit (requiring 4 times more memory) and 256 levels are enough to convey height up to 64m in 0.25m increment.

- REPORT: Specifies the file to which the run report should be appended.

Example of ITCPCD results

Area(p)	Area(ha)	ITCs	Closure	Density	SP01	ITCs01	PER01	CC01	SD01	DIA01	SP02	ITCs02
344478	8.61	2329	59.2	270	49	1193	51.2	62.5	138	5.8	50	…
394856	9.87	2858	57.3	289	50	1024	35.8	29.0	103	4.5	47	…
291189	7.28	1562	48.4	214	50	376	24.1	18.4	51	4.7	47	…
114189	2.85	797	56.4	279	50	478	60.0	54.9	167	4.9	49	…
751854	18.80	5330	56.5	283	49	1241	23.3	24.7	66	5.2	50	…
963858	24.10	6416	52.0	266	46	2087	32.5	38.3	86	5.4	49	…
226425	5.66	1456	60.1	257	49	603	41.4	45.5	106	5.7	50	…
290765	7.27	2060	56.2	283	49	605	29.4	29.8	83	5.1	50	…
321607	8.04	2392	55.8	297	49	766	32.0	29.6	95	4.7	46	…
155049	3.88	1116	56.6	287	49	511	45.8	43.7	131	4.9	46	…
249622	6.24	1743	58.2	279	50	628	36.0	30.1	100	4.7	49	…
648686	16.22	4386	58.0	270	50	2218	50.6	53.2	136	5.4	51	…

An example of ITC results

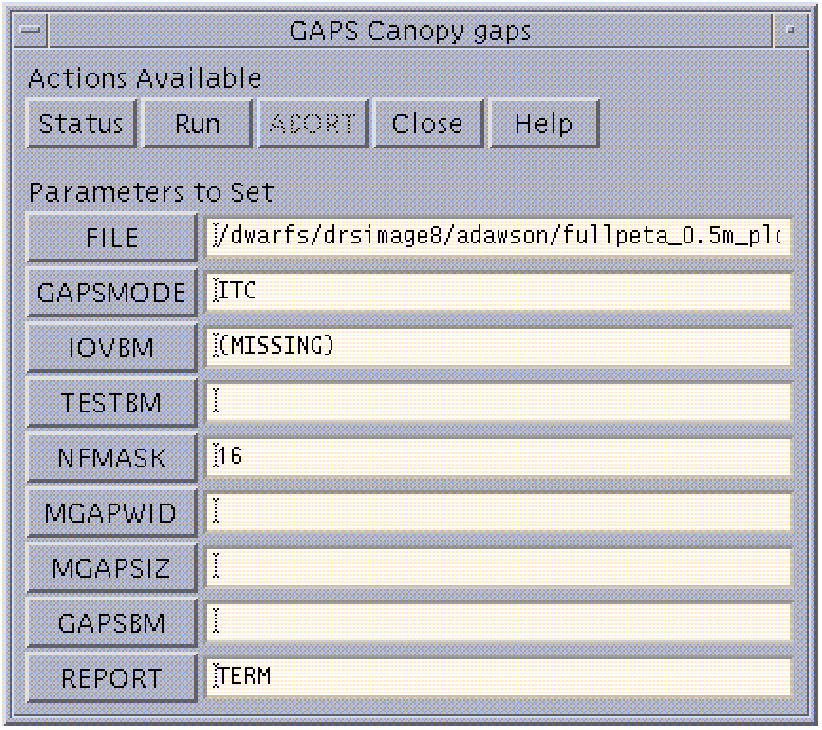


Cover image from BC-X-396 (see ref. on page 9) : Results of species classification and regrouping of individual tree crowns and tree clusters over the original panchromatic IKONOS image (1 m/pixel) for part of a 10 000 ha area (11.7 x 8.6 km^2) in the "Lac à l'Ours" region of Québec that was analyzed with the individual tree crown approach. This work was done in collaboration with CLC-Camint (Gatineau) and Industries Davidson Inc. and was funded in part by the "Programme de mise en valeur des ressources du milieu forestier - Volet 1" of the Quebec Department of Natural Resources. The tree species in the forested areas are indicated by the following colours:

White pine	Red
Fir-Spruce	Brown
Cedar	Orange
Maple	Cyan
Poplar	Blue
White birch	Grey
Yellow birch	Yellow
Other hardwood	Green
Regeneration	Lite green
Bare area	White

Canopy gaps

An interesting side-effect of the delineation of tree crowns in high spatial resolution images is the possibility to also analyse forest gaps. To do so, select **GAPS**



GAPS: From a bitmap showing (distinct) individual tree crowns (ITCs) (GAPSMODE = ITC) or a fuller vegetation mask bitmap (GAPSMODE = VEGM), and for bitmaps representing test areas (or for the whole image), this program generates a bitmap of forest gaps (patches or openings) showing areas that are devoid of trees (i.e., no canopy). The gaps are grown by a minimum expansion factor (MGAPWID = 2), typically 2m x 2m blocks, meaning that the growing process will not follow valleys of shade (areas devoid of tree crown or vegetation) that are not at least 2m wide. Later, gaps smaller than n square metres (MGAPSIZ=n) are filtered out (by default 2m * 2m or MGAPWID * MGAPWID). Within the program, each gap is considered an object and is stored in a list where descriptive parameters are stored. In full image mode (no TESTBM), average information about gaps and a histogram showing gap size distribution are output. For test areas (TESTBM = n,m,...), information about individual gaps are output. When ITC's are being used (GAPSMODE=ITC), this program also generates information about: stems/hectare, average crown area and diameter, canopy closure, etc., for each of the testing areas.

NOTE: To generate a surrogate gap density image (as opposed to a bitmap of specific gaps), one can use the program CCLOSURE and invert the resulting image grey-levels.

The program **GAPS** is controlled by the following parameters:

- FILE: Use the default

- GAPSMODE: Specifies whether IOVBM contains individual tree crowns, such as produced by the ITC suite, or a plainer vegetation mask, where trees are not differentiated (and thus info. such as stem density, etc, is not relevant).

- IOVBM: Specifies a bitmap showing (distinct) individual tree crowns (ITC) such as the one generated by program ITCISOL (GAPSMODE=ITC) or a plainer vegetation mask (GAPSMODE=VEGM), such as typically obtained by vegetation index or canopy closure program.

- TESTBM: Specifies input bitmaps containing the testing areas for which we desire to know about forest gaps (patches or openings). If none specified, the whole image is considered.

- NFMASK: Specifies optional input bitmaps (non forested areas) to be used as masks eliminating certain areas from processing and thus, of acquiring gaps statistics (e.g., average gap area). For example: to eliminate roads, pastures, man-made areas.

- MGAPWID: Specifies the minimum gap expansion width in metre (default MGAPWID= 2m). Gaps will be grown by this minimum expansion block (2x2). If such a block cannot pass between two trees than gap expansion in that direction is stopped.

- MGAPSIZ: Specifies the minimum gap area in m2 (default is MGAPWID * MGAPWID) desired. Gaps smaller than that desired size will be erase from the output bitmap (GAPSBM).

- GAPSBM: Specifies the output bitmap where forest gaps (or canopy openings devoid of obvious trees) will be written. If unspecified, a new bitmap will be created.

- REPORT: Use same default as before.

ITC-based forest inventory with aerial images

The process to achieve an ITC-based forest inventory for a given region using aerial images is essentially the same as the one outlined above for satellite images. However, because there are substantial differences between the two types of images, due to the sensors themselves or to the way the images are acquired and pre-processed, the ITC analysis process entails numerous additional considerations to insure good species recognition. A full overview of these considerations is beyond the scope of this manual thus, only BRDF corrections and some concepts of signature extension will be addressed in this section (see some papers at http://cfs.nrcan.gc.ca/index/gougeon-publications/4).

BRDF correction and normalization across the whole dataset

Since insuring radiometric consistency throughout the forested area to be analysed is essential for species recognition via digital image analysis, how can this be achieved and why is it desperately needed? The last question is the easiest to answer and will be addressed first.

Most of the processing tasks in the computer image analysis (i.e., ITC analysis) of a given forested area covered by satellite or aerial images can be made fairly automatic. The most significant human contribution, apart from fetching and organizing the datasets, is in the training of the ITC classifier to recognize the forest species of interest. It consists mostly in pointing out to the machine sample trees, or preferably sample areas (fastest), representative of all the species of interest, and sometimes, even of species in a specific situations (e.g., trees of species A on sun facing slopes, trees of species A on North facing slopes). Good interpretive skills and auxiliary data are needed for this endeavour and, knowing which situations to depict to the computer can be an art as well as a science.

The purpose of this training is to create spectral, textural, structural and/or contextual signatures that are representative of the species in given situations, in order for these signatures to be used to classify the bulk of the trees in the images. If these samples are to be picked up from anywhere in the image and/or from any image in a set of images, and if the resulting signatures are to be applied to the full forested area to be analysed, THEN all of these images will need to be radiometrically corrected and normalized to each other.

How do we achieve this? What are the factors affecting the uniformity of radiometry throughout a series of aerial images? What are the factors on a single aerial image?

The first and most important factor affecting the radiometry on a single aerial image is certainly vignetting. By vignetting we mean, the radial variations in apparent colour from the centre to the boundaries of the images due to the optic properties of lens and due to objects increasingly appearing to lean from the nadir view (above view) at the center of the aerial image. This is caused by the use of the wide angle lens (50-65^{o} *vs* 2-3^{o} for satellite sensors) needed to cover large areas at low altitude. The second most important factor is the sun's illumination angle making the objects on one side of the image essentially backlit, while they are front lit on the other side.

Differences in radiometry between aerial images are often attributable to the use of automatic exposure calibration (i.e., variable aperture and/or shutter speed), different acquisition times and atmospheric conditions (as neighboring lines are rarely sequential in time), the presence of clouds and/or cloud shadows, and often, as orthomosaics are generally preferred by groups without stereo viewing capabilities, the normalization and calibration processing, and the manual interventions (e.g., cloud removal) that are typically involved in making such mosaics as seamless as possible.

Push-broom sensors, gathering aerial images one line at the time, do not exhibit the radial distortions found with frame (2D) cameras, but they are affected by the sun's illumination angle and their wide across track view angle. Both these affects can be parametrized and partially alleviated by what are known as a BRDF corrections. Such corrections attempts too make the radiances on the image sides similar to that at the image centre. For a given sun illumination angle (azimuth and elevation), the bi-directional reflectance distribution function (BRDF) fits a curve to the distribution of radiances from one side of the image to the other. The correction aspect consists in substracting the inverse of the curve from the data, after having normalized it to have zero difference at nadir. By imposing a specific value at nadir to all the images, one can further normalized images between one another.

Although a normalization between images can be achieved with some sort of histogram equalization (or histogram matching), such process are typically adversely affected by the quantity of non-vegetation material (such as lakes, swamps, dead trees, sandy and rocky areas) present in a given image. Similarly, with BRDF corrections, vegetation is best corrected by analysing data gathered only from the vegetation. Such data should preferably be gathered from long strips (long flight lines) to minimize the effects of species composition within the forested areas.

To be more precise, data can also be gathered from numerous features (e.g, water, softwood, hardwood) such that multiple correction curves are applied to the image, one for each such feature. Small, conically-shaped coniferous trees will have a different BRDF than the bigger, more rounded crowns of typical hardwood trees. Ideally, a weighted correction curve taking all features simultaneously into consideration should be applied (Yuan and Leckie, 1992).

Similarly, the radial distortion patterns found with frame cameras (or scanned photos) can also be partially alleviated using a proper radial correction function, or at least, by running BRDF corrections in both directions.

MFPWBRDF (Multi-Feature Piece-Wise BRDF Corrections) calculates and applies Multi-Feature Piece-Wise BRDF Correction Curves to image channels such that the resulting image channels have their spectral values less influenced by view and sun angles (and possibly, additional color balancing done by the supplier of an image mosaic to render the image visually appealing to humans)

Piece-Wise means that a series of correction curves are calculated across the image, one for each vertical image strip of the mosaic. At this point in time, estimations of strips' border columns are supplied by the user via the parameter POSTS (see STRATEGY section).

Multi-Feature means that different corrections curves can be applied to different feature of the image (hardwood/softwood trees, shade) in order to correct their spectral values differently. This is usually helpful because different features react slightly differently to being front lit or being back lit, or being seen away from nadir. Bitmaps of these features (e.g., hardwood ITCs, softwood ITCS) are supplied by the user when numerous DBIB are used (see STRATEGY section).

Notes: MFPWBRDF can still be used to do the work of older BRDF programs such as BRDF_COR.F or PWBRDFCC.F

For examples:

- A generic (almost non-feature-based) correction is obtained by supplying a rather generic bitmap, such as the ITC bitmap, as the sole DBIB.
- A continuous (i.e., non-piece-wise) BRDF correction curve is achieved by NOT specifying any POSTS parameters (e.g., to correct a single image strip)
- Viewing only of histograms, fitted curves, and correction curves is achieved by not specifying any output channel (i.e., faster practice runs).

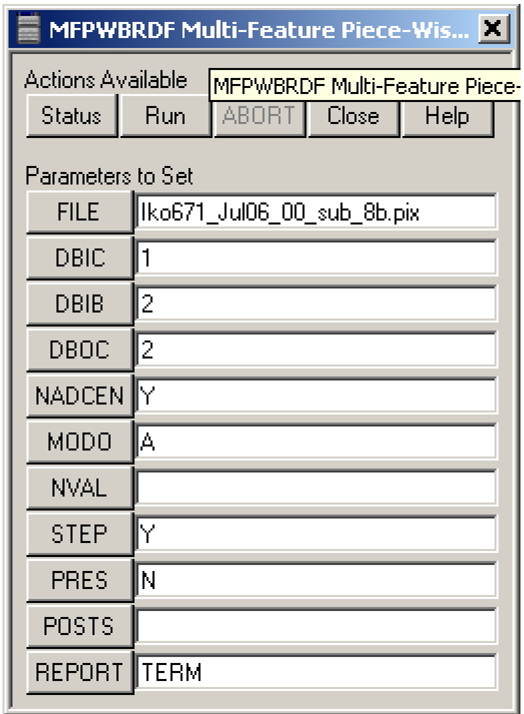
A strategy to run MFPWBRDF

To get typical features such as hardwood trees, softwood trees, shade:

- Run ITCVFOL and ITCISOL on the smoothed (FAV) nearIR channel.
- The VFOL bitmap can be then be used as the shaded area mask
- Do a quick ITC classification with only softwood and hardwood training areas to get the softwood and hardwood masks.
- Run MFPWBRDF using these three masks.
- At first, do dry runs (by not specifying any output channel)
- Look at the graphs such as in:

  xgraph columnCH*BM*.his fittedCH*BM*.curve &
- The graphs inflection points should be a good indication of where the image strips of the mosaic start and stop. Enter them as POSTS for the next run.

Note:
A texture image can also give good information about the mosaic stitches, as they usually have been fuzzyfied to make them less obvious to the naked eye (have weaker texture)



MFPWBRDF is controlled by the following parameters:

Name	Prompt	Count	Type
FILE	Database File Name	1-64	Char
DBIC	Database Input Channel(s)	1-8	Int
DBIB	Segment # for bitmaps to use as masks	1	Int
DBOC	Database Output Channel(s)	1-8	Int
NADCEN	Is nadir centered? (yes/no)	1	Char
MODO	Mode of operation (AUTO/MANUAL)	1	Char
NVAL	Normalization Value (to inforce)	1	Int
STEP	Step Smoothing Required	1	Char
PRES	Preserve Step	1	Char
POSTS	Column # at strip boundaries	1-8	Int
REPORT	Specifies the file for the report	1-64	Char

- FILE: Specifies name of PCIDSK database file from which the image channel and bitmap segment are read and written.

- DBIC: Specifies the input channel(s) needing BRDF corrections

- DBIB: Specifies the input bitmap (segment #) from the database to be used as a mask. The information for the column histogram and thus, the BRDF correction curve will only come from data under the mask. From example, a mask of individual tree crowns (ITCs) or one of softwood areas. With multiple features (DBIB>1), the correction curve generated from one feature (mask) is only applied to the image areas under that mask.

- DBOC: Specifies the output database channel(s) to store the corrected image. If DBOC is NOT SPECIFIED, it is assumed that only the column histogram, the curve fitted to the histogram and the BRDF correction curve are needed for visualization purposes.

- NADCEN: Specifies (yes/no) whether nadir is at center of the image file. Is nadir (roughly) the center column of the image file? Or are nadir(s) (in a multistrip image mosaic) aligned North-South? Nadir is typically at the center of the image with raw data or roughly corrected data or North-South aligned strip. Nadir is typically NOT a center column when an image is fully geometrically corrected (true north is at top) from a flight that was not flown North-South.

  IF NADCEN ="NO, the program finds a different center for each line and uses it to centre the BRDF curve. This is accomplished by moving all of the lines to the left side of a virtual internal image array.

- MODO: Specifies whether to run the program in automatic(AUTO) mode or in manual (MANUAL) mode. Unless you have specific needs that can only be met via the manual mode, use of the automatic mode is recommended. The manual mode allows the user to specify: the polynomial order, the histogram columns to be disregarded when calculating the correction curve (as not populated enough, thus non significant).

- NVAL: Normalization value(s) to enforce (Integer) at nadir. Parameter to set the levels to which the data will be normalized. NVAL is especially useful to normalize the image data relative to another image (e.g., for signature extension, to create a normalized mosaic of images). Typically NVAL enforcement is only used in such cases (i.e., typically, the user leaves NVAL unset (empty) for a single image run).
  Of course, we need as many NVALs as there are channels and features, as there will be that many curves to anchor on specific values.
  The order is: CH1F1 CH1F2 CH1F3 ... CH2F1 CH2F2 CH2F3 ... CH3F1

  In the old BRDF_COR program :

  If this parameter is left empty, the image data was normalized to the fitted curve value deemed to be at nadir (i.e., image center). (i.e., aprox. the average grey level at nadir as per the column histogram)

  In the MFPWBRDF program :

  If this parameter is left empty, the image data is normalized to the average grey level of the fitted curve (separately for each curve if multiple features (DBIB>1) and multiple channels (DBIC>1) are used.

- POSTS: Column #s at strip boundaries. If there are multiple strips within a mosaiced image, POSTS can be used to specify the image column # (i.e., pixel #) where each strip starts thus allowing for independent BRDF correction of each strip (i.e., the piece-wise aspect of MFPWBRDF). There can be up to eight POSTS. The number of POSTS is typically one less than the number of stips (i.e., first and last columns of image data are assumed POSTS by default).

- OTHER:

STEP	Step Smoothing Required	1	Char
PRES	Preserve Step	1	Char
SEED	Random number seed	2	Int
NOFF	Historical NBOFF,NCOFF,NPOFF	3	Real

Lots of historical parameters from task AC on ARIES that have to do with randomizing on a line by line basis the correction look-up table (i.e., curve) used for image correction in order not to produce noticeable column-based artifacts. If the correction curve modifies the data by only a few grey-levels across the image, the column where the correction changes by one grey-level (says -5 to -4 of correction) may be very noticeable especially on the screen with the "infreq" LUT or during subsequent classification of the image. Randomizing the position of that column as well as randomizing the value on both sides of the transition helps in producing a more natural looking image.

- Typical value may be:

```
STEP   - Step Smoothing Required (Y/N)          :Y
PRES   - Preserve step? (Y/N)                   :N
SEED   - Random Number Seed                     >   1357   1357
NOFF   - Historical NBOFF,NCOFF,NPOFF           >     2      2      2
```

*** This randomization may only be needed with poor 8 bit data. For example, with CASI 16-bit data, correction values for even a minor BRDF correction of the image can easily span 200 grey levels, thus the discrete correction LUT still appears like a continuous function.

- REPORT: Specifies the file to append generated report to:

ITC Signature-related Utilities

If you have not kept the statistical summary of the signatures you have generated with ITCSSG, you can use **ITCDSI** to redisplay the signature stats.

Note: This is also a good way to verify that a signature has not been corrupted (e.g., by moving it within the file or from other files)

ITCDSI (ITC-Suite Display Signature Information)

It displays the signature information contained in ITC signature segments. The following information is displayed for each signature: Segment Number, Training Bitmap Number, Number of Trees Processed, Input Channels, ITC Means and standard deviation for each channel, components of principal Eigenvector, Eigenvalues, and Covariance Matrix.

ITCDSI is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	64	Char
SIGNSEG	Signature Segment List	16	Int
REPORT	Report Mode: TERM/OFF/filename	64	Char

Some information that may be required to run ITCDSI

- FILE: Specifies the name of the PCIDSK file containing the input segments.

- SIGNSEG: Specifies a list of the segments containing species signature information.

- REPORT: Specifies the file to which the generated report should be appended.

ITCSSM Individual Tree Crown (ITC) Species Signature Merging

ITCSSM makes possible the merging of ITC-based signatures from different (BRDF corrected & normalized) images into a single ITC-type signature segment. The signatures can also come from the same file, and be directed to the same file, if desired.

This is useful when not enough individual crowns are available in a single image to create a robust (stable) species signature or when, on the same image, more generic signatures are needed for a quick test (e.g., combining white spruce and black spruce to create a spruce signature and check its affect on classification results)

The program can also be used to "just" copy ITC species signatures to a different file if FILI2 and SIGN2 are not used.

NOTE: Presently PCI ImageWorks6.3 does not copy the ITC signatures properly, presumably because they are stored in TEXT segments and PCI has a filter passing only ASCII characters (same for IIA)

ITCSSM will only allow "close" signatures to be merged, where "close" is defined as: "means are within one standard deviation of each other, respectively".

ITCSSM is controlled by the following global parameters:

Name	Prompt	Count	Type
FILI1	Input PCI Database File Name 1	64	Char
FILI2	Input PCI Database File Name 2	64	Char
FILO	Output PCI Database File Name	64	Char
SIGN1	Input Signature segment from FILI1	1	Int
SIGN2	Input Signature segment from FILI2	1	Int
SIGNOUT	Output Signature segment to FILO	1	Int
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILI1: Specifies the name of the PCI file containing the input ITC-based species signature segment(s).

- FILI2: Specifies the name of the PCI file containing one of the other input ITC-based species signature segment(s).

- FILO: Specifies the name of the PCI file that will receive the output ITC-based species signature segment. FILO need not be different from FILI1 or FILI2. That is, a total of three, two or only one file can be involved.

- SIGN1: Input Signature segment(s) from FILI1. Accepts the use of ranges (e.g.: 2,-6).

- SIGN2: Input Signature segment(s) from FILI2. Accepts the use of ranges (e.g.: 2,-6).

- SIGNOUT: Signature segment(s) in FILO to contain the resulting merged (combined) ITC-based species signature(s) OR the copied signature(s) (when FILI2 or SIGN2 not used). Accepts the use of ranges (e.g.: 2,-6). Only used to overwrite existing signatures.

- REPORT: Specifies the file to which the generated report should be appended.

ITCSSM2 Individual Tree Crown Species Signature Merging 2)

ITCSSM2 makes possible the merging of ITC-based signatures from different (BRDF corrected & normalized) images into a single ITC-type signature segment.

This is useful when not enough individual crowns are available in a single image to create a robust (stable) species signature or when, on the same image, more generic signatures are needed for a quick test (e.g., combining white spruce and black spruce to create a spruce signature and check its affect on classification results).

ITCSSM2 differs from ITCSSM in that, instead of merging signatures from the ITC signature segments, it does it from the dump file (SDBOUT) that can be optionallly generated when ITCSSG is run.

This allow for a more accurate "merged signature" to be created as it is done from all of the original crown signatures (ITCs) being regrouped into a species signature (as opposed to combining two species signatures into one).

A newer, combined dump of all ITC signatures will be produced if the SDBMOUT parameter contains an output file name.

ITCSSM2 can also be used without FILE2 to just recreate an ITC species signature from its ITCSSG SDBOUT dump.

In that mode (single signature mode), channels offsets can be used to add/substract offsets from the multispectral values of all ITCs and thus, from the species signature. This make possible the extension of the signature to another image that is considered just slighly off in the multispectral space without having to normalized the full image channels themselves (i.e., dont normalize the images, offset the signatures). The number of offsets must be equal the number of channels. Offsets are only valid with the MEAN signature types.

ITCSSM is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE1	Input ITCSSG SDBOUT File Name 1	64	Char
FILE2	Input ITCSSG SDBOUT File Name 2	64	Char
FILO	Output PCI Database File Name	64	Char
OFFSETS	Channel offsets for sign. extension	8	Int
SIGNOUT	Output Signature segment to FILO	1	Int
SDBMOUT	Merged Signature Database Filename	64	Char
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILE1: Specifies the name of one of the input ITCSSG SDBOUT file containing all of the Individual Tree Crown (ITC) signatures that were used to create one species signature.

- FILE2: Specifies the name of the other input ITCSSG SDBOUT file containing all of the Individual Tree Crown (ITC) signatures that were used to create another species signature.

- FILO: Specifies the name of the PCI file that will receive the output ITC-based species signature segment.

- OFFSETS: Offsets to add to each channel values of the ITCs signatures and thus, the species signature, in order to extend a signature to an image that appears to be only slightly off in multispectral space from the original image from which the input signature (FILE1) came.

- Offsets are only valid with the MEAN signature types. The number of offsets must be equal the number of channels.

- SIGNOUT: Signature segment in FILO to contain the resulting merged (combined) ITC-based species signature.

- SDBMOUT: Specifies the name of an optional Signature DataBase output file. If a filename is specified, the signature information for each ITC and the species signatures will be written to a plain text file, making possible more detailed analyses later (SAS, Splus, Exel).

- REPORT: Specifies the file to which the generated report should be appended.

ITCDUMP Individual Tree Crown (ITC) Dump

ITCDUMP dumps "individual tree crown signatures" to a plain text file and can even dump the multispectral pixel values within an ITC with DETAIL=1. The information dumped depends on the level of detail parameter DETAIL, and the signature type parameter SIGTYPE. Currently there are 5 levels of detail that can be chosen.

ITCDUMP is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	PCI Database File Name	64	Char
DBIC	Database Input Channel List	8	Int
ISOLBIT	ITC Bitmap from ITCISOL	1	Int
TRAINSEG	Training Segments (BM/Vect)	16	Int
DBIW	Database Input Window	4	Int
DETAIL	Level of Detail	1	Int
CLASCODE	Class code (used in SLayer mode)	16	Int
SIGTYPE	MEAN/TCL/TCL2/TEXTUR/STRUCT	64	Char
TREETYPE	ITC/TT/ManBM/ManVec/SLayer	64	Char
EXTBIT	Extra Bitmap Mask	1	Int
BITBOUND	Boundary ITCs:INC/EXC/AUTO/CGRAV/POINTS	64	Char
SDBOUT	Signature Database Filename	64	Char
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILE: Specifies the name of the PCI file containing the input images and bitmaps and/or vectors.

- DBIC: Specifies the input database channel(s) holding the input MSS image. A list of up to 8 channels may be specified.

- ISOLBIT: Typically specifies a bitmap of individual tree crowns (ITCs) produced by the ITCISOL program.

- Based on masks formed by ANDing this ITC bitmap and training bitmaps, regions of the image are scanned for tree crowns (min. 2x2 pixels) and a signature is calculated for each ITC and/or"species" (class) based on the MSS data under the crowns in that region of the image. If ITCs are to be used in TRAINSEG (rather than training areas), the ITCs should preferably have been generated by using DCPE, and thus be exactly the same as the equivalent crown in ISOLBIT.

- If as specified by (TREETYPE=ManBM or ManVec) and in the TRAINSEG, manually delineated tree crowns (bitmaps or vectors, respectively) are to be used for the ITCs, the ISOLBIT is disregarded.

- In single input layer mode (TREETYPE=SLayer), ISOLBIT is used to specify the layer of training manually delineated tree crowns from which to generate the signatures. CLASCODE specifies which signatures will actually be dumped.

- PHILOSOPHIE The program of the ITC suite were primarily designed for the semi- automatic analysis of forested image using the ITCVFOL & ITCISOL automatically delineated tree crowns, thus, the ITC bitmap (ISOLBIT) tends to be a dominant factor of every program. This is also generally true for ITCDUMP, except in ManBM, ManVec, and SLayer special modes.

- TRAINSEG: Specifies a list of Training Segments (bitmaps or vectors) to be used, one for each species (class) of ITC. The dump output will be sorted by training segment.

  These bitmaps may contain filled training AREAS (for uniform forest stands) OR the full crown of individual trees (for mixed stands). These ITCs should preferably have been generated by using DCPE, and thus be exactly the same as the equivalent crown in ISOLBIT). These bitmaps (each in turn) will be ANDed together bitwise with the ISOLBIT to produce a mask which will be used to gather MSS data (if at least a minimum 2x2 pixel area exist for a tree crown) Pointers to ITCs to be used (e.g., an external DB of ground tree positions) can be used with BITBOUND in POINTS mode and EXTBIT bitmap containing pointers to the tree crown to consider. In that case, training areas (or full crowns) are still needed to indicate species.

  In ManVec mode, the training segments are vector layers made of individual tree crowns (close polygons - PCI shapes), typically delineated manually on the screen by an interpreter.

  The ISOLBIT and the BITBOUND parameter are disregarded. This is more a research mode to see if purer signatures are generated by human interpretation.

- DBIW: Specifies the image (bitmap) window to be read from the input channels (and/or input bitmaps).

- DETAIL: Specifies the level of detail to be dumped

  LEVEL 1 : ITC Pixel Dump

  The multispectral content of each ITC is dumped (by pixel). It also dumps Pixel and line positions of each pixel and gives the ITC a tree number. EXTBIT mask can be used to get only pixels from the lit side, shaded side, or local maxima (TREETOP) within the crown (use ITCMG to create mask).

  LEVEL 2 : ITC Signature Dump (SELECTED Signatures)

  Selected Signatures (based on the SIGTYPE parameter) are generated and dumped for each ITC (with its position, geo. position, crown area, ...)

  LEVEL 3 : ITC Signature and Species Signature Dump (SELECTED Signatures)

Selected Signatures (based on the SIGTYPE parameter) for each ITC as well as each species are generated and dumped.

LEVEL 4 : ITC Signature Dump (ALL Signatures)

ALL signature types for each ITC are generated and dumped. The SIGTYPE parameter is ignored at this level.

LEVEL 5 : ITC Signature & Matrix Dump (SELECTED Signatures)

Selected ITC signatures (based on the SIGTYPE parameter) are generated and dumped, along with the ITC Correlation and Covariance matrix. These matrices are only alculated in the TCL signature type (SIGTYPE).

- CLASCODE: This optional parameter allows the user to enter a specific class code (e.g., 183) for each class to be considered when in single layer mode (TREETYPE = SLayer). In this mode, ISOLBIT points to a single vector layer containning numerous manual tree crowns (vector polygons). In this mode, the number of classes specified by CLASCODE will generally govern the number of signatures that will be dumped. The dump output will be sorted by class code.

- SIGTYPE: Specifies which type of signature is to be dumped. Possible types include: MEAN/TCL/TCL2/TEXTUR/STRUCT. In Dump Levels 1 and 4 SIGTYPE is ignored.

Signature Description

MEAN: Multispectral mean of each ITC are dumped and if DETAIL=3 the means are averaged to create the species signature to dump as well. MEAN can be used with EXTBIT to create LIT side MEAN and TT (tree top) MEAN signatures.

TCL: First eigen vector & corresponding intercept of each ITC are dumped and if DETAIL=3 they are averaged to create the species signature to dump as well

TCL2: First eigen vector & corresponding intercept & eigenvalues of each ITC are dumped and if DETAIL=3 they are averaged to create the species signature to dump as well.

TEXTUR: Multispectral variance of each ITC (a simple texture parameter) are dumped and if DETAIL=3 they are averaged to create species textural signature to dump as well.

STRUCT: 3D moments (now Kurtosis) of each ITC are dumped and if DETAIL=3 they are averaged to create species structural signature.

The user can select more than one SIGTYPE, for example (m=3), SIGTYPE = MEAN,TEXTUR,STRUCT or SIGTYPE = MEAN+TEXTUR+STRUCT. A covariance of appropriate size (mn*mn), describing the covariance of each feature selected will be created and added to the vectors. If the user wants to dump other signatures, than ITCDUMP is run again (Here, n is number of channels).

- <u>TREETYPE</u>: Tree Type: ITC | TT | ManBM | ManVec | Slayer

  ITC and TT (regular non-research modes)

  Specifies whether species signature generation and dump is to be done based on a full crown delineation per tree (type = ITC) or only one pixel per tree crown (type = TT), the so called "tree tops" type of ITCMG (local maximum *within* an ITC). The default is ITC. TT can only be used with SIGTYPE=MEAN.

  Mode mostly for research purposes:

  ManBM → The training bitmaps are made of individual tree crowns that were (typically) delineated manually on the screen by an interpreter. The ISOLBIT and the BITBOUND parameter are disregarded. This is more a research mode to see if purer signatures are generated by human interpretation.

  ManVec → The training bitmaps are made of individual tree crowns that were (typically) delineated manually on the screen by an interpreter, but the manually delineated tree crownsexist in vector form as close polygons (PCI shapes).

  The diffrent species prototype crowns are stored in different PCI vector layer segments (as opposed to bitmaps).The ISOLBIT and the BITBOUND parameter are disregarded. This is more a research mode to see if purer signatures are generated by human interpretation.

  SLayer → Permits the generation of multiple signatures from manually delineated tree crown (vector polygons) by specifying a single input layer in ISOLBIT (similarly to ITCSC) and a field of that layer (TRAINF) that identifies the class code of each tree crown. The parameter CLASCODE selects which classes are of interest for a given run of ITCDUMP and thus, how many signatures will be dumped.

- <u>EXTBIT:</u> Specifies a segment which contains an Extra Bitmap Mask. This is an additional bitmap which is used to mask which parts of the ISOLBIT should be used to generate the signatures. Generally this is a bitmap from the ITCMG program. For example, say a bitmap is generated by ITCMG of type LIT, and specified as EXTBIT. The bitmap contains all the pixels that form the lit side of the tree. When the tree is being processed, only those pixels that are in the LIT mask are used in the processing of the individual tree signature (also used with TT or SHADE, or any other crown sub-area bitmap)

In the BITBOUND=POINTS mode, the EXTBIT bitmap points to the tree crowns that should be considered.

- BITBOUND: Possible values: INC / EXC /AUTO / CGRAV / POINTS (Inclusive or Exclusive or Automatic or Center_of_gravity or Pointers).

  Specifies whether tree crowns that fall on the boundary of Training (testing) areas (TRAINSEG) should be included (INC) or excluded (EXC), or have their insertion decided upon automatically (AUTO) based on having 50% of their crown area inside the area, or based on their "center of gravity" (stem?) being inside (CGRAV) the training (testing) area. POINTS is a separate case in which the EXTBIT bitmap contains pointers to the tree crown to consider.

  Inclusive: All crowns that have at least 2x2 pixels (and 10% of their crown) inside the training (testing) area are included in the output.

  Exclusive: Crowns that are only partially in the training (testing) area (trees on area boundaries) are disgarded (generally). Exception: If a tree less than 10% of its crown area sticking out of the testing area, it is considered IN.

  Automatic Crowns are included in the output if more than 50% their crown area is inside the training (testing) area.

  CGRAV : Crowns are included in the output if their center of gravity (tree stem?) is inside the training (testing) area.

  POINTS : Crowns are included in the output if their is a pointers (a set pixel) in EXTBIT that points to the crown. If this is the case, the full crown content is used independent of the size of the pointer.

  NOTE: Not applicable with manual tree crowns (ManBM and ManVec).

- SDBOUT: Specifies the name of the Signature DataBase output file. The information corresponding to the level of detail will be written to a plain text file, making possible more detailed analyses later (SAS, Splus, Excel).

- REPORT: Specifies the file to which to write/append the generated report.

ITCSSBD ITC Species Signature Bhattacharyya Distances

Bhattacharyya (JM) distances between signatures for all channel combinations.

ITCSSBD first displays the signature information contained in ITC signatures. ITCSSBD then iteratively calculates the pairwise separability of the signatures based upon differing channel combinations sorted by number of channels and the assending band combination bit-number equivalent. (ie. Combination 14 = 01110000; includes band positions 2,3,4 of a 7 band set)

Each iteration is accompanied by 1) a count of Bhattacharyya pairs having poor separability (less than 1); 2) and their sum of their differences from one. 3) from 1&2 the cumulative best scenario is stored (lowest 1 then lowest2)

ITCSSBD is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	64	Char
SIGNSEG	Input Signature Segments	16	Int
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILE: Specifies the name of the PCIDSK file containing the input images.
- SIGNSEG: Specifies a list of the segments containing the ITC species signatures.
- REPORT: Specifies the file to which to write/append the generated report.

DETAILS

The following has been extracted from the PCI "SIGSEP" help documentation:

Both TD and BD separability measures yield real values between 0 and 2, where 0 indicates complete overlap between the signatures of two classes, and 2 indicates a complete separation between the two classes. TD and BD measures are monotonically related to classification accuracies. The larger the separability values are, then the better the final classification results will be (using the MCL or MINDIS programs). The following rules are suggested for each the possible ranges of separability values `x':

0.0 < x < 1.0 (very poor separability)
1.0 < x < 1.9 (poor separability)
1.9 < x < 2.0 (good separability)

Very poor separability (0.0 < x 1.0) indicates that the two signatures are statistically very close to each other. The user has two options. One signature can be arbitrarily discarded (which is suggested when the separability is closer to 0), or the two signatures can be merged using the SIGMERG program (which is suggested when the separability is closer to 1).

Poor separability (1.0 < x 1.9) indicates that the two signatures are separable, to some extent. However, it is desirable to improve separability, if possible. Low signature separability is usually caused by improper combinations of image bands, and/or training sites which have large internal variability within each class.

The user is encouraged to use this program to examine the quality of training sites (bitmaps) and class signatures, before running a classification program. In order to improve class separabilities, the user may consider the following options:

- Choose a different combination of multispectral image bands, which are better suited for separating certain classes when creating signature segments;
- Create a new set of classes which are more separable, given the available image data;
- Modify the existing training sites for classes which have the largest internal variance; or
- Merge those pairs of classes whose signature separabilities are too low.

```
BD Measure

  BD(i,j) = 2*[1-exp(-a(i,j))]

where

  BD(i,j) = Bhattacharrya Distance between class i and j

  a(i,j)  = 0.125*T[M(i)-M(j)]*Inv[A(i,j)]*[M(i)-M(j)]
           + 0.5  *ln{det(A(i,j))/SQRT[det(S(i))*det(S(j))]}

where

  T, M, S, and Inv are as defined for TD measure
  A(i,j) = 0.5*[S(i)+S(j)]
  det()  = determinant of a matrix
  ln{}   = natural logarithm of scalar value
  SQRT[] = square root of scalar value
```

The program calculates the separabilities of all the possible pairs among `n' classes, where `n' is the number of classes.

Reference:

Richards, J. A., 1986, "Remote Sensing Digital Image Analysis". Springer-Verlag, Berlin, Heidelburg, New York, London, Paris, Tokyo, pp. 206-225.

Note: The formula to calculate the Bhattacharrya Distance measure given in the above book is incorrect. Check the reference in the book to find the right formula.

Post-Processing Tasks

ITCAREAS From a bitmap showing individual (distinct) tree crowns (ITCs) (such as the one generated by the ITC Suite program ITCISOL), this program generates a raster image where the crown area of each ITC is written at its centre of gravity location OR, is writen at every pixel under the crown (i.e., painting the full crown with its crown area value) The later can be useful as a classification feature in order to introduce crown size as a classification criteria.

ITCAREAS is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	64	Char
ISOLBIT	Bitmap of tree crowns (from ITCISOL)	1	Int
ITCPAINT	Paint factor (ITC | CG)	64	Char
DBOC	Output Channel (ITC area image)	1	Int
REPORT	Reporting device	64	Char

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).
- ISOLBIT: Specifies a bitmap of ITCs (Individual Tree Crowns), typically produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as the basis of the tree crown information generated for the given testing areas (TESTSEG).
- ITCPAINT: Specifies whether to paint all the pixels under the crown (ITC) OR only one pixel at ITC centre of gravity (CG) with the value of crown area in the output raster image
- DBOC : Specifies the ouput image (8 bit) to contain in each ITC centre of gravity location the crown area (in pixels) of that ITC
- REPORT Specifies the file to which to write/append the generated report.

ITCHEIGHTS From a bitmap showing individual (and distinct) tree crowns (ITCs) (such as the one generated by the ITC Suite program ITCISOL) and for a channel (8 or 16 bit) containing a height-related image, like a Digital Canopy Model (DCM) from Lidar first returns (DCM = DSM - DTM), this program generates a raster image where the height of each ITC is written at its centre of gravity location. The height information will be reported using the maximum height within each tree crowns (ITC).

ITC_HT is controlled by the following global parameters:

```
Name      Prompt                                    Count   Type

FILE      Database File Name                        64      Char
ISOLBIT   Bitmap of tree crowns (from ITCISOL)      1       Int
HEIGHTCH  Optional height channel (i.e., DCM)       1       Int
ITCPAINT  Paint factor (ITC | CG)                   64      Char
DBOC      Output Channel (ITC area image)           1       Int
REPORT    Reporting device                          64      Char
```

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

- ISOLBIT: Specifies a bitmap of ITCs (Individual Tree Crowns), typically produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as the basis of the tree crown information generated for the given testing areas (TESTSEG).

- HEIGHTCH: Height channel (i.e., DCM). A channel (8 or 16 bit) containning a height-related image, like a Digital Canopy Model (DCM) from Lidar first returns (DCM=DSM-DTM). If specified, height information will be reported using the maximum height within each tree crowns (ITC).

  NOTE: The height channel is treated as an 8 bit channel, as 8 bit (256 levels) is more than enough to cover the height of most trees in Canada at a quarter metre resolution.

- ITCPAINT: Specifies whether to paint all the pixels under the crown (ITC) OR only one pixel at ITC centre of gravity (CG) with the value of crown area in the output raster image

- DBOC: Specifies the ouput image (8 bit) to contain in each ITC centre of gravity location the crown area (in pixels) of that ITC

- REPORT: Specifies the file to append generated report to:

CROWNSIZ From a bitmap showing individual (distinct) tree crowns (such as the one generated by the program ITCISOL), this program generates a raster image where each pixel value is relative to the size of crowns in a given neighbourhood.

CROWNSIZ is controlled by the following global parameters:

```
Name     Prompt                                   Count   Type

FILE     Database File Name                       64      Char
DBIB     Bitmap of tree crowns(from ITCISOL?)     1       Int
DBOC     Output Channel (crown size image)        1       Int
NFMASK   Non-forested Area Input Bitmap (a mask)  1       Int
REPORT   Reporting device                         64      Char
```

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

- DBIB: Specifies a bitmap, often produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as reference in evaluating crown size

- DBOC: Specifies the ouput image to contain in each pixels an average crown size value assessed from a local neighbourhood.

- NFMASK: Specifies an optional input bitmap (non forested mask) to be used as mask eliminating certain areas from processing. For exemple: to eliminate roads, pastures, open areas, ...

- REPORT: Specifies the file to append generated report to:

NOTE: The resulting image can be displayed via the Pseudo-color LUT or with others like STEMDENS, fed to RTV or COUNTOUR, raster-to-vector programs in the PCI system that are typically used with elevation data to produce isolines. These lines can be fed to a GIS and help in delineating forest stands.

CRO_MARK From a bitmap showing individual (distinct) tree crowns (such as the one generated by program ITCISOL), this program generates a bitmap where tree crown centers are marked (optionally -> with a cross mark)

CRO_MARK is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	Database File Name	64	Char
DBIB	Bitmap of tree crowns(from ITCISOL?)	1	Int
DBOB	Bitmap of crown center markings	1	Int
REPORT	Reporting device	64	Char

- FILE: Specifies the name of the PCIDSK file containing the input and output channels (images) or bitmaps (themes).

- DBIB: Specifies a bitmap, often produced by the ITCISOL (Individual Tree Crown Isolation) program, to be used as reference from marking the tree crowns.

- DBOB: Specifies an output bitmap to contain the marks pointing to the tree crown found from DBIB. If not specified, a new bitmap is created.

- REPORT: Specifies the file to append generated report to:

DETAILS

From a bitmap showing individual (distinct) tree crowns (such as the one generated by program ITCISOL), this program generates a bitmap where tree crown centers are marked (optionally -> with a cross mark)
This is done by first scanning the input bitmap, detecting the next tree crown, and replacing it by one pixel indicating the center of gravity of the crown (or optionally a cross) (*** modification of code needed to get a cross)

ITCMARA Individual Tree Crown **Manual vs Automatic Recognition Accuracy**

This program is generally used to compare manually (human-interpreted) and automatically (ITC suite) delineated tree crowns and determine the classification accuracy of the "well delineated" tree crowns and the overall recognition (delineation & classification) accuracy after the ITC suite was used to analyse an image for which "ground truth" and/or interpreted thruth is available (typically for a PLOT). It provides copious information on the types of intersections found between the manual and the automatic tree crowns in order to analyse the weaknesses (delineation & classification) of the ITC suite.

It can also be used to compare the results of two different systems of automatic crown delineation and classification, or results obtained at two different spatial resolutions (if moved to the same file) for plots or the full image area.

The automatically generated Individual Tree Crown (ITC), that were produced (ITCVFOL & ITCISOL) and classified (ITCSSG & ITCSC) via the ITC suite, are compared with manually delineated tree crowns (bitmap or vector), considered "the truth", to see if they sufficiently match spatially to be considered representative of the same tree, and to see if their species match.

At first, a confusion matrix is generated showing the classification and recognition accuracies of the well delineated (judged 1:1) tree crowns. Tables are also generated showing errors in regrouping ITC crowns and in separating ITC crowns, in general or by species, in order to further analyse the strengths and weaknesses of the ITC suite analysis of that image.

For the classification and recognition accuracy phase (1st phase), crowns are considered well recognized (diagonal elements) if they meet both intersection thresholds (MCIPER & ACIPER) and are of the same species. Off-diagonal crown counts, crowns of the wrong species, must also meet these delineation thresholds (mis-classification of 'well delineated' tree crowns.

When in plot mode (PLOT), additional information about intersections is also generated for the manual tree crown and the ITCs in two output layers (MANINFO & ITCINFO, respectively). When specified, the layers are overwritten. The fields (attributes) of these layers are associated with the crown's center of gravity mark (vector). These fields are:

- species of crown, area of crown, number of intersections and, for each intersection (up to 5):
    - actual intersection percentage
    - species of intersecting tree
    - ID of intersecting tree
- flag (MTAT) of intersections matching MCIPER and ACIPER 1 ->ACIPER met 2 -> MCIPER met 3-> both met 4-> both PER met & crowns are of the same species

- for the manual crowns, the original shapeID in the ground truth database is added as a field and the ground truth data are attached as additional fields (if available), simplifying subsequent queries

When using a plot (PLOT) and creating output layers (MANINFO & ITCINFO) a thorough analysis of intersections follows. List of crowns encountering various types of intersections, from Type 1 (Perfect Match) to various types considered Good, Poor, Partial, OverSplit, Undersplit, ... This complex analysis is based on the content of two output layers (MANINFO & ITCINFO) created in the previous stage.

Another classification confusion matrix is generated for all of the matches (between ITCs and manual crowns) considered 'good'. This gives a more lenient recognition accuracy (i.e., intersections dont have to be perfect, that is, 1:1 and greater than MCIPER and ACIPER).

NOTE: If a test set of crowns consist only of manually "selected" (using DCPE for example) automatically generated crowns (i.e., ITCs), as opposed to to manually "delineated" crowns, the use of ITCCA is recommended.

NOTE: If used wisely, ITCMARA can also be used to compare classifications done at different spatial resolutions (scale) or even to compare results with the ITC suite with results from another individual tree based classification system (see warning below).

***** WARNING *****

When the manually delineated tree crowns are in bitmap format the crowns MUST NOT be touching each other (not 4-connected). It is assumed that the automatically generated crowns are not touching each other either, which should be the case if generated by the ITCVFOL & ITCISOL combination.

ITCMARA is controlled by the following global parameters:

Name	Prompt	Count	Type
FILE	PCI Database File Name	64	Char
ISOLBIT	Bitmap from ITCISOL (the ITCs)	1	Int
MANCRSEG	Manual Crown Bitmaps or vector layers	16	Int
CLASSBIT	Classification Bitmaps (from ITC suite)	16	Int
CLASCODE	Class codes	16	Int
MCIPER	Manual crown intersection percentage	1	Int
ACIPER	Automatic crown intersection percentage	1	Int
PLOT	Plot area (sub-area) for which to repor	1	Int
MANINFO	Output layer of MAN/ITC intersect info.	1	Int
ITCINFO	Output layer of ITC/MAN intersect info.	1	Int
REPORT	Report Mode: TERM/OFF/filename	64	Char

- FILE: Specifies the name of the PCI file containing the testing bitmaps (or vector segments), the ITC bitmap, and the classification bitmaps.

- ISOLBIT: Specifies a bitmap produced by the ITCISOL (Individual Tree Crown Isolation) program to be used as a mask of the image. This bitmap will be used along with the CLASSBITs to construct a bitmap of the unclassified tree which will be used to construct the confusion matrix.

- MANCRSEG: (Manual tree crown bitmap or vector layer segments) Specifies a list of bitmaps OR vector layers containning the manually delineated crowns of various species (by species) to be used as "ground truth" to assess the results the ITC suite analysis of a full image or a smaller forested area (PLOT).

  The test bitmaps contain "filled" tree crowns. One testing bitmap is used per species to compare against the classification results and thereby build up the confusion matrices (for recognition accuracy assessments) and gather additional comparative data.

  The number of bitmaps (or segments) in MANCRSEG should be the same as the number of bitmaps in CLASSBIT (i.e., MANCRSEG should represent the same number of species and in the same sequential order as CLASSBIT). Presently, bitmap and vector layers can not be mixed in the same run of ITCMARA (i.e., all manual crown segments must be of the same type).

  In Slayer Mode :

  If there is only one segment in MANCRSEG the program will go into Slayer (Single layer) mode. The CLASCODE parameter will then select which trees will be used in the comparisons. The user will be prompted for a field (CLASST) from the layer which will be used to retrieve the clascode information. The number of clascodes must be equal to the number of bitmaps in CLASSBIT.

  If the CLASST parameter is set to a field name (rather than its default of NOTSET), the user will not be prompted and the name specified by CLASST will be used. This is very useful when ITCMARA is to be run in automatic unattended scripts, as these scripts have no capability of answering questions from programs.

  Just define CLASST in advance of running ITCMARA in your script:

  CLASST = "class_lit_3ch" run ITCMARA

  If you'll rather be prompted, make sure CLASST = "NOTSET" or CLASST = , which will do the above by default.

If a single vector layer that is representative of a single species is needed then Slayer mode can be bypassed by pressing the key when prompted for a field name.

A single Bitmap segment can still be used if needed, which will bypass Slayer mode.

- CLASSBIT: Specifies a list of Classification bitmaps. These are bitmaps that were generated from the ITC suite as a result of an ITC classification. One bitmap is specified per species, showing the results of the species classification. This is used to compare against the Testing Bitmaps or vector layers (MANCRSEG) in order to generate the confusion and other matrices (and various other information)

- CLASCODE: Class codes to improve reporting about intersections in output layers with code corresponding to species (or species & conditions) rather than just an index code corresponding to the order (0-15) used in MANCRSEG and CLASSBIT.

  In SLayer mode, CLASCODE must be specified.

- MCIPER: (Manual crown intersection percentage) Specifies the minimum percentage of area of a manually delineated crown that needs to be part of the intersection area with an automatically delineated (ITCVFOL&ITCISOL) crown before the crowns are considered as the same tree.

  *** Applies only to 1st confusion matrix generated (Phase1) ***
  MCIPER and ACIPER are both expected to be above 50%.

  This is the way this part of the code enforces that only one intersection per tree (the main one) is considered. Values lower than 50 invalidate the 1st confusion matrix, but do not affect the rest of ITCMARA.

- ACIPER: (Automatic crown intersection percentage) Specifies the minimum percentage of area of an automatically delineated crown (ITCVFOL&ITCISOL) that needs to be part of the intersection area with a manually delineated crown before the crowns are considered as the same tree.

  *** Applies only to 1st confusion matrix generated (Phase1). ***
  MCIPER and ACIPER are both expected to be above 50%.

  This is the way this part of the code enforces that only one intersection per tree (the main one) is considered. Values lower than 50 invalidate the 1st confusion matrix, but do not affect the rest of ITCMARA.

- PLOT: (Plot area (sub-area) for which to report) If a segment (bitmap/vectors) depicting specific plot test area(s) is specified, ITCMARA will only report for the crowns considered inside these areas (e.g., if the manual crown's center of gravity (stem) is in the plot). (PRESENTLY -> if the manual crown's touches the plot).

Note: ITCs are used if inside the plot (by center of gravity) OR if they intersect significantly with a manual crown considered inside the plot. Thus, ITCs outside the plot can be in the ITCINFO layer and will be reported on when in manual tree centric rules. However, when in ITC-centric mode, only ITC in the plot (by center of gravity) are considered for reporting.

If PLOT is unspecified, then ITCMARA reports for the full image, but not at the same level of details.

- <u>MANINFO</u>: (Output layer of MAN/ITC intersect information) Specifies an optional output layer containing information for each manual crown about its species index, the number of intersections it has with ITC crowns, and for each of five main intersections {intersection size, ITC crown ID, species}.

  For these manual crowns, the center of gravity will be the main unique identifier.

- <u>ITCINFO</u>: (Output layer of ITC/MAN intersect information) Specifies an optional output layer containing information for each ITC about its species index, the number of intersections it has with manual crowns, and for each of five main intersections {intersection size, manual crown ID, species}.

  For these ITCs, the center of gravity will be the main unique identifier.

- <u>REPORT</u>: Specifies the file to which the generated report should be appended.

TECHNICAL NOTES

- Intersections (at least one pixel) must be inside the PLOT area to be considered, but PLOT is extended by manual crowns sticking out.

- Within an individual crown, intersections are consideredsignificant and counted only if their size is greater than 5% (MINPER) of the manual tree crown size.

- Manual tree crowns (vector or bitmap) must have their center ofgravity (stem) inside the PLOT area to be considered. **PRESENTLY ** -> Manual crowns are considered in plot if theytouch the plot.

- Presently, manual crown types (bitmap & vector) can not be mixedin the same run of ITCMARA (i.e., all manual crown segments mustbe of the same type).

- Presently, manual crowns can not be in a single layer (i.e., asmany manual crown layers as there are classes are needed).

IR (Image Recording Program): IR prepares MSS image channels, LUTs, pseudocolour images, bitmaps, vectors, etc. to be sent to the QCR-Zi film recorder **(or a wide colour printer**) by amalgamating all of this information into a single 2D array (i.e., burning into the images the bitmap and vector information). Before finishing, it calls "record image", which interact with the QCR via the GPIB bus (unless writing to an output file).

Compensation for the gamma factor of the viewing screen and the film used is also included in the calculations. Maximizing, centering, rotating stretching the images are also possible.

IR is controlled by the following global parameters:

Name	Prompt	Count	Type
IRFILE	Database File Name	64	Char
IRDBIC	Database Input Channel List	3	Int
IRDBLUT	Database Look-Up Table Segment	3	Int
IRDBIW	Database Input Window	4	Int
IRPCIC	Pseudo-Colour Image Channel	1	Int
IRDBPCT	Database Pseudocolour LUT	1	Int
IRBM	Database Input Bitmap	16	Int
IRBMCOL	Bitmap Colours	16	Int
FILMRES	Film Resolution: 2K/4K/8K	64	Char
FILMOW	Film Output Window	4	Int
IRACENT	Autocentering Mode: ON/OFF	64	Char
IRANGLE	Angle (degrees)	1	Int
FILMTYPE	Film Type	64	Char
IRMODULE	Film Module (35/68/810)	1	Int
SGAMMA	Gamma Factor Of Your Screen	3	Float
IRSTRETC	Pixel Value Scaling Mode:ON/OFF	64	Char
IRMAXIMI	Maximize FILMOW: ON/OFF	64	Char
IRDBVS	Database Vector Segment	8	Int
IRVCOL	Vector Colours	8	Int
IRVWIDTH	Vector Width (1 - 8)	8	Int
IRDBOC	OPTIONAL output channels	3	Int
IRFILO	OPTIONAL output Database File	64	Char

- IRFILE: Specifies the name of the PCIDSK file containing the input images, bitmaps and/or vectors.

- IRDBIC: Specifies the input database channel(s) holding the input image. A list of channels may be specified (typically three for a colour image and one for a black&white (grey level) recording). Of course, a grey-level image can be recorded on colour film by specifying the same channel three times (it will be a bit brownish, but this makes possible real colour bitmap (theme) or vector overlays. A channel is not required.

- IRDBLUT: Specifies the segments that hold the look-up tables for the above channels. The order in the list should correspond to the order of the channels.

- IRDBIW: Specifies the database input window. The values for this parameter are interpreted as:

  xoffset, yoffset, xsize, ysize

  Where xoffset, yoffset are the respective offsets in the x (pixel) and y (line) direction, and xsize, ysize is the size of the image in the x (pixel) and y (line) direction (respectively).

- IRPCIC: Specifies a channel which contains a pseudo-colour image. This is interpreted as an overlay to the image channels specified by IRDBIC. Values from 1-255 are mapped through a Pseudocolour Table (PCT) specified by IRDBPCT. A value of 0 provides a "hole" to the image beneath.

- IRDBPCT: Specifies the segment which contains the Pseudocolour Table (PCT) for the Pseudo-Colour Image Channel (PCIC). The PCIC is interpretted as an overlay to the image channels specified by DBIC. Values from 1-255 are mapped through the PCT. A value of 0 provides a "hole" to the image beneath.

- IRBM: Specifies a list of bitmap segments to overlay on the image channels. If colour bitmaps are to be overlaid on a black and white image, specify the input channel 3 times (e.g., irdbic = 1,1,1). At the moment, IRPCIC and IRBM cannot be used at the same time.

- IRBMCOL: Specifies a list of bitmap colours to which the specified bitmaps in IRDBIB will be colour-mapped. The values refer to a table of predefined RGB colour combinations similar to imageworks colours. One value is needed for each bitmap specified in IRBM.

  The colour codes available, and their RGB values, are:

BCOL	Colour	Red	Green	Blue
1	Red	255	31	31
2	Green	31	255	31
3	Blue	31	31	255
4	Purple	255	0	255
5	Yellow	255	255	0
6	Light Blue	0	255	255
7	White	255	255	255
8	Pink (Purple)	255	110	255
9	Light Orange	255	180	0
10	Dark Green	0	110	0
11	Green-Blue	0	110	128
12	Light Pink	255	180	255
13	Orange	255	110	0
14	Medium Green	0	180	0
15	Medium Blue	0	128	255
16	White	255	255	255
17	lite brown	200	128	0

18	dark brown	128	50	0
19	lite grey	196	196	196
20	dark grey	64	64	64
21	pink	255	64	128

- FILMRES: Specifies the film resolution. This can be one of 2K/4K/8K. The actual viewable area on 35mm film are:

2K	2048x1366
4K	4096x2732
8K	8192x5464

On 8x10 film, the viewable area at 8k is 8192x6460

- FILMOW: Specifies the output window on the film. These values will be interpreted as xoffset, yoffset, xsize, ysize (see DBIW). If an output window is not specified, it will be the same size as the data base input image. If IRACENT is set to ON, it overrides any FILMOW offsets.

- IRACENT: Specifies whether or not the image should automatically be centred on the film. Possible values are ON/OFF. If IRACENT is set to ON, it overrides any FILMOW offsets.

- IRANGLE: Specifies the angle that the image should be rotated when it is printed. Possible values include 0/90/180. Rotation angles are in degrees. Rotation is with respect to the centre of the image frame.

- FILMTYPE: Specifies the type of film that is being printed to. Note that for black and white film types, only one channel of image data is printed and can be specified in IRDBIC (an overlay channel can also be specified, as well as bitmaps). As well, for B&W films an average colour index is used from RGB values in PCT (if PCT is specified). Of course, a grey-level image can be recorded on colour film by specifying the same channel three times (it will be a bit brownish, but this makes possible real colour bitmap (theme) or vector overlays.

Valid entries are:

For 35mm: For 6X8 film: For 8X10 film:

100KODACOLOR, POS6X8, POS809, 100EKTACHROME, NEG6X8, TRANS891, 200EKTACHCHROME, 64KODACHROME, 40POLACHROME

For Black and White film of all types: BW

- IRMODULE: Specifies the film container module (35mm, 6x8in, 8x10in) Valid entries are: 35, 68, 810.

- SGAMMA: Gamma factor is a measure of the nonliniearity of the response of the screen's phosphors to input voltages. In short, just because the signal intensity is doubled doesn't mean that the screen's brightness will double. Supplying the gamma factor of the screen will allow this nonliniearity to be compensated for and allow color consistancy across devices. The gamma factor of a screen is one floating point value for a black and white image and three (RGB) values for a color image. Acceptable gamma factors are between 0.0 and 5.0. Values below 1 cause the image to be generally brightened and values above 1 cause the image to be generally darkened. A gamma factor of 1 has no effect. If gamma factors vary from channel to channel, enter a gamma factor for each channel respectively. If one value only is entered, the other values will be assumed to be the same. When no value is entered, all gamma factors are set to 1.

  HOW IT WORKS

  IR compensates by doing two things: First it compensates for the gamma of the output device, in this case the QCR, and second, it imposes a gamma equal to the gamma factor of the screen onto the image. These two corrections work together to ensure that what comes out matches what went in.

  DETERMINING GAMMA

  The gamma factor of an output device can be found using gamma factor test images which are located in:

  $PUBLIC_SRC/Image/Redgamma.* , Grngamma.* , Blugamma.* , gamma.*

  The test image works by comparing various levels of the three colors to a 0-255 alternating pattern of the color in question. When viewed from about 2m the eye averages the 0 255 pattern so that it appears the same color as one of the color patches on the right. The color patch which matches is the gamma factor. The gamma test image is simply displayed on the screen or sent to the output device.

  NOTE FOR ADVANCED USERS OF GAMMA:

  The different film types used by the QCR all have gamma factors associated with them. These gamma factors are hard coded into the IR program. But for some applications these factors may need to be changed. To do so intelligibly one must first understand the difference in compensating and imposing a gamma factor. When imposing a gamma factor all values in the image are raised to the gamma power and normalized between 0 and 255. This is why gamma values above 1 brighten and below 1 darken. Compensation is just the opposite in that it removes a gamma factor by raising all the pixel values to the 1/gamma power. If the hard coded gamma factors don't seem to be working then one can compensate for the remaining gamma by first finding out the residual gamma factor of the output and dividing the screen gamma by this value and using the result at the EASI prompt. For example:

If the film being used was found to have a residual gamma of 1.5 and the screen gamma was known to be 2.8 then to both impose the gamma of the screen and compensate for the gamma of the film the required value to be entered at the EASI prompt would be 2.8/1.5, or, 1.87.

- IRSTRETC: Specifies whether pixel values will remain as seen on the screen (OFF) when no lookup tables has been call or whether they will be stretched over the full range of possible values (ON). This is accomplished by eliminating superfluous data : the first and last 2% - 3% of the data (ON). The remaining data will be spread from 0 - 255, therefore using the full possible pixel range. If the input data is 16 bit, this option will be automatically activated. Caution: the image will not look the same as it did on the screen. Mostly useful for16 bit data. For 8bit data, when one desires a look like that of the screen with a particular LUT (say root LUT), save these LUTs in segments and specify them with IRDBLUT.

- IRMAXIMI: Specifies whether or not the maximum output window size (depending on filmtype) that will allow the image's proportions to remain the same will be used. If no filmow is specified and maximize is "OFF", the output window will be the same size as the input window. If maximize is "ON", it will override filmow, ignoring both offsets and window sizes, but the image will remain uncentered unless acentre is "ON". If the angle is 90 degrees, the image will be maximized to fit the film size at that angle.

- IRDBVS: Specifies a list of vector segments to overlay on the image channels, to a maximum of eight. If colour vectors are to be overlaid on a black and white image, specify the input channel three times, (e.g., irdbic = 1,1,1). Points are displayed as points, not as crosses. EXTREMELY SLOW if lots of vectors.

- IRVCOL: Specifies a list of vector colours to which the specified vectors in DBVS will be colour-mapped. The values refer to a table of predefined RGB colour combinations. One value is needed for each vector specified in DBVS. For a table of color values and codes, see DBIB.

- IRVWIDTH: Specifies the thickness of each vector. If nothing is specified, the default is 1. A value can be entered for each vector, respectively, but if less widths are specified than vectors, they will all be set to the same width as the first. Values should be between 1 and 8. VWIDTH will also determine the thickness of points.

- IRDBOC: To create an ouput RGB image in the input file (IRFILE) or in an optional output file (IRFILO) instead of sending it to the QCR image recorder. Specifies the output database channel(s) (8bit) to hold the output image. A list of three channels is typically specified for colour images.

- IRFILO: Specifies the name of an optional output PCIDSK file to contain and an optional output RGB image(instead of sending image to QCR). IRDBOC specifies the channels to used. This is typically done to look at the image that could have gone to the QCR image recorder (say in a debugging mode or not to waste film when unsure) OR to send the image to another device (e.g.: BIGPLOT1 via PSIMAGE) OR to create an RGB image (with bitmaps and vectors burned in) that could be transform into a TIF (or other format) image.

  Note1: The RGB output image can also be written to 8bit channel in the input image (IRFILE) if IRFILO is not used.

  Note2: Gamma adjustment has been bypassed to speed up program and because we don't know the gamma of the intended output device.

  Note3: If an output file is used (IRFILO), the PCI file (three 8-bit channels) has to have been created before the IR run.

  Hints: Create the output file (IRFILO) of a size proportional to the final poster you want. For example, for BIGPLOT1, a 300 DPI 36 inches wide plotter, file would have to be of size 36x300=10800 pixels to use width to its maximum. Make sure you use the same scaling factor in the line direction to maintain proportionality.

  Use IRMAXIMI="ON to scale input image to output image, whether to scale up or down. Leave other parameters on default (e.g.: POS809)

EXAMPLE

Here's an example of an IR run outpiut to a file and then printed on BIGPLOT:

```
IRFILE   Database File Name:                    31K03NO_PS_8b.pix
IRDBIC - Database Input Channels >              4 4 4
IRDBLUT - Database Look-Up Tables >
IRDBIW - Database Input Window >
IRPCIC - Pseudo-Colour Image Channel >
IRDBPCT - Database Pseudo-Colour LUT >
IRBM - Database Input Bitmap >                  45 46 47 48 49 12 11
IRBMCOL - Bitmap Colours >                      1 3 10 5 2 6 13
FILMRES - Film Resolution: 2K/4K/8K :           8K
FILMOW - Film Output Window >
IRACENT - Autocentring Mode: ON/OFF :           OFF
IRANGLE - Rotation angle (degrees) >
FILMTYPE - Film Type :                          POS809
```

```
IRMODULE- Film Module (35/68/810) >           810
SGAMMA - Gamma Factor of your screen >
IRSTRETC- Pixel Value Scaling Mode:ON/OFF :   OFF
IRMAXIMI- Maximize FILMOW: ON/OFF :           ON
IRDBVS - Database Vector Segment >            51
IRVCOL - Vector Colours >                     16
IRVWIDTH- Vector Width (1 - 8) >              2
IRDBOC - Optional Output Channels >           1 2 3
IRFILO - Optional Output File Name:           IR_test.pix
```

After the IR run, look at the results in "IR_test.pix". You should have an RGB image containing everything (i.e., with bitmaps and vectors burned into the image)

```
Use PSIMAGE to produce a postscript file:

MAPFILE - Map Database file name :            IR_test.pix
DBIC -    Database Input Channel List }               1 2 3
OVERLAP - Overlap Between Sections: YES/NO:   NO
SECTIONS- Sections to Print }
MEDIASIZ- Media Size :                        36I,36I
MAPDEVIC- Target Printer for Map output:      C300
PRINTDEV- Printer Device Name (Port) :        IR_test.ps
COPIES -  Number of copies to print >
```

Using a Postscript viewer, look at the resulting file "IR_test.ps".

Print that Postscript file on bigplot using:

```
 system> lp -dbigplot1 IR_test.ps
```

Under these circumstances (i.e., POS809), image size will be:

8192P and 6460L (POS809 defaults) divided by 300dpi, thus 27.3 " by 21.5"