Table 133. The overall accuracy of individual scenes following the every-pixel, 3x3 homogeneity, and 5x5 homogeneity assessments. The 5x5 homogeneity assessment results were used to determine the order (or relative area present), of each scene, in the final statewide land cover mosaic.

| Scene | Every-Pixel | 3x3 Homogeneous | 5x5 Homogeneous (determined area) |
|---|---|---|---|
| 1733 | 90.9 | 96.2 | 100.0 |
| 1835 | 5.8 | 79.5 | 90.4 |
| 1735 | 58.9 | 77.2 | 90.3 |
| 1535 | 36.1 | 76.9 | 90.0 |
| 1533 | 59.1 | 75.0 | 87.5 |
| 1633 | 54.9 | 71.4 | 87.2 |
| 1734 | 58.2 | 74.4 | 83.7 |
| 1434 | 62.2 | 79.4 | 83.0 |
| 1634 | 59.8 | 76.7 | 82.8 |
| 1534 | 47.5 | 66.0 | 80.5 |
| 1834 | 63.7 | 77.0 | 80.0 |
| 1435 | 47.5 | 66.1 | 76.7 |
| 1935 | 27.6 | 60.0 | 71.4 |
| 1635 | 35.0 | 51.8 | 42.9 |

The overall area of 123,872 $km^2$ is slightly larger than the 102,830 $km^2$ reported as the are of Virginia (Woodward and Hoffman 1991). This is due to the 1km buffer and the large amount of open water in the Chesapeake Bay included in this mosaic. The land area in each land cover type differs slightly when the 1 km buffer and Chesapeake Bay are removed (Table 135). Without the buffer and the ocean water, the total area of Virginia is estimated at 114,602 $km^2$. This is still larger than the 102,830 $km^2$ reported as the area of Virginia (Woodward and Hoffman 1991). However, coastal acreage determination, boundary disputes, and scale all make accurate area estimates difficult.

A total of 1773 reference points were used to evaluate this mosaic (Table 138). The majority of these points, 43% (782), were interpreted as deciduous forest. The percentage of reference points in each category matched fairly closely to the percentage of pixels (or area) in each category (Figure 26). The 2 largest discrepancies were between the coniferous forest and mixed forest classes. However, the sum of the percentages of the 3 forest categories, calculated from both the mosaic pixels and the reference points, is approximately 60%. This also is true of the 30% herbaceous/shrub and 10% water/disturbed/wetlands combinations.

The statewide mosaic was assessed for thematic accuracy on the same 3 levels (every-pixel, 3x3 homogeneous, and 5x5 homogeneous) as the individual scenes. The 3x3 homogeneity filter reduced the assessable area in Virginia to 53.3% of the every-pixel (full image) level (Table 136). Mixed forest and shrub were the land cover types most impacted (Figure 27). Water retained over 90% of its original area. Almost 60% of the deciduous forest area was assessable at the 3x3 level. The 5x5 homogeneity filter reduced the assessable area in Virginia to 32.1% of the every-pixel level (Table 137).

Table 134. Number of pixels, area, and proportion of each land cover class within the Virginia mosaic of classified scenes.

| | Pixels | Hectares | Acres | Square Kilometers | Proportion of Total Area |
|---|---|---|---|---|---|
| Deciduous Forest | 48,254,537 | 4,342,908.8 | 10731348.4 | 47,063.1 | 0.380 |
| Coniferous Forest | 24,737,613 | 2,226,385.4 | 5,501,409.0 | 24,126.8 | 0.195 |
| Mixed Forest | 2,641,516 | 237,736.5 | 587,447.9 | 2,576.3 | 0.021 |
| Shrub/Scrub | 9,891,704 | 890,253.5 | 2,199,820.5 | 9,647.5 | 0.078 |
| Herbaceous | 25,371,416 | 2,283,427.7 | 5,642,360.7 | 24,745.0 | 0.200 |
| Open Water | 11,252,462 | 1,012,721.7 | 2,502,440.1 | 10,974.6 | 0.089 |
| Disturbed | 3,725,851 | 335,326.6 | 828,593.7 | 3,633.9 | 0.029 |
| Coastal Wetland | 1,132,668 | 101,940.1 | 251,894.6 | 1,104.7 | 0.009 |
| Other | 123 | 11.1 | 27.4 | 0.1 | 0.000 |
| Total | 127,007,890 | 11,430,711.2 | 28,245,342.3 | 123,872.0 | 1.000 |

Table 135. Number of pixels, area, and proportion of each land cover class within the Virginia mosaic. These values were calculated without the 1 kilometer buffer and the majority of open water in the Chesapeake Bay.

| | Pixels | Hectares | Acres | Square Kilometers | Proportion of Total Area |
|---|---|---|---|---|---|
| Deciduous Forest | 47,086,848 | 4,237,816.7 | 1,0471,665.5 | 45,924.3 | 0.401 |
| Coniferous Forest | 24,436,864 | 2,199,318.0 | 5,434,525.3 | 23,833.5 | 0.208 |
| Mixed Forest | 2,604,588 | 234,412.9 | 579,235.5 | 2,540.3 | 0.022 |
| Shrub/Scrub | 9,804,267 | 882,384.1 | 2,180,375.4 | 9,562.2 | 0.083 |
| Herbaceous | 25,103,380 | 2,259,304.4 | 5,582,752.1 | 24,483.6 | 0.214 |
| Open Water | 3,709,578 | 333,862.1 | 824,974.7 | 3,618.0 | 0.032 |
| Disturbed | 3,663,620 | 329,725.8 | 814,754.1 | 3,573.2 | 0.031 |
| Coastal Wetland | 1,093,981 | 98,458.3 | 243,290.9 | 1,067.0 | 0.009 |
| Total | 117,503,126 | 10,575,282.4 | 26,131,573.5 | 114,602.0 | 1.000 |

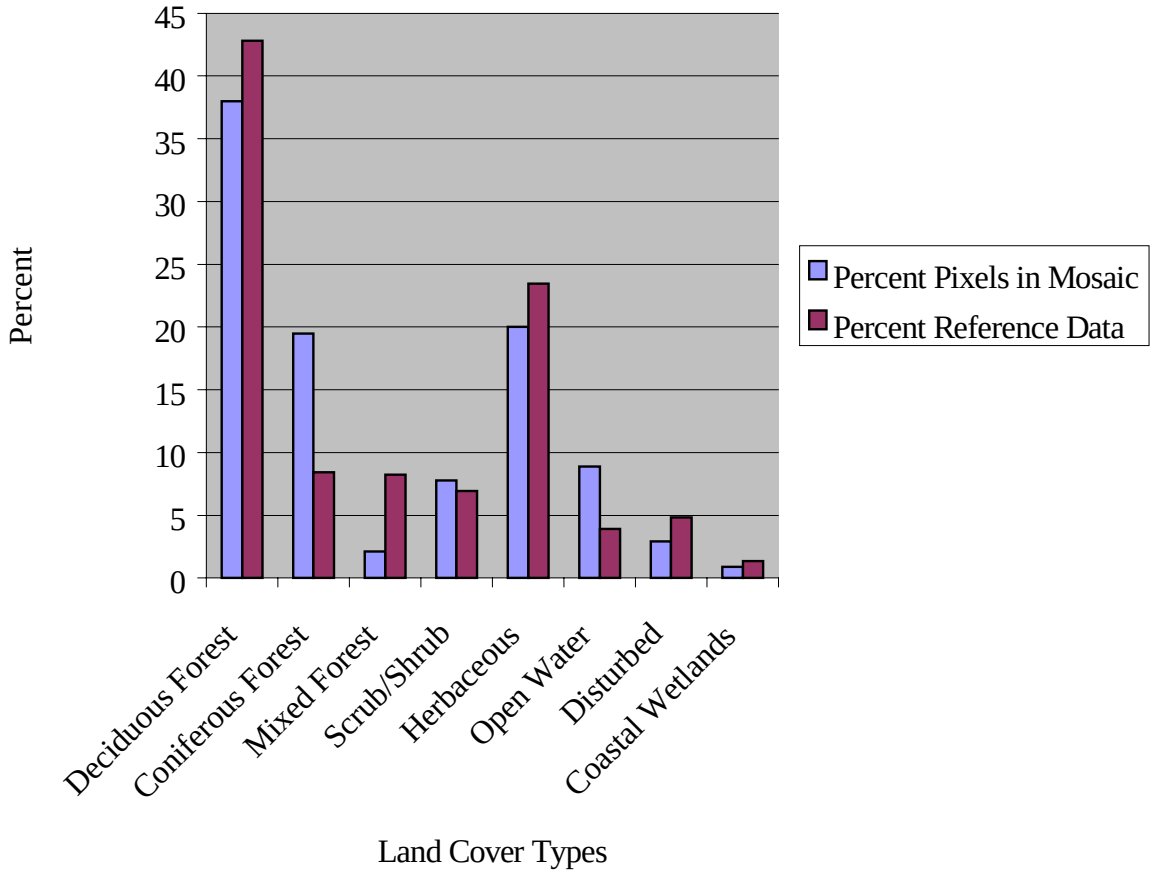



Figure 26. Comparison of the percentage of land cover classes in Virginia from the classified mosaic and reference data.

Table 136. Results of the 3x3 homogeneous filter on land cover types within the Virginia mosaic in area, proportion of total area, and proportion remaining from the Virginia mosaic every-pixel level.

| | Pixels | Hectares | Acres | Proportion of Total Area | Proportion of Every-Pixel |
|---|---|---|---|---|---|
| Deciduous Forest | 28,508,755 | 2,565,788.0 | 6,340,062.0 | 0.421 | 0.591 |
| Coniferous Forest | 10,749,071 | 967,416.4 | 2,390,486.0 | 0.159 | 0.435 |
| Mixed Forest | 425,805 | 38,322.5 | 94,694.8 | 0.006 | 0.161 |
| Shrub/Scrub | 2,137,539 | 192,378.5 | 475,367.3 | 0.032 | 0.216 |
| Herbaceous | 13,975,160 | 1,257,764.0 | 3,107,936.0 | 0.206 | 0.551 |
| Open Water | 10,185,663 | 916,709.7 | 2,265,190.0 | 0.150 | 0.905 |
| Disturbed | 1,372,235 | 123,501.2 | 305,171.3 | 0.020 | 0.368 |
| Coastal Wetland | 365,170 | 32,865.3 | 81,210.2 | 0.005 | 0.322 |
| Total | 67,719,398 | 6,094,746.0 | 15,060,117.0 | 1.000 | 0.533 |

Table 137. Results of the 5x5 homogeneous filter on land cover types within the Virginia mosaic in area, proportion of total area, and proportion remaining from the Virginia mosaic every- pixel level.

| | Pixels | Hectares | Acres | Proportion of Total Area | Proportion of Every-Pixel |
|---|---|---|---|---|---|
| Deciduous Forest | 17,315,691 | 1,558,412.2 | 3,850,837.0 | 0.424 | 0.359 |
| Coniferous Forest | 4,771,323 | 429,419.1 | 1,061,095.0 | 0.117 | 0.193 |
| Mixed Forest | 109,245 | 9,832.1 | 24,295.0 | 0.003 | 0.041 |
| Shrub/Scrub | 514,099 | 46,268.9 | 114,330.5 | 0.013 | 0.052 |
| Herbaceous | 7,816,979 | 703,528.1 | 1,738,418.0 | 0.191 | 0.308 |
| Open Water | 9,495,182 | 854,566.4 | 2,111,634.0 | 0.232 | 0.844 |
| Disturbed | 652,087 | 58,687.8 | 145,017.6 | 0.016 | 0.175 |
| Coastal Wetland | 165,580 | 14,902.2 | 36,823.3 | 0.004 | 0.146 |
| Total | 40,840,186 | 3,675,616.7 | 9,082,449.0 | 1.000 | 0.322 |

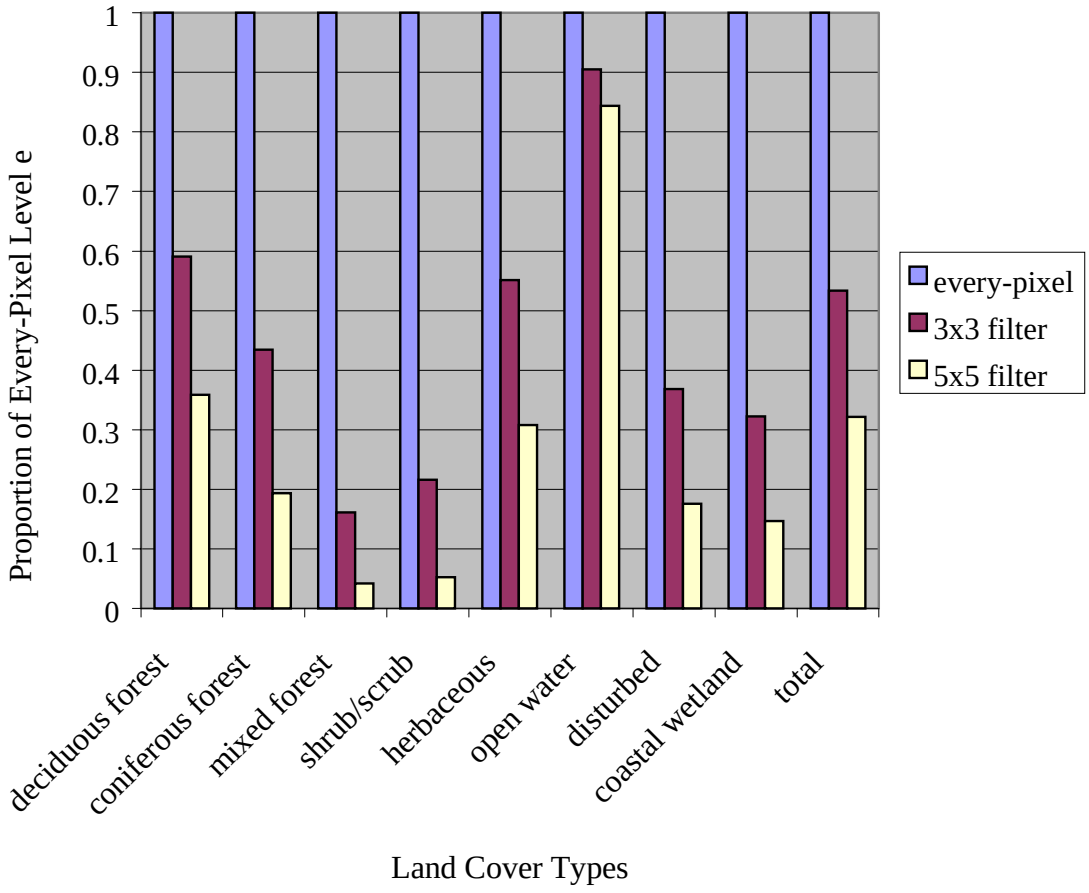



Figure 27. Proportion of pixels (or area), in each land cover category, remaining after using the 3x3 homogeneous and the 5x5 homogeneous filters on the statewide mosaic.

The mixed forest and shrub cover-types were the most impacted (Figure 27). Deciduous forest retained 35.9% of its original area, which was slightly over the overall total of 32.2%. Open water was least affected after the 5x5 homogeneous filter.

At the every-pixel level, deciduous forest had a user's accuracy (error of commission) of 68.1% (Table 139). Deciduous forest was confused with mixed forest, shrub/scrub, and herbaceous (Table 138). These 3 cover-types each had over 65 pixels labeled deciduous when the reference points indicated mixed forest, shrub/scrub , or herbaceous. The deciduous forest producer's accuracy was 72.3%. The highest category of omitted pixels was coniferous forest at 128 pixels. Mixed forest was the second highest category of omission error.

Coniferous forest had a user's accuracy of 25.6% at the every-pixel level. The highest confusion for this type of error was with deciduous forest and mixed forest. The producer's accuracy for coniferous forest was 54.4%. The categories with the most confusion resulting in omissions include deciduous forest and shrub/scrub.

Mixed forest had a user's accuracy of 9.1% and a producer's accuracy of 3.4%. It was most confused, in terms of both commission and omission, with deciduous forest and coniferous forest.

At the every-pixel level, shrub/scrub achieved a user's accuracy of 20.3%. Herbaceous and deciduous forest were most often the source of commission error. A 22.0% producer's accuracy resulted. Deciduous forest was the category of greatest confusion in errors of omission.

Herbaceous land cover had the second most reference points of any category at the every-pixel level. Disturbed land and deciduous forest were the greatest sources of

Table 138. Error matrix for the statewide mosaic at the every-pixel level. Reference data (aerial videography points) are shown as column headings, while actual pixel values are displayed in the left column as row headings. The number of points classified correctly in each cover-type is in bold.

| | Deciduous Forest | Coniferous Forest | Mixed Forest | Shrub/ Scrub | Herbaceous | Water Open | Disturbed | Coastal Wetland | Total |
|---|---|---|---|---|---|---|---|---|---|
| Deciduous Forest | **549** | 38 | 70 | 65 | 68 | 1 | 12 | 3 | 806 |
| Coniferous Forest | 128 | **81** | 53 | 14 | 23 | 1 | 14 | 2 | 316 |
| Mixed Forest | 39 | 6 | **5** | 1 | 1 | 1 | 1 | 1 | 55 |
| Shrub/Scrub | 21 | 13 | 10 | **27** | 54 | 1 | 7 | 0 | 133 |
| Herbaceous | 15 | 4 | 5 | 12 | **260** | 2 | 30 | 4 | 332 |
| Open Water | 3 | 2 | 1 | 1 | 2 | **63** | 2 | 1 | 75 |
| Disturbed | 2 | 5 | 1 | 3 | 6 | 0 | **18** | 4 | 39 |
| Coastal Wetland | 1 | 0 | 0 | 0 | 1 | 0 | 0 | **9** | 11 |
| Other | 1 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 6 |
| Total | 759 | 149 | 146 | 123 | 416 | 70 | 86 | 24 | 1773 |

Table 139. User's and producer's accuracy for each land cover class, along with overall accuracy and the Kappa statistic, for the statewide mosaic at the every-pixel level.

| | User's | Producer's |
|---|---|---|
| Deciduous Forest | 0.681 | 0.723 |
| Coniferous Forest | 0.256 | 0.544 |
| Mixed Forest | 0.091 | 0.034 |
| Shrub/Scrub | 0.203 | 0.220 |
| Herbaceous | 0.783 | 0.625 |
| Open Water | 0.840 | 0.900 |
| Disturbed | 0.462 | 0.209 |
| Coastal Wetland | 0.818 | 0.375 |
| | | |
| Overall Accuracy | 0.571 | |
| Kappa | 0.557 | |

commission error. A user's accuracy of 78.3% resulted. The herbaceous producer's accuracy of 62.5% was the result of confusion with deciduous forest shrub/scrub and coniferous forest.

Open water had the greatest accuracy in both user's (84.0%) and producer's (90%) categories.

Disturbed lands resulted in 46.2% user's accuracy at the every-pixel level. The categories of the most reference points (not labeled as disturbed) falling on pixels that were labeled disturbed (i.e., errors of commission) include herbaceous and coniferous forest. The producer's accuracy was 20.9% for disturbed at the every-pixel level. The main cover-types causing confusion were herbaceous, coniferous forest, and deciduous forest.

Wetlands resulted in a relatively high user's accuracy of 81.8% at the every-pixel level. The only sources of confusion, categorized as commission error, were from herbaceous and deciduous forest. The producer's accuracy was much less, resulting in 37.5%. Errors of omission occurred due to classification confusion with disturbed, herbaceous, and deciduous forest.

The overall accuracy at the every-pixel level was 57.1% with a Kappa value of 0.557. The overall accuracy increased to 72.5% after the 3x3 homogeneous evaluation (Table 141). Many points (998) were used in this assessment (Table 140).

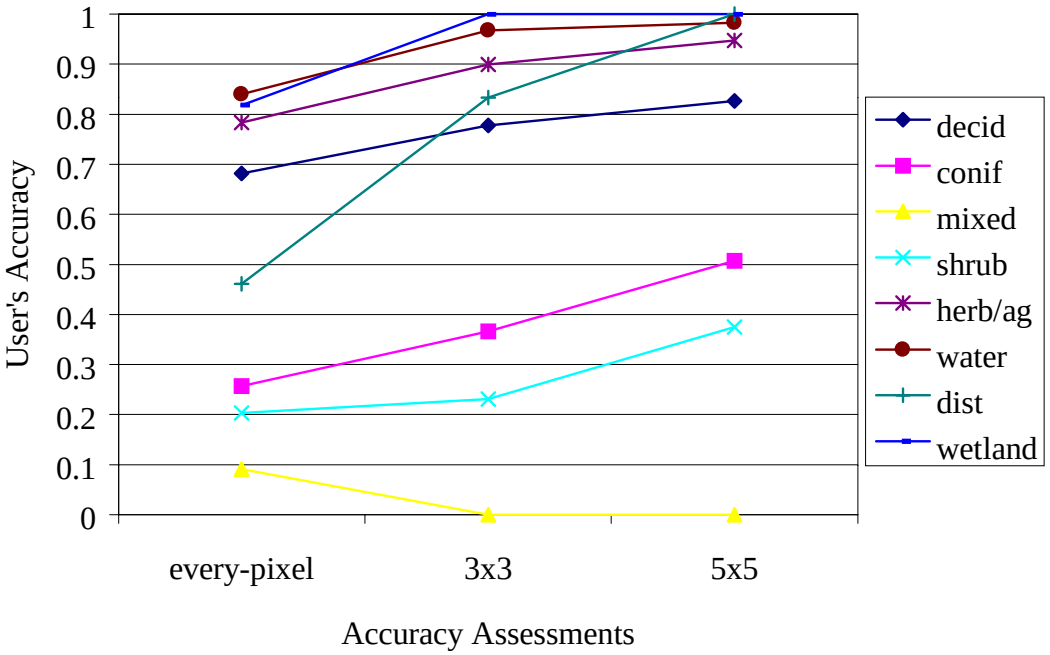
The majority of land cover classes increased in both user's and producer's accuracy following the 3x3 homogeneous assessment (Figure 28). However, the mixed forest user's and producer's accuracies were reduced to zero. This was the only decrease

Table 140. Error matrix for the statewide mosaic at the 3x3 homogeneous level. Reference data (aerial videography points) are shown as column headings, while actual pixel values are displayed in the left column as row headings. The number of points classified correctly in each cover-type is in bold. The number of reference points for each category that falls on non-homogeneous pixels is shown in the last row.

| | Deciduous Forest | Conifer Forest | Mixed Forest | Shrub/ Scrub | Herbaceous | Open Water | Disturbed | Coastal Wetland | Total |
|---|---|---|---|---|---|---|---|---|---|
| Deciduous Forest | **399** | 17 | 29 | 37 | 27 | | 2 | 2 | 513 |
| Coniferous Forest | 45 | **51** | 28 | 3 | 6 | 1 | 4 | 1 | 139 |
| Mixed Forest | 15 | 2 | | | | | | | 17 |
| Shrub/Scrub | 11 | 5 | 2 | **9** | 11 | | 1 | | 39 |
| Herbaceous | 3 | 1 | 1 | 2 | **188** | | 12 | 2 | 209 |
| Open Water | | | 1 | | | **61** | 1 | | 63 |
| Disturbed | | | | | 1 | | **10** | 1 | 12 |
| Coastal Wetland | | | | | | | | **6** | 6 |
| Other | | | | | | | | | |
| Total | 473 | 76 | 61 | 51 | 233 | 62 | 30 | 12 | 998 |
| Non-Homogeneous | 286 | 74 | 86 | 72 | 183 | 8 | 56 | 13 | 778 |

Table 141. User's and producer's accuracy for each category, along with overall accuracy and Kappa statistic, for the statewide mosaic at the 3x3 homogeneous level.

| | User's | Producer's |
|---|---|---|
| Deciduous Forest | 0.778 | 0.844 |
| Coniferous Forest | 0.367 | 0.671 |
| Mixed Forest | 0.000 | 0.000 |
| Shrub/Scrub | 0.231 | 0.176 |
| Herbaceous | 0.900 | 0.807 |
| Open Water | 0.968 | 0.984 |
| Disturbed | 0.833 | 0.333 |
| Coastal Wetland | 1.000 | 0.500 |
| | | |
| Overall Accuracy | 0.725 | |
| Kappa | 0.715 | |



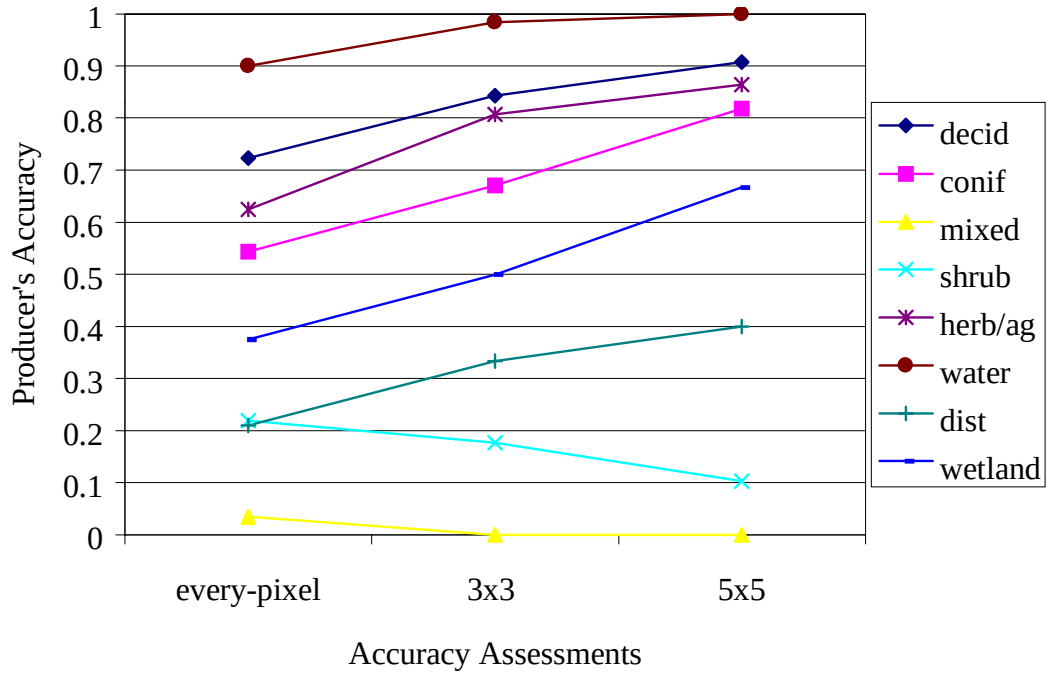




Figure 28. User's and producer's accuracy for each land cover type throughout the every-pixel, 3x3 homogeneous, and 5x5 homogeneous assessment procedures.

in user's accuracy via the 3x3 homogeneous filter. Scrub/shrub was the only other category to experience a decrease in producer's accuracy at this level.

These trends continued following the 5x5 homogeneity accuracy assessment (Figure 28). Mixed forest remained at zero accuracy for both user's and producer's. Shrub/scrub decreased to 10.3% producer's accuracy. The rest of the accuracies all increased following the 5x5 filter.

Deciduous forest accuracies increased to 82.7% for user's and 90.8% for producer's (Table 143). The greatest source of commission error (i.e., decrease in user's accuracy) was from confusion with shrub/scrub, herbaceous, and mixed forest (Table 142). The category most often labeled something other than deciduous forest, but which should have been labeled deciduous forest (i.e., omission errors) was coniferous forest. This is not a surprise since such results can occur due to topo-shading and edge phenomena.

At the 5x5 homogeneous level, coniferous forest's user's accuracy was 50.7%. Confusion with deciduous forest and mixed forest resulted in the relatively low user's accuracy (or high level of commission error) for coniferous forest areas. The producer's accuracy for coniferous forest was 81.8%. Deciduous forest (60.1% of the total area) was, again, the category causing the most confusion.

Mixed forest had zero accuracy in both user's and producer's accuracy measures. Mixed forest was only confused with deciduous forest in the user's accuracy category, resulting in the high commission error. Mixed forest was confused with both deciduous and coniferous forest in the producer's accuracy measurement, resulting in the same high degree of omission error.

Table 142. Error matrix for the statewide mosaic at the 5x5 homogeneous level. Reference data (aerial videography points) are shown as column headings, while actual pixel values are displayed in the left column as row headings. The number of points correctly classified in each cover-type is in bold. The number of reference points for each category that falls on non-homogeneous pixels is shown in the last row.

| | Deciduous Forest | Coniferous Forest | Mixed Forest | Shrub/ Shrub | Herbaceous | Open Water | Disturbed | Coastal Wetland | Total |
|---|---|---|---|---|---|---|---|---|---|
| Deciduous Forest | **286** | 5 | 11 | 24 | 17 | | 2 | 1 | 346 |
| Coniferous Forest | 20 | **36** | 10 | 1 | 2 | | 1 | 1 | 71 |
| Mixed Forest | 8 | | | | | | | | 8 |
| Shrub/Scrub | | 2 | 1 | **3** | 1 | | 1 | | 8 |
| Herbaceous | 1 | 1 | | 1 | **127** | | 4 | | 134 |
| Open Water | | | | | | **59** | 1 | | 60 |
| Disturbed | | | | | | | **6** | | 6 |
| Coastal Wetland | | | | | | | | **4** | 4 |
| Other | | | | | | | | | |
| Total | 315 | 44 | 22 | 29 | 147 | 59 | 15 | 6 | 637 |
| Non-Homogeneous | 444 | 106 | 125 | 94 | 269 | 11 | 71 | 19 | 1139 |

Table 143. User's and producer's accuracy for each land cover class, along with overall accuracy and Kappa statistic, for the statewide mosaic at the 5x5 homogeneous level.

| | User's | Producer's |
|---|---|---|
| Deciduous Forest | 0.827 | 0.908 |
| Conifer Forest | 0.507 | 0.818 |
| Mixed Forest | 0.000 | 0.000 |
| Shrub/Scrub | 0.375 | 0.103 |
| Herbaceous | 0.948 | 0.864 |
| Open Water | 0.983 | 1.000 |
| Disturbed | 1.000 | 0.400 |
| Coastal Wetland | 1.000 | 0.667 |
| | | |
| Overall Accuracy | 0.818 | |
| Kappa | 0.810 | |

Shrub/scrub increased in user's accuracy to only 37.5% following the 5x5 homogeneity filter. Shrub/scrub confusion with coniferous forest, mixed forest, herbaceous and disturbed resulted in the relatively high commission error. However, there were only 8 shrub/scrub pixels assessed at this evaluation level. The producer's accuracy decreased to 10.3% for shrub/scrub after the 5x5 filter. The major source of confusion was with deciduous forest (the shrub/scrub type is often a young age class of such deciduous forests).

The areas classified as herbaceous resulted in 94.8% user's accuracy at the 5x5 assessment level. Disturbed land cover was the primary confusion source. The producer's accuracy for herbaceous was 86.4%, following the 5x5 homogeneous procedure. Deciduous forest caused the most omission error.

Open water was nearly 100% accurate in both the user's and producer's accuracy categories. One reference pixel was a source of commission error due to a confusion with the disturbed class.

The assessment of disturbed land resulted in 100% user's accuracy. The producer's accuracy was significantly less at 40%, following the 5x5 filter. This omission error was mainly from herbaceous and deciduous forest.

Wetlands user's accuracy was also 100%. Wetlands producer's accuracy was 66.7%, following the 5x5 homogeneous filter. Sources of confusion included deciduous and coniferous forests.

Using 637 reference points in the final 5x5 homogeneous assessment, an overall accuracy of 81.8% was reported. The resulting Kappa value was 0.81.

Throughout each assessment level, the overall accuracy and the Kappa values matched closely (Figure 29). The result of each evaluation increased following each successive homogeneous filter.

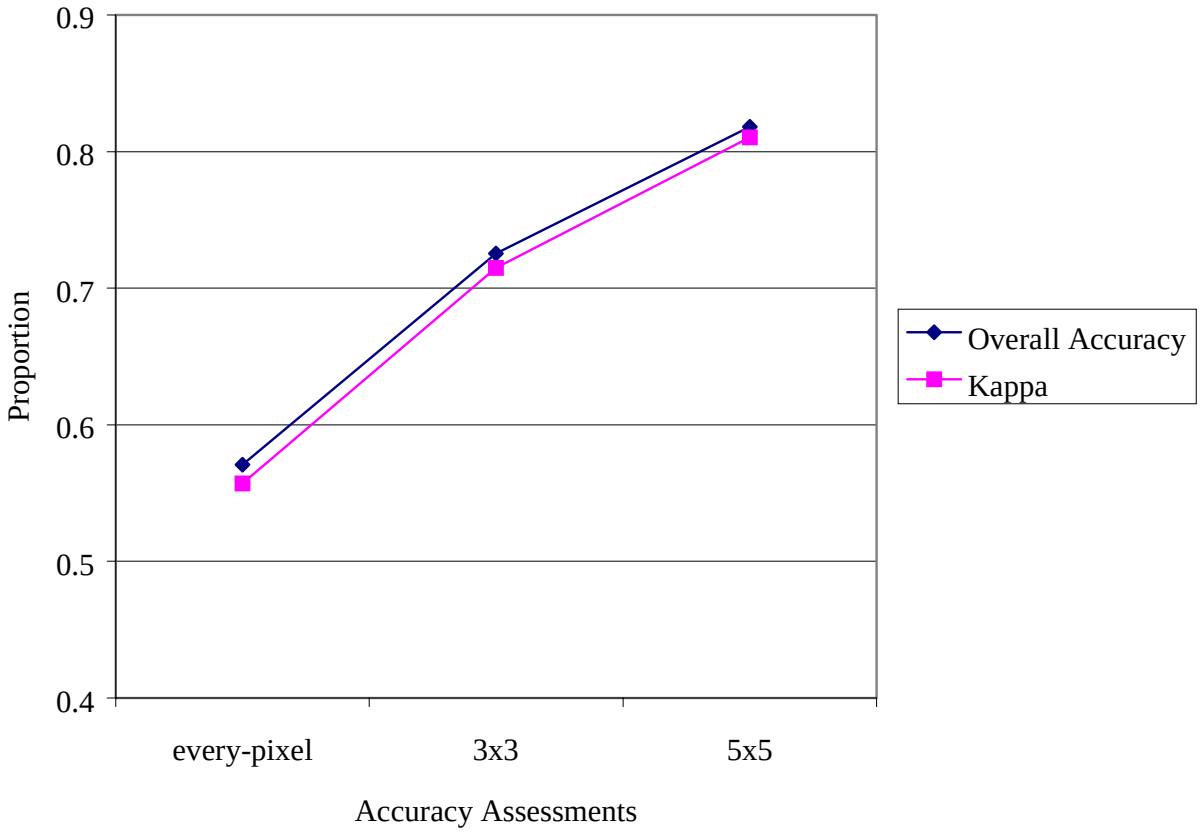



Figure 29. Overall accuracy and Kappa values for the Virginia land cover mosaic throughout the 3 accuracy assessment levels.