Individual Tree Crown (ITC) Delineation on Ikonos and QuickBird Imagery: the Cockburn Island Study.*

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Abstract

For forestry applications with high spatial resolution (< 1 m/pixel) imagery, an Individual Tree Crown (ITC) approach is generally preferable to pixel-based analyses. This paper presents preliminary results of ITC delineations using a valley following approach over Cockburn Island (Lake Huron, Ontario), first with an Ikonos image (100 cm/pixel), then with a QuickBird image (70 cm/pixel), to examine some of the benefits of the added spatial resolution. Six test areas, typically containing only one situation (i.e., big or small trees, deciduous or coniferous), were analysed on both images. For reference, local maxima (or Tree Top) analyses were also performed and are shown for both media. As expected, the results favour QuickBird with gains in areas of trees with narrow crown (less omission errors), better separation of tree clusters and finer delineation of crown boundaries. In general, the QuickBird image analysis produced 50% more tree crowns and is in closer agreement with its Tree Top counts. From visual inspection, it is obvious that a significant number of tree clusters remain.

This work is part of a larger "proof of concept" project, done in collaboration with forestry and forest inventory companies**,** that intends to check if an ITC approach can lead to better forest management maps. The project will evaluate the automatic creation of forest stand polygons, their species composition (up to 10 species) and parameters such as stem density and crown closure, as well as, the synergistic effects of using a large scale photography (LSP) sampling strategy for volume estimation.

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Résumé

Pour les applications forestières à partir d'images à haute résolution spatiale (< 1 m/pixel), une approche « à l'arbre près » est généralement préférable aux analyses par pixel. Cet article présente des résultats préliminaires de délinéations de cimes à partir d'un procédé de « suivi de vallées » sur l'île Cockburn (Lac Huron, Ontario), premièrement avec une image Ikonos (100 cm/pixel), puis avec une image QuickBird (70 cm/pixel), pour étudier les bénéfices potentiels d'une résolution accrue. Six régions tests ne contenant typiquement qu'une seule situation (c.-à-d., grands ou petits arbres, feuillus ou conifères) furent analysées sur les deux images. En guise de référence, des analyses par maxima locaux (détection du faîte des arbres) furent aussi réalisées et sont présentées pour ces deux médias. Tel que prévu, les résultats favorisent QuickBird avec des gains dans les régions peuplées d'arbres à petite cime (moins d'erreurs d'omission), une meilleure séparation des îlots d'arbres et une délinéation plus fine des cimes. En général, l'analyse « à l'arbre près » de l'image Quickbird a produit 50% plus de cimes et correspond mieux avec les comptes d'arbres faits par détection des faîtes d'arbres. Une inspection visuelle nous révèle qu'un nombre significatif d'îlots d'arbres perdure.

Ces travaux font partie d'un projet de grande envergure, fait en collaboration avec des compagnies forestières et d'autres productrices d'inventaires forestiers, pour vérifier si l'approche « à l'arbre près » peut mener à de meilleurs inventaires d'aménagement forestier. Ce projet va évaluer la délinéation automatique des peuplements forestiers, leur composition en espèces (jusqu'à 10 essences) et des paramètres tels la densité et la fermeture du couvert, de même que, les effets synergistiques d'une utilisation de photographies à grande échelle pour un échantillonnage menant au volume.

Introduction

The sustainable management of forests largely depends on precise and accurate forest information. The information contained in conventional photo-interpreted forest management inventories is still the cornerstone of most forestry decisions, although, operational inventories conveying more information are usually carried out before most important forest operations. There is a need to improve the precision, accuracy and timeliness of forest management inventories and, if possible, to improve them to such an extent that operational inventories become less needed. Ultimately, individual tree based inventories may have the potential to fill this mandate. Are we anywhere close to this?

In digital remote sensing image analysis, the need to extract information from high resolution (<1 m/pixel) imagery for forestry applications such as forest inventories is already better served by using an Individual Tree Crown (ITC) approach rather than by conventional pixel-based analyses. The ITC approach (Gougeon and Leckie, 2003a), which was developed with images from airborne multispectral sensors at 30-60 cm/pixel, is now being applied to Ikonos and QuickBird satellite images. While it is known that, for plantation coniferous trees at a spatial resolution of 31 cm/pixel, 81% of the automatically delineated ITCs correspond to real individual crowns according to photo-interpreters (Gougeon, 1995), little is known for the 100 and 70 cm/pixel Ikonos and QuickBird panchromatic images. On-going research with

Ikonos images reveals that, on average, tree counts can be 15% off with coniferous trees in ideal situations (Gougeon and Leckie, 2003b). Of course, this is different from a one to one (1:1) relationship, as errors of omission and commission often cancel out, and is to be compared with counts that were 7.7% off in the aforementioned research at 31 cm/pixel. Finally, deciduous tree crowns are typically harder to delineate properly.

Nevertheless, even though the objects being analysed were often tree clusters rather than individual tree crowns, comprehensive ITC image analyses of Ikonos images have led to ITC-based Forest Cover Maps that were superior to conventional forest management inventory maps in many ways (CLC-Camint, 2002). Will the added spatial resolution of QuickBird imagery make any difference in the delineation of "real" individual tree crowns? Will that make any difference for management inventory purposes? These are but some of the questions needing answers.

After introducing the goals of the overall project and the methodology used for this study, this paper presents preliminary crown delineation results and counts from six representative sites of Cockburn Island (Lake Huron, Ontario), first, from the analysis of an Ikonos panchromatic image (100 cm/pixel) and then, from a QuickBird image (70 cm/pixel), to examine some of the benefits of the added spatial resolution. Local maxima (or Tree Top) results are also presented as reference. This paper does not address the potential benefits of the higher spatial resolutions, panchromatic and multispectral, to the species recognition component of a full ITC analysis, an important factor in the production of ITC-based Forest Cover Maps.

The Cockburn Island Project

This preliminary work is part of a large project in northcentral Ontario, including sites on Cockburn Island, Ontario (Lat. 45^{o} 90' N, Long. 83^{o} 22' W). In 2003, a project funded by Ontario's Living Legacy Trust was initiated to test the utility and accuracy of a fully-operational large-scale stereo photography (LSP) and data analysis system for wildlife habitat assessment and multi-value forest resource inventory in a variety of deciduous forest types in the Great Lakes-St. Lawrence (GLSL) forest region of Ontario. Data from matching ground-based sample plots will be statistically compared to LSP-generated data in leaf-on and leaf-off conditions to determine what tree-, plot-, and stand-level variables, can be directly or indirectly estimated from the photos, how similar the estimates from the two LSP missions and the ground-based method are to one another, and cost-benefit analysis of the two data capture methods.

For these purposes, and since then, a considerable dataset has been accumulated. It consist of an Ikonos image (panchromatic at 1 m/pixel, multispectral at 4 m/pixel), a QuickBird image (panchromatic at 70 cm/pixel, multispectral at 2.4 m/pixel), a recent Forest Resources Inventory (FRI) (done the conventional way: by photo-interpretation with field work), series of LSP plots (leaf-on, leaf-off and infrared), series of field plots, and even, a stereo pair of Ikonos images to possibly create a DEM.

The extended Cockburn Island project will compare Ikonos and QuickBird ITC-derived species composition (up to 10 species) with the photo-interpreted species composition for the stands of the current, recently created, forest inventory. It will check stand parameters such as density,

crown closure and average crown area per species, and examine the semi-automatic creation of ITC-derived stand polygons. A sampling of the area with large-scale photography (LSP), originally designed to test volume estimations in non-boreal forests, but also for ecological assessments, will be used to test "real" individual tree crown training and testing of the ITC classifications. The project is meant to be a solid demonstration to forest agencies that ITC analysis and LSP sampling can lead to something similar (or better) than Ontario's FRI maps, with a cost benefit analysis (CLC-Camint and R&B Cormier) and arguments for/against using QuickBird rather than Ikonos.

Here, for this Ikonos *vs* QuickBird crown delineation and count assessment, six representative test areas of approximately 3.7 ha each were selected within the different forest types present on the images (**Figure 1**). The sites content varies from deciduous trees (Sites 1& 2) to smaller crown coniferous trees (Sites 5 & 6), and includes a mixedwood area (Site 3) and a coniferous regenerating area (Site 4).

Methods

The ITC crown separation (ITCVFOL) and delineation (ITCISOL) software (Gougeon, 1995; Gougeon and Leckie, 2003a) are applied to the six test areas on both images in order to compare their performance. The ITC crown separation technique relies on following the valleys of shade that typically exist between the more illuminated tree crowns in a panchromatic image, while the ITC delineation process finishes the delineation by following each crown contour and creating distinct objects. The software uses thresholds and other parameters that may influence the results. These where kept constant for each media. For comparaison, the local maxima technique (also known as the Tree Top technique) (Gougeon and Moore, 1989; Gougeon and Leckie, 2003a) is applied to the same areas using the same thresholds and preprocessing (a 3x3 smoothing).

Results and Discussion

The ITC delineation results from the northwest sub-section of five test sites (Sites 1 & 3-6) for the Ikonos and QuickBird images are presented on the right-hand side of **Figures 3 and 4**, respectively. For comparisons, the left-hand side shows the panchromatic images and the results from the Tree-Top technique. The delineation differences are quite obvious. The delineated crowns with the QuickBird image are much rounder and appear more appropriate. This is mostly attributable to the higher spatial resolution. However, there are still some tree clusters and, some of the smaller objects may correspond to sections of crowns rather than full crowns. This phenomenon affects the deciduous and mixed stands more than the coniferous stands. On the other hand, the delineation process seems able to pickup some small co-dominant or even intermediate trees, as particularly noticeable on Site 3.

In general, as seen **Table 1** and **Figure 2**, the QuickBird ITC delineation counts are, on average, 52% higher than the Ikonos counts for the same forest type. They correspond much better with their Tree-Top counts. The Tree-Tops themselves appear to correspond well with our perception of tree crowns in the image. The QuickBird Tree-Top counts are, on average, 30% higher than

their Ikonos counterparts. The Ikonos delineation counts are the lowest, which is reflected in the prevalence of tree clusters rather than real individual tree crowns.

Site 4, containing very dense regenerating conifers in its northeast corner, illustrates more dramatically the advantages of QuickBird's higher spatial resolution. The ITC delineation technique appears incapable of properly separating the trees in that corner on the Ikonos image. More successful delineations have been achieved with various media at resolution close to 1 m/pixel by doubling the spatial resolution of the image (Gougeon and Leckie, 2003b). This resolution doubling does not create any new information, but allows smaller tree crowns to be detected. This was not tested here. The Tree-Top technique, usually preferred for regeneration assessments, is not as dramatically affected with this subsection of Site 4. Trees appear to be well counted within the very dense regenerating conifers although, the Ikonos count is still 20% lower than the QuickBird count.

Without counts on the ground or better, a ground location for each tree, the results of this study are only relative and qualitative. Nevertheless, one could conclude that QuickBird added spatial resolution gets us a bit closer to a "real" individual tree based forest inventory from satellite imagery. But, this may be only an idealistic goal. With Ikonos imagery, we may already be at a point where the ITC approach and techniques can be used to secure "stand-level" information that is superior to some of the information provided by the conventional forest inventory process (e.g., species composition, species distribution within a stand) and this, knowing full well that we are doing an ITC analysis "in name" only, that is, not expecting results to be exact at the tree level (CLC-Camint, 2002).

Will the added spatial resolution of QuickBird's panchromatic (70 cm/pixel) and multispectral (2.4 m/pixel) bands help provide better information at the stand level than Ikonos? Will that be worth the additional image price? Will the wider field of view make a difference? Will the delineation of more ITCs and less clusters make average crown diameter useful for volume estimations? Will it make density more useful? Isn't better radiometric resolution more important overall? Will any of these (and others) make any difference for management inventory purposes or for other forestry applications? These are but some of the questions still needing answers.

Conclusion

This paper summarily compared Ikonos and Quickbird panchromatic imagery for their individual tree crown delineation (and tree counting) capabilities in various forest conditions as an initial step towards their evaluation for the semi-automatic production of forest management inventories that are hopefully more precise, accurate and timely than their conventional photo-interpreted counterparts. QuickBird's added spatial resolution appears to detect more trees, less tree clusters and provide better crown boundaries. It may be detecting smaller codominant trees, and even intermediate trees, that Ikonos is not. How will that influence the precision of information at the forest stand level? Will the added spatial resolution of the multispetral imagery help with ITC species classification? Will the final results of the project, ITC cover maps grounded by LSP plots from both Ikonos and Quickbird, be better than conventional forest management maps? At this point, we still have more questions than answers.

References

CLC-Camint, 2002. Vers une meilleure connaissance forestière grâce aux images satellitaires à haute résolution Ikonos - Phase II. Rapport final: Programme de mise en valeur des ressources du milieu forestier - Volet I. CLC-Camint Inc., Hull, Québec. Avril 2002. 88 p.

Gougeon, F.A. and Moore, T. 1989. Classification individuelle des arbres à partir d'images à haute résolution spatiale. Pages 185-196 in M.Bernier, F.Bonn and P.Gagnon (eds.) Télédétection et gestion des ressources Vol.VI - 6e Congrès de L'association québécoise de télédétection. Sherbrooke, Québec, Canada, May 4-6, 1988. L'association québécoise de télédétection. Sainte-Foy (Québec).

Gougeon, F.A. 1995. A crown-following approach to the automatic delineation of individual tree crowns in high spatial resolution aerial images. Canadian Journal of Remote Sensing 21(3):274-284.

Gougeon, F.A. and Leckie, D. 2003a. Forest information extraction from high spatial resolution images using an individual tree crown approach. Information Report BC-X-396. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC.

Gougeon, F.A. and Leckie, D. 2003b. The Individual Tree Crown (ITC) approach applied to Ikonos images of a Coniferous Plantation Area. (In writing)

Table 1 – Tree counts from six sites on the QuickBird and Ikonos images procured with the ITC and the local maxima (or Tree Top) approaches. Sites vary from deciduous trees to smaller crown coniferous trees, with a mostly mixedwood site (3) and a coniferous regeneration site (4)

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All sites
QB_ITCs	1322	1268	1303	1480	1560	1570	8503
QB_TTs	1398	1304	1283	1520	1550	1524	8579
IKO_ITCs	865	846	897	942	1022	1026	5598
IKO_TTs	1046	1009	1013	1219	1135	1192	6614

Figure 3 (page 8) – Results from the local maxima (or TreeTop) and ITC analyses of the IKONOS panchromatic image (100cm/pixel) for the northeast corners of sites 1, 3, 4, 5 and 6.

Figure 4 (page 9) – Results from the local maxima (or TreeTop) and ITC analyses of the QuickBird panchromatic image (70cm/pixel) for the northeast corners of sites 1, 3, 4, 5 and 6.

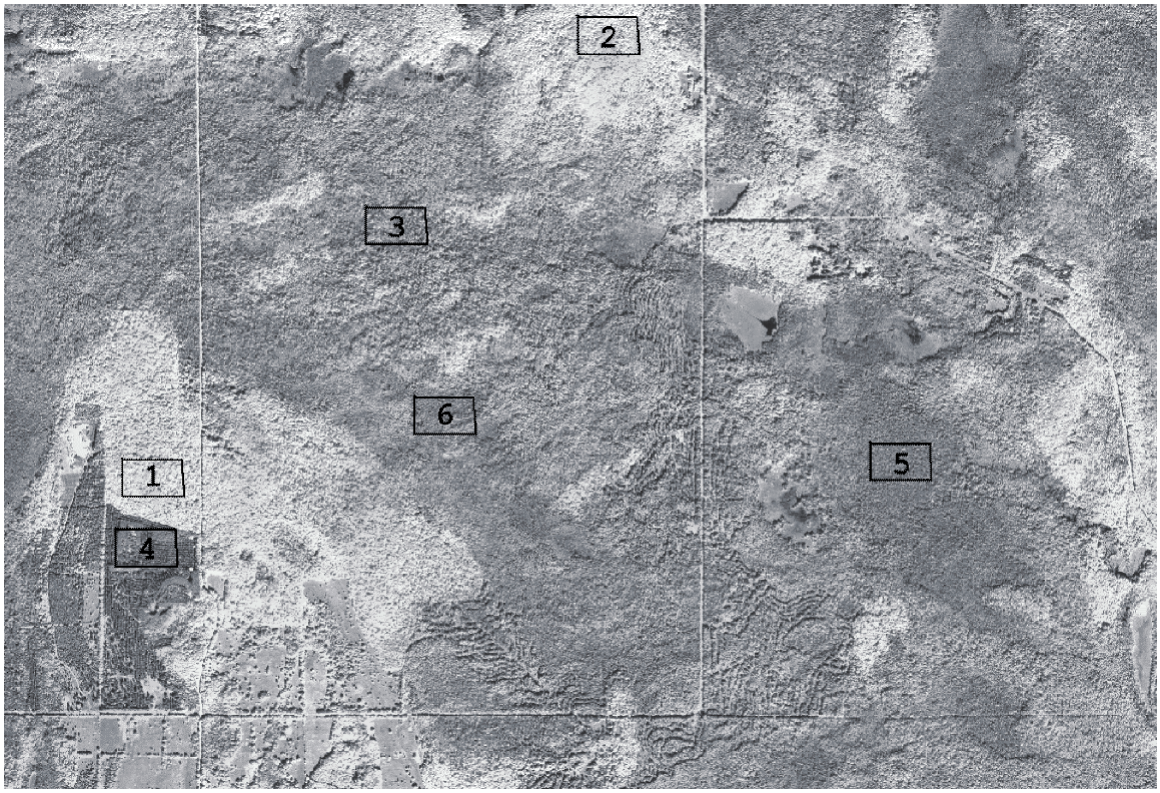

Figure 1 – Locations of the six test sites on part of the QuickBird image of Cockburn Island, Ontario. Site contents vary from medium size crown deciduous trees (Sites 1&2), to small crown coniferous trees (Sites 5&6), to very small regenerating coniferous trees (Site 4), with a mixedwood area (Site 3).

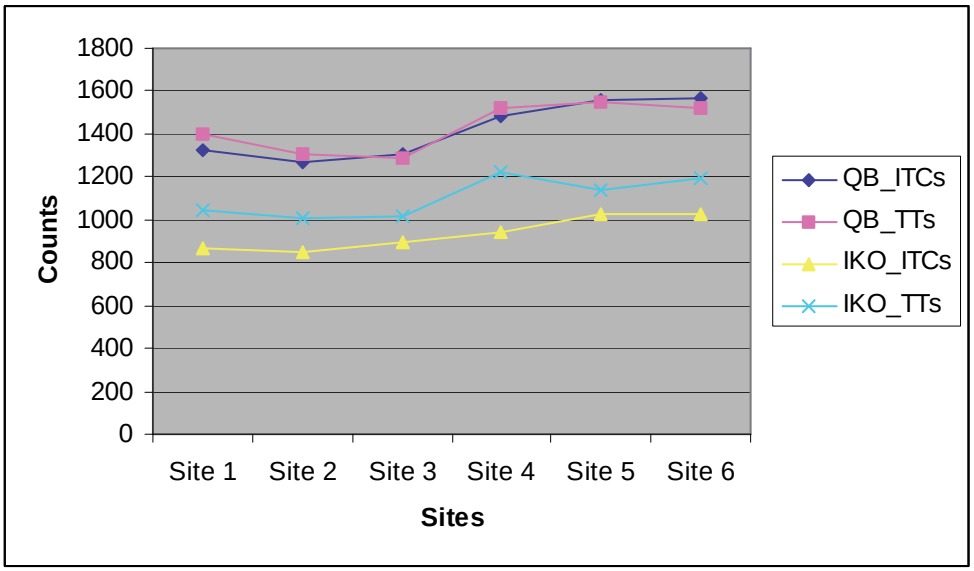

Figure 2 – Tree counts from six sites on the QuickBird (QB) and Ikonos (IKO) images procured with the ITC and the local maxima (or TreeTop) approaches. Site contents vary from medium size crown deciduous trees (Sites 1&2), to small crown coniferous trees (Sites 5&6), to very small regenerating coniferous trees (Site 4), with a mixedwood area (Site 3).

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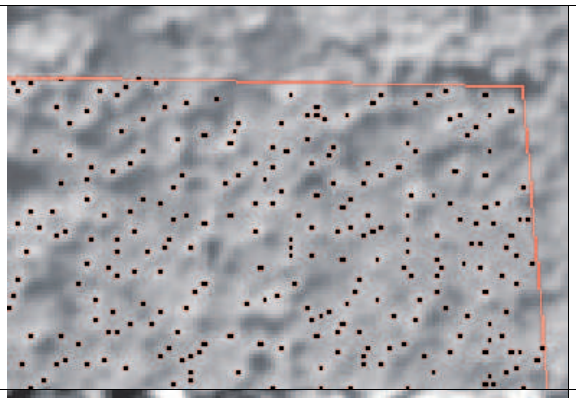
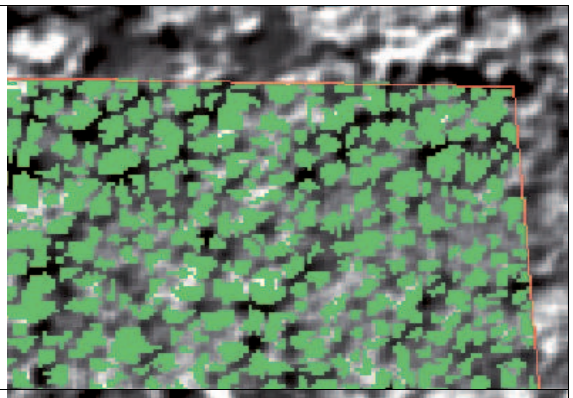
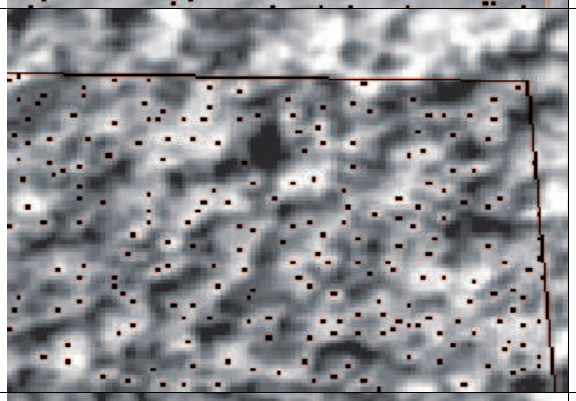
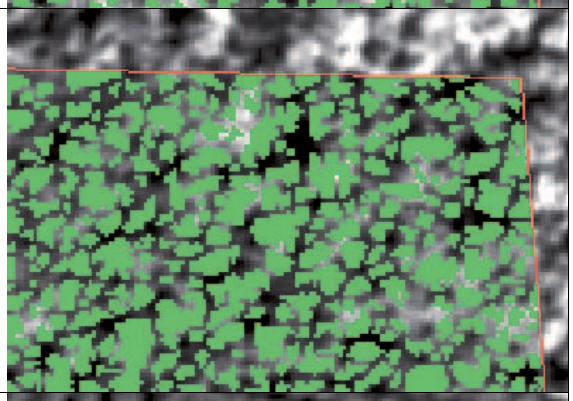
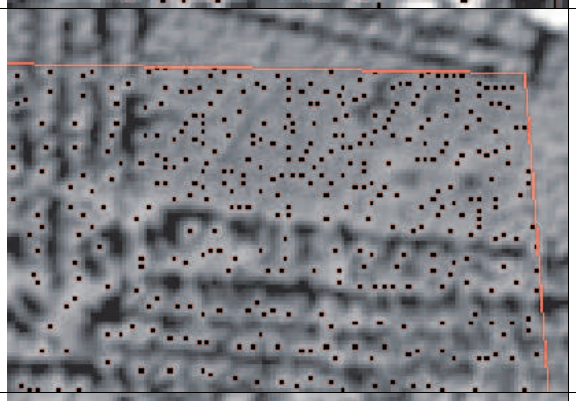
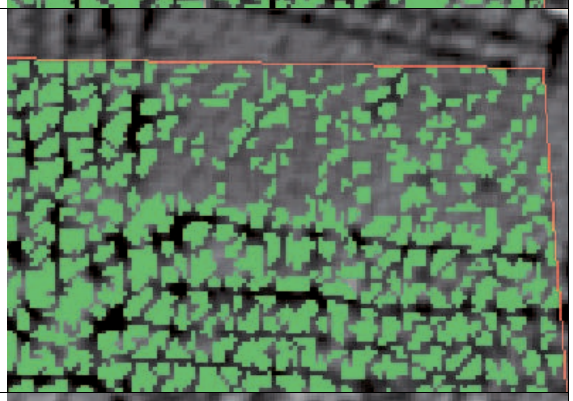
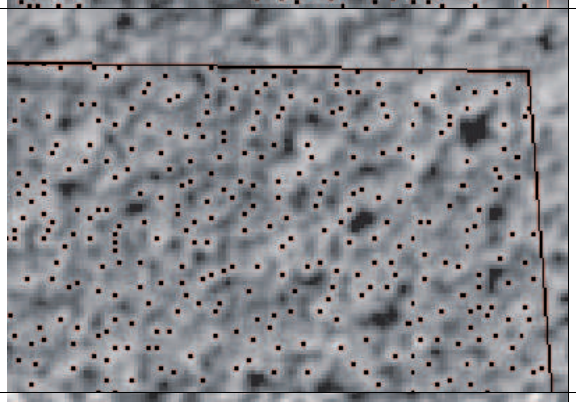
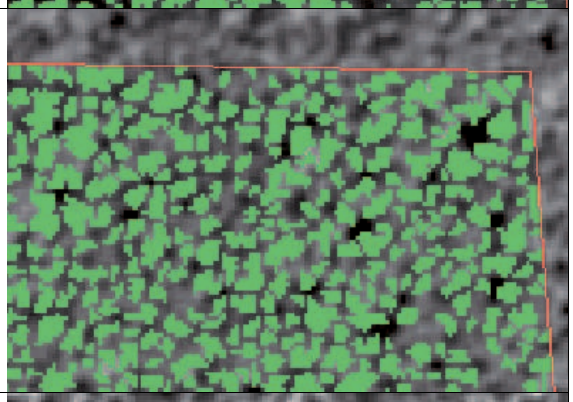
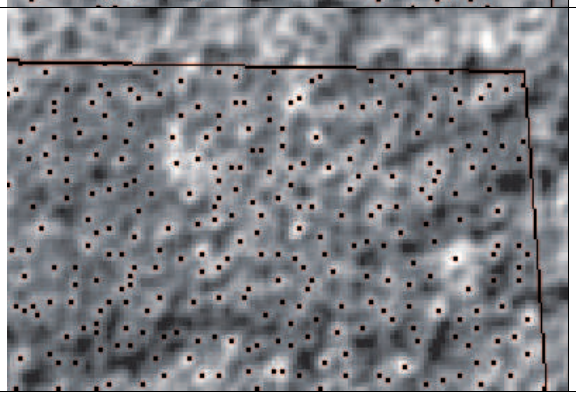
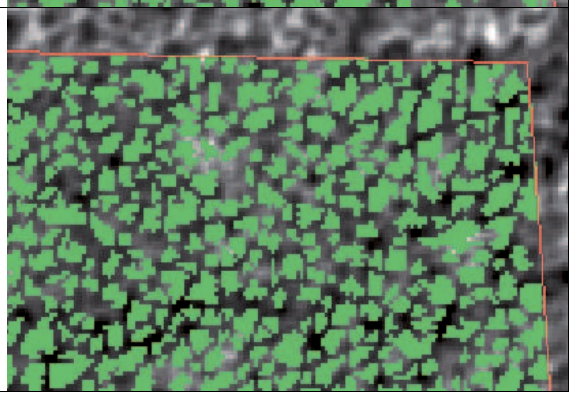
1		
3		
4		
5		
6		

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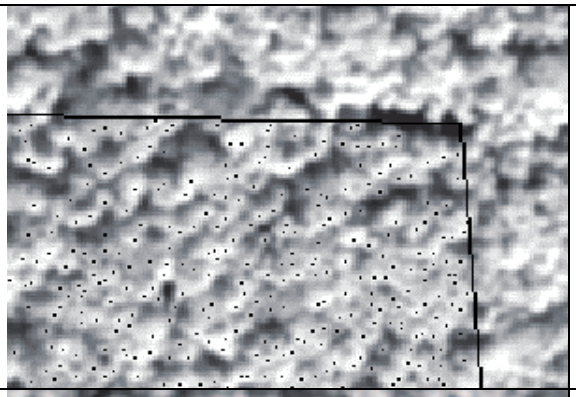
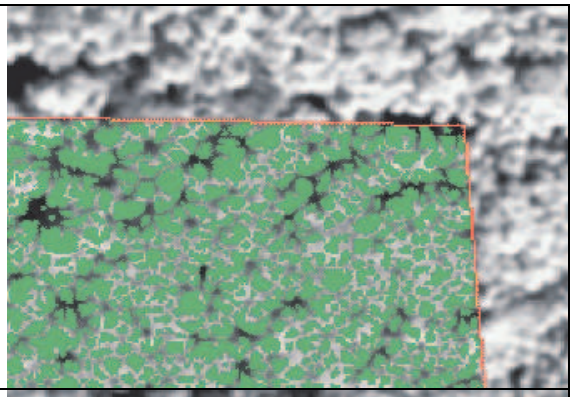
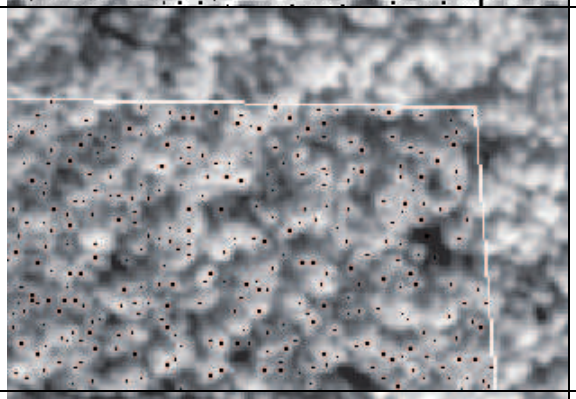
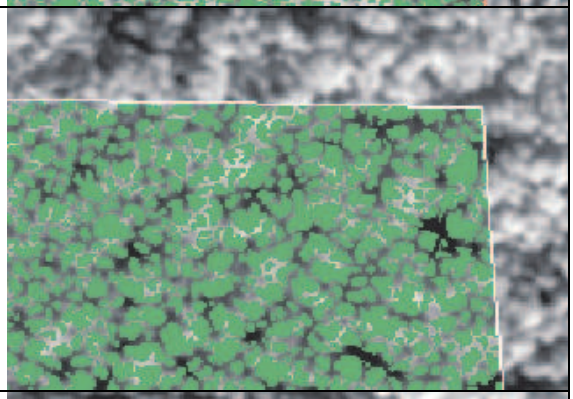
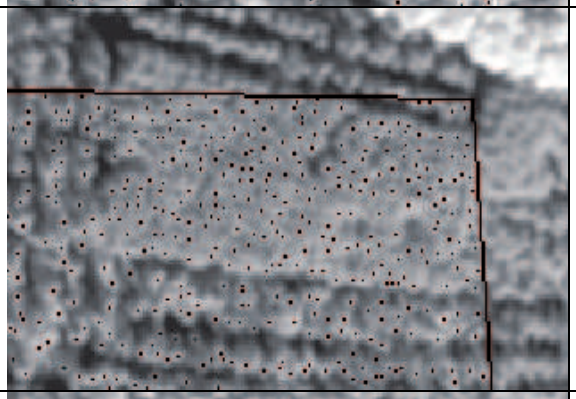
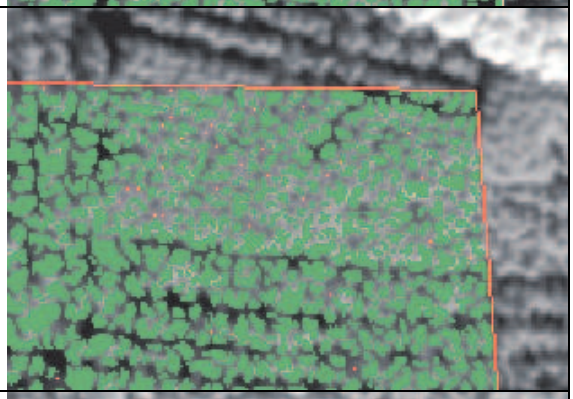
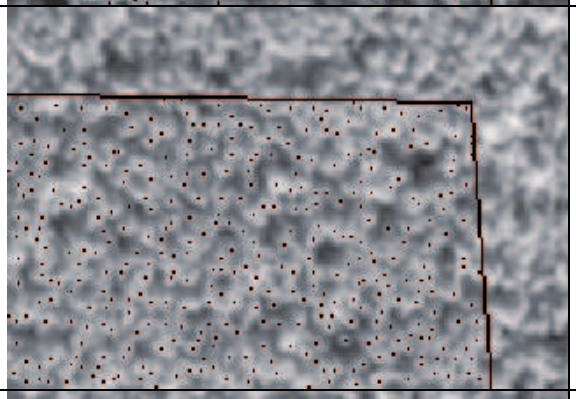
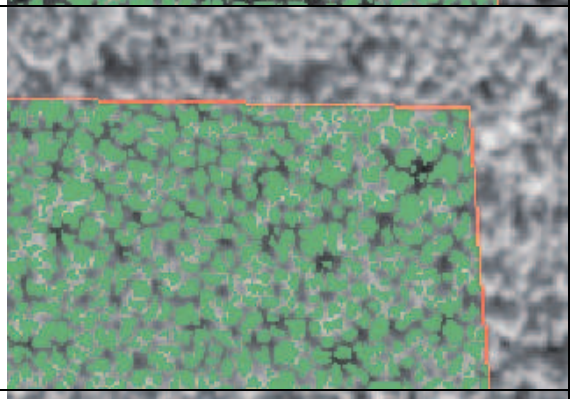
1		
3		
4		
5		
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