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LAND COVER AND LAND USE CHANGE RESEARCH

Improvements in Landsat Pathfinder methods for monitoring tropical deforestation and their extension to extra-tropical areas

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Proposal Abstract:

The Landsat Pathfinder (now the Deforestation Mapping Group) project has demonstrated the feasibility of monitoring forest cover change over very large areas using Landsat data. To extend this approach to satisfy the needs of the Global Observations of Forest Cover will require an assessment that the overall approach successfully used in Landsat Pathfinder for the humid tropics can also be used in other regions and that more automated procedures are used.

Specifically we will carry out large scale prototyping of several advanced processing procedures, including pre-processing to reduce atmospheric and MTF effects, multi-temporal unsupervised processing, application of decision-tree methodologies, mixture modeling and other advanced procedures developed under previous research. We will assess the improvements they introduce using data from areas in the Pan-Amazon and Central Africa as part of the previous Landsat Pathfinder work. We will also investigate how the original Landsat methodology and the enhancements proposed operate in selected areas throughout the globe, where rapid rates of deforestation are occurring, including extra-tropical forests in South America (Paraguay), southern Africa, central Asia, sites in the Eastern United States, as well as selected sites in the boreal forest.

ESE Keywords:

[The url http://lcluc.gsfc.nasa.gov/RIF list of keywords is not available, but we can add keywords based on the content if necessary]

carbon, deforestation, forest cover mapping, Landsat imagery, image processing, automated classification

NASA ESE Scientific Question

The general premise of the work is focused on answering what are the changes in land cover and/or land use? The development of methods suggested in the research proposal are anticipated to improve the classification of forest cover change in tropical and extra-tropical areas.

Proportion of social science used in study

We have not included any aspects of the human dimensions into this work.

Themes covered in project

The themes covered in this work are broken into the stated categories and are shown in Figure 1.

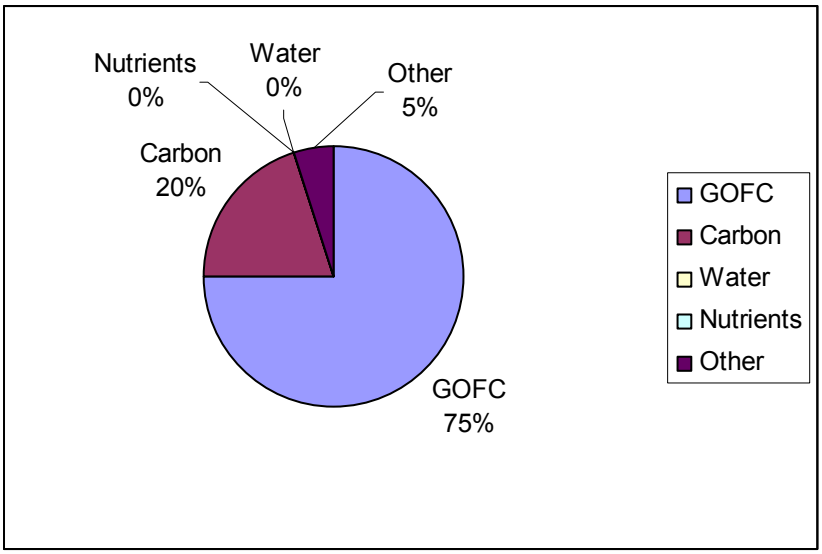

FIGURE 1: The relative proportion of science themes undertaken for the reporting period.

Goals for this Period of Performance

The goals and workplan for the three year term of this project are outlined below.

Year 1

Assess whether the overall approach successfully used in Landsat Pathfinder for the humid tropics can also be used in other regions to satisfy the needs of the Global Observations of Forest Cover	The Pathfinder classification methodology has been applied to 17 scenes in regions of boreal forest types in North America and Asia.
Carry out large scale prototyping of several advanced processing procedures: improved multi-temporal unsupervised processing; application of decision-tree and other advanced procedures; pre-processing to reduce atmospheric and MTF effects.	The improved hybrid classification method has been applied to 69 scenes in tropical and extra-tropical regions. We have compared our classification results with the results of two other classification approaches: recursive hierarchical image segmentation and a supervised decision tree classifier, C5.0 Pre-processing strategies have not been implemented or tested but will be included in process tests in the next year**.**

Year 2

Test the mixture modeling and supervised components of the approach to assess whether they bring substantial additional benefits.	
Assess Landsat Pathfinder methods including enhancements in test sites in the boreal zone.	An additional 80 scenes in the North American boreal forests will be processed. Field work is planned for the summer of 2001.

Year 3

The most spatially and temporally complex areas will be examined to assess whether the classification processes provide sufficiently reliable performance.	Areas to be considered include sub-tropical forests in South America (e.g., Chacoan woodlands), wooded grasslands of Eastern Africa (e.g., miombo and mopane woodlands) deciduous and mixed temperate forests in southeastern North America, and boreal forests from central Asia in Mongolia, Russia and Alaska.
Investigate the contribution of coarser resolution data sets for improved characterization of forest types in terms of leaf type and duration.	We will examine the extent to which we can use multi-temporal sequences of MODIS data, especially the NDVI and its improved vegetation indices to assist the characterization of forest types especially in relation to leaf type and duration.
Participate with GOFC activities providing advice on how to improve the characterization and monitoring of forest cover.	

Progress Report

I. A new hybrid classification method has been used to process 69 scenes. The method has been applied to 17 scenes over boreal forests in North America and Asia.

Number of Landsat Scenes Processed into Classified Product by Continent

Tropical			Extra-Tropical		
South America			North America		
	Bolivia	9		Canada	20
	Colombia	6			
	Peru	20			
	Venezuela	4			
Africa			Asia		
	DRC	3		Mongolia	7

II. We have compared our classification results with two other classification approaches.

A. Recursive hierarchical image segmentation (with Dr. James Tilton, NASA GSFC)
B. Supervised decision tree classifier C5.0

A. Recursive hierarchical image segmentation (RHIS)

Dr. James Tilton has developed a recursive hierarchical image segmentation program to overcome the lack of spatial information in spectral clustering and the over segmentation that can occur in region growing.

> "Characteristic feature thresholding or clustering is often ineffective because it does not exploit spatial information… With straightforward region growing, spectrally similar but spatially disjoint regions are never associated together, thus complicating their identification… A hybrid region growing and spectral clustering approach has been developed to overcome these problems. The hybridization with spectral clustering allows association of spectrally similar but spatially disjoint regions." (excerpts from Tilton, 7 June, 2000 http://code935.gsfc.nasa.gov/code935/tilton/index.html)

Three Landsat scenes were classified using RHIS and compared to the classification from the Deforestation Mapping Group method. Two scenes were from Central Africa and one from South America.

Table I.

Confusion Matrix Table comparing classifications produced by current DMG methods and by recursive hierarchical image segmentation for Landsat scene 176062, acquired 6 December 1999 in the Democratic Republic of Congo.

The table displays how pixels classified by the DMG method were classified by the RHIS, i.e., 84.4% of pixels classified as forest by the DMG method were classified as forest by the RHIS, 1.2% were classified as water by RHIS, etc. The water class had the best agreement between the two methods. Similar percentages of forest (84.4%) and non-forest (84.7%) were classified as such by RHIS. The greatest disagreements occurred between the shadow class (63.7% was classified as water by RHIS, a common confusion) and the degraded class.

DMG	RHIS					
Class	Forest	Water	Cloud	Shadow	Degraded	Non-forest
Forest	84.4	1.2	0.0	0.0	11.3	3.0
Water	0.1	99.3	0.2	0.0	0.0	0.5
Cloud	0.3	0.6	91.3	0.0	0.1	7.7
Shadow	12.2	63.7	2.2	0.1	0.2	21.8
Degraded	20.3	0.2	0.0	0.0	53.2	26.4
Non-forest	4.6	0.5	0.3	0.0	9.9	84.7

Average accuracy 68.83%
Overall accuracy 78.99%
Kappa coefficient 0.6832 Standard deviation 0.00010

Table II.

Confusion Matrix Table comparing classifications produced by current DMG methods and by recursive hierarchical image segmentation for Landsat scene 174059, acquired 16 November 1998 in the Democratic Republic of Congo

DMG	RHIS					
Class	Forest	Water	Cloud	Shadow	Degraded	Non-forest
Forest	98.7	0.0	0.1	0.0	1.0	0.0
Water	18.4	80.8	0.0	0.3	0.3	0.2
Cloud	12.6	0.2	79.0	2.4	0.6	5.2
Shadow	27.0	4.0	0.2	60.3	0.0	8.5
Degraded	30.8	0.0	0.0	0.0	67.9	1.3
Non-forest	11.4	0.0	0.6	0.0	49.7	38.3

Average accuracy = 70.83%
Overall accuracy = 96.71%
Kappa Coefficient = 0.67048 Standard Deviation = 0.00027

Table III.

Confusion Matrix Table comparing classifications produced by current DMG methods and by recursive hierarchical image segmentation for Landsat scene 006066, acquired 16 October 1996 in Peru.

DMG	RHIS					
Class	Forest	Water	Cloud	Shadow	Degraded	Non-forest
Forest	97.5	0.0	0.1	0.5	0.0	1.8
Water	6.1	87.4	0.5	2.8	0.1	3.1
Cloud	9.6	0.6	86.6	0.1	0.3	2.9
Shadow	54.1	0.8	0.9	42.9	0.0	1.4
Degraded	65.9	0.1	0.0	0.1	0.5	33.4
Non-forest	14.7	0.8	0.5	0.2	2.2	81.7

Average accuracy = 66.10%
Overall accuracy = 87.56%
Kappa Coefficient = 0.67659 Standard Deviation = 0.00013

B. A supervised decision tree classifier (C 5.0) which recursively partitions training samples into subsets so that the total information gain ratio is maximized was used to classify two Landsat scenes in Mongolia.

The results from the decision tree classifier were compared to the DMG classification for one scene in Mongolia and are shown in the tables below.

Table IV.

Confusion Matrix Table comparing classifications produced by current DMG methods and by a decision tree classifier for Landsat scene 136024, acquired 6 June 1992 in Mongolia. A deciduous class was added to the DMG classification but accounts for only 1.25% of the area classified. The greatest discrepancy occurs between forest, woodland and non-forest which is most likely a function of differences in interpretation. There was also significant confusion between the water, cloud, shadow, ice and non-forest classes.

DMG	C5						
Class	Forest	Woodland	Water	Cloud	Shadow	Ice	Nonforest
Forest	49.6	19.6	0.0	4.1	4.7	0.0	21.9
Deciduous	13.4	15.1	0.0	12.1	0.3	0.0	59.1
Woodland	1.6	12.4	0.0	0.1	0.0	0.0	85.9
Water	0.1	0.0	50.0	3.1	1.7	43.2	1.8
Cloud	1.1	0.1	0.0	84.8	1.2	0.5	12.3
Shadow	8.2	4.6	0.1	41.4	16.1	0.7	29.0
Ice	0.0	0.0	0.7	4.3	2.0	66.0	27.0
Nonforest	1.0	1.1	0.0	10.8	0.5	0.1	86.5

Average accuracy = 52.18%
Overall accuracy = 74.40%
Kappa Coefficient = 0.54958 Standard Deviation = 0.00012

Table V.

Confusion Matrix Table comparing the same classifications for the same Landsat scene as presented in Table IV with water, cloud, shadow and ice classes eliminated from the computation, which improves the overall accuracy. The discrepancy in the woodland classification is apparent.

DMG	C5		
Class	Forest	Woodland	Non-forest
Forest	54.4	21.6	24.1
Deciduous	15.3	17.3	67.5
Woodland	1.6	12.4	86.1
Non-forest	1.2	1.2	97.6

Average accuracy = 54.78%
Overall accuracy = 85.94%
Kappa Coefficient = 0.66715 Standard Deviation = 0.00015

Conclusions

Based on the work described above the following conclusions have been reached:

- The improved Deforestation Mapping Group (DMG) classification methods have successfully been extended to extra-tropical areas.

- Alternative classification approaches have been compared to the DMG method. While the RHIS warrants continued research, the accuracy achieved and computational effort required indicate that it should not replace the current DMG methodology at this time. The decision tree classifier appears to be less satisfactory but differences in image interpretation confound the results. The levels of human intervention required by the decision tree classifier and the improved DMG classification method are similar.

Publications to date

Kalluri, Sataya, Arthur Desch, Troy Curry, Alice Altstatt, Didier Devers, John Townshend, and Compton Tucker. "Historical Satellite Data Used to Map Pan-Amazon Forest Cover". EOS, Transactions, American Geophysical Union. Volume 82(18): 201, 206-207. 2001.