A COMPARISON OF FIA PLOT DATA DERIVED FROM IMAGE PIXELS AND IMAGE OBJECTS

Charles E. Werstak, Jr.[1]

Abstract.—The use of Forest Inventory and Analysis (FIA) plot data for producing continuous and thematic maps of forest attributes (e.g., forest type, canopy cover, volume, and biomass) at the regional level from satellite imagery can be challenging due to differences in scale. Specifically, classification errors that may result from assumptions made between what the field data represent and what the corresponding spectral information of the image pixels depict. This investigation aimed at determining whether image objects derived from Landsat TM imagery can be used as an alternative to a 3 by 3 neighborhood of pixels for characterizing forested FIA plots. Results showed strong positive correlations between the different scales of base map units across all of the image derivatives. Further examination of the data using the Wilcoxon signed rank test for paired samples indicated that in most cases, finer level image objects were a better representation of the 3 by 3 neighborhood of pixels than coarser ones and some image derivatives performed better than others. The same tests were applied to a subset of plots dominated by quaking aspen (*Populus tremuloides* Michx.) with similar results. Information gained may provide further insight into object based segmentation and classification methods using FIA plot data, satellite imagery, and ancillary geospatial data.

INTRODUCTION

Several studies have compared image pixel-based classification to image object-based segmentation and classification for mapping different vegetation attributes from remote sensing imagery, many of which have shown that using image object-based segmentation combined with decision tree image classification methods often achieve higher accuracies (Chubey et al. 2006, Gao and Mas 2008, Hay et al. 2005, Karl and Maurer 2010, Kim et al. 2010, Yasumasa et al. 2011).

Quaking aspen (*Populus tremuloides* Michx.) was selected as the species of interest because it is a critical species that supports wildlife and livestock, watershed function, the forest products industry, landscape diversity, and recreation in the Interior West (Bartos and Campbell 1998). Studies have indicated that changes in fire regimes, an increase in herbivore presence in young aspen stands, and recent drought episodes are the main factors for increased mortality rates in aspen (Deblander et al. 2010).

This objective of this investigation was to determine whether different scales of image objects derived from Landsat TM imagery can be used as an alternative to a 3 by 3 neighborhood of pixels for characterizing canopy cover of forested Forest Inventory and Analysis (FIA) plots and aspen dominated FIA plots.

FIA PLOT DATA

Multi-condition forested plots having 10 or greater percent canopy cover of live trees were queried from the FIA database for Utah, inventory years 2000-2009, resulting in 3,224 plots. Basal area per acre

[1] Biological Scientist, U.S. Forest Service, Rocky Mountain Research Station, 507 25th Street, Ogden, Utah 84401. To contact, call 801-625-5699 or email at cewerstak@fs.fed.us.

was computed by species and summed to the plot level. The Interior West core optional variable crown cover percent (CRCOVPCT_RMRS) was used in conjunction with basal area per acre, to calculate tree cover and tree cover by species (absolute cover) for the plots (USDA Forest Service 2011). Ultimately, these values were used to calculate the percent canopy cover by species (relative cover) for the plots.

PREDICTOR DATA

Three different Landsat TM scenes acquired over Utah during the summer of 2009 were used in the analysis (Table 1). The scenes were converted to Top-Of-Atmosphere (TOA) reflectance using standard Landsat-specific methods. The following vegetation indices and image transformations were calculated for each scene:

1. Enhanced vegetation index (EVI)
2. Normalized difference vegetation index (NDVI)
3. Normalized difference moisture index (NDMI)
4. Modified soil adjusted vegetation index (MSAVI2)
5. Tasseled cap transformation (TCAP)
6. Principal components analysis (PCA)

Layer stacks were created for each scene using the following derivatives: Landsat TM reflectance bands 1:6, NDVI, PCA first principal component, and TCAP bands 1:3. Due to anomalies with the blue bands resulting from the TOA conversion, EVI was calculated on the Landsat Standard Terrain Correction (Level 1T) product.

NEIGHBORHOOD PIXELS AND IMAGE OBJECTS

A 3 by 3 neighborhood of pixels was generated for each forested FIA plot location to correspond to the FIA plot design. To create the 3 by 3 neighborhoods around the 3,224 FIA plots, point feature classes of the X and Y plots (plot center of subplot one) were converted to 30 m thematic raster images, and then 3 by 3 neighborhood filters were applied. As a Landsat pixel is 30 m by 30 m or 900 m^2, a 3 by 3 neighborhood consisting of nine pixels is 8,100 m^2 or a little greater than 2 acres. The area of one FIA subplot is 168.11 m^2, therefore the area of four FIA subplots is 1809.56 m^2. The outermost circumference of four FIA subplots is 6052.08 m^2 or just under 1.5 acres, which is almost 75 percent of the 3 by 3 neighborhood pixel area (Fig. 1A).

Several different scales of image objects were generated from the Landsat TM layer stacks using Trimble eCognition software (Definiens 2009). Using National Agriculture Image Program (NAIP) 1 m color-infrared imagery acquired in 2011 as a backdrop, the different scales of image objects were visually evaluated to determine which scale(s) best delineated forest stands (Figs. 1B, 1C, and 1D). Ultimately, two different scales of image objects (scale parameter 25 or “coarse”, and scale parameter 15 or “fine”) were identified for use in this analysis. Table 1 is a summary of the image object acreages for each TM scene.

Table 1.—Acreage summaries for image objects corresponding to forested FIA plots. Image object size is a function of the scale parameter.

TM Scene (Path/Row)	Number of FIA Plots	eCognition Scale Parameter	Average Size (Acres)	Minimum Size (Acres)	Maximum Size (Acres)
37/32	691	25	161.36	10.23	717.00
37/32	691	15	62.14	2.45	232.40
38/31	153	25	158.28	21.57	695.21
38/31	153	15	60.54	9.56	175.02
38/33	466	25	161.86	12.90	607.58
38/33	466	15	61.66	5.56	248.42

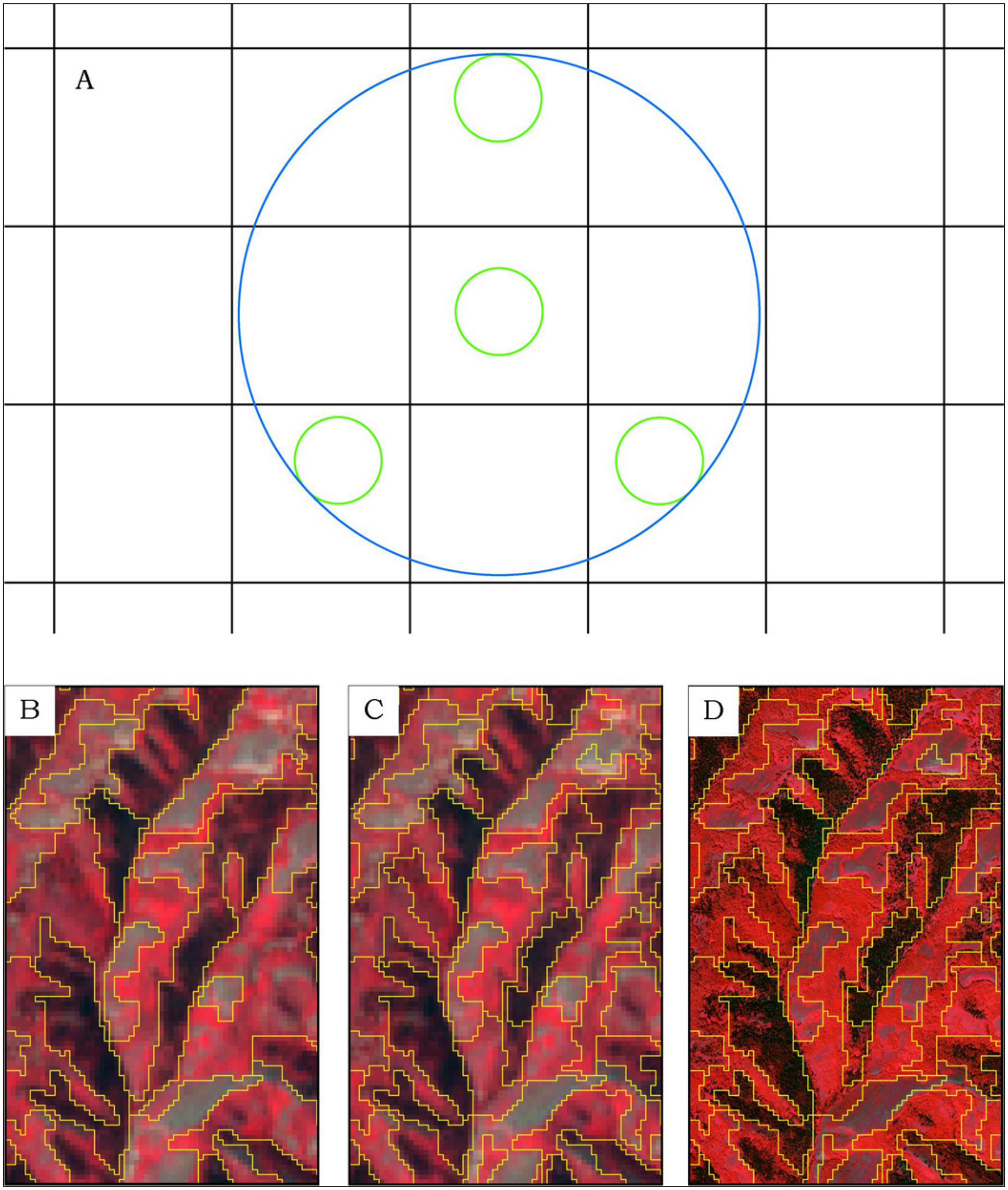

Figure 1.—An example of the FIA plot design over a grid of Landsat TM pixels (A) followed by examples of the two different scales of image objects used in the analysis overlaid on Landsat TM (RGB 4, 3, 2) and 2011 1 m NAIP (RGB 4, 3, 2) (D). Scale factor 25 (B) is coarse, scale factor 15 (C) is fine, and scale factor 15 (D) is fine.

MAP UNIT COMPARISONS

Zonal statistics were calculated for the predictor data using the two different scales of image objects and the 3 by 3 neighborhood pixel areas for each Landsat TM scene. Simple linear correlation was used to examine the relationships between the zonal means of the 3 by 3 neighborhood pixel areas and the corresponding image objects for the forested FIA plots for all of the predictor layers. The scatterplots (Fig. 2A) showed strong positive correlations between the different scales of base map units across all of the image derivatives with the finer scaled image objects consistently having higher Pearson's r values (Table 2). This was expected due to eCognition's homogeneity criterion, which is a combination of spectral homogeneity and shape homogeneity, used to produce image objects. Essentially, the upper heterogeneity threshold is determined by the maximum standard deviation derived from the weighted input image layers and controlled by the scale parameter—the lower the scale parameter, the lower the threshold, the smaller the image objects (Definiens 2009).

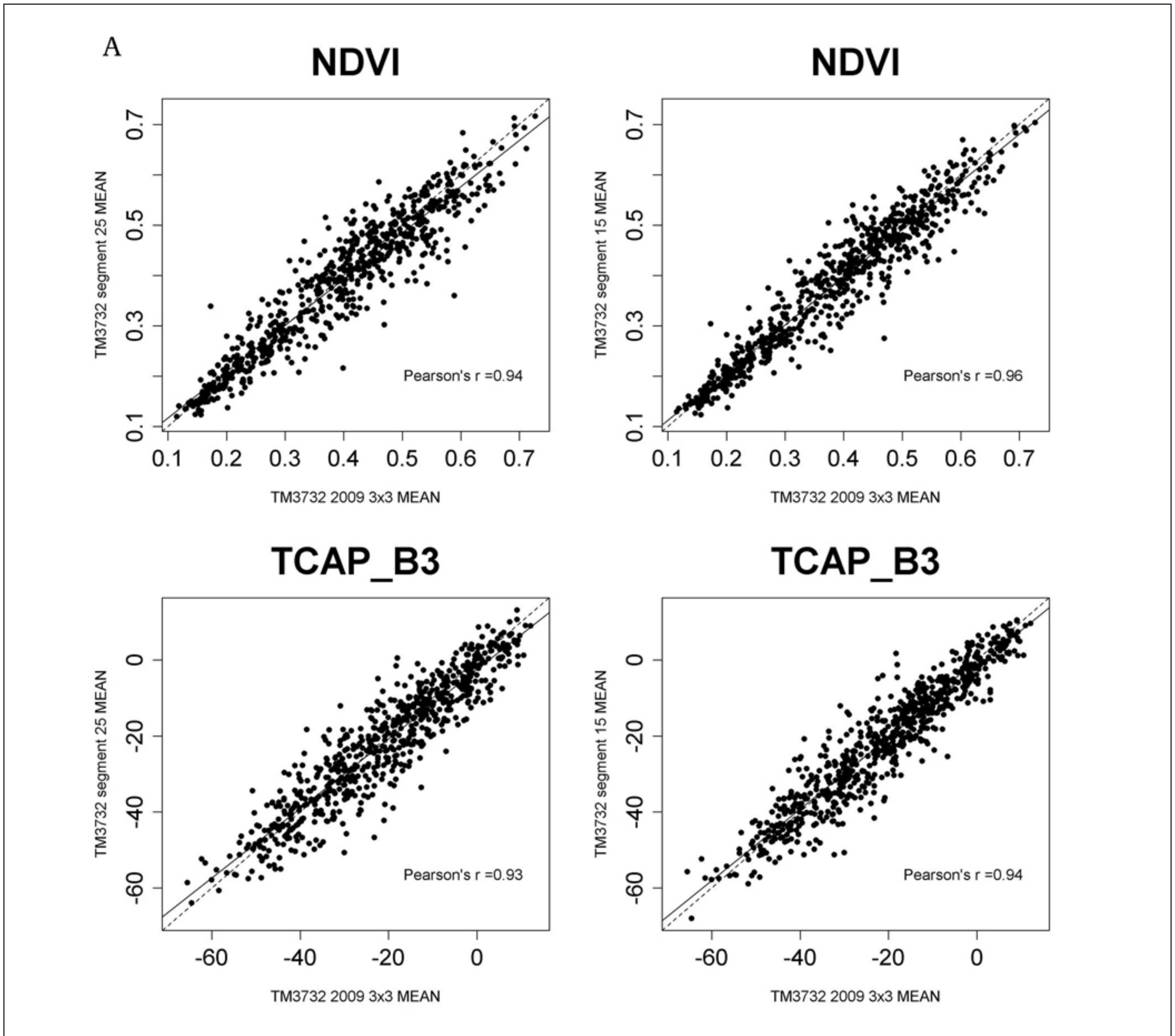

Figure 2A.—An example of scatterplots (NDVI and TCAP Band 3—Wetness) for forested FIA plots showing strong positive correlations between the 3 by 3 pixel area values and the image object values.

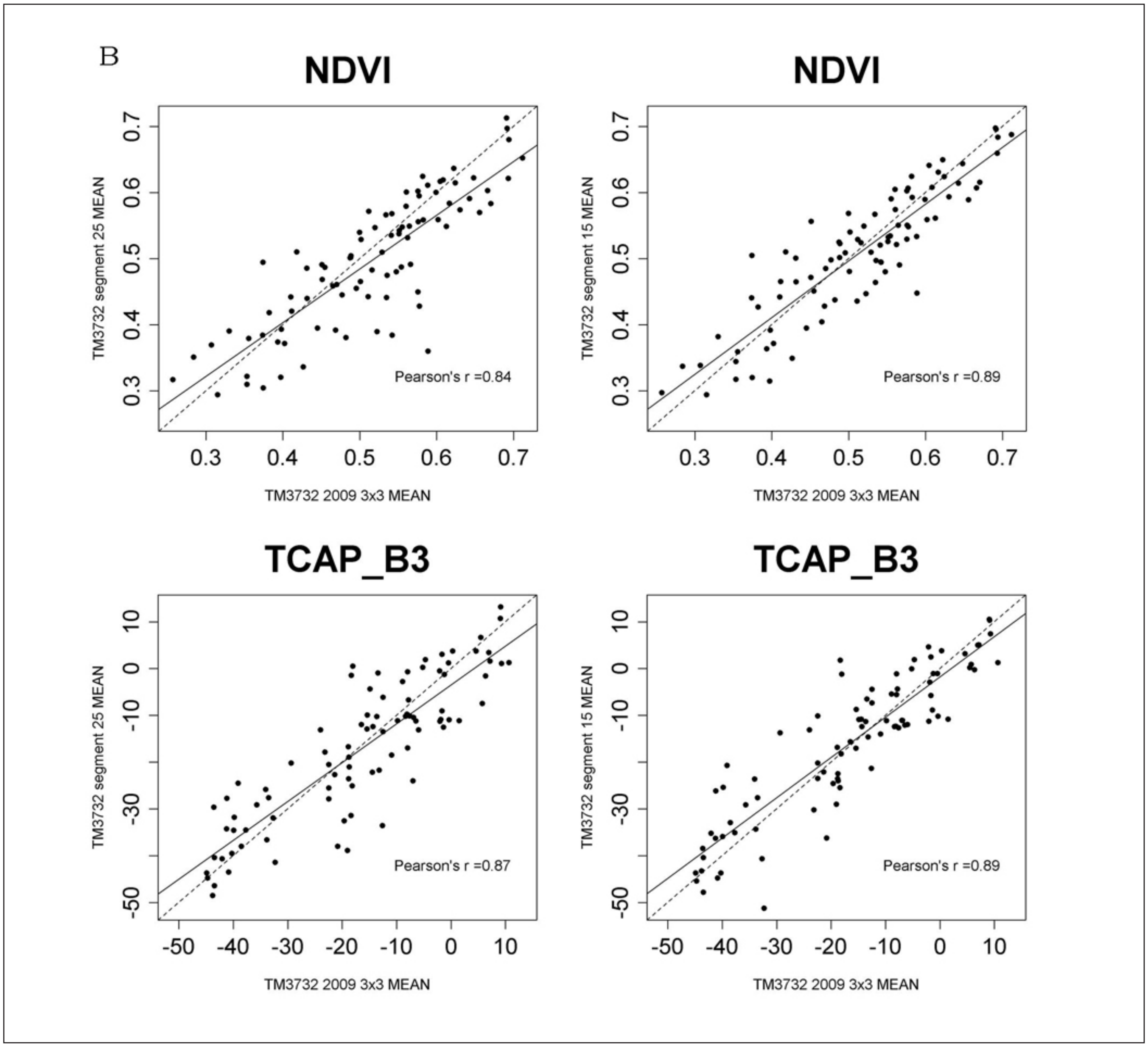

Figure 2B.—An example of scatterplots (NDVI and TCAP Band 3—Wetness) for aspen plots with a relative cover >50 percent showing strong positive correlations between the 3 by 3 pixel area values and the image object values.

Table 2.—Results of the 3 by 3 neighborhood pixels compared to image objects for forested FIA plots. P values less than α = 0.05 are bold.

TM Scene (Path/Row)	N	Image Derivative	Pearson's r Scale 25	Pearson's r Scale 15	Wilcoxon Signed Rank Test Scale 25	Wilcoxon Signed Rank Test Scale 15
37/32	691	EVI	0.9	0.94	0.1551	0.7078
		MSAVI2	0.95	0.96	**0.0001**	**0.0311**
		NDMI	0.91	0.93	**0.0041**	**0.0199**
		NDVI	0.94	0.96	**0.0006**	0.0665
		PCA(1)	0.95	0.97	**0.0290**	0.0505
		TCAP(1)	0.95	0.97	**0.0445**	0.0567
		TCAP(2)	0.93	0.95	**0.0171**	0.3549
		TCAP(3)	0.93	0.94	**0.0059**	**0.0203**
38/31	153	EVI	0.91	0. 95	0.0953	**0.0097**
		MSAVI2	0.94	0.96	0.8931	0.2189
		NDMI	0.92	0.95	0.5368	0.9075
		NDVI	0.94	0.96	0.9594	0.1984
		PCA(1)	0.93	0.96	0.4797	0.7150
		TCAP(1)	0.93	0.95	0.5119	0.7993
		TCAP(2)	0.92	0.96	0.3960	**0.0373**
		TCAP(3)	0.93	0.95	0.6072	0.8845
38/33	466	EVI	0.93	0.95	0.5420	0.4122
		MSAVI2	0.96	0.97	0.1684	0.3393
		NDMI	0.94	0.95	**0.0048**	**0.0228**
		NDVI	0.96	0.97	0.2911	0.4211
		PCA(1)	0.97	0.98	0.2528	0.9638
		TCAP(1)	0.97	0.98	0.4766	0.7257
		TCAP(2)	0.95	0.96	0.4616	0.3658
		TCAP(3)	0.94	0.96	**0.0009**	**0.0204**

FIA plots with a relative cover greater than 50 percent of quaking aspen were filtered from the whole sample and simple linear correlations applied. The scatterplots again showed strong positive correlations (Fig. 2B) and the finer scaled objects consistently had higher Pearson's r values (Table 3).

To get a further understanding of the relationships between the pixel-based and object-based values, a Wilcoxon signed rank test for paired samples was used to test for differences between the 3 by 3 pixel neighborhood and a) the coarser image object values, and b) the finer image object values. Results (Table 2) of the test when applied to the forested FIA plots showed that:

1. Sometimes finer scale objects more closely represented the 3 by 3 pixel area values.
2. Often the 3 by 3 pixel area values were the same as the image object values.
3. Sometimes the 3 by 3 pixel area values were different than the image object values.
4. Rarely the coarser scale objects more closely represented the 3 by 3 pixel areas.

MSAVI2, NDMI, and TCAP(3) from TM scene 3732 and NDMI and TCAP(3) from TM scene 3833 had very low p values for the 3 by 3 pixel areas when compared to both scales of image objects, meaning that neither scale of image objects are the same as the 3 by 3 pixel areas for those particular image derivatives. Applying a Wilcoxon signed rank test for paired samples to the subset of quaking aspen plots (Table 3) had comparable results to that of the forested FIA test where similar derivatives were significantly different from the 3 by 3 pixel values at both scales.

1. Often finer scale objects more closely represented the 3 by 3 pixel area values;

Table 3.—Results of the 3 by 3 neighborhood pixels compared to image objects for aspen plots with a relative cover ≥50 percent. P values less than α = 0.05 are bold.

TM Scene (Path/Row)	N	Image Derivative	Pearson's r Scale 25	Pearson's r Scale 15	Wilcoxon Signed Rank Test Scale 25	Wilcoxon Signed Rank Test Scale 15
37/32	88	EVI	0.83	0.92	**0.0040**	0.0745
		MSAVI2	0.83	0.89	**0.0098**	0.2078
		NDMI	0.85	0.89	0.3207	0.8183
		NDVI	0.84	0.89	**0.0118**	0.2123
		PCA(1)	0.85	0.89	0.4202	0.1062
		TCAP(1)	0.85	0.89	0.2479	**0.0461**
		TCAP(2)	0.83	0.9	**0.0042**	0.1035
		TCAP(3)	0.87	0.89	0.5114	0.7704
38/31	34	EVI	0.91	0.92	0.9596	0.1906
		MSAVI2	0.91	0.94	**0.0249**	0.1629
		NDMI	0.91	0.94	**0.0328**	0.2556
		NDVI	0.91	0.94	**0.0299**	0.1682
		PCA(1)	0.9	0.95	0.1430	**0.0036**
		TCAP(1)	0.9	0.95	0.1629	**0.0038**
		TCAP(2)	0.92	0.95	0.3880	0.8527
		TCAP(3)	0.91	0.94	**0.0445**	0.2280
38/33	43	EVI	0.89	0.93	**0.0066**	**0.0010**
		MSAVI2	0.96	0.97	**0.0006**	**0.0002**
		NDMI	0.9	0.93	**0.0005**	**0.0006**
		NDVI	0.94	0.96	**0.0006**	**0.0001**
		PCA(1)	0.99	0.99	0.9762	0.9381
		TCAP(1)	0.99	0.99	0.7154	0.6712
		TCAP(2)	0.93	0.96	**0.0013**	**0.0007**
		TCAP(3)	0.9	0.93	**0.0019**	**0.0048**

2. Sometimes the 3 by 3 pixel area values were the same as the image object values;
3. Sometimes the 3 by 3 pixel area values were different than the image object values and
4. Rarely the coarser scale objects more closely represented the 3 by 3 pixel areas.

EVI, MSAVI2, NDMI, NDVI, TCAP(2), and TCAP(3) from TM scene 3833 all had very low p values for the 3 by 3 pixel areas when compared to both scales of image objects meaning that neither scale of image objects are the same as the 3 by 3 pixel areas for those particular image derivatives.

The very low p values from both the forested FIA plots and quaking aspen plots may be attributed to complex forest stand characteristics (structure and composition) coupled with the local variance structure of the imagery and therein, the resulting image objects. In other words, the differences in the local variance structure related to the forest stand structure and composition with respect to the scale of the image objects generated for these scenes and for those particular derivatives.

Additionally, the results of the Wilcoxon signed rank test for paired samples when applied to the subset of quaking aspen plots seems to infer that an even finer scale of image objects may be needed to delineate and characterize specific forest types more effectively.

FUTURE WORK

Additional analyses is needed to further understand the relationships between forested FIA plots and image objects for use in producing continuous and thematic maps of forest attributes at the regional level. Finer scales of image objects may help to better delineate smaller homogeneous forest stands, mixed forest stands where the proportions of a particular species (e.g., quaking aspen) are less than what is typically considered "dominant" (>50 percent relative cover), and forest structure.

ACKNOWLEDGMENTS

The author thanks R. Justin DeRose, Tracey Frescino, Sara Goeking, Jim Menlove, Paul Patterson, Alicia Peduzzi, Mark Riley, Bonnie Ruefenacht, and John Shaw for their insight and reviews which greatly improved the content of this work.

LITERATURE CITED

Bartos, D.L.; Campbell, R.B., Jr. 1998. **Decline of quaking aspen in the Interior West—examples from Utah.** Rangelands. 20: 17-24.

Chubey, M.S.; Franklin, S.E.; Wulder, M.A. 2006. **Object-based analysis of Ikonos-2 imagery for extraction of forest inventory parameters.** Photogrammetric Engineering and Remote Sensing. 72(4): 383-394.

DeBlander, L.T.; Shaw, J.D.; Witt, C.; Menlove, J.; Thompson, M.T.; Morgan, T.A.; DeRose, R.J.; Amacher, M.C. 2010. **Utah's forest resources, 2000-2005.** Resour. Bull. RMRS-RB-10. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 144 p.

Definiens. 2009. **eCognition developer 8 reference book, version 1.2.0 user guide.** Munich, Germany: Definiens. 236 p.

Gao, Y.; Mas, J.F. 2008. **A comparison of the performance of pixel-based and object-based classifications over images with various spatial resolutions.** Archives of International Society for Photogrammertry and Remote Sensing. Available at http://www.isprs.org/proceedings/XXXVIII/4-C1/Sessions/Session1/6589_Y_Gao_Proc_pap.pdf. (Accessed August 31, 2012).

Hay, G.J.; Castilla, G.; Wulder, M.A.; Ruiz, J.R. 2005. **An automated object-based approach for the multiscale image segmentation of forest scenes.** International Journal of Applied Earth Observation and Geoinformation. 7(4): 339-359.

Karl, J.; Maurer, B. 2010. **Spatial dependence of predictions from image segmentation: avariogram-based method to determine appropriate scales for producing land management information.** Ecological Informatics. 5: 194-202.

Kim, S.-R.; Lee, W.-K.; Kwak, D.-A.; Biging, G.S.; Gong, P.; Lee, J.-H.; Cho, H.-K. **Forest cover classification by optimal segmentation of high resolution satellite imagery.** Sensors. 11(2): 1943-1958.

USDA Forest Service. 2011. **Interior West Forest Inventory and Analysis P2 field procedures, v5.00.** Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 398 p. Available at www.fs.fed.us/rm/ogden/data-collection/pdf/iwfia_p2_50.pdf.

Yasumasa, H.Y.; Tomoaki, T. 2010. **Image segmentation and classification of Landsat thematic mapper data using a sampling approach for forest cover assessment.** Canadian Journal of Forest Research. 41(1): 35-43.