GeoArea Auto-Key Results Summary

- 19,446 plots available for the analysis, 16,157 plots were able to be 'auto-keyed' (83%). The number of plots not auto-keyed is significant, and should be addressed in the future.
- A separate "Recommendations Summary" report was developed and provided. This particular report is more about results than it is about generalizations or recommendations about modifying the sequence tables.
- The number of available plots per GA varied significantly, from 1295 to 3827. This situation mirrors what is available to the mapping process, which could have an important impact on map quality variability by map zone.
- ES were often auto-keyed in a GeoArea but were NOT attributed by experts in that GeoArea. Most of these are spatially peripheral to the particular GeoArea or have limited extents. However, sometimes plots were auto-keyed to ES that likely do not occur in that GeoArea.
- Some ES are under-represented in the sample—some are not important to that GA but others are and these should be sampled more intensely in the future. <u>More explicitly, new field inventories are needed to enhance the number of samples of some ES for both mapping and AA purposes. These would also help to clarify distribution and floristic components of some ES</u>.
- Original % Agreement: results low to moderate, with poorest results in HI, AK and SE. Across the country as a whole, agreement was in the mid to high 40% range
- Recomputed % Agreement: results were primarily moderate, with the exception of HI which was still low. Across the nation as a whole, agreement was in the mid to high 50% range, excepting HI. We consider this recomputed % agreement to be the more robust number.
- The impact of auto-key/expert disagreement on map quality is still unknown---we have not had the time to connect these results to LF National 1.0.0 map agreement results (not a goal of this project)
- Very high agreements (>80%) between the auto-key and experts for individual ES did occur, but were not the majority. Many of the lower agreements could potentially be attributed to low sample size for that ES.
- Specific recommendations on where to focus future sequence table revisions are defined in each GeoArea report. Sequence Table teams should refer to the specific relevant GeoArea reports.

<u>Original % Agreement</u>**:** all cells [agreement floor]
<u>Recomputed % Agreement</u>: Eliminated the '*Not a System*' row and the '*Can't Assign*' and '*Other*' columns in the contingency table [agreement ceiling]

GeoArea	Original % Agreement	Recomputed % Agreement
1	36	63
2E	40	51
2W	46	54
3	54	66
4	53	66
5	44	57
6	45	61
7E	40	48
7W	39	48
8	33	49
HI	24	27

Specific results copied from GeoArea Reports

GeoArea 1

GeoArea 1 encompasses the southern Midwest to the southeast coastal regions extending from the West Gulf Coastal Plain and Mississippi Delta to the Mid-Atlantic Coastal Plain south to the Florida Peninsula (**Error! Reference source not found.**, map zones 37, 45, 46, 55, 56, and 58). This GeoArea includes a total of 6 map zones, originally clustered for purposes of designing and implementing auto-keys (**Error! Reference source not found.**). The total number of plots in this GeoArea analysis was 1,384. A total of 36 natural ecological system types were assigned to a total of 949 plots by the auto-keys. A total of 78 ecological system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for sparsely vegetated types or wetland/riparian types).

An additional 12 types were assigned by the auto-key but were not assigned by experts:

- Crosstimbers Oak Forest and Woodland
- Florida Peninsula Inland Scrub
- Lower Mississippi River Dune Woodland and Forest
- Mississippi Delta Maritime Forest
- Southern Atlantic Coastal Plain Dune and Maritime Grassland
- Texas Saline Coastal Prairie
- Texas-Louisiana Coastal Prairie Pondshore
- Caribbean Swamp Systems
- Gulf and Atlantic Coastal Plain Floodplain Systems
- Gulf and Atlantic Coastal Plain Small Stream Riparian Systems
- Gulf and Atlantic Coastal Plain Swamp Systems
- Gulf and Atlantic Coastal Plain Tidal Marsh Systems

Of the twelve types, six represent the aggregated wetland systems used in the LANDFIRE map legend. For those types, the experts assigned individual ecological system classification to the plots.

Comparison of Auto-key and Expert Assignments

Of the 36 natural ecological system types assigned labels by the auto-keys, 10 types (27%) had fewer than 20 samples available for this analysis (Table 4). These under-sampled types tended to include types that are found on the periphery of their range within this GeoArea (e.g., Caribbean Swamp Systems), while others are generally within this range, but are restricted in extent (e.g. Southern Atlantic Coastal Plain Dune and Maritime Grassland), occupy small extents (e.g. Lower Mississippi River Dune Woodland and Forest), or are degraded with limited high quality sites available for sampling (e.g. Texas Saline Coastal Prairie; Southern Coastal Plain Blackland Prairie). These 10 under-sampled types were excluded from further analysis.

Table 1. Under-sampled types within GeoArea 1

EVTCode	EVT Name	Ecological System elcode	Total Plots
2513	Lower Mississippi River Flatwoods	CES203.193	8

EVTCode	EVT Name	Ecological System elcode	Total Plots
2381	Lower Mississippi River Dune Woodland and Forest	CES203.531	5
2328	Southern Coastal Plain Limestone Forest	CES203.502	4
2430	Southern Coastal Plain Blackland Prairie and Woodland	CES203.478	2
2306	East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland	CES203.482	2
2487	Texas-Louisiana Coastal Prairie Pondshore	CES203.541	2
2329	East Gulf Coastal Plain Southern Loess Bluff Forest	CES203.556	2
2452	Atlantic Coastal Plain Peatland Pocosin and Canebrake	CES203.267	1
2426	Southern Atlantic Coastal Plain Dune and Maritime Grassland	CES203.273	1
2384	Mississippi Delta Maritime Forest	CES203.513	1

Of the 36 types, none had >80% agreement between expert and auto-key assignments. Table 2 represents a summary of the 26 adequately-sampled types where agreement between expert assignment and auto-key ranged from just below 80% down to zero. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. The following are some specific examples of levels of disagreement and possible explanations based on interpretations from the contingency table in the Results Workbook.

For the Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland (CES203.254) of the ten plots where the experts and the auto-key disagreed, eight of them (17% of the total) had been labeled by the expert as being Atlantic Coastal Plain Upland Longleaf Pine Woodland (CES203.281). Longleaf pine dominance is common to both systems, so subcanopy and understory species composition are central to distinguishing those two systems.

Six of the 11 mismatches in the Florida Longleaf Pine Sandhill (CES203.284) assignment had been classed as the Eastern Gulf Coastal Plain Interior Longleaf Pine Woodland (CES203.496). Again longleaf dominance is common, but biogeographic range and subcanopy and understory indicators may be useful in making the distinction.

For several ecological systems (e.g. East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest, Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest) the rapid rate of land use change and disturbed nature of the landscape make assignment to an ecological system difficult. In these cases a portion of the plots that had been assigned by the auto-key as a system were classified by the experts are “can’t assign” or a ruderal vegetation type.

In some cases, subtle differences in the descriptions between ecological systems make them difficult to distinguish with limited data provided. For example, the experts have a range of confidence when assigning labels to the plots which had been auto-keyed to Southern Coastal Plain Seepage Swamp and

Baygall (CES 203.505). The experts assigned some of those plots to Southern Coastal Plain Mesic Slope Forest (CES203.476; 4 plots), Southern Coastal Plain Dry Upland Hardwood Forest (CES203.560; 1 plot), Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin and Baygall (CES203.252; 1 plot), and Southern Coastal Plain Nonriverine Cypress Dome (CES203.251; 1 plot). Two of the plots were labeled as "can't assign".

Table 2. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2346	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland	CES203.254	47	37	79%	29	7	1
2356	Florida Longleaf Pine Sandhill	CES203.284	50	39	78%	28	9	2
2372	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	CES203.506	30	23	77%	13	4	6
2349	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	CES203.496	50	38	76%	25	13	0
2347	Atlantic Coastal Plain Upland Longleaf Pine Woodland	CES203.281	50	37	74%	17	14	6
2371	West Gulf Coastal Plain Pine-Hardwood Forest	CES203.378	49	36	73%	31	1	4
2348	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	CES203.293	48	32	67%	19	8	5
2307	East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	CES203.483	29	18	62%	12	5	1
2460	Southern Coastal Plain Nonriverine Cypress Dome	CES203.251	15	9	60%	3	6	0
2322	Crowley's Ridge Mesic Loess Slope Forest	CES203.079	10	5	50%	5	0	0
2461	Southern Coastal Plain Seepage Swamp and Baygall	CES203.505	48	22	46%	8	10	4
2453	Central Florida Pine Flatwoods	CES203.382	24	11	46%	2	9	0
2378	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	CES203.056	28	12	43%	8	4	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2449	Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	CES203.265	26	10	38%	9	1	0
2335	Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	CES203.241	47	15	32%	11	4	0
2462	West Gulf Coastal Plain Seepage Swamp and Baygall	CES203.372	10	3	30%	1	2	0
2323	West Gulf Coastal Plain Mesic Hardwood Forest	CES203.280	47	14	30%	9	5	0
2454	East Gulf Coastal Plain Near-Coast Pine Flatwoods	CES203.375	24	6	25%	3	3	0
2468	Atlantic Coastal Plain Streamhead Seepage Swamp-Pocosin-Baygall	CES203.252	48	9	19%	5	2	2
2325	East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	CES203.477	18	2	11%	1	1	0
2458	West Gulf Coastal Plain Pine-Hardwood Flatwoods	CES203.278	49	4	8%	3	1	0
2330	Southern Coastal Plain Dry Upland Hardwood Forest	CES203.560	49	4	8%	1	2	1
2343	Southern Atlantic Coastal Plain Mesic Hardwood Forest	CES203.242	47	3	6%	1	0	2
2357	Southern Coastal Plain Mesic Slope Forest	CES203.476	49	1	2%	1	0	0
2308	Crosstimbers Oak Forest and Woodland	CES205.682	17	0	0%	0	0	0
2486	Texas Saline Coastal Prairie	CES203.543	12	0	0%	0	0	0

The Crosstimbers Oak Forest and Woodland system was expertly labeled with 1 plot to West Gulf Coastal Plain Mesic Hardwood Forest, 1 plot to "can't assign" and 15 plots to "other". In the contigency table, "other" refers to other ecological system types that were not in the original sequence tables for the GeoArea, and hence the systems don't show up in the contigency table. But the expert reviewer determined that the plot represented one of these peripheral ecological systems, and labeled the plot to it. This points to another source of error that might be easy to correct – biogeography and how the types are filtered and made available to the experts for review.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 1 had over 1,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the

reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Quercus alba*), then sort by % cover of that species, from high to low. For example, in the Atlantic Coastal Plain in the southeast, distinct longleaf pine (*Pinus palustris*) dominated ecological systems occur. In this region the tree canopy can be dominated by longleaf pine with highly variable cover values (< 10% to > 75%). In these cases, the reviewer would need to use information about the canopy density, as well as subcanopy and understory composition to distinguish between the Atlantic Coastal Plain Upland Longleaf Pine Woodland (CES203.281), Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods (CES203.265), and plots representing dense longleaf pine stands planted for timber management. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in the Atlantic Coastal Plain in the southeast, distinct longleaf pine (*Pinus palustris*) dominated ecological systems occur. In this region the tree canopy can be dominated by longleaf pine with highly variable over values (< 10% to > 75%) can be found. In these cases, the reviewer would need to use information about the canopy density, as well as subcanopy and understory composition to distinguish between the Atlantic Coastal Plain Upland Longleaf Pine Woodland (CES203.281), Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods (CES203.265), and plots representing dense longleaf pine stands planted for timber management.

In cases like this, the determination of which ecological system type to assign to the plot might require:

a) review of the image clip for the context of the plot,
b) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish between Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland (CES203.254) and Florida Longleaf Pine Sandhill (CES203.284).
c) consideration of topographic setting (e.g. well drained dry uplands which could support scrub oaks vs. saturated flats suitable for wetland grasses),
d) consideration of any available height data for the plot (e.g. were the longleaf pines all tall, apparently mature trees; or were they short),
e) careful consideration of the full floristic composition of the plot and cover for each species.
f) awareness of possible errors in the plot data, such as mis-identification of pine or oak species by the field crews, unevenness in how the cover values were estimated in the field or converted

into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs. an aerial view of the plot).

Below are some examples of comments relevant to the examples above. Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland (CES203.254)

- *Pinus taeda* dominated, but xeric oaks, and *P. palustris* present.
- *Pinus palustris* as an indicator.
- *Pinus palustris* not in data, but it is a turkey oak sandhill, part of the longleaf sandhill system.

And the Atlantic Coastal Plain Upland Longleaf Pine Woodland (CES203.281)

- May have dominance with Pinus taeda due to lack of fire.
- Data are inadequate to make a high confidence assignment, and include some apparent errors (i.e. *Persea borbonia* and *Quercus laurifolia*)
- There is 2% slope, so this would probably not be a flatwoods.
- This is a poor example of CES203.281 Atlantic Coastal Plain Upland Longleaf Pine Woodland, which is dominated by *Pinus taeda* rather than *Pinus palustris*. It retains characteristic oaks of CES203.281.
- The "*Quercus laurifolia*" in this sample is presumably *Quercus hemisphaerica*.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 78 types assigned to plots by experts, 38 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 40 types, the numbers of samples labeled to a given type ranged from 123 (for West Gulf Coastal Plain Pine-Hardwood Forest) down to 10 (for Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods). For 35 (87%) of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots. Six (6) types indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 3. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin and Baygall	*Pinus taeda* and *Acer rubrum* by themselves do not have much indicator value
West Gulf Coastal Plain Small Stream and River Forest	Some obligate wetland plants in here, and some that can be upland or wetland
Atlantic Coastal Plain Blackwater Stream Floodplain Forest	This is a successional ruderal forest dominated by *Liriodendron tulipifera*, it may be CES203…
East Gulf Coastal Plain Small Stream and River Floodplain	Hard to tell if this is a large river, small stream, or what. Presence of *Taxodium ascendens* is questionable

Forest	when *Betula nigra* is codominant.
Southern Coastal Plain Seepage Swamp and Baygall	*Persea borbonia* is listed, an apparent mistake, more likely in a wetland would be *Persea palustris*

These and other comments, point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. In some cases it was not possible to determine if a plot was in a wetland or upland, due to obvious plant misidentifications, no information about plot size, and no environmental or soils information. Similarly, repeated references to photos in the comments further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling. Many of the plots included in the expert review had only cursory information on the vegetation and diversity of plants.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 211 samples, experts were able to assign 187 (89%) to an individual ecological system type; a total of 40 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate, or were introduced types with no relevant system; these samples were labeled with broad "unclassified" types, such as "Unclassified Herbaceous" or "Introduced Upland Vegetation-Treed". Of 175 samples, experts were able to assign 121 (69%) to an individual ecological system type; a total of 41 individual ecological system types were assigned to these samples.

GeoArea 2E

GeoArea 2E encompasses 3 map zones (**Error! Reference source not found.**): the Northwestern Rocky Mountains (10), Northern Rocky Mountains (19), and Middle Rocky Mountains (21). These map zones were originally clustered for purposes of designing and implementing auto-keys. The total number of plots in this GeoArea analysis was 1,971. A total of 40 natural ecological system types were assigned to a total of 1,532 plots by the auto-keys. A total of 49 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 9 types were assigned by the auto-key but were not assigned by experts:

- Columbia Basin Palouse Prairie
- Columbia Plateau Scabland Shrubland
- Great Basin Xeric Mixed Sagebrush Shrubland
- Rocky Mountain Bigtooth Maple Ravine Woodland

- Inter-Mountain Basins Montane Riparian Systems
- Inter-Mountain Basins Sparsely Vegetated Systems
- Rocky Mountain Alpine/Montane Sparsely Vegetated Systems
- Rocky Mountain Montane Riparian Systems
- Rocky Mountain Subalpine/Upper Montane Riparian Systems

Five of these types are the aggregated types used by the LANDFIRE but the first four are Ecological Systems that could have been selected by the experts. The concepts and descriptions for these types may need to be revisited, with the likelihood of occurrence in the GeoArea reevaluated. If the type is still expected to occur additional guidance on how to apply the system relative to this GeoArea may need to be incorporated into the descriptions.

Comparison of Auto-key and Expert Assignments

Of the 40 natural types assigned labels by the auto-keys, 8 types (20%) had fewer than 10 samples available for this analysis (Table 4). These under sampled types tended to include types that are found on the periphery of their range within this GeoArea (e.g. Great Basin Xeric Mixed Sagebrush Shrubland, Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland , Columbia Basin Foothill and Canyon Dry Grassland, and Rocky Mountain Bigtooth Maple Ravine Woodland), others are within this range but are relatively rare types (Rocky Mountain Alpine Fell-Field, Rocky Mountain Alpine Turf, Inter-Mountain Basins Greasewood Flat). The Columbia Basin Palouse Prairie was historically extensive but the vast majority of its historic range has been converted to agriculture and representative plots sites are very difficult to find.

Table 4. Under-sampled types within GeoArea 2E.

EVTCode	EVT Name	System elcode	Total Plots
2153	Inter-Mountain Basins Greasewood Flat	CES304.780	8
2143	Rocky Mountain Alpine Fell-Field	CES306.811	6
2012	Rocky Mountain Bigtooth Maple Ravine Woodland	CES306.814	6
2144	Rocky Mountain Alpine Turf	CES306.816	5
2079	Great Basin Xeric Mixed Sagebrush Shrubland	CES304.774	4
2134	Columbia Basin Foothill and Canyon Dry Grassland	CES304.993	4
2142	Columbia Basin Palouse Prairie	CES304.792	1
2057	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	CES306.819	1

Of the 40 types, 6 had >80% agreement between expert and auto-key assignments. Table 5 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 26, or 72% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment.

Table 5. Summary of types with adequate samples where agreement between auto-key and expert was below 80%.

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2106	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	CES306.994	50	39	78%	24	13	2
2124	Columbia Plateau Low Sagebrush Steppe	CES304.080	50	38	76%	33	4	1
2047	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	CES306.802	51	37	73%	30	7	0
2011	Rocky Mountain Aspen Forest and Woodland	CES306.813	50	35	70%	25	8	2
2080	Inter-Mountain Basins Big Sagebrush Shrubland	CES304.777	50	34	68%	16	18	0
2139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	CES306.040	50	28	56%	19	9	0
2168	Northern Rocky Mountain Avalanche Chute Shrubland	CES306.801	50	26	52%	9	16	1
2126	Inter-Mountain Basins Montane Sagebrush Steppe	CES304.785	50	24	48%	20	4	0
2045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	CES306.805	50	21	42%	14	6	1
2169	Northern Rocky Mountain Subalpine Deciduous Shrubland	CES306.961	50	21	42%	10	10	1
2140	Northern Rocky Mountain Subalpine-Upper Montane Grassland	CES306.806	50	20	40%	17	3	0
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	CES306.830	48	18	38%	10	8	0
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	CES304.776	50	18	36%	9	7	2
2125	Inter-Mountain Basins Big Sagebrush Steppe	CES304.778	55	16	29%	9	7	0
2145	Rocky Mountain Subalpine-Montane Mesic Meadow	CES306.829	98	27	28%	14	10	3
2115	Inter-Mountain Basins Juniper Savanna	CES304.782	11	3	27%	1	2	0
2046	Northern Rocky Mountain Subalpine Woodland and Parkland	CES306.807	50	11	22%	10	1	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	CES306.955	50	11	22%	5	6	0
2127	Inter-Mountain Basins Semi-Desert Shrub-Steppe	CES304.788	50	7	14%	4	1	2
2161	Northern Rocky Mountain Conifer Swamp	CES306.803	50	7	14%	3	3	1
2166	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	CES306.959	50	7	14%	6	1	0
2165	Northern Rocky Mountain Foothill Conifer Wooded Steppe	CES306.958	50	0	0%	0	0	0
2167	Rocky Mountain Poor-Site Lodgepole Pine Forest	CES306.960	48	0	0%	0	0	0
2009	Northwestern Great Plains Aspen Forest and Parkland	CES303.681	36	0	0%	0	0	0
2123	Columbia Plateau Steppe and Grassland	CES304.083	19	0	0%	0	0	0
2065	Columbia Plateau Scabland Shrubland	CES304.770	14	0	0%	0	0	0

Analysis of the contingency table (in the Results Workbook for GA 2E) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types.Three types of disagreement between somewhat floristically similar types in the plot assignments became apparent through this analysis: where change occurs along an elevation gradient or along a moisture gradient and where types have different geographic ranges.

- **Confusion amongst systems determined along an elevation gradient reduced agreement** - In the mountainous Northern Rocky Mountain GeoArea there are a number of Ecological Systems that grade into another somewhat similar, but higher, elevation system.
    - Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland and
    - Northern Rocky Mountain Subalpine-Upper Montane Grassland
    - Northern Rocky Mountain Montane-Foothill Deciduous Shrubland and
    - Northern Rocky Mountain Subalpine Deciduous Shrubland
    - Inter-Mountain Basins Big Sagebrush Steppe and
    - Inter-Mountain Basin Montane Sagebrush Steppe
    - Rocky Mountain Limber Pine-Juniper Woodland and
    - Rocky Mountain Subalpine Montane Limber-Bristlecone Pine Woodland

Confusion between some of these pairs of systems is very high and reduced the agreement between auto-key and expert assignments, for example including plots assigned to the Northern Rocky Mountain Subalpine-Upper Montane Grassland to the totals for the Northern Rocky Mountain Lower Montane Foothill and Valley Grassland increases agreement between the autokey and expert assignments from 56 to 88 percent. Some assignment overlap between these types is to be expected and is likely unavoidable due to their occurrence along an ecological gradient and the many species that they share.

The descriptions for most of these types are already relatively detailed with extensive lists of characteristic understory species. The problem when classifying plots to these systems arises when a plot has some species that are characteristic of each system. In this case the expert weighs the coverage of each species and attempts to determine which of the two system descriptions the plot fits most closely. The addition of elevation variables to the sequence table process should help to improve classification of these types and the development of more nuanced rules determining which species presence (or prevalence) trumps the presence of other more generalist species would help provide more consistency in how these systems are assigned through either proccess.

While most of the systems where confusion along an elevation gradient are well described, distinctions between the Rocky Mountain Limber Pine Juniper Woodland and the Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland are not as clear as they could be. Better description of the range of the Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland outside the zone of occurrence of Bristlecone Pine would also be helpful. Experts assigned the Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland to 14 plots in this GeoArea while the AutoKey only used it once. This may indicate some confusion on how common this system should be in the GeoArea.

- **Confusion amongst systems determined along a moisture gradient reduced agreement**- Evaluation of the contingency table indicates that confusion between drier systems and a similar but more mesic system was also a factor in reducing agreement between the auto-key and expert assignments. Examples of these pairs of systems include
    - Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
    - Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
    - Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
    - Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodlands
    - Northern Rocky Mountain Subalpine-Upper Montane Grassland
    - Rocky Mountain Subalpine-Montane Mesic Meadow

As with the elevation gradient systems, some assignment overlap between these types is to be expected. Again the development of clearer rules on how to handle plots that contain elements of both the drier and more mesic systems would also be helpful in increasing system assignment consistency for these types of systems. Additionally, guidance on the likely relative abundance of one system compared to the other in a pair would be helpful in making a call. For example the auto-key only slightly favored the assignment of the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland to the Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodlands (44–38 plots). However, the experts assigned the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland much more frequently than the more mesic system (60-21 plots). At least from the point of view of one expert, this was done consciously with the understanding that in this GeoArea the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland would be the more prevalent system.

- **Confusion amongst floristically similar systems with different ranges reduced agreement**- Another type of disagreement between the auto-key and expert assignments appears to have arisen due to the application of different geographic ranges to determine the assignment of two somewhat floristically similar systems. Examples of this type of confusion included.
    - Northwestern Great Plains Aspen Forest and Woodlands
    - Rocky Mountain Aspen Forest and Woodland
    - Middle Rocky Mountain Douglas-Fir Forest and Woodland

- Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
- Intermountain Basins Juniper Savanna
- Rocky Mountain Foothill Limber Pine-Juniper Woodland

One example of this type of confusion is that 23 of the 63 plots assigned to the Rocky Mountain Aspen Forest and Woodland by the experts were assigned to the Northwestern Great Plains Aspen and Forest and Parkland by the auto key and both of the plots assigned by the experts to the Northwestern Great Plains Aspen Forest and Woodland were assigned by the Auto key to the Rocky Mountain Aspen Forest and Woodland.

Another example is the Middle Rocky Mountain Montane Douglas-fir Forest and Woodland. This system was used much more extensively by the auto-key than by the experts (50-16), a difference that can be at least partially attributed to the different ranges applied in the two attribution processes. The Middle Rocky Mountain Montane Douglas-fir Forest and Woodland is a forest or woodland system dominated by *Pseudotsuga menziesii* that occurs outside of the range of true firs such as *Abies concolor*, *Abies grandis,* and *Abies lasiocarpa.* The auto-key process assigned plots across the GeoArea to this system if they were dominated by *Pseudotsuga menziesii* (or closely associated species) and did not contain fir (or closely associated species). This tended to work well for plots that contained sufficiently detailed lists of species but resulted in the inclusion of some *Pseudotsuga menziesii* dominated plots occurring within the true fir zone that did not include fir species in their species lists. The experts were able to use the FS sections to identify these plots occurring within the true fir zone systems and assign them to more suitable systems.

Better application of reviewed and established ranges documenting where each system occurs and the other does not would greatly reduce this type of disagreement. In areas where two similar systems both occur, the development of more detailed guidance on each systems occurrence and the use of elevation, soil and other non-floristic variable to make plot assignments would increase plot assignment accuracy.

- Other points of interest in contingency table evaluation
- **Inter-Mountain Basins Big Sagebrush Shrubland and Intermountain Basins Big Sagebrush Steppe-** There was considerable disagreement between expert and auto-key plots assigned to Inter-Mountain Basins Big Sagebrush Shrubland and Inter-Mountain Big Sagebrush Steppe. Developing greater clarification on how to distinguish these two systems should help to reduce this disagreement.
- **Rocky Mountain Poor-Site Lodgepole Pine and Rocky Mountain Lodgepole Pine Forest-** Forty-seven of the 48 plots assigned to the Rocky Mountain Poor-Site Lodgepole Pine system by the auto-key were assigned to the more generic Rocky Mountain Lodgepole Pine Forest by the experts. The Rocky Mountain Poor-Site Lodgepole pine system occurs on very specific soil types and because soil information was not available the experts may not have felt comfortable making this distinction. Currently the Rocky Mountain Poor-Site Lodgepole system description focuses on where concentrations of this system can be expected to occur in Oregon, describing occurrences in this GeoArea 2E as patchy. More details on where concentrations of this system may occur in this GeoArea would aid in the assignment of plots to this system by either method.
- **Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland**- Only thirty-six percent of the auto-key plots assigned this system were assigned it by the experts, while 86% of the plots assigned to this system by the experts were also assigned by the auto-key. The majority of the extra plots assigned this system by the auto-key were assigned to a conifer forest type by the

experts. This indicates that the experts were looking for a higher coverage of *Populus tremuloides* before assigning this system and/or a more restricted range than the auto-key used. This is an example of a system where the concept of it's geographic range and composition may not be consistently applied by the auto-keys or experts, and requires review.

- **Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest –** The experts assigned plots to this system much more often than the auto-key (132-46). Some of this difference can be explained by the previously discussed differences in the application of the Middle Rocky Mountain Montane Douglas-fir Forest and Woodland but much of it cannot. Expert confidence in assigning this system was generally high with 83% high 15% moderate and 2% low. Because this is a widespread system in this GeoArea further analysis of the discrepancy may be warranted before another classification effort is initiated.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 2E had nearly 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Picea engelmannii;),* then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

As an example, in GeoArea 2E spruce and fir species may occur in a large variety of ecological systems including Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland, Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland, Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest, Northern Rocky Mountain Mesic Montane Mixed Conifer Forest, Northern Rocky Mountain Subalpine Woodland and Parkland, Rocky Mountain Lodgepole Pine Forest, Northern Rocky Mountain Conifer Swamp, and Rocky Mountain Subalpine-Montane Riparian Woodland. The experts must select the best of these choices using information on a sites elevation, slope, species dominance, tree canopy cover, presence of other tree species, mesic or xeric understory species, photographs, hydrology and soil and geologic information if available

In cases like this, the determination of which system type to assign to the plot might require:

- review of the image clip for the context of the plot,
- review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Columbia Plateau from Northern Rocky Mountain systems for example..
- consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
- consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
- careful consideration of the full floristic composition of the plot and cover for each species.
- awareness of possible errors in the plot data, such as mis-identification of juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 49 types assigned to plots by experts, 13 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 36 types, the numbers of samples labeled to a given type ranged from 132 (Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest) down to 12 (Northern Rocky Mountain Conifer Swamp). For 41 (87%) of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots. 2 types indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Appendix. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 6. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low.

Type Name	Expert Comment
Rocky Mountain Cliff, Canyon and Massive Bedrock	Steep borderline sparsely vegetated site with 14% total vegetation cover, with nothing dominant
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	Plot is sparsely vegetated for this system
Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland	Very limited species information reduced confidence
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Hydrology information is not provided, if plot is riparian then assignment should be CES306.833
Northern Rocky Mountain Avalanche Chute Shrubland	Cannot tell snowpack conditions from information given

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of

classification refinement is likely needed in order to improve auto-keys. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were those labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 219 samples, experts were able to assign 181 (83%) to an individual ecological system type; a total of 31 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another class of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Grassland" or "None". Of 220 samples, experts were able to assign 172 (78%) to an individual ecological system type; a total of 31 individual ecological system types were assigned to these samples.

GeoArea 2W

GeoArea 2W encompasses 7 map zones (**Error! Reference source not found.**): Northern Cascades (1), Oregon Coastal Range (2), Cascade Mountain Range (7), Grande Coulee Basin of the Columbia Plateau (8), Blue Mountain Region (9), Snake River Plain (18), and Wyoming Basin (22). These map zones were originally clustered for purposes of designing and implementing auto-keys. The total number of plots in this Geo Area analysis was 3,827. A total of 105 natural ecological system types were assigned to a total of 3,551 plots by the auto-keys. A total of 121 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

Seventeen types were assigned by the auto-key but were not assigned by experts:

- Mediterranean California Mesic Serpentine Woodland and Chaparral
- Mediterranean California Subalpine Meadow
- Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
- Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
- Western Great Plains Shortgrass Prairie
- Inter-Mountain Basins Montane Riparian Systems
- Inter-Mountain Basins Sparsely Vegetated Systems
- Mediterranean California Sparsely Vegetated Systems
- North Pacific Sparsely Vegetated Systems
- North Pacific Swamp Systems
- Pacific Coastal Dunes and Other Sparsely Vegetated Systems
- Pacific Coastal Marsh Systems
- Rocky Mountain Alpine/Montane Sparsely Vegetated Systems

- Rocky Mountain Montane Riparian Systems
- Rocky Mountain Subalpine/Upper Montane Riparian Systems
- Western Great Plains Floodplain Systems
- Western Great Plains Sparsely Vegetated Systems

Twelve of these types are the aggregated types used by the LANDFIRE but the first five are Ecological Systems that could have been selected by the experts. The concepts and descriptions for these types may need to be revisited, with the likelihood of occurrence in the GeoArea reevaluated. All 5 of them are peripheral to the map zones in this GeoArea. If the type is still expected to occur additional guidance on how to apply the system relative to this GeoArea may need to be incorporated into the descriptions.

Comparison of Auto-key and Expert Assignments

Of the 93 natural types assigned labels by the auto-keys, 15 types (16%) had fewer than 10 samples available for this analysis (Table 4). These under sampled types tended to include types that are found on the periphery of their range within this GeoArea (e.g. Great Basin Semi-Desert Chaparral, Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland, Mediterranean California Subalpine Meadow and Western Great Plains Shortgrass Prairie), others are within this range but are relatively rare types (Rocky Mountain Alpine Fell-Field, and Rocky Mountain Alpine Turf). Some such as the North Pacific Montane Grassland and Northern Rocky Mountain Western Larch Savanna are types that may not be well understood or are obsolete. These concepts may need to be revisited and removed or refined.

Table 7. Under-sampled types within GeoArea 2W.

EVTCode	EVT Name	System elcode	Total Plots
2103	Great Basin Semi-Desert Chaparral	CES304.001	7
2086	Rocky Mountain Lower Montane-Foothill Shrubland	CES306.822	7
2138	North Pacific Montane Grassland	CES204.100	6
2144	Rocky Mountain Alpine Turf	CES306.816	7
2052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	CES306.825	6
2137	Mediterranean California Subalpine Meadow	CES206.940	5
2143	Rocky Mountain Alpine Fell-Field	CES306.811	5
2012	Rocky Mountain Bigtooth Maple Ravine Woodland	CES306.814	5
2149	Western Great Plains Shortgrass Prairie	CES303.672	3
2062	Inter-Mountain Basins Curl-leaf Mountain-mahogany Woodland and Shrubland	CES304.772	4
2107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	CES306.818	2
2034	Mediterranean California Mesic Serpentine Woodland and Chaparral	CES206.928	1
2114	California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna	CES206.936	1

2054	Southern Rocky Mountain Ponderosa Pine Woodland	CES306.648	1
2010	Northern Rocky Mountain Western Larch Savanna	CES306.837	1

Of the 76 adequately-sampled types, 17 had >80% agreement between expert and auto-key assignments. Table 5 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 59, or 71% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. Fourteen of the types in Table 3 had 40% or more of the expert assigned plots assigned with moderate or low confidence; the names of these types are bolded within the table.

There are a wide variety of reasons for expert unease with their assignments but some patterns may warrant further exploration. Rocky Mountain Foothill Limber Pine-Juniper Woodland was often confused with the Colorado Plateau Pinyon-Juniper Woodland, which reduced expert confidence. Additional clarification on how to distinguish these two systems may be necessary. North Pacific Montane Shrubland showed uncertainty on whether to assign plots to this shrub system or a forested type because the plot was in harvested area. Greater clarification on how to handle these disturbed areas may be helpful in increasing certainty when assigning these types of plots. The Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland ecosystem had moderate and low confidence due to uncertainty on whether to place the plot in an Aspen-Mixed conifer system or into the aspen component of a conifer dominated system. Low and moderate plot confidence associated with the Inter-Mountain Basins Semi-Desert Shrub-Steppe indicated some confusion on whether to use this system or other sagebrush systems, especially when a high degree of exotic species were present, further reducing expert confidence in assigning plots to this system. Comments associated with the Sierran-Intermontane Desert Western White Pine-White Fir Woodland indicate some uncertainty on whether to assign this system or Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland or the California Montane Jeffrey Pine-(Ponderosa Pine) Woodland. Comments related to the Columbia Plateau Steppe and Grassland plots indicated that experts had difficulty selecting between this system and the similar to Columbia Basin Foothill and Canyon Dry Grassland. Often the systems which exhibited lower expert confidence in assigning plots also exhibited lower agreement with the auto-key assigned plots.

Table 8. Summary of types with adequate samples where agreement between auto-key and expert was below 80%.

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2053	Northern Rocky Mountain Ponderosa Pine Woodland	CES306.030	19	15	79%	15	0	0
2018	East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	CES204.086	50	38	76%	34	4	0
2081	Inter-Mountain Basins Mixed Salt Desert Scrub	CES304.784	50	38	76%	31	6	1

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2039	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	CES204.002	50	37	74%	35	2	0
2049	**Rocky Mountain Foothill Limber Pine-Juniper Woodland**	CES306.955	50	37	74%	17	20	0
2029	Mediterranean California Mixed Oak Woodland	CES206.909	11	8	73%	7	1	0
2008	North Pacific Oak Woodland	CES204.852	50	36	72%	36	0	0
2011	Rocky Mountain Aspen Forest and Woodland	CES306.813	50	36	72%	32	4	0
2140	**Northern Rocky Mountain Subalpine-Upper Montane Grassland**	CES306.806	49	35	71%	21	13	1
2060	East Cascades Oak-Ponderosa Pine Forest and Woodland	CES204.085	37	26	70%	23	3	0
2042	North Pacific Mesic Western Hemlock-Silver Fir Forest	CES204.097	50	33	66%	27	6	0
2028	Mediterranean California Mesic Mixed Conifer Forest and Woodland	CES206.915	50	33	66%	30	3	0
2047	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	CES306.802	50	33	66%	29	4	0
2084	**North Pacific Montane Shrubland**	CES204.087	14	9	64%	5	4	0
2098	**California Montane Woodland and Chaparral**	CES206.925	14	9	64%	4	5	0
2043	Mediterranean California Mixed Evergreen Forest	CES206.919	50	32	64%	32	0	0
2065	Columbia Plateau Scabland Shrubland	CES304.770	50	32	64%	21	9	2
2156	North Pacific Lowland Riparian Forest and Shrubland	CES204.869	30	19	63%	17	2	0
2070	Rocky Mountain Alpine Dwarf-Shrubland	CES306.810	21	13	62%	8	5	0
2106	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	CES306.994	50	29	58%	24	5	0
2135	Inter-Mountain Basins Semi-Desert Grassland	CES304.787	19	10	53%	7	3	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2038	North Pacific Maritime Mesic Subalpine Parkland	CES204.837	50	26	52%	20	6	0
2027	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	CES206.916	50	26	52%	24	2	0
2079	**Great Basin Xeric Mixed Sagebrush Shrubland**	CES304.774	50	26	52%	7	15	4
2045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	CES306.805	50	25	50%	25	0	0
2139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	CES306.040	50	24	48%	20	4	0
2037	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	CES204.001	50	23	46%	22	1	0
2171	North Pacific Alpine and Subalpine Dry Grassland	CES204.099	50	23	46%	21	2	0
2178	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	CES204.842	50	23	46%	20	3	0
2061	**Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland**	CES304.776	50	23	46%	13	9	1
2063	North Pacific Broadleaf Landslide Forest and Shrubland	CES204.846	50	21	42%	16	5	0
2055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	CES306.828	50	20	40%	16	3	1
2127	**Inter-Mountain Basins Semi-Desert Shrub-Steppe**	CES304.788	50	19	38%	11	7	1
2115	**Inter-Mountain Basins Juniper Savanna**	CES304.782	16	6	38%	2	4	0
2056	Rocky Mountain Subalpine Wet-Mesic Spruce-Fir Forest and Woodland	CES306.830	11	4	36%	4	0	0
2172	**Sierran-Intermontane Desert Western White Pine-White Fir Woodland**	CES204.101	50	18	36%	3	15	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	CES306.830	39	14	36%	13	1	0
2030	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland	CES206.923	50	17	34%	15	2	0
2174	North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	CES204.098	50	16	32%	14	2	0
2126	Inter-Mountain Basins Montane Sagebrush Steppe	CES304.785	50	16	32%	11	4	1
2145	Rocky Mountain Subalpine-Montane Mesic Meadow	CES306.829	50	16	32%	10	5	1
2169	Northern Rocky Mountain Subalpine Deciduous Shrubland	CES306.961	50	14	28%	11	2	1
2031	California Montane Jeffrey Pine(-Ponderosa Pine) Woodland	CES206.918	20	5	25%	5	0	0
2125	Inter-Mountain Basins Big Sagebrush Steppe	CES304.778	49	11	22%	8	2	1
2123	**Columbia Plateau Steppe and Grassland**	CES304.083	50	8	16%	2	4	2
2161	**Northern Rocky Mountain Conifer Swamp**	CES306.803	13	2	15%	0	2	0
2158	North Pacific Montane Riparian Woodland and Shrubland	CES204.866	50	7	14%	6	1	0
2053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	CES306.030	31	4	13%	4	0	0
2035	North Pacific Dry Douglas-fir (-Madrone) Forest and Woodland	CES204.845	50	5	10%	5	0	0
2033	**Mediterranean California Subalpine Woodland**	CES206.910	12	1	8%	0	1	0
2142	**Columbia Basin Palouse Prairie**	CES304.792	50	4	8%	0	2	2
2165	**Northern Rocky Mountain Foothill Conifer Wooded Steppe**	CES306.958	50	4	8%	1	2	1
2083	North Pacific Avalanche Chute Shrubland	CES204.854	50	0	0%	0	0	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2173	North Pacific Wooded Volcanic Flowage	CES204.883	50	0	0%	0	0	0
2044	Northern California Mesic Subalpine Woodland	CES206.911	50	0	0%	0	0	0
2167	Rocky Mountain Poor-Site Lodgepole Pine Forest	CES306.960	50	0	0%	0	0	0
2021	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	CES206.917	41	0	0%	0	0	0
2022	Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland	CES206.914	31	0	0%	0	0	0
2166	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	CES306.959	25	0	0%	0	0	0

Systems with lower expert confidence that also exhibited lower agreement with the auto-key assignments were evaluated through a contingency table (in the Results Workbook for GA 2W). Three types of disagreement between somewhat floristically similar types in the plot assignments became apparent through this analysis: where change occurs along an elevation gradient or along a moisture gradient and where types have different geographic ranges.

- **Confusion amongst systems determined along an elevation gradient reduced agreement** - In this mountainous GeoArea there are a number of Ecological Systems that grade into other somewhat similar systems, but ones that occur at different elevations.
    - Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland and Northern Rocky Mountain Subalpine-Upper Montane Grassland
    - Northern Rocky Mountain Montane-Foothill Deciduous Shrubland and Northern Rocky Mountain Subalpine Deciduous Shrubland
    - Inter-Mountain Basins Big Sagebrush Steppe and Inter-Mountain Basin Montane Sagebrush Steppe
    - North Pacific Maritime Mesic Subalpine Parkland North Pacific Mountain Hemlock Forest

Confusion between some of these pairs of systems is very high and reduced the agreement between auto-key and expert assignments, for example including plots assigned to the Northern Rocky Mountain Subalpine-Upper Montane Grassland to the totals for the Northern Rocky Mountain Lower Montane Foothill and Valley Grassland increases agreement between the autokey and expert assignments from 49-63 percent. Some assignment overlap between these types is to be expected and is likely unavoidable due to their occurrence along an ecological gradient and the many species that they share.

The descriptions for most of these types are already relatively detailed with extensive lists of characteristic understory species. The problem when classifying plots to these systems arises when a

plot has some species that are characteristic of each system. In this case the expert weighs the coverage of each species and attempts to determine which of the two system descriptions the plot fits most closely. The addition of elevation information to the sequence table process should help to improve classification of these types and the development of more nuanced rules determining which species presence (or prevalence) trumps the presence of other more generalist species would help provide more consistency in how these systems are assigned through either process.

- **Confusion amongst systems determined along a moisture gradient--** Evaluation of the contingency table indicates that confusion between drier systems and a similar but more mesic system was also a factor in reducing agreement between the auto-key and expert assignments. Example of these type of systems include:
    1. Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
       Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
    2. Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
       Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodlands
    3. Northern Rocky Mountain Subalpine-Upper Montane Grassland
       Rocky Mountain Subalpine-Montane Mesic Meadow
    4. North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
       North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
    5. North Pacific Mesic Western Hemlock-Silver Fir Forest
       North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest

As with the elevation gradient systems, some assignment overlap between these types is to be expected. Development of clearer rules on how to handle plots contained elements of both the drier and more mesic systems would also be helpful in increasing system assignment consistency.

- **Confusion amongst floristically similar systems with different ranges** - Another type of disagreement between the auto-key and expert assignments appears to have arisen due to the application of different geographic ranges to determine the assignment of two somewhat floristically similar systems. Examples of this type of confusion included:

    - Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
        - California Montane Jeffery Pine- (Ponderosa Pine) Woodland
        - Northern Rocky Mountain Foothill Conifer Wooded Steppe
    - Intermountain Basins Juniper Savanna
        - Great Basin Pinyon-Juniper Woodland
        - Rocky Mountain Foothill Limber Pine Juniper Woodland
    - North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest
        - North Pacific Mesic Western Hemlock-Silver Fir Forest

One example of this type of confusion is that 22 of the 57 plots assigned to the California Montane Jeffrey Pine-(Ponderosa Pine) Woodland by the experts were assigned to the Northern Rocky Mountain Ponderosa Pine Woodland and Savanna by the auto key. Similarly 10 of the same 57 plots assigned to the California Montane Jeffrey Pine-(Ponderosa Pine) Woodland by the experts were assigned to the Northern Rocky Mountain Foothill Conifer Wooded Steppe by the auto key.

Better application of reviewed and established ranges documenting where each system occurs and the other does not would greatly reduce this type of disagreement. In areas where two similar systems both occur, the development of more detailed guidance on each systems occurrence and the use of

elevation, soil and other non-floristic variables to make plot assignments would increase plot assignment accuracy.

- **Other points of interest in contingency table evaluation**
    - **Inter-Mountain Basins Big Sagebrush Shrubland and Intermountain Basins Big Sagebrush Steppe-** There was considerable disagreement between expert and auto-key plots assigned to Inter-Mountain Basins Big Sagebrush Shrubland and Inter-Mountain Big Sagebrush Steppe. Twenty of the 94 plot assigned to the Inter-Mountain Basins Big Sagebrush Shrubland by the experts were assigned to the Inter-Mountain Basins Big Sagebrush Steppe by the auto-key. Confusion in the other direction also occurred but was not as substantial-- 5 of the 46 plots the experts assigned to the Inter-Mountain Basins Big Sagebrush Steppe were assigned to the Inter-Mountain Basins Big Sagebrush Shrubland by the auto-key. Developing greater clarification on how to distinguish these two systems should help to reduce this disagreement.
    - **Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland**- Only forty-seven percent of the auto-key plots assigned this system were assigned it by the experts, while 100% of the plots assigned to this system by the experts were also assigned by the auto-key. The majority of the extra plots assigned this system by the auto-key were assigned to a conifer forest type by the experts. This indicates that the experts were looking for a higher coverage of *Populus tremuloides* before assigning this system and/or a more restricted range than the auto-key used. This is an example of a system where the concept of it's geographic range and composition may not be consistently applied by the auto-keys or experts, and requires review.
    - **Substantial confusion occurred amongst Columbia Plateau grassland types**. The Columbia Plateau Steppe and Grassland will be used as an example as it exhibited the most extensive confusion. The experts and the auto-key both assigned a similar number of plots to this system (52 and 50) but had less than 16% agreement between these assignments. Fourteen of the plots assigned by the experts to this system were assigned by the auto-key to the Columbia Basin Palouse Prairie, with the Inter-Mountain Basin Semi-Desert Shrub-Steppe being the next highest source of disagreement. Twelve of the plots assigned to this system by the auto-key were assigned to the Northern Rocky Mountain Lower Montane Foothill and Valley Grassland and 10 were assigned to the Columbia Basin Foothill and Canyon Dry Grassland. Lower in elevation but similar types of disagreement among the low elevation grassland types in the central portion of this GeoArea indicates a need for better clarification of differences in these types. Some expert comments indicate that the addition of soil and slope information to the assignment process would help to clarify these types.
    - The **North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-Field and Meadow** system was easily confused with the **North Pacific Alpine and Subalpine Dry Grassland** system**.** They are floristically similar, and occur adjacent to each other often in an inter-digitated fashion. More nuanced floristic and local environmental information would help clarify the differences between these two ecosystems.
    - The **North Pacific Broadleaf Landslide Forest and Shrubland** was easily confused with the **North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest.** These systems occur within the same geography and elevation and have differences in the abundance of certain key species, indicating recent disturbance. Detailed information that was available to the experts in aerial photographs (proximity to human

development) and the percent slope were important additional variables that need to be incorporated into the auto-key.

- **Mediterranean California Mixed Evergreen Forest** was often miss-labled by the auto key as **Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland, North Pacific Dry Douglas-fir-(Madrone) Forest and Woodland, Mediterranean California Mesic Mixed Conifer Forest and Woodland,** or the **Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland.** More detailed information on geographic location and species composition is necessary to differentiate between these systems, as they share many of the same floristic details.
- The confirmation of soil information (especially the presence of serpentine soils) would greatly aid in the correct identification of these systems **Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland** and **Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland** from their surrounding and often similar floristic forests.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 2W had nearly 4,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Picea engelmannii;),* then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

As an example, in GeoArea 2W Engelmann spruce may occur in a large variety of ecological systems including Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland, Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland, Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest, Northern Rocky Mountain Mesic Montane Mixed Conifer Forest, Northern Rocky Mountain Subalpine Woodland and Parkland, Rocky Mountain Lodgepole Pine Forest, Northern Rocky Mountain Conifer Swamp, and Rocky Mountain Subalpine-Montane Riparian Woodland. For a plot containing a high coverage of Engelmann spruce the experts must select the best of these choices using information on a site's elevation, slope, species dominance, tree canopy cover, presence of other tree

species, mesic or xeric understory species, photographs, hydrology and soil and geologic information if available.

In cases like this, the determination of which system type to assign to the plot might require:

g) review of the image clip for the context of the plot,
h) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Columbia Plateau from Northern Rocky Mountain systems for example..
i) consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
j) consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
k) careful consideration of the full floristic composition of the plot and cover for each species.
l) awareness of possible errors in the plot data, such as mis-identification of juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 121 types assigned to plots by experts, 44 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 77 types, the numbers of samples labeled to a given type ranged from 154 (North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest) down to 10 (5 systems). For all of these types, experts reported at least moderate confidence in their labels for at least 20% of the type's plots. 2 types indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 9. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low.

Type Name	Expert Comment
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	Need geomorphology, soils and hydrologic info to determine type of wetland. This may be shrub-swamp or bog/fen.
Mediterranean California Mixed Oak Woodland	May be the Med Cal Lower Montane Black Oak woodland without the Ponderosa Pine
North Pacific Bog and Fen	Need soils information to determine type of wetland (organic soils)
Rocky Mountain Alpine Turf	high forb & gram cover, high elevation, but not really alpine turf species, could also be subalpine mesic

	meadow
Rocky Mountain Alpine Bedrock and Scree	Not sure if I can assume that the coverage not accounted for in the species list is rock but assuming that it is and there were not other species on the plot that were not recorded I would go with this system.

These and other comments point to several important aspects for consideration. Some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. Also, the inclusion of some landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many moderate-low confidence types where auto-keys might be prone to error. Additional floristic information is cited in some cases where suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 311 samples, experts were able to assign 282 (91%) to an individual ecological system type; a total of 63 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate, or were introduced types with no relevant system; these samples were labeled with broad "unclassified" types, such as "Unclassified Grassland" or "Introduced Upland Vegetation-Shrub". Of 276 samples, experts were able to assign 203 (74%) to an individual ecological system type; a total of 69 individual ecological system types were assigned to these samples.

GeoArea 3

GeoArea 3 encompasses Northern California Coastal Range, Southern California Coastal Range, California Central Valley, and Sierra Nevada Mountain Range (**Error! Reference source not found.**). This GeoArea includes a total of 4 map zones (Map zones 3-6), originally clustered for purposes of designing and implementing auto-keys (**Error! Reference source not found.**). The total number of plots in this Geo Area analysis was 2,049. A total of 57 natural ecological system types were assigned to a total of 2,099 plots by the auto-keys. A total of 75 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 14 types were assigned by the auto-key but were not assigned by experts:

- Baja Semi-Desert Coastal Succulent Scrub
- California Mesic Serpentine Grassland
- Columbia Plateau Western Juniper Woodland and Savanna
- Mediterranean California Alpine Fell-Field
- North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest

- Northern California Mesic Subalpine Woodland
- California Montane Riparian Systems
- Inter-Mountain Basins Montane Riparian Systems
- Inter-Mountain Basins Sparsely Vegetated Systems
- Mediterranean California Sparsely Vegetated Systems
- North American Warm Desert Riparian Systems
- North American Warm Desert Sparsely Vegetated Systems
- Pacific Coastal Dunes and Other Sparsely Vegetated Systems
- Pacific Coastal Marsh Systems

Comparison of Auto-key and Expert Assignments

Of the 75 natural types assigned labels by the auto-keys, 17 types (24%) had fewer than 10 samples available for this analysis (Table 4). These under-sampled types tended to include types that are found on the periphery of their range within this GeoArea (e.g., Inter-Mountain Basins Greasewood Flat, Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland, Columbia Plateau Western Juniper Woodland and Savanna, Inter-Mountain Basins Big Sagebrush Steppe, Inter-Mountain Basins Mixed Salt Desert Scrub, Inter-Mountain Basins Semi-Desert Grassland, North Pacific Hypermaritime Seasonal Sitka Spruce Forest, North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest), while others are generally within this range, but are less common types, or simply have had inadequate sampling effort (for example were difficult to access) across this region. These include Mediterranean California Alpine Dry Tundra, Mediterranean California Alpine Fell-Field, Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland, California Mesic Serpentine Grassland, Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland, California Coastal Closed-Cone Conifer Forest and Woodland, Baja Semi-Desert Coastal Succulent Scrub and California Maritime Chaparral.

Table 10. Under-sampled types within GeoArea 3

EVT Code	EVT Name	System elcode	total Plots
2136	Mediterranean California Alpine Dry Tundra	CES206.939	8
2153	Inter-Mountain Basins Greasewood Flat	CES304.780	8
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	CES304.776	7
2022	Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland	CES206.914	6
2073	Baja Semi-Desert Coastal Succulent Scrub	CES206.934	6
2131	California Northern Coastal Grassland	CES206.941	5
2130	California Mesic Serpentine Grassland	CES206.943	5
2067	Mediterranean California Alpine Fell-Field	CES206.900	4
2021	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	CES206.917	4
2177	California Coastal Closed-Cone Conifer Forest and Woodland	CES206.922	3
2017	Columbia Plateau Western Juniper Woodland and Savanna	CES304.082	3
2125	Inter-Mountain Basins Big Sagebrush Steppe	CES304.778	3
2036	North Pacific Hypermaritime Seasonal Sitka Spruce Forest	CES204.841	2

EVT Code	EVT Name	System elcode	total Plots
2039	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	CES204.002	1
2096	California Maritime Chaparral	CES206.929	1
2081	Inter-Mountain Basins Mixed Salt Desert Scrub	CES304.784	1
2135	Inter-Mountain Basins Semi-Desert Grassland	CES304.787	1

A total of 18 types (or nearly 32% of 57 types) had >80% agreement between expert and auto-key assignments. All of these types had at least 25 sample plots. Expert self-assessment of confidence for these types were predominantly 'high'.

Table 11 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 22, or nearly 39% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. For example some plots assigned by the auto-key to Mediterranean California Mixed Evergreen Forest were most frequently mistaken for Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland probably because they included *Pseudotsuga menziesii* and *Quercus chrysolepis,* which is common to both ecosystems. These types do transition into one another, so additional floristic indicators might be identified to better distinguish them. This same general pattern, one of carefully reviewing the dominant tree, shrub, or grass elements shared among related types, should be the focus of auto-key improvements for these types.

Table 11. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2043	Mediterranean California Mixed Evergreen Forest	CES206.919	49	38	78%	37	1	0
2034	Mediterranean California Mesic Serpentine Woodland and Chaparral	CES206.928	50	38	76%	37	1	0
2097	California Mesic Chaparral	CES206.926	50	36	72%	34	2	0
2029	Mediterranean California Mixed Oak Woodland	CES206.909	50	32	64%	32	0	0
2011	Rocky Mountain Aspen Forest and Woodland	CES306.813	33	21	64%	21	0	0
2030	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland	CES206.923	38	24	63%	24	0	0
2126	Inter-Mountain Basins Montane Sagebrush Steppe	CES304.785	36	20	56%	20	0	0

2088	Sonora-Mojave Mixed Salt Desert Scrub	CES302.749	24	13	54%	13	0	0
2028	Mediterranean California Mesic Mixed Conifer Forest and Woodland	CES206.915	50	25	50%	25	0	0
2099	California Xeric Serpentine Chaparral	CES206.927	47	23	49%	22	1	0
2098	California Montane Woodland and Chaparral	CES206.925	59	28	47%	28	0	0
2027	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	CES206.916	50	19	38%	19	0	0
2033	Mediterranean California Subalpine Woodland	CES206.910	49	18	37%	18	0	0
2118	Southern California Oak Woodland and Savanna	CES206.938	50	17	34%	17	0	0
2112	California Central Valley Mixed Oak Savanna	CES206.935	47	15	32%	15	0	0
2014	Central and Southern California Mixed Evergreen Woodland	CES206.920	50	14	28%	14	0	0
2105	Northern and Central California Dry-Mesic Chaparral	CES206.931	50	14	28%	14	0	0
2108	Sonora-Mojave Semi-Desert Chaparral	CES302.757	50	13	26%	13	0	0
2008	North Pacific Oak Woodland	CES204.852	16	3	19%	3	0	0
2082	Mojave Mid-Elevation Mixed Desert Scrub	CES302.742	50	7	14%	6	1	0
2103	Great Basin Semi-Desert Chaparral	CES304.001	16	2	13%	2	0	0
2044	Northern California Mesic Subalpine Woodland	CES206.911	26	0	0%	0	0	0

Analysis of the contingency table (see Results Workbook) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. Here we summarize a cross-section of results from GeoArea 3. It's important to note that the sequence table for these California map zones did not include any ability to key plots based on an elevation criterion. Some of the disagreements between the auto-keyed results and the expert results might be resolved in the future by the addition of elevation rules in the sequence table.

The Mediterranean California Mesic Mixed Conifer Forest and Woodland (50%) and the Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland (38%) are very similar types distiguished on a

moisture gradient, and were often confused with each other in the auto-key. Information on elevation, aspect and additional component species composition aided experts in teasing these two systems apart.

Auto-key often mistook Great Basin Xeric Mixed Sagebrush Shrubland for Inter-Mountain Basins Montane Sagebrush Steppe, which relies on the identification of the subspecies of several *Artemisia* species for proper classification; they also intergrade at higher elevation where they transition from one system to the other. Additional elevation and geographic information would help the auto-key process.

Mediterranean California Subalpine Woodland (37%) and Northern California Mesic Subalpine Woodland (0%) were often confused with lower elevation forest types. Elevation is a key factor that would aid the auto-key process.

Southern California Oak Woodland and Savanna (34%) and California Central Valley Mixed Oak Savanna (32%) were often confused with California Coastal Live Oak Woodland and Savanna as both can have *Querus agrifolia* mixed with other oak species. For stands with limited species compositional information, the addition of geographical location confirms the type of oak savanna.

Chaparral is complex and very diverse in California, so location and geography as well as species composition is critical to classify to the different types. The Auto-key and expert tended to disagree between the Northern and Central California Dry-Mesic Chaparral system and the Southern California Dry-Mesic Chaparral system. The species composition tends to intergrade where the two become adjacent, and correct identification of *Ceanothus* species becomes critical. Again location/geographic information and accurate species identification will be very helpful.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 3 had over 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Pinus contorta*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in the lower foothills of the Sierra-Nevada there is a transition from Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland to Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland. In these areas, the tree canopy might be a mix of ponderosa, black oak (*Quercus kelloggii*), incense cedar (*Calocedrus decurrens)* and *Quercus chrysolepis*, along with a variable mixture of deciduous shrubs and grasses. Cover of the trees can vary from 10% to more than 80% . In these cases, the reviewer would encounter plots of mixed composition, and need to determine whether those plots represented Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland*,* the Mediterranean California Mesic Mixed Conifer Forest and Woodland or the Mediterranean California Mesic Serpentine Woodland and Chaparral.

In cases like this, the determination of which system type to assign to the plot might require:

m) review of the image clip for the context of the plot,
n) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Southern California Coastal Mountains from Northern California Coast, and the Central Valley from Mojave Desert,
o) consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
p) consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
q) careful consideration of the full floristic composition of the plot and cover for each species.
r) awareness of possible errors in the plot data, such as mis-identification of juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Below are some examples of comments relevant to the above example:

- Coastal Chaparral species composition changes from north to south, but where northern and southern coastal California intergrade, it is helpful to know if the location is on the drier interior aspect or ocean facing part of the same mountain range. This is particularly useful if the full species composition is unavailable. Information or confirmation of soil types to identify serpentine areas would also be beneficial. Closely aligned chaparral includes California Xeric Serpentine Chaparral, California Maritime Chaparral, Southern California Dry-Mesic Chaparral, Northern and Central California Dry-Mesic Chaparral, and Southern California Coastal Scrub
- Coast live oak is the characteristic species of the California Coastal Live Oak Woodland and Savanna, however it is a wide-spread species in California and may occur in the foothills of the Sierra-Nevada or along the western edges of the central valley where it mixes with other oak species and is often a part of the Mediterranean California Mixed Oak Woodland, the California Central Valley Mixed Oak Savanna or the Mediterranean California Mixed Evergreen Forest. Again full species composition and geographic location aid the accuracy of point classification.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 75 types assigned to plots by experts, 32 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 43 types, the numbers of samples labeled to a given type ranged from 152 (for Southern California Dry-Mesic Chaparral) down to 11 (for Mojave Mid-Elevation Mixed Desert Scrub). For all of these types, experts reported at least moderate confidence in their labels for at least 70% of the type's plots. In fact the vast majority of plot labels were given with high confidence, and almost no plots were given low confidence. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 12. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Great Basin Semi-Desert Chaparral	Need Quercus species identified
Mediterranean California Mesic Serpentine Woodland and Chaparral	Not sure soils are serpentine
Southern California Coastal Scrub	Has half Maritime and half dry Chaparral spp, so it depends on the location of the stand
Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	need var of lodgepole

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 212 samples, experts were able to assign 209 (99%) to an individual ecological system type; a total of 26 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

For example experts were able to differentiate Mediterranean California Foothill and Lower Montane Riparian Woodland, California Central Valley Riparian Woodland and Shrubland and Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland, based on species composition and geographic location, while the Landfire auto-key had these lumped into a single "California Montane Riparian Systems."

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Grassland" or "None". Of 177 samples, experts were able to assign 137 (77%) to an individual ecological system types; a total of 45 individual ecological system types were assigned to these samples.

GeoArea 4

GeoArea 4 encompasses the desert southwest and adjacent interior Rocky Mountains, extending from the heart of the Great Basin (Map zones 12 & 17), east to the Southern Rocky Mountains (Map zone 28), and south throughout the Chihuahuan Desert (Map zones 25-26) (**Error! Reference source not found.**). This GeoArea includes a total of 11 map zones, originally clustered into grouping for purposes of designing and implementing auto-keys (**Error! Reference source not found.**). Importantly, this area includes the first set of sequence tables and auto-keys developed for the LANDFIRE, so lessons learned in their development were initiated here. The total number of plots in this Geo Area analysis was 2,127. A total of 75 natural ecological system types were assigned to a total of 1,764 plots by the auto-keys. A total of 97 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 9 types were assigned by the auto-key but were not assigned by experts. Those types included:

- Rocky Mountain Foothill Limber Pine-Juniper Woodland
- Mediterranean California Subalpine Woodland
- Madrean Oriental Chaparral
- Columbia Plateau Low Sagebrush Steppe
- Rocky Mountain Alpine Fell-Field
- Sonoran Brittlebush-Ironwood Desert Scrub
- Western Great Plains Foothill and Piedmont Grassland
- Columbia Plateau Western Juniper Woodland and Savanna
- Columbia Plateau Steppe and Grassland

Of the 75 natural types assigned labels by the auto-keys, 18 types (24%) had fewer than 20 samples available for this analysis (Table 4). These under-sampled types tended to include types that are found on the periphery of their range within this GeoArea (e.g., Columbia Plateau Low Sagebrush Steppe [n=5], Western Great Plains Foothill and Piedmont Grassland [n=1], Madrean Upper Montane Conifer-Oak Forest and Woodland [n=4], or Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland [n=2]), while others are generally within this range, but are less common types, or simply have had inadequate sampling effort across this region. These include Rocky Mountain Alpine Turf, Rocky Mountain Alpine Dwarf-Shrubland, Rocky Mountain Alpine Fell-Field, Chihuahuan Sandy Plains Semi-Desert Grassland, Sonoran Granite Outcrop Desert Scrub, and Chihuahuan-Sonoran Desert Bottomland and Swale Grassland.

Table 13. Under-sampled types within GeoArea 4.

EVT Code	Ecological System Name	NatureServe CES code	Number of plots
2033	Mediterranean California Subalpine Woodland	CES206.910	13
2101	Madrean Oriental Chaparral	CES302.031	12

EVT Code	Ecological System Name	NatureServe CES code	Number of plots
2144	Rocky Mountain Alpine Turf	CES306.816	10
2133	Chihuahuan Sandy Plains Semi-Desert Grassland	CES302.736	9
2070	Rocky Mountain Alpine Dwarf-Shrubland	CES306.810	7
2124	Columbia Plateau Low Sagebrush Steppe	CES304.080	5
2090	Sonoran Granite Outcrop Desert Scrub	CES302.760	5
2122	Chihuahuan Gypsophilous Grassland and Steppe	CES302.732	4
2111	Western Great Plains Mesquite Woodland and Shrubland	CES303.668	4
2026	Madrean Upper Montane Conifer-Oak Forest and Woodland	CES305.798	4
2504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	CES302.746	3
2143	Rocky Mountain Alpine Fell-Field	CES306.811	2
2058	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	CES206.912	2
2089	Sonoran Brittlebush-Ironwood Desert Scrub	CES302.758	1
2147	Western Great Plains Foothill and Piedmont Grassland	CES303.817	1
2017	Columbia Plateau Western Juniper Woodland and Savanna	CES304.082	1
2123	Columbia Plateau Steppe and Grassland	CES304.083	1
2031	California Montane Jeffrey Pine(-Ponderosa Pine) Woodland	CES206.918	1

A total of 23 types (or nearly 31% of 75 types) had >80% agreement between expert and auto-key assignments. All of these types had at least 25 sample plots. Expert self-assessment of confidence for these types were predominantly 'high' although the several types with more 'moderate' or even 'low' confidence included Western Great Plains Sandhill Steppe, Inter-Mountain Basins Mixed Salt Desert Scrub, and Rocky Mountain Gambel Oak-Mixed Montane Shrubland.

Table 5 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 35, or nearly 47% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. For example, some plots assigned by the auto-key to Colorado Plateau Pinyon-Juniper Woodland were most frequently mistaken for Madrean Pinyon-Juniper Woodland because they included Madrean floristic elements (*Juniperus coahuilensis*). These types do transition into one another, so additional floristic indicators might be identified to better distinguish them. This same general pattern, one of carefully reviewing the dominant tree, shrub, or grass elements shared among related types, should be the focus of auto-key improvements for these types.

Table 14. Summary of types with adequate samples where agreement between auto-key and expert was below 80%.

EVT Code	EVT Name	NatureServe Code	# Plots	# Agree	%	High Conf	Med Conf	Low Conf
2016	Colorado Plateau Pinyon-Juniper Woodland	CES304.767	30	23	77%	21	2	0
2074	Chihuahuan Creosotebush Desert Scrub	CES302.731	30	22	73%	17	5	0
2012	Rocky Mountain Bigtooth Maple	CES306.814	30	22	73%	21	1	0

	Ravine Woodland							
2064	Colorado Plateau Mixed Low Sagebrush Shrubland	CES304.762	30	21	70%	20	1	0
2146	Southern Rocky Mountain Montane-Subalpine Grassland	CES306.824	30	21	70%	20	1	0
2116	Madrean Juniper Savanna	CES301.730	22	15	68%	9	6	0
2075	Chihuahuan Mixed Salt Desert Scrub	CES302.017	30	20	67%	15	5	0
2135	Inter-Mountain Basins Semi-Desert Grassland	CES304.787	30	19	63%	17	0	2
2121	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	CES302.735	30	18	60%	13	3	2
2127	Inter-Mountain Basins Semi-Desert Shrub-Steppe	CES304.788	30	18	60%	16	1	1
2051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	CES306.823	30	18	60%	11	6	1
2059	Southern Rocky Mountain Pinyon-Juniper Woodland	CES306.835	30	18	60%	12	6	0
2503	Chihuahuan Loamy Plains Desert Grassland	CES302.061	30	16	53%	4	12	0
2100	Chihuahuan Mixed Desert and Thornscrub	CES302.734	30	16	53%	13	1	2
2082	Mojave Mid-Elevation Mixed Desert Scrub	CES302.742	30	16	53%	10	6	0
2149	Western Great Plains Shortgrass Prairie	CES303.672	30	15	50%	4	11	0
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	CES304.776	30	15	50%	8	7	0
2119	Southern Rocky Mountain Juniper Woodland and Savanna	CES306.834	30	14	47%	9	5	0
2093	Southern Colorado Plateau Sand Shrubland	CES304.793	29	13	45%	9	4	0
2109	Sonoran Paloverde-Mixed Cacti Desert Scrub	CES302.761	30	13	43%	5	7	1
2117	Southern Rocky Mountain Ponderosa Pine Savanna	CES306.649	28	12	43%	6	6	0
2095	Apacherian-Chihuahuan Mesquite Upland Scrub	CES302.733	30	12	40%	2	5	5
2125	Inter-Mountain Basins Big Sagebrush Steppe	CES304.778	30	12	40%	6	6	0
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	CES306.830	30	12	40%	11	1	0
2144	Rocky Mountain Alpine Turf	CES306.816	10	4	40%	4	0	0

2076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	CES302.737	30	11	37%	6	5	0
2077	Chihuahuan Succulent Desert Scrub	CES302.738	29	10	34%	2	2	6
2091	Sonoran Mid-Elevation Desert Scrub	CES302.035	30	8	27%	7	1	0
2115	Inter-Mountain Basins Juniper Savanna	CES304.782	30	8	27%	4	4	0
2145	Rocky Mountain Subalpine-Montane Mesic Meadow	CES306.829	27	5	19%	5	0	0
2052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	CES306.825	30	5	17%	0	5	0
2108	Sonora-Mojave Semi-Desert Chaparral	CES302.757	21	3	14%	3	0	0
2086	Rocky Mountain Lower Montane-Foothill Shrubland	CES306.822	30	3	10%	0	3	0
2103	Great Basin Semi-Desert Chaparral	CES304.001	30	2	7%	0	2	0
2049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	CES306.955	29	0	0%	0	0	0

Analysis of the contingency table (Appendix spreadsheet) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. Here we summarize a cross-section of results from GeoArea 4.

Desert scrub types can present challenges where relatively few species are reliably present and canopy cover varies from relatively dense to quite sparse, all relative to the size of a given sample plot. Autokey-assigned plots for Mojave Mid-Elevation Mixed Desert Scrub (53% agreement) was most commonly assigned by experts to Inter-Mountain Basins Semi-Desert Shrub Steppe, Great Basin Pinyon-Juniper Woodland, and Inter-Mountain Basin Mixed Salt Desert Scrub. Each of these types would be commonly found immediately adjacent and share some small portion of their floristics.

Auto-key assigned plots for Sonoran Paloverde-Mixed Cacti Desert Scrub (43% agreement) included somewhat greater uncertainty reported by experts, but was most commonly assigned to Sonora-Mojave Creosotebush-White Bursage Desert Scrub, Sonoran Mid-Elevation Desert Scrub, Apacherian-Chihuahuan and Semi-Desert Grassland and Steppe. The shared component of Creosotebush likely explains the first and most substantial discrepancy. Grass species found with the other types may have triggered confusion with other types.

Auto-key assigned plots for Chihuahuan Succulent Desert Scrub (34%) also included somewhat greater uncertainty reported by experts, but was most commonly assigned to Apacherian-Chihuahuan Semi-Desert Grassland and Steppe and Chihuahuan Mixed Desert and Thornscrub; two types sharing key floristic components of either grass or succulent plant species.

Auto-key assigned plots for Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland (40%) appear to have had high confidence from experts, but were only assigned to one other type, the Rocky Mountain Dry-Mesic Spruce-Fir Forest. Apparently additional floristic information (below tree and shrub canopy) would have enabled better assignment of these types.

Auto-key assigned plots for Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland (17%) appear to have had only moderate confidence from experts, but was by far most often assigned to Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland. Again, additional floristic information (below tree and shrub canopy) would have enabled better assignment of these types.

Finally, auto-key-assigned plots for Rocky Mountain Lower Montane-Foothill Shrubland (10%) tended to be assigned by experts to Rocky Mountain Gambel Oak-Mixed Montane Shrubland, Inter-Mountain Basins Montane Sagebrush Steppe, Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland. Each of these types tends to occur adjacent to this shrubland type, with greater or lesser degrees of shared floristics.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 4 had over 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Pinus edulis*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in the lower montane areas of the southwest, transitions from ponderosa pine woodlands to pinyon-juniper woodlands occur. In these areas, the tree canopy might be a mix of ponderosa, pinyon, and juniper, along with a variable mixture of deciduous shrubs and grasses. Cover of the trees can vary from 10% to more than 80% . In these cases, the reviewer would encounter plots of mixed composition, and need to determine whether those plots represented *Southern Rocky Mountain Ponderosa Pine Woodland, Southern Rocky Mountain Pinyon-Juniper Woodland, Madrean Pinyon-Juniper Woodland* or *Colorado Plateau Pinyon-Juniper Woodland.*

In cases like this, the determination of which system type to assign to the plot might require:

a) review of the image clip for the context of the plot,

b) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Colorado Plateau from Southern Rocky Mountain systems or from Madrean,
c) consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
d) consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
e) careful consideration of the full floristic composition of the plot and cover for each species.
f) awareness of possible errors in the plot data, such as mis-identification of juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Below are some examples of comments relevant to the above ponderosa pine/pinyon-juniper example:

- Pinus ponderosa is dominant conifer after Juniperus scopulorum which has low diagnostic value.
- Pinus ponderosa is < 10%. Similar to CES305.797 Madrean Pinyon-Juniper Woodland but without Madrean oaks. Juniper deppeana is not a strong indicator of Madrean as it occurs in Southern Rocky Mtns.
- Presense of Madrean element, Juniperus coahuilensis suggestes this is CES305.797 Madrean Pinyon-Juniper Woodland stand, but location on Kaibab Plateau indicates Colorado Plateau Pinyon-Juniper Woodland.
- Juniperus deppeana alone is not enough to label to Madrean woodland system because Juniperus deppeana is also found in the Southern Rocky Mountains.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improve Auto Keys

Of the 97 types assigned to plots by experts, 23 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 74 types, the numbers of samples labeled to a given type ranged from 72 (for Southern Rocky Mountain Ponderosa Pine Woodland) down to 10 (for Rocky Mountain Cliff, Canyon and Massive Bedrock). For 36 (50%) of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots. Several (6) indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Appendix. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 15. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low.

Type Name	Expert Comment
Inter-Mountain Basins Semi-Desert Shrub-Steppe (39% mod conf)	Landform, substrate (sand?) and hydrology information would improve assignment confidence.
Apacherian-Chihuahuan Mesquite Upland Scrub (24% low conf)	There is not enough information to determine if the plot is upland or wash or bosque, with confidence.

Madrean Juniper Savanna (48% mod conf)	Keys to Southern Rocky Mountain Juniper Woodland and Savanna because of lack of Madrean juniper, but understory is characterized by Madrean/desert species, *Rhus microphylla, Prosopis glandulosa, Mimosa aculeaticarpa var. biuncifera, Pleuraphis* spp. etc.
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub (43% mod conf)	Substrate appears to be sand. *Atriplex* can dominate this system.
Sonoran Paloverde-Mixed Cacti Desert Scrub (50% mod conf, 20% low conf)	This plot is codominated *Encelia farinosa* and *Larrea tridentata* but is very diverse with 18 shrubs and cacti.
Colorado Plateau Pinyon-Juniper Shrubland (50% mod conf, 21% low conf)	Plot information is not adequate to label plot with confidences. By location and photo I assume it is a sparse PJ
Chihuahuan Succulent Desert Scrub (20% mod conf, 60% low conf)	*Nolina microcarpa* dominated stands are not well understood.

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. This is perhaps most likely with desert scrub and related vegetation shared with northern Mexico. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Another class of samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives forcused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 329 samples, experts were able to assign all but 35 (89%) to an individual wetland, riparian, or sparsely vegetated ecological system type. A total of 62 individual ecological system types were include among those labeled to samples by experts within this GeoArea. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

GeoArea 5

GeoArea 5 encompasses the northern Great Plains Steppe, Black Hills, Dakota Mixed Grass Prairie, Northern Tall Grass Prairie and Central Tall Grass Prairie ecoregions. This GeoArea includes a total of 9 map zones (20, 29, 30, 31, 38, 39, 40, 42, and 43; **Error! Reference source not found.**) originally clustered into grouping for purposes of designing and implementing auto-keys. The total number of plots in this Geo Area analysis was 1,456. A total of 55 natural ecological system types were assigned to

a total of 1,044 plots by the auto-keys. A total of 66 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 20 types were assigned by the auto-key but were not assigned by experts:

- Boreal Aspen-Birch Forest
- Boreal White Spruce-Fir-Hardwood Forest
- Central Interior Highlands Calcareous Glade and Barrens
- Central Interior Highlands Dry Acidic Glade and Barrens
- Inter-Mountain Basins Semi-Desert Grassland
- Northern Rocky Mountain Foothill Conifer Wooded Steppe
- Northwestern Great Plains Canyon
- Ozark-Ouachita Dry-Mesic Oak Forest
- Western Great Plains Tallgrass Prairie
- Boreal Acidic Peatland Systems
- Central Interior and Appalachian Floodplain Systems
- Central Interior and Appalachian Shrub-Herbaceous Wetland Systems
- Central Interior and Appalachian Swamp Systems
- Eastern Great Plains Floodplain Systems
- Rocky Mountain Alpine/Montane Sparsely Vegetated Systems
- Rocky Mountain Montane Riparian Systems
- Rocky Mountain Subalpine/Upper Montane Riparian Systems
- Western Great Plains Depressional Wetland Systems
- Western Great Plains Floodplain Systems
- Western Great Plains Sparsely Vegetated Systems

The first nine types are uncommon in this GeoArea because it is at the edge of their geographic range, they are uncommon throughout their entire range, or both. The last 11 types are aggregates of individual Systems used by Landfire for mapping. The expert reviewers attributed sites to individual Systems and so would not have used these units in their review process.

Comparison of Auto-key and Expert Assignments

Of the 55 natural types assigned labels by the auto-keys, 27 types (49%) had fewer than 10 samples available for this analysis (Table 4). All but five, Northwestern Great Plains Canyon, Rocky Mountain Foothill Limber Pine-Juniper Woodland, Paleozoic Plateau Bluff and Talus, Central Tallgrass Prairie, and North-Central Interior Oak Savanna, are at the edge of their geographic range in this GeoArea and are more common elsewhere. Most of these are types found more commonly in the Rocky Mountains or inter-mountain basins further west but that also occur in this GeoArea in the isolated mountain ranges and scattered drier habitats of MapZones 20 and 29 (essentially central and southeastern Montana and northeastern Wyoming). Of the five types that are concentrated within this GeoArea but still have <10 plots, four are truly rare across the landscape and the other, Paleozoic Plateau Bluff and Talus, is restricted to a relatively small area on the eastern edge of GeoArea 5 and has some of its occurrences in the adjacent GeoArea 7W.

Table 16. Under-sampled types within GeoArea 5.

EVT Code	EVT Name	System elcode	total Plots

EVT Code	EVT Name	System elcode	total Plots
2308	Crosstimbers Oak Forest and Woodland	CES205.682	9
2125	Inter-Mountain Basins Big Sagebrush Steppe	CES304.778	9
2066	Inter-Mountain Basins Mat Saltbush Shrubland	CES304.783	9
2051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	CES306.823	9
2049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	CES306.955	9
2311	North-Central Interior Dry Oak Forest and Woodland	CES202.047	8
2341	Northwestern Great Plains Canyon	CES303.658	8
2062	Inter-Mountain Basins Curl-leaf Mountain-mahogany Woodland and Shrubland	CES304.772	8
2106	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	CES306.994	7
2150	Western Great Plains Tallgrass Prairie	CES303.673	6
2086	Rocky Mountain Lower Montane-Foothill Shrubland	CES306.822	6
2518	North-Central Interior Wet Flatwoods	CES202.700	5
2401	Central Interior Highlands Calcareous Glade and Barrens	CES202.691	4
2517	Paleozoic Plateau Bluff and Talus	CES202.704	4
2132	Central Mixedgrass Prairie	CES303.659	4
2135	Inter-Mountain Basins Semi-Desert Grassland	CES304.787	4
2117	Southern Rocky Mountain Ponderosa Pine Savanna	CES306.649	4
2140	Northern Rocky Mountain Subalpine-Upper Montane Grassland	CES306.806	4
2363	Central Interior Highlands Dry Acidic Glade and Barrens	CES202.692	3
2421	Central Tallgrass Prairie	CES205.683	3
2009	Northwestern Great Plains Aspen Forest and Parkland	CES303.681	3
2081	Inter-Mountain Basins Mixed Salt Desert Scrub	CES304.784	3
2057	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	CES306.819	3
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	CES306.830	3
2394	North-Central Interior Oak Savanna	CES202.698	2
2147	Western Great Plains Foothill and Piedmont Grassland	CES303.817	2
2365	Boreal White Spruce-Fir-Hardwood Forest	CES103.021	1

A total of 5 types (or 9% of 55 types) had >80% agreement between expert and auto-key assignments. All of these types had >10 sample plots. Expert self-assessment of confidence for these types was predominantly 'moderate' to 'high' although plots assigned to Rocky Mountain Lodgepole Pine Forest had a nearly evenly distributed confidence rating between 'low' to 'high'. This was because lodgepole pine can be a component of several other montane types, particularly in early successional stages, so the abundance of lodgepole pine was not always a clear determinant of the type.

Table 17 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 23, or 41% of the total types assigned. Analysis of the nature of the disagreements between expert and auto-key attribution reveals some of the sources of these disagreements and suggests some methods to help reduce these in the future. The following are some specific examples of levels of disagreement and possible explanations based on interpretations from the contingency table.

Northwestern Great Plains Mixedgrass Prairie – 6 sites (12%) were confused with floristically similar shrub or shrub-steppe types, Inter-Mountain Basins Big Sagebrush Shrubland or Inter-Mountain Basins Big Sagebrush Steppe. These types can grade into each other with the cover of shrubs determining which type fits best. Careful determination of shrub cover is important for consistent assignment of sites among these types.

Middle Rocky Mountain Montane Douglas-fir Forest and Woodland – This type was confused with three others with Inter-Mountain Basins Big Sagebrush Steppe being the most common (13% of the time). This is likely due to different interpretations of whether there was enough tree cover to fit the sites into a forest/woodland type versus a shrub type.

North-Central Interior Dry-Mesic Oak Forest and Woodland – This type was confused with two other upland forests, North-Central Interior Maple-Basswood Forest (8%) and North-Central Interior Dry Oak Forest and Woodland (2%), and two savanna/open woodland types, Eastern Great Plains Tallgrass Aspen Parkland (2%) and North-Central Interior Oak Savanna (2%).

North-Central Interior Maple-Basswood Forest – Seven plots (14%) percent of the sites auto-keyed to this type were assigned to the "Can't assign" by the expert reviewer indicating not enough data to assign the type or that the site did not fit any natural type. The auto-key may have been too aggressive in assigning sites based on limited data and may have included non-natural sites.

Western Great Plains Dry Bur Oak Forest and Woodland – This type was confused with Western Great Plains Wooded Draw and Ravine most commonly. These two types often occur in similar environmental settings in the Great Plains. Dominance by bur oak is a good characteristic for this type but where there is a mix of species such as American basswood, green ash, bur oak, and elm then classification is difficult.

Eastern Great Plains Tallgrass Aspen Parkland – This type was not confused with any other natural type but 24% of the sites were not assigned by the expert reviewer. The dominant tree species in this type – quaking aspen – is also a common early successional species in old fields, logged, or burned areas so the dominance of just that species is not enough to assign a site to this type. Ground layer data and aerial photos are helpful in distinguishing disturbed sites from natural sites that fit this type.

Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland – Nearly all the disagreements between this type and others was in the assignment of sites auto-keyed to this type into the Rocky Mountain Lodgepole Pine Forest. Thirty-eight percent of the auto-keyed plots were assigned by the expert to the Rocky Mountain Lodgepole Pine Forest. Lodgepole pine can be a strong component of early successional stages of this Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland. In this case, sites with some subalpine fir and/or Englemann spruce were assigned to this type even if lodgepole pine was dominant but the auto-key placed those plots in the Rocky Mountain Lodgepole Pine Forest.

Inter-Mountain Basins Big Sagebrush Shrubland – Every site auto-keyed to this type and expert-assigned to another was to the Inter-Mountain Basins Big Sagebrush Steppe. The primary difference between these two is the cover of shrubs. A difference in interpretation of this cover resulted in this discrepancy in this case.

Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest – This type was confused primarily with two other conifer forests in the area. This type is typically dominated by Ponderosa pine, Douglas fir, or a mix of the two. It was confused with the more pure ponderosa pine type of the lower elevations (Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna) and the more pure Douglas fir type also found nearby at low elevations (Middle Rocky Mountain Montane Douglas-fir Forest and Woodland). The interface of these types is poorly differentiated unless prairie understory is present.

Inter-Mountain Basins Montane Sagebrush Steppe – This type was confused almost entirely (54%) with the Inter-Mountain Basins Big Sagebrush Steppe. Careful identification of the sub-species of *Artemisia tridentata* is important to differentiate these types. In some cases, the auto-key would have been keying on other floristic components (others shrubs, or the bunch grasses) suggestive of the more montane system, but the expert might have keyed based more on elevation.

Northwestern Great Plains Shrubland – This type was confused with Northwestern Great Plains Mixedgrass Prairie most often (25%). Since the associated species and geographic ranges overlap extensively, this confusion is based on different interpretations of the cover of shrubs. If a site has >25% shrub cover it will fit this type best but <25% shrub cover it will likely fit the mixedgrass prairie type best.

Western Great Plains Sandhill Steppe – This type was confused with four floristically related grassland types – Central Mixedgrass Prairie, Northwestern Great Plains Mixedgrass Prairie, Western Great Plains Sand Prairie, and Western Great Plains Shortgrass Prairie. These disagreements in assignments were due to differences in interpretation of the cover of shrubs. The auto-key calculated a higher cover for these sites and placed them in a shrubland type whereas the expert reviewer thought they fit a grassland type.

Western Great Plains Sand Prairie – Most of the disagreements (38%) with assignments of sites auto-keyed to this type were with assignments made by the expert reviewer to the Northwestern Great Plains Mixedgrass Prairie. Some of the species common to the Western Great Plains Sand Prairie can increase under grazing of the Northwestern Great Plains Mixedgrass Prairie. The expert reviewer judged some of these sites to fit the Northewestern Great Plains Mixedgrass Prairie best even though they had a relatively high cover of junegrass, *Sporobolus* spp., etc.

Western Great Plains Wooded Draw and Ravine – This type was confused with multiple other natural types and 6 plots (12%) were expert labeled with “Can’t assign” categories indicating not enough data to assign the type or that the site did not fit any natural type. The auto-key may have been too aggressive in assigning sites based on limited data and may have included non-natural sites.

Boreal Aspen-Birch Forest – This type was not assigned by the expert reviewer to any sites. It is not supposed to occur in GeoArea 5 and should be removed with a better geographic delineation of its distribution in the auto-key. All sites auto-keyed to this type were assigned by the expert reviewer to the Eastern Great Plains Tallgrass Aspen Parkland.

Table 17. Summary of types with adequate samples where agreement between auto-key and expert was below 80%.

	Plots with Expert Matches

EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2141	Northwestern Great Plains Mixedgrass Prairie	CES303.674	50	37	74%	15	13	9
2166	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	CES306.959	23	17	74%	6	9	2
2310	North-Central Interior Dry-Mesic Oak Forest and Woodland	CES202.046	50	36	72%	13	19	4
2314	North-Central Interior Maple-Basswood Forest	CES202.696	50	31	62%	22	6	3
2013	Western Great Plains Dry Bur Oak Forest and Woodland	CES303.667	39	23	59%	9	11	3
2331	Eastern Great Plains Tallgrass Aspen Parkland	CES205.688	23	13	57%	1	6	6
2055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	CES306.828	50	28	56%	10	13	5
2080	Inter-Mountain Basins Big Sagebrush Shrubland	CES304.777	46	25	54%	14	10	1
2045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	CES306.805	50	27	54%	15	7	5
2126	Inter-Mountain Basins Montane Sagebrush Steppe	CES304.785	50	20	40%	10	6	4
2085	Northwestern Great Plains Shrubland	CES303.662	28	10	36%	6	3	1
2094	Western Great Plains Sandhill Steppe	CES303.671	15	5	33%	1	4	0
2148	Western Great Plains Sand Prairie	CES303.670	49	16	33%	10	3	3
2153	Inter-Mountain Basins Greasewood Flat	CES304.780	28	8	29%	1	4	3
2385	Western Great Plains Wooded Draw and Ravine	CES303.680	50	12	24%	6	5	1
2054	Southern Rocky Mountain Ponderosa Pine Woodland	CES306.648	50	10	20%	4	5	1
2139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	CES306.040	23	4	17%	1	3	0
2167	Rocky Mountain Poor-Site Lodgepole Pine Forest	CES306.960	10	1	10%	0	1	0

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2145	Rocky Mountain Subalpine-Montane Mesic Meadow	CES306.829	13	1	8%	0	1	0
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	CES304.776	14	1	7%	0	1	0
2301	Boreal Aspen-Birch Forest	CES103.020	19	0	0%	0	0	0
2165	Northern Rocky Mountain Foothill Conifer Wooded Steppe	CES306.958	13	0	0%	0	0	0
2304	Ozark-Ouachita Dry-Mesic Oak Forest	CES202.708	11	0	0%	0	0	0

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 5 had almost 1,500 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Pinus edulis*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in the lower montane areas of central Montana, forests dominated by ponderosa pine, Douglas fir, or a combination can occur. The reviewer would need to determine if those plots represented Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna, Northern Rocky Mountain Ponderosa Pine Woodland and Savanna, Middle Rocky Mountain Montane Douglas-fir Forest and Woodland, or Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest.

In cases like this, the determination of which system type to assign to the plot might require:

g) review of the image clip for the context of the plot,
h) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), may help distinguish the Great Plains-Black Hills type from the Rocky Mountain types,
i) consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
j) consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
k) careful consideration of the full floristic composition of the plot and cover for each species.
l) awareness of possible errors in the plot data, such as misidentification of juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs. an aerial view of the plot).

Below are some examples of comments relevant to the above example:

- Tree cover almost too low for a treed System but photo and Source data appear to show enough tree cover so site not a grassland.
- Little P. ponderosa but this site is too low and within a Great Plains grassland landscape so it can't be Rocky Mountain Foothills Limber Pine-Juniper System.
- There are several dry-mesic forest Systems with mixed conifer canopies possible in this area but this seems the best fit.
- Probably enough Pseudotsuga menziesii to fit this System better than the Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer System.
- Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest can also be dominated by P. menziesii but since there is little besides that species in the canopy it seems to fit the assigned System best.
- Moderately low cover of Pseudotsuga and high cover of Juniperus but still seems to fit this System fairly well. Dry site.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 66 types assigned to plots by experts, 35 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 31 types, the numbers of samples labeled to a given type ranged from 138 (Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna) down to 10 (Southern Rocky Mountain Ponderosa Pine Woodland). For all (100%) of these types, experts reported moderate or high confidence in their labels for at least 20% of the type's plots. 15 types indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Appendix. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 18. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low.

Type Name	Expert Comment

Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	Little P. ponderosa but this site is too low and within a Great Plains
Northwestern Great Plains Mixedgrass Prairie	Lots of exotic cover but the few native grasses indicate this System.
North-Central Interior Floodplain	Floristics and photo look like a floodplain but very little floristic data to go by.
Inter-Mountain Basins Big Sagebrush Steppe	Borderline herbaceous cover for this System but fits here best.
Rocky Mountain Lodgepole Pine Forest	Low cover in all three strata but fits a treed System best.
North-Central Interior Dry-Mesic Oak Forest and Woodland	Quercus ellipsoidalis seems odd in this mix but, if present, pushes this to an upland System.

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. In this GeoArea, this is particularly true in the transition from lower montane/foothill types to Great Plains types. As currently defined there is no clear differentiation between these types. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were those labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 279 samples, experts were able to assign 237 (85%) to an individual ecological system type; a total of 32 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another class of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Grassland" or "None". Of 133 samples, experts were able to assign 94 (71%) to an individual ecological system type; a total of 25 individual ecological system types were assigned to these samples.

GeoArea 6

GeoArea 6 encompasses the Great Plains Tablelands, Southeastern Great Plains, Western Great Plains, Southern Great Plains, Edwards Plateau and Western Gulf Plains (**Error! Reference source not found.**). This GeoArea includes a total of 6 map zones (27, 32, 33, 34, 35, and 36), originally clustered for purposes of designing and implementing auto-keys (**Error! Reference source not found.**). The total number of plots in this Geo Area analysis was 1,295. A total of 52 natural ecological system types were

assigned to a total of 930 plots by the auto-keys. A total of 54 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types). Other "additional" systems are characteristic of peripheral areas such as Chihuahuan Desert, which is transitional to the Southern Plains and high Rocky Mountain forest systems which may occur on isolated mountains on the western edge of the GeoArea. These systems were added to the sequence tables because of the potential inclusion of plots from these areas.

An additional 22 types were assigned by the auto-key but were not assigned by experts:

- Chihuahuan Loamy Plains Desert Grassland
- Chihuahuan Sandy Plains Semi-Desert Grassland
- Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
- Inter-Mountain Basins Montane Sagebrush Steppe
- Madrean Pinyon-Juniper Woodland
- Northwestern Great Plains Canyon
- Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna
- Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland
- Rocky Mountain Foothill Limber Pine-Juniper Woodland
- Rocky Mountain Lodgepole Pine Forest
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
- West Gulf Coastal Plain Pine-Hardwood Forest
- Central Interior and Appalachian Floodplain Systems
- Central Interior and Appalachian Riparian Systems
- Gulf and Atlantic Coastal Plain Floodplain Systems
- Gulf and Atlantic Coastal Plain Small Stream Riparian Systems
- Inter-Mountain Basins Sparsely Vegetated Systems
- Rocky Mountain Montane Riparian Systems
- Western Great Plains Depressional Wetland Systems
- Western Great Plains Floodplain Systems
- Western Great Plains Sparsely Vegetated Systems

Comparison of Auto-key and Expert Assignments

Of the 52 natural types assigned labels by the auto-keys, 23 types (44%) had fewer than 10 samples available for this analysis (Table 4). These under-sampled types tended to include types that are found on the geographic periphery of their range within this GeoArea (e.g., Chihuahuan Loamy Plains Desert Grassland, Chihuahuan Mixed Desert and Thornscrub, Chihuahuan Sandy Plains Semi-Desert Grassland, Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub, Madrean Encinal, Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna), or with the inclusion of atypical environments such as a mountain range in a primarily grassland mapzone. These systems include Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland, Southern Rocky Mountain Montane-Subalpine Grassland, and Inter-Mountain Basins Montane Sagebrush Steppe. Other undersampled systems are generally within this range, but are less common types, or simply have had inadequate sampling effort across this region. These include Central and South Texas Coastal Fringe Forest and Woodland, Edwards Plateau Mesic Canyon, Llano Uplift Acidic Forest-Woodland-Glade, Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland, Southeastern Great Plains Tallgrass Prairie, and West Gulf Coastal Plain Pine-Hardwood Forest.

Table 19. Under-sampled types within GeoArea 6

EVT Code	EVT Name	System elcode	total Plots
2503	Chihuahuan Loamy Plains Desert Grassland	CES302.061	9
2051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	CES306.823	8
2504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	CES302.746	7
2410	Llano Uplift Acidic Forest-Woodland-Glade	CES303.657	7
2064	Colorado Plateau Mixed Low Sagebrush Shrubland	CES304.762	7
2371	West Gulf Coastal Plain Pine-Hardwood Forest	CES203.378	5
2117	Southern Rocky Mountain Ponderosa Pine Savanna	CES306.649	5
2179	Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	CES303.650	4
2341	Northwestern Great Plains Canyon	CES303.658	4
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	CES304.776	4
2338	Central and South Texas Coastal Fringe Forest and Woodland	CES203.464	3
2423	Southeastern Great Plains Tallgrass Prairie	CES205.685	3
2390	Tamaulipan Mixed Deciduous Thornscrub	CES301.983	3
2100	Chihuahuan Mixed Desert and Thornscrub	CES302.734	3
2133	Chihuahuan Sandy Plains Semi-Desert Grassland	CES302.736	3
2150	Western Great Plains Tallgrass Prairie	CES303.673	3
2050	Rocky Mountain Lodgepole Pine Forest	CES306.820	2
2052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	CES306.825	2
2367	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	CES202.313	1
2122	Chihuahuan Gypsophilous Grassland and Steppe	CES302.732	1
2076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	CES302.737	1
2524	Edwards Plateau Mesic Canyon	CES303.038	1
2148	Western Great Plains Sand Prairie	CES303.670	1
2153	Inter-Mountain Basins Greasewood Flat	CES304.780	1
2126	Inter-Mountain Basins Montane Sagebrush Steppe	CES304.785	1
2023	Madrean Encinal	CES305.795	1
2057	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	CES306.819	1
2146	Southern Rocky Mountain Montane-Subalpine Grassland	CES306.824	1
2049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	CES306.955	1

A total of 4 types (or nearly 8% of 52 types) had >80% agreement between expert and auto-key assignments. All of these types (Western Great Plains Sandhill Steppe, Southern Rocky Mountain Juniper Woodland and Savanna, Southern Rocky Mountain Ponderosa Pine Woodland, and Western Great Plains Shortgrass Prairie) had at least 20 sample plots. Expert self-assessment of confidence for these types were predominantly 'high' although Southern Rocky Mountain Juniper Woodland and

Savanna had nearly equal 'high' and 'moderate' attributions. This is largely because of transitional confusion between a tree savanna site and a grassland plot with scattered trees.

Table 20 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 35, or nearly 47% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. For example, some plots assigned by the auto-key to Edwards Plateau Dry-Mesic Slope Forest and Woodland were most frequently confused with Edwards Plateau Limestone Savanna and Woodland because differences in classification depend on dominance patterns within a group of shared species, some of which occur in the ground flora which tended to be poorly sampled in the available plot data. These types do transition into one another, so additional floristic indicators might be identified to better distinguish them. This same general pattern, one of carefully reviewing the dominant tree, shrub, or grass elements shared among related types, should be the focus of auto-key improvements for these types.

Table 20. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2519	East-Central Texas Plains Post Oak Savanna and Woodland	CES205.679	50	37	74%	2	21	14
2308	Crosstimbers Oak Forest and Woodland	CES205.682	50	36	72%	5	15	16
2132	Central Mixedgrass Prairie	CES303.659	50	36	72%	8	25	3
2107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	CES306.818	14	10	71%	10	0	0
2383	Edwards Plateau Limestone Savanna and Woodland	CES303.660	50	34	68%	1	15	18
2095	Apacherian-Chihuahuan Mesquite Upland Scrub	CES302.733	45	29	64%	0	29	0
2081	Inter-Mountain Basins Mixed Salt Desert Scrub	CES304.784	15	9	60%	9	0	0
2523	Edwards Plateau Dry-Mesic Slope Forest and Woodland	CES303.656	50	29	58%	4	20	5
2059	Southern Rocky Mountain Pinyon-Juniper Woodland	CES306.835	50	26	52%	24	2	0
2393	Edwards Plateau Limestone Shrubland	CES303.041	12	2	17%	2	0	0
2111	Western Great Plains Mesquite Woodland and Shrubland	CES303.668	50	7	14%	2	5	0

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2086	Rocky Mountain Lower Montane-Foothill Shrubland	CES306.822	20	2	10%	2	0	0
2121	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	CES302.735	21	2	10%	0	2	0
2391	Tamaulipan Mesquite Upland Scrub	CES301.984	50	4	8%	0	0	4
2525	Edwards Plateau Riparian	CES303.652	25	2	8%	0	0	2
2147	Western Great Plains Foothill and Piedmont Grassland	CES303.817	26	1	4%	1	0	0
2127	Inter-Mountain Basins Semi-Desert Shrub-Steppe	CES304.788	27	1	4%	0	0	1
2025	Madrean Pinyon-Juniper Woodland	CES305.797	50	0	0%	0	0	0
2055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	CES306.828	17	0	0%	0	0	0

Analysis of the contingency table (Results Workbook) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. Here we summarize results for selected systems in GeoArea 6:

East-Central Texas Plains Post Oak Savanna and Woodland – low confidence in plot assignment was generally related to the low species diversity represented in the plot data.

Crosstimbers Oak Forest and Woodland – low confidence in plot assignment was generally related to the low species diversity represented in the plot data. In addition, the species recorded or the photo indicated a disturbed condition. In one case, the species identification was questioned.

Central Mixedgrass Prairie – was most often confused with Western Great Plains Shortgrass Prairie and Western Great Plains Foothill and Piedmont Grassland. There are several shared species between these systems and past grazing practices can influence composition and abundance of key species. For example, long-term heavy livestock grazing of Central Mixedgrass Prairie can reduce or eliminate indicator mid-grasses, leaving the site strongly dominated by grazing tolerant shortgrasses such as *Bouteloua gracilis*, which is characteristic of Western Great Plains Shortgrass Prairie. Western Great Plains Foothill and Piedmont Grassland is also characterized by mid-grasses, but these systems are typically geographically separate from each other (Central Plains versus Western Great Plains near the foothills). Clarifying geographic distribution may help with this one. Also, a better understanding of successional patterns under grazing pressure, and more complete species compositional data in the plots would help distinguish these types.

Rocky Mountain Gambel Oak-Mixed Montane Shrubland – was most often confused with Western Great Plains Sandhill Steppe, so identification of oak species may be an issue.

Edwards Plateau Limestone Savanna and Woodland – was most often confused with systems with which it interfingers. More complete species compositional data in the plots (more thorough data collection in the field) would help distinguish these types.

Apacherian-Chihuahuan Mesquite Upland Scrub – was mostly confused with Western Great Plains Mesquite Woodland and Shrubland. Both systems are dominated by *Prosopis glandulosa*, and transition into one another as the Chihuahuan Desert grades into the Southern Great Plains. Refining geographic distribution of the auto-key and more complete species compositional data in the plots with Chihuahuan Desert indicator species would help distinguish these two types. An additional complexity is that mesquite, while a native species, is invasive in some over-grazed upland areas, making it difficuylt to distinguish if a plot is a degraded example of a grassland system, or represents a more "natural" mesquite upland area.

Inter-Mountain Basins Mixed Salt Desert Scrub – was not consistently confused with any particular system. The *Atriplex* spp. that are characteristic of this systems also occur in other systems so more complete species compositional data in the plots would help distinguish these types (look for saline bottomland indicator species).

Edwards Plateau Dry-Mesic Slope Forest and Woodland – was most often confused with systems with which it interfingers. More complete species compositional data in the plots (more thorough data collection in the field) would help distinguish these types. In several cases, the identification of recorded species was questioned.

Southern Rocky Mountain Pinyon-Juniper Woodland – was frequently confused with the similar Southern Rocky Mountain Juniper Woodland and Savanna. Auto-key criteria and mis-labeled plots need to be reviewed to figure out how to better distinguish. The image clips were critical during expert review to determine if the plot is a juniper savanna or a more open area within a juniper woodland. This contextual information for the plot is vital and hard to replicate in the auto-key. Additionally, More complete species compositional data in the plots (more thorough data collection in the field) would help distinguish these types, as high cover of grasses is important for the savanna systems.

Tamaulipan Mesquite Upland Scrub – a large number of these plots (44) were not assigned because in many cases the only species listed was *Prosopis glandulosa*. Since this species is often an off-site invader, it was difficult to assign these plots to a system.

Western Great Plains Mesquite Woodland and Shrubland – a large number of these plots (31) were not assigned because in many cases the only species listed was *Prosopis glandulosa*. Since this species is often an off-site invader, and can dominate multiple systems, it was difficult to assign these plots to a system.

Rocky Mountain Lower Montane-Foothill Shrubland – was most often confused with Western Great Plains Shortgrass Prairie and Western Great Plains Foothill and Piedmont Grassland.
This system is often adjacent to these other systems and shareS many herbaceous species. Both of these grassland types may have some shrubs present so confusion may relate to amount of shrub cover needed to label to a shrubland system.

Western Great Plains Foothill and Piedmont Grassland – was most often confused with Central Mixedgrass Prairie and Western Great Plains Shortgrass Prairie. Central Mixedgrass Prairie is also characterized by mid-grasses, but systems are typically geographically separate from each other (Central Plain versus Western Great Plains near the foothills). This system often transitions at lower elevations to Western Great Plains Shortgrass Prairie, and is differentiated by the abundance of midgrasses. There are several shared species between these systems and past grazing practices can influence specie composition and reduce the abundance of key midgrass species. Clarifying geographic distribution may help distinguish from Central Mixedgrass Prairie. More complete species compositional data in the plots (more thorough data collection in the field) would help distinguish these types.

Inter-Mountain Basins Semi-Desert Shrub-Steppe – was most often confused with Western Great Plains Shortgrass Prairie. Review of sequence table to clarify that Western Great Plains Shortgrass Prairie may have also an open short shrub component composed of species of *Ericameria, Eriogonum*, *Gutierrezia Krascheninnikovia, Lycium,* or *Opuntia*, especially on disturbed sites.

Madrean Pinyon-Juniper Woodland – was most often confused with Southern Rocky Mountain Juniper Woodland and Savanna and Southern Rocky Mountain Pinyon-Juniper Woodland. Madrean Pinyon-Juniper Woodland is uncommon in this GeoArea other than transition areas with Chihuahuan Desert. Refined geographic distribution information and more complete species compositional data in the plots (more thorough data collection in the field) would help distinguish these types.

Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland – although these plots were codominated by *Picea engelmannii*, elevation was much too low. According to photos, some plots could be mesic or riparian so the spruce might be mis-identified *Picea pungens*, or the acronym PIEN could also be a typo for *Pinus engelmannii*, a Madrean species.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 6 had over 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by graminoides, then sort alphabetically by the dominant and codominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Quercus stellata*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the

descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics. For example, in the transition zone between the southwestern portion of this GeoArea and the Chihuahuan Desert, labeling of grassland plots to a desert grassland system or a Great Plains grassland system requires an understanding of diagnostic species, floristic composition and geographic distribution of the systems in question. Complete species list is necessary to confidently distinguish these types.

In cases like this, the determination of which system type to assign to the plot might require:

m) review of the image clip for the context of the plot
n) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Western Great Plains from Central Great Plains or Chihuahuan Desert from Edwards Plateau,
o) consideration of topographic setting (e.g. north-facing slopes at lower elevations could support ponderosa pine woodlands),
p) consideration of any available height data for the plot (e.g. were the ponderosa pines all tall, apparently mature trees; or were they short),
q) careful consideration of the full floristic composition of the plot and cover for each species.
r) awareness of possible errors in the plot data, such as mis-identification of oak or juniper species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Below are some examples of comments relevant to the above:

- This plot appears to be a small patch of Junipers in opening surrounded by PJ woodland. It is possible that it is a disturbed CES303.817 Western Great Plains Foothill and Piedmont Grassland or CES306.822 Rocky Mountain Lower Montane-Foothill Shrubland. The image clip is critical to determine tree savanna from open woodland
- Plot species list is incomplete. Plot photo shows *Artemisia filifolia* in foreground and *Aristida* sp. indicate similarities to CES303.671 Western Great Plains Sandhill Steppe
- Incomplete species list, Jumiper cover in photo is very low<5% not 10% so not savanna.
- Substrate information would improve assignment confidence.
- Significant cover of suffrutescent /dwarf-shrubs such as *Gutierrezia sarothrae*, *Krascheninnikovia lanata, Yucca glauca* and *Artemisia frigida* is included in concept of shortgrass steppe/prairie.
- This diverse plot is more similar to CES302.735 Apacherian-Chihuahuan Semi-Desert Grassland and Steppe than Western Great Plains Shortgrass Prairie. The desert grasslands extends up north into the Pecos Valley and then transitions to the CES303.672 Western Great Plains Shortgrass Prairie in the plains.
- Scattered PJ trees near bottom of canyon as indicated by relatively mesic *Juniperus scopulorum*. No other species reported so likely bare rock dominates ground surface. Could also be assigned to the Southwestern Canyons.
- Landform and hydrology information would improve confidence in assignment.
- If plot in far southern part of subsection MZ 27, then it could be desert scrub such as Apacherian-Chihuahuan Mesquite Upland Scrub or Western Great Plains Mesquite Woodland and Shrubland.
- Plot photo shows plot is in a transition zone between CES306.834 Southern Rocky Mountain Juniper Woodland and Savanna and CES306.822 Rocky Mountain Lower Montane-Foothill Shrubland with widely scattered juniper trees (5%) in a very dense *Cercocarpus montanus* shrubland.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 54 types assigned to plots by experts, 31 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 23 types, the numbers of samples labeled to a given type ranged from 114 (for Western Great Plains Shortgrass Prairie) down to 10 (for Inter-Mountain Basins Mixed Salt Desert Scrub). For 27 (50%) of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots and 11 indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 21. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Edwards Plateau Limestone Savanna and Woodland	Could also be CES303.651 Edwards Plateau Floodplain
Southeastern Great Plains Riparian Forest	Vegetation supports this assignment, but photo does not indicate a creek
Crosstimbers Oak Forest and Woodland	Seems disturbed with a depauperate species list
Southeastern Great Plains Floodplain Forest	Could also be Southeastern Great Plains Riparian Forest
Llano Uplift Acidic Forest, Woodland and Glade	Limited species information makes attribution difficult
Ozark-Ouachita Dry-Mesic Oak Forest	CES202.707 Ozark-Ouachita Dry Oak Woodland might be a better choice
Llano Estacado Caprock Escarpment and Breaks Shrubland and Steppe	Questionable species id

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. This is perhaps most likely with desert scrub and related vegetation shared with northern Mexico. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That

meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 228 samples, experts were able to assign 159 (70%) to an individual ecological system type; a total of 17 individual ecological system types were assigned to these samples. The ability to assign plots to wetland and riparian systems would be expected to increase if more information on landform, soil, and or landscape context could be provided, as suggested above.

The riparian systems groups are labeled to individual system with greater accuracy than the sparsely vegetated system groups in this GeoArea. Sparsely vegetated systems have low vegetation cover, variable species composition, and are often defined more based on substrate (e.g., sand dunes, rock outcrop) which is not currently used in the auto-key. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Shrubland" or "None". Of 137 samples, experts were able to assign 70 (51%) to an individual ecological system type; a total of 20 individual ecological system types were assigned to these samples.

GeoArea 7E

GeoArea 7E encompasses the southern, central and northern Appalachian, Blue Ridge, Piedmont, High Allegheny Plateau ecoregions. This GeoArea includes a total of 9 map zones (54, 57, 59, 60, 61, 63, 64, 65, 66; **Error! Reference source not found.**) originally clustered for purposes of designing and implementing auto-keys. The total number of plots in this Geo Area analysis was 1,713. A total of 35 natural ecological system types were assigned to a total of 1,233 plots by the auto-keys. A total of 71 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated or wetland/riparian types).

An additional 17 types were assigned by the auto-key but were not assigned by experts, including 3 standard systems:

- Acadian-Appalachian Subalpine Woodland and Heath-Krummholz
- Central Appalachian Alkaline Glade and Woodland
- Eastern Serpentine Woodland

and 14 broader groups of systems ("aggregates"):

- Boreal Acidic Peatland Systems
- Central Interior and Appalachian Floodplain Systems
- Central Interior and Appalachian Riparian Systems
- Central Interior and Appalachian Sparsely Vegetated Systems
- Central Interior and Appalachian Swamp Systems
- Gulf and Atlantic Coastal Plain Floodplain Systems
- Gulf and Atlantic Coastal Plain Small Stream Riparian Systems
- Gulf and Atlantic Coastal Plain Sparsely Vegetated Systems
- Gulf and Atlantic Coastal Plain Swamp Systems
- Gulf and Atlantic Coastal Plain Tidal Marsh Systems
- Laurentian-Acadian Floodplain Systems

- Laurentian-Acadian Shrub-Herbaceous Wetland Systems
- Laurentian-Acadian Sparsely Vegetated Systems
- Laurentian-Acadian Swamp Systems

Comparison of Auto-key and Expert Assignments

Of the 35 natural types assigned labels by the auto-keys, 9 types (26%) had fewer than 10 samples available for this analysis (Table 4). Seven of these undersampled types are relatively uncommon and occur naturally in small patches rarely exceeding a few hundred acres in extent: Central Appalachian Alkaline Glade and Woodland [n=8]; Southern Appalachian Grass and Shrub Bald [n=6]; Northern Atlantic Coastal Plain Maritime Forest [n=6]; Northern Atlantic Coastal Plain Dune and Swale [n=4]; Eastern Serpentine Woodland [n=2]; Acadian-Appalachian Subalpine Woodland and Heath-Krummholz [n=1]; and Northeastern Interior Pine Barrens [n=1]. The remaining two types are at the edge of their range in this GeoArea: Southern Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest [n=7], and Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest [n=5]. These under-sampled types were excluded from further analysis.

Table 22. Under-sampled types within GeoArea 7E

EVT Code	EVT Name	System elcode	total Plots
2400	Central Appalachian Alkaline Glade and Woodland	CES202.602	8
2501	Southern Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest	CES203.304	7
2414	Southern Appalachian Grass and Shrub Bald	CES202.294	6
2379	Northern Atlantic Coastal Plain Maritime Forest	CES203.302	6
2335	Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	CES203.241	5
2436	Northern Atlantic Coastal Plain Dune and Swale	CES203.264	4
2375	Eastern Serpentine Woodland	CES202.347	2
2389	Acadian-Appalachian Subalpine Woodland and Heath-Krummholz	CES201.568	1
2354	Northeastern Interior Pine Barrens	CES202.590	1

A total of 2 types having more than 20 sample plots (or nearly 6% of 35 types) had >80% agreement between expert and auto-key assignments. These types were Southeastern Interior Longleaf Pine Woodland [n=24; 88% agreement between expert and auto-key assignment] and Northern Atlantic Coastal Plain Pitch Pine Barrens [n=49; 84% agreement]. Self-assessments of confidence for these types were predominantly 'high' or 'moderate'.

Table 23 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 24, or nearly 69% of the total types assigned. Analysis of the contingency table (Results Workbook) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. It appears, however, that the greatest percentage of errors occurred among floristically similar groups in areas of geographic transition. In only XXX systems were there no apparent floristic similarity between the assignments when they did not agree. Here we summarize a cross-section of results from GeoArea 7.

There was 72% (36 of 50 plots) where the expert assignment and the auto-key matched for the Southern Appalachian Oak Forest. The experts had high confidence in their assignments for 82% of the plots, and indicated that they used oaks species composition and elevation to label their plots. Of the 14 mis-matches, 6 had been labeled as Southern Appalachian Cove Forest, 3 as Southern Appalachian Low Elevation Pine, and 2 as Allegheny-Cumberland Dry Oak Forest and Woodland.

Agreement in the Southern Piedmont Dry Oak Forest was 69% (35 of 50 plots). The experts were highly confident in their assignment for 80% of the plots and identified species composition as a major indicator of the system. Experts labeled 4 of the 15 mismatched plots as Southern Piedmont Mesic Forest, 4 plots as Southern Appalachian Oak Forest and 2 plots as Southern Appalachian Low Elevation Pine Forest. The experts were likely to be incorporating specific species in calling mesic forest and on the ecoregional and elevation information on labeling the Southern Appalachian types.

Those systems primarily characterized by dry-site oaks were confused with each other. Significant numbers of plots assigned by the auto-key to Central Appalachian Dry Oak-Pine Forest were assigned to either Allegheny-Cumberland Dry Oak Forest and Woodland (n=22]; Northeastern Interior Dry-Mesic Oak Forest [n=24]; or Central Appalachian Pine-Oak Rocky Woodland [n=21] by expert attribution. Only 5% of plots assigned by experts were not either high or medium confidence. All three forested types are characterized by widespread oak species such as white oak (*Quercus alba*) or chestnut oak (*Quercus prinus)*, but have different geographic ranges. Central Appalachian Pine -Oak Rocky Woodland shares many of the same characteristic tree species but has an open canopy and a steeper environmental setting. Reviewer comments indicated that in some cases, assignment could be equally applied to two floristically related systems, and that sufficient species information for high confidence was lacking. Experts used subsection of occurrence to discriminate in geographic transition areas, and where the subsection spanned two related types, confidence in assignment was lower.

Floristically related spruce-fir and northern hardwood systems of the central and southern Appalachians were also confused with each other. For example, a number of Central and Southern Appalachian Spruce-Fir Forest plots were erroneously identified as Southern Appalachian Northern Hardwood Forest or Appalachian (Hemlock)-Northern Hardwood Forest by the auto-key. A significant number of plots [n=27] auto-keyed to South-Central Interior Mesophytic Forest were assigned to Appalachian (Hemlock)-Northern Hardwood Forest by experts. This is likely because both systems share characteristic species such as sugar maple (*Acer saccharum)*, beech (*Fagus grandifolia),*and hemlock (*Tsuga canadensis).* Expert confidence in attributions to Appalachian (Hemlock)-Northern Hardwood Forest indicates a higher degree of uncertainty.

A similar pattern was noted in northern analogs of spruce-fir and northern hardwood systems: a number of plots keyed as Acadian Low-Elevation Spruce-Fir-Hardwood Forest were assigned to Acadian-Appalachian Montane Spruce-Fir Forest by experts. Discrepancies were also noted between low-elevation and montane spruce-fir systems; 9 plots assigned by auto-key to Acadian-Appalachian Montane Spruce-Fir Forest were attributed to Acadian Low-Elevation Spruce-Fir-Hardwood Forest by experts. It's possible these disagreements have to do with the elevation rules used in the auto-keys within the GeoArea versus a more local-scale elevation break that the expert reviewer may have used (perhaps even adjusting for latitude).

Discrepancies between auto-key and expert attribution were also common in coastal plain hardwood systems. The auto-key and experts agreed on the assignment of 19 plots to the Northern Atlantic Coastal Plain Hardwood Forest, but experts attributed an additional 31 plots to this type that had been

auto-keyed to Southern Atlantic Coastal Plain Mesic Hardwood Forest. These two systems are described as overlapping in the coastal plain with GeoArea7E. It is likely the experts relied heavily on biogeography in addition to species composition, while the 2 sequence tables drafted for this GeoArea relied more on species composition. It's possible that the expert assigning the plots had a different understanding of the ranges of the two types than had been initially incorporated in the sequence table.

North-Central Interior Wet Flatwoods showed 27% agreement (4 of the 15 plots). This system has little floristic similarity to other systems, so errors were caused by other factors. A high proportion of the total number of plots (9 out of 15) could not be assigned due to lack of information; experts had medium confidence in most of the plots assigned, but confidence was not high in any of the assignments. Three of the plots that could not be assigned had attributed by the auto-key to an aggregated wetland system (Central Interior and Appalachian Swamp Systems, Laurentian-Acadian Floodplain Systems, and Gulf and Atlantic Coastal Plain Swamp Systems). Two of the plots that had been assigned to a single system had been assigned by experts to two different upland types. With so few plots finding patterns in the disagreement is a challenge and each of the plots should be explored to help identify potential refinements in characterizing this small patch partially isolated wetland system.

Southern Ridge and Valley / Cumberland Dry Calcareous Forest showed little agreement (14%) with 30 of the 37 plots being assigned by experts to five different systems (South Central Interior Mesophytic Forest (5 plots), Appalachian (Hemlock)-Northern Hardwood Forest (1 plot), Allegheny-Cumberland Dry Oak Forest and Woodland (7 plots), Central Appalachian Dry Oak-Pine Forest (3 plots), Northeastern Interior Dry-Mesic Oak Forest (12 plots), Southern Appalachian Oak Forest (2 plots). The remaining two mismatched plots were labeled can't assign and "other". The experts actually only labeled 6 plots as the Southern Ridge and Valley/ Cumberland Dry Calcareous Forest and when they did they had high confidence (83%). It is likely the sequence table was labeled plots as this system because species composition is similar across a variety of systems in the GeoArea with biographic boundaries constraining the concept. If the sequence table drafted for the entire GeoArea did not take into account ecoregional boundaries that could explain the low agreement and the assignment by experts to a diversity of systems.

Table 23. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2315	Southern Appalachian Oak Forest	CES202.886	50	36	72%	28	5	3
2368	Southern Piedmont Dry Oak(-Pine) Forest	CES202.339	50	35	70%	29	6	0
2369	Central Appalachian Dry Oak-Pine Forest	CES202.591	50	33	66%	16	17	0
2350	Central and Southern Appalachian Spruce-Fir Forest	CES202.028	45	28	62%	27	0	1
2302	Laurentian-Acadian Northern Hardwoods Forest	CES201.564	50	31	62%	11	18	2

				Plots with Expert Matches				
EVT Code	EVT Name	System elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2374	Acadian-Appalachian Montane Spruce-Fir Forest	CES201.566	50	29	58%	19	9	1
2370	Appalachian (Hemlock)-Northern Hardwood Forest	CES202.593	51	28	55%	6	14	8
2373	Acadian Low-Elevation Spruce-Fir-Hardwood Forest	CES201.565	50	26	52%	0	26	0
2318	Southern and Central Appalachian Cove Forest	CES202.373	50	26	52%	17	9	0
2303	Northeastern Interior Dry-Mesic Oak Forest	CES202.592	48	19	40%	5	11	3
2324	Northern Atlantic Coastal Plain Hardwood Forest	CES203.475	51	19	37%	7	11	1
2309	Southern Appalachian Northern Hardwood Forest	CES202.029	27	10	37%	6	4	0
2353	Southern Appalachian Low-Elevation Pine Forest	CES202.332	50	16	32%	9	3	4
2366	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	CES201.563	44	14	32%	2	12	0
2317	Allegheny-Cumberland Dry Oak Forest and Woodland	CES202.359	50	14	28%	10	4	0
2377	Central Appalachian Pine-Oak Rocky Woodland	CES202.600	50	14	28%	5	8	1
2518	North-Central Interior Wet Flatwoods	CES202.700	15	4	27%	0	4	0
2352	Southern Appalachian Montane Pine Forest and Woodland	CES202.331	50	12	24%	8	3	1
2320	Central and Southern Appalachian Montane Oak Forest	CES202.596	50	12	24%	7	4	1
2316	Southern Piedmont Mesic Forest	CES202.342	52	12	23%	9	3	0
2362	Laurentian-Acadian Northern Pine(-Oak) Forest	CES201.719	50	9	18%	1	5	3
2376	Southern Ridge and Valley/Cumberland Dry Calcareous Forest	CES202.457	37	5	14%	4	0	1
2321	South-Central Interior Mesophytic Forest	CES202.887	50	6	12%	0	6	0

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2343	Southern Atlantic Coastal Plain Mesic Hardwood Forest	CES203.242	50	4	8%	1	3	0

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 7E had over 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Pinus strobus*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in the northern Appalachian and sub-boreal region of the northeast, transitions from northern hardwoods to spruce-fir forests occur. In these areas, the tree canopy might be a mix of beech, sugar maple, yellow birch, red spruce, white pine, hemlock, paper birch, and balsam fir, often with little variation in tree canopy cover. In these cases, the reviewer would encounter plots of mixed composition, and need to determine whether those plots represented*Acadian Low-Elevation Spruce-Fir-Hardwood Forest, Laurentian-Acadian Pine-Hemlock-Hardwood Forest, Laurentian-Acadian Northern Hardwoods Forest, Acadian Low-Elevation Spruce-Fir-Hardwood Forest, Acadian-Appalachian Subalpine Woodland and Heath-Krummholz*, *Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp*, or *Acadian-Appalachian Montane Spruce-Fir Forest.*

In cases like this, the determination of which system type to assign to the plot might require:

s) review of the image clip for the context of the plot,
t) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish Acadian vs. Appalachian systems
u) consideration of topographic setting (e.g. highest elevations near summits support woodlands and Krummholz; valley bottoms and topographic depressions support swamps or spruce flats),

v) consideration of any available height data for the plot (e.g. were the conifers tall, apparently mature trees; or were they short and stunted),
w) careful consideration of the full floristic composition of the plot and cover for each species.
x) awareness of possible errors in the plot data, such as mis-identification of spruce species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs. an aerial view of the plot).

Below are some examples of comments relevant to the above spruce – fir and northern hardwood example:

- Near absence of species composition data, however the two co-dominants, the elevation, and subsection of occurrence suggest this is a northern hardwood forest
- This could also be a hemlock swamp; wetland status unknown
- Difficult to determine whether this is a wetland or not. Also, elevation of 1500 feet is close to the transition between montane and lowland
- somewhat sloping and has a small amount of Larix, so wetland status is questionable.
- hemlock not present in plot and land use not known; could be recovering pine plantation
- successional? Near altered land, Fraxinus abundant
- steep slope and relatively high elevation
- Subsection of occurrence, elevation and presence of Abies

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 71 types assigned to plots by experts, 37 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 34 types, the numbers of samples labeled to a given type ranged from 152 (Central Appalachian Dry Oak-Pine Forest) down to 10 (Northern Atlantic Coastal Plain Dune and Swale). For 35 (95%) of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots. None indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 24. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Appalachian (Hemlock)-Northern Hardwood Forest	Sounds like a transitional plot, not much to choose from.
Laurentian-Acadian Northern Hardwoods Forest	Seems early successional, disturbed area.
Southern Appalachian Oak Forest	Species mix describe in this type, but oaks not dominating.
Northeastern Interior Dry-Mesic Oak Forest	Appears to be transitional to Central Appalachian Dry Oak - Pine Forest

Type Name	Expert Comment
Southern and Central Appalachian Cove Forest	This is pretty high ~3500 feet, so is close to CES202.029
Laurentian-Acadian Pine-Hemlock-Hardwood Forest	Could also be low-elevation spruce fir forest

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys.

Second, the inclusion of some limited landform, soil, wetland status, and/or landscape context information could greatly assist with some determinations within the key, or by a subsequent expert reviewer. For example, spruce flats and acidic swamps share the same canopy dominants with several upland systems in the Acadian / Appalachian regions, and topographic position, wetland status, or soil type could easily improve auto-key results. Aerial photos can provide some additional information where the tree canopy is at least partially open, or the photography was taken under leaf-off conditions. In the heavily forested northeast, many of the photos were taken during the growing season and appeared as a solid green mat, providing little to no additional information.
Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 438 samples, experts were able to assign 306 (70%) to an individual ecological system type; a total of 49 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Grassland" or "None". Of 42 samples, experts were able to assign 18 (43%) to an individual ecological system type; a total of 12 individual ecological system types were assigned to these samples.

GeoArea 7W

GeoArea 7W encompasses 10 map zones (**Error! Reference source not found.**): Northern Lake Country (41), Ozark Highlands (44), Appalachia Bluegrass Hills (47), Cumberland Highlands (48), Central Till Plains (49), Central Great Lakes Uplands (50), Great Lakes Plains (51), Eastern Till Plains (52), Appalachia (53), and Allegheny Plateau (62). These map zones were originally clustered for purposes of designing and implementing auto-keys (**Error! Reference source not found.**). The total number of plots in this Geo Area analysis was 1,908. A total of 43 natural ecological system types were assigned to a total of 1,403 plots by the auto-keys. A total of 69 system types were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 11 types were assigned by the auto-key but were not assigned by experts:

- Crosstimbers Oak Forest and Woodland
- Lower Mississippi River Dune Woodland and Forest
- Mississippi Delta Maritime Forest
- Southern Atlantic Coastal Plain Dune and Maritime Grassland
- Texas Saline Coastal Prairie
- Texas-Louisiana Coastal Prairie Pondshore
- Caribbean Swamp Systems
- Gulf and Atlantic Coastal Plain Floodplain Systems
- Gulf and Atlantic Coastal Plain Small Stream Riparian Systems
- Gulf and Atlantic Coastal Plain Swamp Systems
- Gulf and Atlantic Coastal Plain Tidal Marsh Systems

The first type is possibly in the GeoArea. The next five types do not occur in GeoArea 7W and should not be attributed in it. The final five types are aggregates of individual Systems used by Landfire for mapping. The expert reviewers attributed sites to individual Systems and so would not have used these units in their review process.

Comparison of Auto-key and Expert Assignments

Of the 43 natural types assigned labels by the auto-keys, 10 types (23%) had fewer than 10 samples available for this analysis (Table 4). Six of these types are probably truly rare in the GeoArea either because it is on the edge of their geographic range, because they are uncommon types throughout their range, or both. The East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland, West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods, Southeastern Interior Longleaf Pine Woodland, West Gulf Coastal Plain Pine-Hardwood Flatwoods, South-Central Interior/Upper Coastal Plain Wet Flatwoods, and North-Central Interior Oak Savanna types fit one or both of these criteria. The other four types - Great Lakes Wooded Dune and Swale, South-Central Interior/Upper Coastal Plain Flatwoods, Central Appalachian Alkaline Glade and Woodland, and Paleozoic Plateau Bluff and Talus are not abundant in the GeoArea but are probably underrepresented in the data compared to their abundance in the GeoArea.

Table 25. Under-sampled types within GeoArea 7W

EVT Code	EVT Name	System elcode	total Plots
2306	East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland	CES203.482	9
2466	Great Lakes Wooded Dune and Swale	CES201.726	8
2326	South-Central Interior/Upper Coastal Plain Flatwoods	CES203.479	8
2506	West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods	CES203.548	7
2351	Southeastern Interior Longleaf Pine Woodland	CES202.319	5
2458	West Gulf Coastal Plain Pine-Hardwood Flatwoods	CES203.278	5
2457	South-Central Interior/Upper Coastal Plain Wet Flatwoods	CES203.480	5
2400	Central Appalachian Alkaline Glade and Woodland	CES202.602	3
2517	Paleozoic Plateau Bluff and Talus	CES202.704	3
2394	North-Central Interior Oak Savanna	CES202.698	1

A total of 4 types (9% of 43 types) had >80% agreement between expert and auto-key assignments. All of these types had at least 10 sample plots. Expert self-assessment of confidence for these types was predominantly 'high' although Laurentian-Acadian Alkaline Conifer-Hardwood Swamp resulted more in 'moderate' and 'low' confidence levels. This type is very common in the northern Great Lakes states and northeastern US but can be difficult to attribute confidently based only on overstory data. Two common overstory species, northern white-cedar (*Thuja occidentalis*) and red maple (*Acer rubrum*), can also dominate in upland forests so hydrology, soil, or understory data are needed to confidently assign sites to this type.

Table 26 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 29, or 67% of the total types assigned. Analysis of the nature of the disagreements between expert and auto-key attribution reveals some of the sources of these disagreements and suggests some methods to help reduce these in the future. The following are some specific examples of levels of disagreement and possible explanations based on interpretations from the contingency table.

Four common types had 66%-75% agreement. Three of these - North-Central Interior Dry-Mesic Oak Forest and Woodland, Southern Interior Low Plateau Dry-Mesic Oak Forest, and Laurentian-Acadian Northern Pine(-Oak) Forest - were most often confused with floristically similar types based on the apparent abundance of dominant species (oaks or pines). North-Central Interior Beech-Maple Forest was most often confused with a similar type that replaces it to the south – South-Central Interior Mesophytic Forest.

Allegheny-Cumberland Dry Oak Forest and Woodland – Fifteen sites (30%) auto-keyed to this type were called Northeastern Interior Dry-Mesic Oak Forest by experts. These are very similar types distinguished primarily by the abundance of oaks favoring dry conditions versus dry-mesic conditions but there is significant overlap in the component species.

North-Central Interior Wet Flatwoods – Thirty sites were auto-keyed to this type and experts disagreed on 13 sites. Nine of these were listed as "Can't assign" or "Other"; designations that were used indicate not enough data to assign the type or that the site did not fit any natural System. The auto-key may have been too aggressive in assigning sites based on limited data and may have included non-natural sites.

Laurentian-Acadian Northern Hardwoods Forest – This type was confused with several other upland forests though no single one was common. The most common confusion was with the "Can't assign" or "Other" expert-assigned categories indicating not enough data to assign the type or that the site did not fit any natural System. The auto-key may have been too aggressive in assigning sites based on limited data and may have included non-natural sites.

Northeastern Interior Dry-Mesic Oak Forest – This type was confused primarily with two others – South-Central Interior Mesophytic Forest (15 times or 30%) and Appalachian (Hemlock-) Northern Hardwood Forest (7 times or 14%). Confusions with these types are likely based on the relative abundance of oaks vs. other mesic trees.

Ozark-Ouachita Dry Oak Woodland – Forty-four percent of the auto-keyed sites were assigned by experts to either Ozark-Ouachita Dry-Mesic Oak Forest (22%) or "Cant' assign" (22%). The Ozark-

Ouachita Dry-Mesic Forest and Ozark-Ouachita Dry Oak Woodland grade into each other and the difference can be based on slight differences in cover of oak species.

South-Central Interior Mesophytic Forest – This type was confused with seven other types but most commonly with Southern Interior Low Plateau Dry-Mesic Oak Forest (25%). This is likely due to differences in the relative abundance of oak species.

North-Central Interior Dry Oak Forest and Woodland – This type was commonly confused with North-Central Interior Dry-Mesic Oak Forest and Woodland (36%). These two types grade into each other and the difference can be based on slight differences in cover of different oak species.

Ozark-Ouachita Dry-Mesic Oak Forest – This type was commonly (46%) confused with Ozark-Ouachita Dry Oak Woodland. These two types grade into each other and the difference can be based on slight changes in the cover of oak species.

Laurentian-Acadian Pine-Hemlock-Hardwood Forest – Most of the sites (56%) auto-keyed to this type were assigned to Laurentian-Acadian Northern Hardwoods Forest. This confusion is likely based on interpretations of the relative abundance of pines and hemlock.

Boreal White Spruce-Fir-Hardwood Forest – Forty percent of the sites auto-keyed to this type were assigned to either the Laurentian-Acadian Alkaline Conifer-Hardwood Swamp (20%) or "Can't assign" (20%). The Laurentian-Acadian Alkaline Conifer-Hardwood Swamp can have a strong component of balsam fir (*Abies balsamifera*), red maple (*Acer rubrum*), and quaking aspen (*Populus tremuloides*) as does this type. Understory data or other information that would indicate wetlands versus uplands would help differentiate these types.

North-Central Interior Maple-Basswood Forest – Thirty-eight percent of the sites auto-keyed to this type were classified as "Can't assign" by the expert reviewer. Most of these were sites that appeared on the aerial photo as not natural types. Of the sites assigned to natural types by the expert, most (18%) were confused with North-Central Interior Dry-Mesic Forest and Woodland. These types grade into each other, particularly from North-Central Interior Dry-Mesic Forest and Woodland into North-Central Interior Maple-Basswood Forest in the absence of fire.

Boreal Aspen-Birch Forest – This type was auto-keyed in areas it should not occur, areas outside the range of boreal types. Early successional sites in the northern Midwest are often dominated by quaking aspen (*Populus tremuloides*) or paper birch (*Betula papyrifera*) but sites must be in the boreal zone to fit this type. Thus, most sites auto-keyed to this type were assigned by experts to non-boreal types. A substantial number of auto-keyed sites (26%) were assigned by the expert to the "Can't assign" category, indicating either not enough data were available or the site was not a natural type. Better delineation of the potential range of this type would improve the auto-key performance for this type.

Eastern Boreal Floodplain – No sites auto-keyed to this type matched the expert attribution. This type can be difficult to distinguish from surrounding uplands based solely on overstory data. Understory or hydrology data would help to identify sites of this type.

Central Interior Highlands Calcareous Glade and Barrens – All sites auto-keyed to this type were assigned by experts to upland forest and woodland types. Based solely on overstory characteristics, glades can easily be confused with dry or dry-mesic upland forests dominated by oaks. This can be seen

in the fact that 67% of the sites auto-keyed to this type were assigned by experts to upland oak-dominated types. Aerial photos, understory data, and soils data could help clear up this confusion.

Central Interior Highlands Dry Acidic Glade and Barrens – All 10 of the sites auto-keyed to this type were assigned by experts to the Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland. This acidic glade can be similar floristically to this type but aerial photos, soil information, and understory data would help solve this confusion.

Table 26. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2310	North-Central Interior Dry-Mesic Oak Forest and Woodland	CES202.046	50	37	74 %	15	13	9
2305	Southern Interior Low Plateau Dry-Mesic Oak Forest	CES202.898	50	35	70 %	29	5	1
2362	Laurentian-Acadian Northern Pine(-Oak) Forest	CES201.719	50	34	68 %	9	9	16
2313	North-Central Interior Beech-Maple Forest	CES202.693	50	34	68 %	10	12	12
2317	Allegheny-Cumberland Dry Oak Forest and Woodland	CES202.359	49	28	57 %	20	7	1
2518	North-Central Interior Wet Flatwoods	CES202.700	30	17	57 %	0	7	10
2302	Laurentian-Acadian Northern Hardwoods Forest	CES201.564	50	28	56 %	11	6	11
2303	Northeastern Interior Dry-Mesic Oak Forest	CES202.592	50	22	44 %	11	8	3
2364	Ozark-Ouachita Dry Oak Woodland	CES202.707	50	21	42 %	11	7	3
2321	South-Central Interior Mesophytic Forest	CES202.887	50	20	40 %	16	2	2
2311	North-Central Interior Dry Oak Forest and Woodland	CES202.047	50	18	36 %	9	4	5
2304	Ozark-Ouachita Dry-Mesic Oak Forest	CES202.708	50	17	34 %	13	3	1
2307	East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	CES203.483	30	10	33 %	10	0	0
2366	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	CES201.563	50	15	30 %	5	5	5

				Plots with Expert Matches				
EVT Code	EVT Name	System Elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2365	Boreal White Spruce-Fir-Hardwood Forest	CES103.021	50	14	28 %	2	1	11
2308	Crosstimbers Oak Forest and Woodland	CES205.682	15	3	20 %	1	2	0
2314	North-Central Interior Maple-Basswood Forest	CES202.696	51	9	18 %	2	6	1
2407	Laurentian Pine-Oak Barrens	CES201.718	49	7	14 %	1	3	3
2323	West Gulf Coastal Plain Mesic Hardwood Forest	CES203.280	47	6	13 %	2	3	1
2301	Boreal Aspen-Birch Forest	CES103.020	50	6	12 %	0	0	6
2370	Appalachian (Hemlock-) Northern Hardwood Forest	CES202.593	50	6	12 %	2	3	1
2334	Ozark-Ouachita Mesic Hardwood Forest	CES202.043	37	4	11 %	3	1	0
2444	Eastern Boreal Floodplain	CES103.588	50	0	0%	0	0	0
2315	Southern Appalachian Oak Forest	CES202.886	49	0	0%	0	0	0
2309	Southern Appalachian Northern Hardwood Forest	CES202.029	46	0	0%	0	0	0
2401	Central Interior Highlands Calcareous Glade and Barrens	CES202.691	24	0	0%	0	0	0
2344	Boreal Jack Pine-Black Spruce Forest	CES103.022	14	0	0%	0	0	0
2409	Great Lakes Alvar	CES201.721	13	0	0%	0	0	0
2363	Central Interior Highlands Dry Acidic Glade and Barrens	CES202.692	10	0	0%	0	0	0

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 7W had almost 2,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Pinus strobus*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, in central, glaciated areas of this GeoArea, forests can transition from dry-mesic oak-dominated to mesic sugar maple-dominated. In these areas, the tree canopy could be a mix of white oak, red oak, and sugar maple in just about any combination. The reviewer would have to determine whether plots represented North-Central Interior Maple-Basswood Forest, North-Central Interior Beech-Maple Forest, or North-Central Interior Dry-Mesic Forest and Woodland.

In cases like this, the determination of which system type to assign to the plot might require:

y) review of the image clip for the context of the plot,
z) review of where the plot was located geographically (USFS Subsections provide local scale geographic location), to distinguish North-Central Interior Beech-Maple Forest from North-Central Interior Maple-Basswood Forest.
aa) consideration of topographic setting (e.g. north-facing slopes indicate the more mesic maple-dominated types versus south-facing or steep slopes indicating the dry-mesic oak type)
bb) consideration of any available height data for the plot (e.g. a canopy of taller oaks over maples indicates the oak type, though in transition to one of the maple types),
cc) careful consideration of the full floristic composition of the plot and cover for each species.
dd) awareness of possible errors in the plot data, such as mis-identification of oak species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs. an aerial view of the plot).

Below are some examples of comments relevant to the above example:

- Composition is not typical (no *Quercus* spp.) and area looks disturbed on photo. Possibly not a natural System.
- Not much *Quercus* spp. and this could be too dry for this System. Lots of disturbance nearby so this site could be a non-natural System, too.
- Only *Quercus macrocarpa* is characteristic of this System. Other species not strongly characteristic but still fit moderately well.
- Composition could fit this System or NCI Maple-Basswood Forest. Moderately steep SW-facing slope fits this *Quercus*-dominated System better.
- This could also be one of the mesic maple systems; it is in the range for North Central Interior Beech Maple forest (look for *Fagus* in rest of polygon). Although unlikely, it is possible that it could be North Central Interior Maple Basswood Forest.
- Almost enough *Quercus* spp. (particularly *Q. muehlenbergii*) to fit NCI Dry-Mesic Oak Forest and Woodland.

- Dominated by early successional trees but some trees characteristic of this System. Possibly too disturbed to be a natural System.
- Little *Quercus* spp. present but *Carya ovata* can be part of this System. Site is likely quite disturbed and may not be a natural System.
- *Quercus ellipsoidalis* tends to indicate a drier setting than this System but probably not enough *Q. ellipsoidalis* to make this not fit.
- Mix of *Acer saccharum* and *Quercus alba* almost allow this to fit NCI Beech-Maple.
- Area is near the border of the NCI Dry-Mesic Oak Forest and Woodland and Southern Interior Low Plateau Dry-Mesic Oak Forest but this Section should be just NCI Dry-Mesic Oak Forest and Woodland. Also, quite a bit of *Acer saccharum* for this System

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 69 types assigned to plots by experts, 32 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 37 types, the numbers of samples labeled to a given type ranged from 143 (for Laurentian-Acadian Alkaline Conifer-Hardwood Swamp) down to 10 (for West Gulf Coastal Plain Small Stream and River Forest). For 34 (91%) of these types, experts reported at least moderate confidence in their labels for at least 20% of the type's plots. 14 had low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 27. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	This may be a seep or other wet area within larger Laurentian Acadian Northern Hardwood matrix
Laurentian-Acadian Northern Hardwoods Forest	Dominated by aspen-birch but not boreal, rather it is early successional.
Ozark-Ouachita Dry Oak Woodland	Canopy coverage is high for this system
Boreal-Laurentian Conifer Acidic Swamp	This is a little out of range but seems best choice
North-Central Interior Wet Flatwoods	The composition matches this System but could also indicate a floodplain.
Boreal White Spruce-Fir-Hardwood Forest	This borders what appears to be wet area and could lean more towards Laurentian - Acadian Alkaline Hardwood Conifer Swamp

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. For example, elucidating a brighter line between characteristics of the various dry-mesic and dry oak forests would help solve much

of the confusion between those types. Second, the inclusion of some limited landform, soil, and/or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. In this GeoArea there were many sites that were auto-keyed to a natural type but which the expert reviewer assigned to a non-natural type, often based on the aerial photograph. Small woodlots in an agricultural field, old fields with scattered tree regeneration, or fencerows might have overstory composition that fits a natural type but they are clearly ruderal or cultural based on their origin, size, and surroundings. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

Other samples were labeled by auto-keys to aggregates of multiple ecological system types. This was because LANDFIRE had mapping objectives focused on uplands where fire regimes are prevalent. That meant that many individual wetland and sparsely-vegetated ecological system types were not treated within the auto-keys. Expert labeling of these samples, however, provides an indication of the feasibility of their inclusion in updated auto-keys. Of 286 samples, experts were able to assign 261 (68%) to an individual ecological system type; a total of 36 individual ecological system types were assigned to these samples. This result indicates the potential for inclusion of these types within subsequent mapping efforts. We cannot yet comment on the issues associated including these types within future regional auto-keys, but this appears to be an issue worthy of exploration.

Another set of samples did not contain enough information for the auto-keys to assign a system or system aggregate; these samples were labeled with broad "unclassified" types, such as "Unclassified Shrubland" or "None". Of 119 samples, experts were able to assign 40 (34%) to an individual ecological system type; a total of 18 individual ecological system types were assigned to these samples.

GeoArea 8

GeoArea 8 encompasses the entire state of Alaska (Map zones 67-78, **Error! Reference source not found.**). This GeoArea includes a total of 12 map zones originally clustered into 4 groups for purposes of designing and implementing auto-keys. The total number of plots in this Geo Area analysis was 1,454. A total of 73 natural ecological system types were assigned to a total of 1,454 plots by the auto-keys. A total of 93 systems were assigned by experts (i.e., these included individual types that had been aggregated to broader classes by LANDFIRE for either sparsely vegetated types or wetland/riparian types).

An additional 12 types were assigned by the auto-key but were not assigned by experts. Those types included:

- Alaska Arctic Floodplain
- Alaska Arctic Large River Floodplain
- Alaska Sub-boreal Avalanche Slope Shrubland
- Alaskan Pacific Maritime Alpine Floodplain
- Alaskan Pacific Maritime Coastal Meadow and Slough-Levee
- Alaskan Pacific Maritime Mountain Hemlock Peatland
- Aleutian Shrub-Sedge Peatland
- Western North American Boreal Alpine Dwarf-Shrub Summit
- Western North American Boreal Alpine Floodplain

- Western North American Boreal Lowland Large River Floodplain Forest and Shrubland
- Western North American Boreal Montane Floodplain Forest and Shrubland
- Western North American Boreal Shrub and Herbaceous Floodplain Wetland

Comparison of Auto-key and Expert Assignments

Of the 73 natural types assigned labels by the auto-keys, none were considered under-sampled (represented by <10 plots). A total of 10 types (or ~7% of 73 types) had >80% agreement between expert and auto-key assignments. All of these types had at least 20 sample plots. Expert self-assessment of confidence for these types were predominantly 'high' although Western North American Boreal Tussock Tundra had 5 plots which were considered to have 'moderate' confidence.

Table 28. Under-sampled types within GeoArea 8

There are no under-sampled types within GeoArea 8.

Table 29 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 80% down to zero. These types total 63, or nearly 86% of the total types assigned. Further analysis of those grouped within the 60-80% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. For example, some plots assigned by autokey were attributed to the Western North American Boreal White Spruce Forest were mistaken for Western North American Boreal White Spruce-Hardwood Forest. Another example was confusion between the Alaskan Pacific Maritime Periglacial Woodland and Shrubland and the other maritime forest systems, especially the Alaskan Pacific Maritime Sitka Spruce Forest and the Alaskan Pacific Maritime Floodplain Forest and Shrubland. All three of these have sitka spruce as a major component, but are distinguished by floodplain settings or by early successional status in areas of recent glacial melt. Clarification of floristics (between the floodplain type and the other 2), or how to distinguish primary successional areas for the periglacial type would help to improve the sequence table as well as expert understanding of the types.

Many types do transition into one another, so additional floristic indicators might be identified to better distinguish them. This same general pattern, one of carefully reviewing the dominant tree, shrub, or grass elements shared among related types, should be the focus of auto-key improvements for these types.

Table 29. Summary of types with adequate samples where agreement between auto-key and expert was below 80%

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
2178	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	CES204.842	20	15	75 %	14	0	1
2611	Western North American Sub-boreal Mesic Bluejoint Meadow	CES105.114	20	14	70 %	11	2	1

				Plots with Expert Matches				
EVT Code	EVT Name	System elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2648	Alaskan Pacific Maritime Mountain Hemlock Forest	CES204.142	20	14	70%	14	0	0
2644	Alaskan Pacific Maritime Sitka Spruce Forest	CES204.151	20	14	70%	11	1	2
2698	Alaska Arctic Wet Sedge Meadow	CES102.185	20	13	65%	5	5	3
2638	Alaska Arctic Mesic Alder Shrubland	CES104.168	20	13	65%	10	3	0
2604	Western North American Boreal Mesic Black Spruce Forest	CES105.107	20	13	65%	9	4	0
2650	Alaskan Pacific Maritime Periglacial Woodland and Shrubland	CES204.311	20	13	65%	13	0	0
2600	Western North American Boreal White Spruce Forest	CES105.104	20	12	60%	9	2	1
2679	Alaska Sub-boreal White Spruce-Hardwood Forest	CES105.136	20	12	60%	9	3	0
2689	Alaska Arctic Non-Acidic Dryas Dwarf-Shrubland	CES104.174	20	11	55%	10	0	1
2635	Western North American Boreal Alpine Ericaceous Dwarf-Shrubland	CES105.133	20	11	55%	9	1	1
2677	Alaska Sub-boreal White-Lutz Spruce Forest and Woodland	CES105.102	20	10	50%	9	1	0
2639	Alaska Arctic Mesic-Wet Willow Shrubland	CES104.169	16	8	50%	5	3	0
2610	Western North American Boreal Mesic Scrub Birch-Willow Shrubland	CES105.113	20	9	45%	6	0	3
2682	Alaska Arctic Scrub Birch-Ericaceous Shrubland	CES104.170	20	8	40%	7	0	1
2603	Western North American Boreal White Spruce-Hardwood Forest	CES105.106	20	8	40%	8	0	0
2040	North Pacific Mesic Western Hemlock-Yellow-cedar Forest	CES204.843	20	8	40%	8	0	0
2693	Alaska Arctic Shrub-Tussock Tundra	CES102.180	20	7	35%	6	1	0

				Plots with Expert Matches				
EVT Code	EVT Name	System elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2705	Alaska Arctic Sedge Freshwater Marsh	CES102.184	20	7	35%	2	2	3
2701	Alaska Arctic Coastal Sedge-Dwarf-Shrubland	CES102.211	20	7	35%	4	3	0
2683	Alaska Arctic Mesic Sedge-Willow Tundra	CES102.187	20	6	30%	6	0	0
2712	Alaska Arctic Coastal Brackish Meadow	CES102.210	20	6	30%	6	0	0
2688	Alaska Arctic Acidic Dryas Dwarf-Shrubland	CES104.173	20	6	30%	6	0	0
2628	Western North American Boreal Low Shrub-Tussock Tundra	CES105.126	20	6	30%	6	0	0
2660	Alaskan Pacific Maritime Wet Low Shrubland	CES204.157	20	6	30%	5	0	1
2605	Western North American Boreal Mesic Birch-Aspen Forest	CES105.108	20	5	25%	5	0	0
2623	Western North American Boreal Black Spruce-Tamarack Fen	CES105.121	20	5	25%	3	2	0
2645	Alaska Sub-boreal and Maritime Alpine Mesic Herbaceous Meadow	CES204.145	20	5	25%	5	0	0
2734	North Pacific Alpine and Subalpine Bedrock and Scree	CES204.853	20	5	25%	4	0	1
2622	Western North American Boreal Black Spruce Wet-Mesic Slope Woodland	CES105.120	20	4	20%	2	2	0
2699	Alaska Arctic Mesic Herbaceous Meadow	CES102.186	20	3	15%	3	0	0
2702	Alaska Arctic Wet Sedge-Sphagnum Peatland	CES102.200	20	3	15%	3	0	0
2717	Alaska Arctic Bedrock and Talus	CES102.228	20	3	15%	2	0	1
2601	Western North American Boreal Treeline White Spruce Woodland	CES105.137	20	3	15%	3	0	0
2690	Alaska Arctic Dwarf-Shrubland	CES104.175	19	2	11%	0	2	0

				Plots with Expert Matches				
EVT Code	EVT Name	System elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2700	Alaska Arctic Polygonal Ground Mesic Shrub Tundra	CES102.206	20	2	10%	2	0	0
2651	Aleutian Mesic Herbaceous Meadow	CES105.232	20	2	10%	2	0	0
2643	Alaskan Pacific Maritime Alpine Dwarf-Shrubland	CES204.310	20	2	10%	2	0	0
2621	Western North American Boreal Black Spruce Dwarf-Tree Peatland	CES105.139	21	2	10%	0	1	1
2684	Alaska Arctic Mesic Sedge-Dryas Tundra	CES102.199	20	1	5%	1	0	0
2703	Alaska Arctic Dwarf-Shrub-Sphagnum Peatland	CES102.201	20	1	5%	0	1	0
2707	Alaska Arctic Polygonal Ground Tussock Tundra	CES102.204	20	1	5%	1	0	0
2691	Alaska Arctic Acidic Dwarf-Shrub Lichen Tundra	CES104.177	20	1	5%	1	0	0
2606	Western North American Boreal Dry Aspen-Steppe Bluff	CES105.109	20	1	5%	0	0	1
2618	Western North American Boreal Herbaceous Fen	CES105.119	20	1	5%	1	0	0
2655	Alaskan Pacific Maritime Floodplain Forest and Shrubland	CES204.154	20	1	5%	1	0	0
2680	Alaskan Pacific Maritime Avalanche Slope Shrubland	CES204.162	20	1	5%	1	0	0
2681	Alaskan Pacific Maritime Poorly Drained Conifer Woodland	CES204.315	20	1	5%	1	0	0
2608	Alaska Sub-Boreal Avalanche Slope Shrubland	CES105.111	21	0	0%	0	0	0
2714	Alaska Arctic Large River Floodplain	CES102.213	20	0	0%	0	0	0
2715	Alaska Arctic Floodplain	CES102.227	20	0	0%	0	0	0
2615	Western North American Boreal Lowland Large River Floodplain Forest and Shrubland	CES105.117	20	0	0%	0	0	0

				Plots with Expert Matches				
EVT Code	EVT Name	System elcode	Total Plots	Total	%	High conf	Med conf	Low conf
2617	Western North American Boreal Shrub and Herbaceous Floodplain Wetland	CES105.118	20	0	0%	0	0	0
2626	Western North American Boreal Wet Meadow	CES105.124	20	0	0%	0	0	0
2631	Western North American Boreal Alpine Dwarf-Shrub Summit	CES105.129	20	0	0%	0	0	0
2620	Western North American Boreal Low Shrub Peatland	CES105.140	20	0	0%	0	0	0
2614	Western North American Boreal Montane Floodplain Forest and Shrubland	CES105.141	20	0	0%	0	0	0
2647	Aleutian Shrub-Sedge Peatland	CES105.238	20	0	0%	0	0	0
2659	Alaskan Pacific Maritime Mountain Hemlock Peatland	CES204.156	20	0	0%	0	0	0
2665	Alaskan Pacific Maritime Coastal Meadow and Slough-Levee	CES204.159	20	0	0%	0	0	0
2676	Alaskan Pacific Maritime Alpine Floodplain	CES204.161	20	0	0%	0	0	0
2637	Western North American Boreal Alpine Floodplain	CES105.135	17	0	0%	0	0	0

Analysis of the contingency table (Results Workbook) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. The results for the Alaska GeoArea in particular show how difficult it is to distinguish plots when the overall floristic diversity is low (such as in arctic Alaska grading into the boreal region), and the difference between the ecological systems is based on often subtle differences in concept and floristics that are not well represented in the plot data. For example the suite of ericaceous and dwarf-shrub species that characterize shrubland communities in Alaska is limited. High elevation shrublands in the boreal regions will have much the same floristics as in the arctic, but are split into different ecological systems.

Boreal spruce and hardwood forests and woodlands have the same predominant tree species (black and white spruce, paper birch, aspen, and balsam poplar), and are important species in some dozen ecological systems, grading from sub-arctic spruce & lichen woodlands to black spruce peatlands. If adequate compositional data are not available in the plots, and the indicators of “wetlands” or “peatlands” or “floodplains” are not clearly understood, then neither the auto-key nor expert will be able to label the plots with confidence.

The contingency table shows this confusion and here we summarize a cross-section of results from GeoArea 8.

Western North American Boreal White Spruce Forest is confused with Western North American Boreal White Spruce-Hardwood Forest, Alaska Sub-boreal White-Lutz Spruce Forest and Woodland, Western North American Boreal Treeline White Spruce Woodland, Western North American Boreal Mesic Black Spruce Forest, Western North American Boreal Lowland Large River Floodplain Forest and Shrubland, and Western North American Boreal Montane Floodplain Forest and Shrubland. All of these have somewhat subtle differences in the structural characteristics, such as the percent of hardwood versus ocnfier in the canopy or relative proportions of white spruce versus black or lutz spruce. They also share a suite of similar shrub and forb species, even the systems found in floodplains will have much the same set of low or dwarf-shrubs and perennial forbs as the adjacent upland systems.

Western North American Boreal Mesic Black Spruce Forest is confused with Western North American Boreal Black Spruce Wet-Mesic Slope Woodland, Western North American Boreal Black Spruce Dwarf-Tree Peatland, Western North American Boreal Black Spruce-Tamarack Fen. All of these systems are dominated by black spruce but are separated by a relative moisture gradient as well as a gradient of peat development. If plots are lacking information on the non-vascular components (which are used as indicators for the fen or peat systems), or similarly lacking the shrub or sedge indicators of peatlands versus fens, then keying them can be especially difficult.

Western North American Boreal Mesic Scrub Birch-Willow Shrubland is confused with many other shrubland types, but especially Western North American Boreal Low Shrub-Tussock Tundra, Western North American Boreal Alpine Floodplain, Alaskan Pacific Maritime Alpine Floodplain, and Western North American Boreal Low Shrub Peatland. Scrub birch (Betula nana or B. glandulosa) occurs across all of Alaska, and ranges from dry uplands, the understory of spruce woodlands, to wetlands and fens (herbaceus indicators are critical to distinguishing across these types). But this example highlights the issue that floodplains in Alaska often do not have clear floristic indicators, as are usually found in drier areas of the western U.S.

Alaskan Pacific Maritime Sitka Spruce Forest is confused with Alaskan Pacific Maritime Periglacial Woodland and Shrubland and Alaskan Pacific Maritime Mountain Hemlock Forest. And the Alaskan Pacific Maritime Poorly Drained Conifer Woodland was confused with North Pacific Mesic Western Hemlock-Yellow-cedar Forest, which in turn was confused with the Alaskan Pacific Maritime Western Hemlock Forest. In coastal maritime Alaska, with very high amounts of precipitation, the shrub and herb composition within the forest and woodland ecological systems is not highly variable. Distinguishing between poorly drained conifer woodlands (swamps), forested uplands, and floodplains is difficult without information as to micro-topographic characteristics of the plot.

Western North American Boreal Alpine Mesic Herbaceous Meadow – This system is characterized by herbaceous species which are found in both meadow and marsh systems. Many of these plots were difficult to assign as a result of a lack of environmental data to determine the level of hydrologic inundation.

Alaska Arctic Non-Acidic Dwarf-Shrub Lichen Tundra – Since this system is defined by high lichen cover, but as non-vascular cover was often not recorded the expert would have to default to other shrub systems such as Alaska Arctic Scrub Birch-Ericaceous Shrubland.

Alaskan Pacific Maritime Avalanche Slope Shrubland – This system was often labeled by experts as North Pacific Alpine and Subalpine Bedrock and Scree resulting from similar environmental and floristic characteristics.

Western North American Boreal Herbaceous Fen – This system is characterized by peat soils, but was difficult for experts to attribute due to lack of environmental data. It was not possible to determine if soils were peat. Therefore it was difficult to determine if these plots represented fen or meadow systems due to similar floristics; if the fen indicators listed in the description were not present or recorded on the plot it would not be possible to know if the plot represented a fen or wet meadow.

Western North American Boreal Spruce-Lichen Woodland – Non-vascular cover was not always recorded in plots making it difficult to attribute to this system.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 8 had over 1,400 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Picea mariana*), then sort by % cover of that species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. Additional fields were provided from which to select or sort plots, such as elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics.

For example, within the group of 5 ecological systems where black spruce is the major tree component as described above differences between them are based on a gradient of moisture and peat development; indicators of such conditions either floristic ot biophysical settings, is necessary to accurately key the types. Since photos or image clips for many plots were either lacking or of poor quality, these were not available to assist the expert in the review and attribution. In addition a complete species list is necessary to confidently distinguish these types, especially in the non-vascular composition of the plot which is rarely collected.

In cases like this, the determination of which system type to assign to the plot might require:

ee) review of the image clip for the context of the plot (recall, very few Alaska plots had useable image clips),
ff) review of where the plot was located geographically (noting that for the GeoArea 8 plots, local geographic information such as USFS Subsection was not available, only very coarse-scale units such as the Map Zones, TNC or Nowacki ecoregions), to distinguish Arctic vs. Boreal for example,
gg) consideration of topographic setting (e.g. north-facing slopes could logically represent the Western North American Boreal Black Spruce Wet-Mesic Slope Woodland),
hh) consideration of any [rarely] available height data for the plot (e.g. were the black spruce trees all tall, apparently mature trees; or were they dwarfed),
ii) careful consideration of the full floristic composition of the plot and cover for each species.
jj) awareness of possible errors in the plot data, such as mis-identification of species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 93 types assigned to plots by experts, 45 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 48 types, the numbers of samples labeled to a given type ranged from 58 (for Western North American Boreal Mesic Scrub Birch-Willow Shrubland) down to 10 (for Western North American Boreal Low Shrub Peatland). For all of these types, experts reported high confidence in their labels for at least 50% of the type's plots. 4 types indicated low confidence for at least 20% of the type's plots. These statistics are listed in the Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 30. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Western North American Boreal Mesic Scrub Birch-Willow Shrubland	Betula glandulosa is not a dominant species in this system.
Western North American Sub-boreal Mesic Bluejoint Meadow	Unidentified sedge is problematic in assigning this system.
Alaska Arctic Polygonal Ground Shrub-Tussock Tundra	The presence of Carex utriculata suggests this is not an upland system, but tussock cover is very low.
Alaska Arctic Acidic Dryas Dwarf-Shrubland	Tussock sedges suggest this might be ecotonal
Alaskan Pacific Maritime Sitka Spruce Beach Ridge	Incomplete floristic data.

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of

classification refinement is likely needed in order to improve auto-keys. This is particularly the case with a number of Alaskan ecological systems, where the literature and supporting plot data are often lacking complete floristic information, and where many species are characteristic in multiple system types across large areas of the state. Another issue is the taxonomic uncertainty for many groups of taxa, such as sedges, willows, and the dwarf or scrub birches; these tend to be difficult to distinguish correctly in the field which in turn leads to uncertainty as to the correct floristic composition for individual system types. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.

GeoArea HI

GeoArea HI encompasses the Hawaiian Island system, map zone 79. The total number of plots in this Geo Area analysis was 248. A total of 12 natural ecological system types were assigned to a total of 248 plots by the auto-keys. A total of 11 system types were assigned by experts. In this GeoArea there were no aggregated systems types for either sparsely vegetated types or wetland/riparian types.

An additional 2 types were assigned by the auto-key but were not assigned by experts:

- Hawai'i Dry Cliff
- Hawai'i Coastal Mesic Forest

Both types unassigned by experts are of very limited extent in Hawai'i.

Comparison of Auto-key and Expert Assignments

Of the 12 natural types assigned labels by the auto-keys, 6 types (50%) had fewer than 10 samples available for this analysis (Table 4). These under-sampled types tended to include types that are less common such as Northern Polynesia Tidal Salt Marsh and Hawai'i Coastal Mesic Forest, types that are difficult to sample such as Hawai'i Dry Cliff, and other types that simply have had inadequate sampling effort across this region such as Hawai'i Dry-Site Lava Flow. These include Hawai'i Lowland Dry Shrubland and Hawai'i Lowland Mesic Shrubland. The extent and condition of native lowland vegetation has been significantly impacted by development and invasive, non-native species.

Table 31. Under-sampled types within GeoArea HI

EVTCode	EVT Name	System elcode	total Plots
2817	Hawai'i Lowland Dry Shrubland	CES412.409	9
2818	Hawai'i Lowland Mesic Shrubland	CES412.412	7
2812	Hawai'i Coastal Mesic Forest	CES412.417	7
2831	Hawai'i Dry-Site Lava Flow	CES412.416	6
2807	Northern Polynesia Tidal Salt Marsh	CES412.224	4
2825	Hawai'i Dry Cliff	CES412.414	1

No types had >47% agreement between expert and auto-key assignments. This is surprising how poorly the auto-key performed when compared to other GeoAreas.

Table 32 provides a summary of adequately-sampled types where agreement between expert and auto-key ranged from just below 50% down to 6%. These six types represent 50% of the total types assigned. Further analysis of those grouped within the 50-6% agreement range suggests subtleties within types that left the expert with greater or lesser confidence in their assignment. This confusion is a result of many factors, some having to do with the fact that much of the dominant species in Hawai'i occur in multiple systems, so differentiation is based on indicator species and environmental factors such as moisture zone and elevation. For example, the widespread often dominant tree, *Metrosideros polymorpha* occurs from near sea level to subalpine elevations and on dry to wet sites. Using indicator species is problematic when floristic composition is poorly known, species lists in the samples are incomplete, or with indicator species that are uncommon enough that they are not consistently present in every plot. Another big issue, especially in lowland tropical vegetation (<1000 m elevation), is introduced species which complicate the use of auto-keys to label plots but dilute the relative cover of key native species.

Table 32. Summary of types with adequate samples where agreement between auto-key and expert was below 50%

			Plots with Expert Matches					
EVT Code	**EVT Name**	**System elcode**	**total Plots**	**total**	**%**	**High conf**	**Med conf**	**Low conf**
2826	Hawai'i Dry Coastal Strand	CES412.418	17	8	47%	4	3	1
2816	Hawai'i Montane-Subalpine Mesic Forest	CES412.406	78	31	40%	0	31	0
2813	Hawai'i Lowland Dry Forest	CES412.408	18	6	33%	2	3	1
2814	Hawai'i Lowland Mesic Forest	CES412.411	34	5	15%	0	4	1
2808	Hawai'i Lowland Rainforest	CES412.226	36	3	8%	1	1	1
2810	Hawai'i Montane Rainforest	CES412.215	31	2	6%	0	2	0

Analysis of the contingency table (Results Workbook) for these types with lesser levels of agreement reveals the many ongoing challenges with finding agreement between experts and auto-keys for complex vegetation types. Here we summarize the results from GeoArea HI

Hawai'i Montane-Subalpine Mesic Forest – was most often confused with Hawai'i Lowland Mesic Forest (32), followed by Hawai'i Montane Rainforest (6), Hawai'i Lowland Dry Forest (4), and Hawai'i Lowland Rainforest (4). This confusion is the result of the elevation break used in the auto-key. The lowland mesic forest was allowed to include plots with <1100 m, when the expert generally used a 1000 m break unless there were ecological justification for increasing it. The confusion between lowland dry forest and lowland rainforest were likely the result of borderline issues with the moisture zone breaks.

Hawai'i Lowland Rainforest – was most often confused with Hawai'i Montane-Subalpine Mesic Forest (16), followed by Hawai'i Montane Rainforest (9), and Hawai'i Lowland Mesic Forest (7). This indicates issues with the elevation zones and moisture zones where the auto-key labels the plots <1100 m first, but the expert thinks these borderline plots are montane. The moisture zones are also an issue which may hinge on Moisture Zone 5 being transitional between wet forest and mesic forest systems.

Hawai'i Lowland Mesic Forest – was most often confused with Hawai'i Lowland Dry Forest (14), followed by Hawai'i Montane-Subalpine Mesic Forest (9) and Hawai'i Montane Rainforest (5). Again,

this indicates an issue with the elevation zones and moisture zones where the auto-key labels the plots <1100 m first, but the expert thinks these borderline plots are montane. The moisture zones are also an issue which may hinge on Moisture Zone 5 being transitional between wet forest and mesic forest systems.

Hawai'i Montane Rainforest– was most often confused with Hawai'i Montane-Subalpine Mesic Forest (14), followed by Hawai'i Lowland Dry Forest (5), Hawai'i Lowland Rainforest (2), and other non auto-key systems (8). The biggest issue is the level 5 moisture zone (seasonally mesic) and its confusion with the montane rainforest system. Moisture Zone 5 may be transitional between wet forest and mesic forest systems, rather than solely mesic.

Hawai'i Lowland Dry Forest– was confused with Hawai'i Lowland Mesic Forest (3), followed by Hawai'i Lowland Rainforest (2), Hawai'i Montane-Subalpine Mesic Forest (1), and other, non auto-key systems (6). The moisture zones in the auto-key need to be reviewed.

Hawai'i Dry Coastal Strand – was most often confused Northern Polynesia Tidal Salt Marsh (4). Both systems occur along coast. The indicator species may need to be restricted more or the order in the auto-key swapped so that the more restrictive brackish water species of the tidal marsh get labeled first.

Expert Assignments

As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea HI had over 200 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer to sort and filter on subsets of plots to select groups of them with similar characteristics. For instance, the reviewer could select all plots found within a particular USFS Section or MapZone, then select all plots dominated by trees, then sort alphabetically by the dominant species. The reviewer could also select all treed plots, then select all plots with the same dominant tree species (such as *Metrosideros polymorpha*), then sort by codominant species, from high to low. **Error! Reference source not found.** shows the main form in the EADB which has these data fields. The filter is also useful to narrow selections. Additional fields were provided from which to select or sort plots, such as % cover of species, elevation, aspect, slope, and total cover by lifeform in the plot.

Once the reviewer had selected a subset of plots for reviewing, the next step was to select an individual plot to review and label. If the expert was working on treed plots first, then they had a further option of selecting the set of ecological systems from which to pick a label for the plots. This was accomplished via a filter on the NLCD land cover class applied to all systems (such as forest and woodland, shrubland, herbaceous, woody wetlands, and so on).

For each plot, the expert reviewed environmental and geographic setting, as well as the floristic and vegetation structural characteristics of the plot. In many cases the expert could then assign an ecological system label with no further information. However, in some cases the reviewer might consult the descriptions for a group of similar ecological systems to clarify their understanding of differences in concept, geographic distribution, floristics, or structural characteristics. For example, in Hawai'i there are several species such as *Metrosideros polymorpha* which occur widely and dominate the canopy of several ecological systems.

In cases like this, the determination of which system type to assign to the plot might require:

kk) review of the image clip or photo for the context of the plot,
ll) review of where the plot was located geographically (wet windward side of island or dryer leeward side of island. In Hawai'i the USFS Subsections and do not vary so not useful.
mm) consideration of topographic setting (e.g. alpine, subalpine, montane, lowland and coastal zones all support different vegetation),
nn) consideration of any available height data for the plot (e.g. were trees normal size or dwarfed from being exposure to extreme weather on a ridge in the cloud forest)
oo) careful consideration of the full floristic composition of the plot and cover for each species. This is especially important in Hawai'i where several species such as *Metrosideros polymorpha* occur widely and dominate the canopy of several ecological systems. Introduced species are a huge problem in lowland Hawai'i, so complete species composition is necessary to determine if the plot represents a disturbed natural system or has converted to a ruderal system dominated by introduced species.
pp) awareness of possible errors in the plot data, such as mis-identification of species by the field crews, unevenness in how the cover values were estimated in the field or converted into the LFRDB (e.g. cover for trees estimated by a person standing on the ground vs an aerial view of the plot).

Below are some examples of comments relevant to the above *Metrosideros polymorpha* example:

- *Metrosideros polymorpha* is dominant tree in several forest and woodland systems has low diagnostic value in determining which forest system.
- Generally*, Metrosideros polymorpha* dominated or codominated forests occurring above 1000 m are considered montane, and if occur in moisture zones 1-3 are thought to be dry forest, or if occur in moisture zones 4 or 5 are assumed to be mesic forest, and if occur in moisture zones 6 or 7 are wet forest (rainforest).
- Generally*, Metrosideros polymorpha* dominated or codominated forests occurring below 1000 m are considered lowland, and if occur in moisture zones 1-3 are thought to be dry forest, or if occur in moisture zones 4 or 5 are assumed to be mesic forest, and if occur in moisture zones 6 or 7 are wet forest (rainforest).
- Presence of indicator species works better in some systems than others as we are still refining them as we learn more.
- Introduced invasive species are converting native systems to ruderal systems so absolute and relative cover of species such as *Morella faya* and *Psidium* spp. are critical in determining system label.

Given all of the above, the reviewer had to make a decision for the plot, and assign an ecological system label. In cases where the assignment was not made with high confidence, the reviewer was requested to provide comments as to the factors they used to assign a label to the plot, or what the alternative assignment could be. Report Section 2.3 below discusses some of the results pertinent to confidence of assignment.

Improving the auto-key process

Of the 11 types assigned to plots by experts, 3 had fewer than 10 samples, so are excluded from this particular analysis. From the remaining 8 types, the numbers of samples labeled to a given type ranged from 71 (Hawai'i Montane-Subalpine Mesic Forest) down to 11 (Hawai'i Lowland Rainforest). For all of these types, experts reported moderate confidence in their labels for at least 20% of the type's plots. Several (3) indicated low confidence for at least 20% of the type's plots. These statistics are listed in the

Results Workbook. A small sampling of expert comments related to moderate or low confidence plots are included in Table 6.

Table 33. A selection of expert comments related to labeling sample plots for types where their confidence was reported as moderate or low

Type Name	Expert Comment
Hawai'i Lowland Mesic Forest	Plot cannot be determined by available floristic data and elevation alone
Hawai'i Lowland Dry Forest	Plot occurs in the relatively recent 1868 lava flow so is dryer than the Price et al. 2007 Moisture Zone
Hawai'i Dry-Site Lava Flow	Plot is in moisture zone 5 so can't assign to CES412.416 Hawai'i Dry-Site Lava Flow.

These and other comments point to several important aspects for consideration. First, some ecological systems concepts are better known and understood than others. Therefore, a certain degree of classification refinement is likely needed in order to improve auto-keys. Second, the inclusion of some limited landform, soil, and or landscape context information could assist with some determinations within the key, or by a subsequent expert reviewer. Similarly, repeated references to photos further indicates the need for expert review of many types where moderate-low confidence of experts suggest that auto-keys might be prone to error. Third, additional floristic information is cited in some cases where their suspected limitations provide the primary source of expert uncertainty in labeling.