Expert Attribution for Auto-Key Improvements (LANDFIRE) and Advancing Methods for integration with the revised US-National Vegetation Classification Standard: GeoArea 1

FINAL REPORT

Prepared by

NatureServe

For the NPS Vegetation Inventory Program & LANDFIRE

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© Milo Pyne – Longleaf Pine in Croatan National Forest, North Carolina

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Contact information:
Prepared by Patrick J. Comer, Chief Ecologist
Email: **pat_comer@natureserve.org**
Phone: 703.797.4802
Mailing address: NatureServe
4001 Discovery Dr. Suite 2110
Boulder, CO 80303

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Introduction

The Inter-agency LANDFIRE Program implemented a series of new procedures and tools for processing vegetation sample plot data to rapidly supply geo-referenced samples for dynamics modeling and vegetation mapping. This effort made substantial advances in processing several hundred thousand vegetation plots nationwide, including standardizing many sample attributes (species taxonomy, structural classes, etc.) and applying labels reflecting the LANDFIRE map legend. However, given the pace of project activity, there was limited time to identify systematic error within the processing *auto-keys* and internalize lessons learned to improve technical procedures. There was also limited ability to develop an expert-reviewed, independent sample data set for use in map accuracy assessment. Additionally, given recent developments, there is a desire to adopt the revised US-National Vegetation Classification (US-NVC) for future mapping of existing vegetation types as part of the LANDFIRE effort.

This project represents a cooperative research effort with federal agency partners to systematically review the results of automated sample plot labeling (*auto-keys*), identify sources of systematic error, and clarify needs for technical improvements. Through this review process, comparisons between the existing LANDFIRE map legend and new types described the US-NVC were evaluated and documented. The effort has also generated an expert-reviewed, independent sample data set for use in map accuracy assessment nationwide.

Project Goals

- Identify “accuracy” issues with the existing auto-keys and resultant labels.
- Identify spatial or thematic gaps in the current LANDFIRE national reference database.
- Develop recommended solutions/approaches to issues encountered.
- Build an independent data set that could be used in other applicable mapping projects (GAP, regional wildlife, state habitat maps, etc.).
- Identify issues specific to labeling training data based on the newly adopted National Vegetation Classification Standard hierarchy.
- Identify and document appropriate updates to NPS vegetation field methods documentation.

In-kind contributions to this effort have come from federal agency partners, including USGS (Gap Analysis Program and Earth Resources Observation and Science (EROS) Data Center), US Forest Service Rocky Mountain Research Station (RMRS) and Forest Inventory Analysis (FIA)), among others. The National Park Service retains considerable expertise in the use of project outputs and benefits directly from project outcomes. NatureServe ecologists have contributed expertise in U.S. vegetation types and processing procedures, and development of the LANDFIRE *auto-key* tools.

Background on LANDFIRE Auto-keys

A major need and hence objective of LANDFIRE was to compile geo-referenced vegetation data for the entire United States. These data needed to be combined into a single database and attributed in a consistent, repeatable fashion to NatureServe’s Terrestrial Ecological Systems or a set of land use or land cover classes. Once attributed with ecological systems, the geo-referenced samples were used as training data in a mapping effort that utilized a modeling process whereby the samples were only one of several inputs to the model. Systems for Environmental Management (SEM), based in Missoula MT, was contracted by LANDFIRE to compile the LANDFIRE Reference Database, or LFRDB, of all relatively recent, geo-referenced vegetation samples (also called “plots”) that could be obtained and processed.

LANDFIRE contracted with NatureServe to work with the LANDFIRE team to develop a methodology to automate attribution of the samples contained in the LFRDB to ecological systems or the other standardized land use/land cover classes. Prototyping and testing of this methodology evolved over several months in 2004 into a process involving two components: a set of floristic and structural rules for each vegetation type, and a computer application to use the plots from the LFRDB and the rules as inputs to generate results useable by LANDFIRE's mapping teams. The sets of floristic rules or criteria are now known as Sequence Tables, and the software application is called the Auto-key.

One of the main requirements for LANDFIRE map units was that they be differentiated floristically. Since abiotic variables were not consistently available for every plot, contextual landscape or abiotic information could not be used to differentiate vegetation types represented by the plots. In addition, sequence tables were intended to work with regional-scale patterns, as opposed to more local-scales. Thus keying each plot using only the required floristic data was the best way to assign a map unit to each plot.

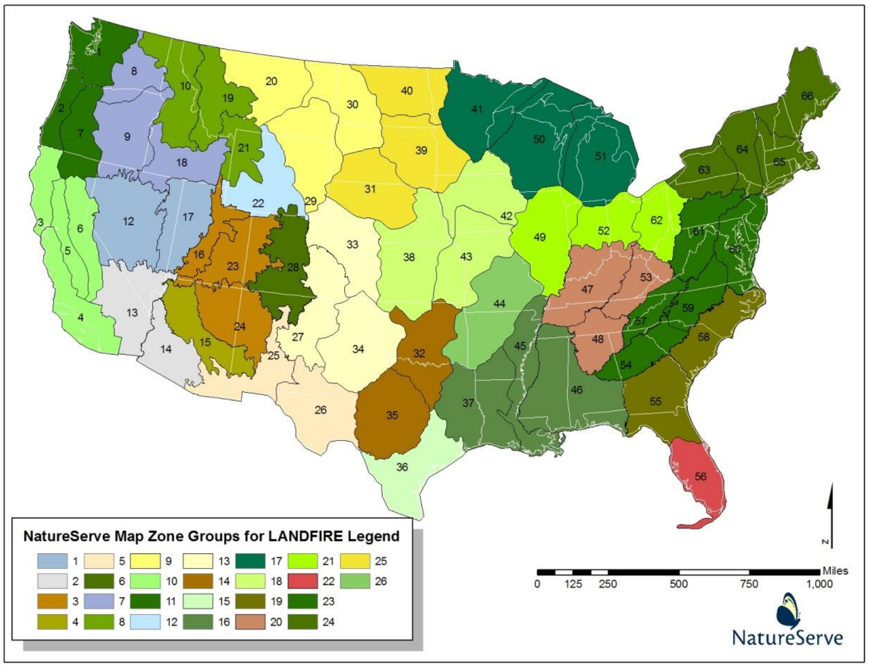
LANDFIRE's short-term needs, and long-term plans, required a repeatable methodology, consistently applied rules to categorize each reference sample, and documentation of the criteria applied. In essence, sequence tables codify the criteria and methods for keying geo-referenced vegetation data to a land cover class, whether it's an ecological system or some other vegetation category. Because of this, the methods are repeatable by anyone who may not necessarily be familiar with the vegetation of the region covered by a particular sequence table.

More details about this methodology include:

1. Each LANDFIRE sequence table was designed to efficiently automate keying of thousands to 10's of thousands geo-referenced vegetation samples to the LANDFIRE map units, which included both Ecological Systems for the 'natural' portions of the landscape, and a variety of land use or land cover classes for the remainder. The objective was to accurately key as many samples as possible, not to attempt to key all samples.
2. Each sequence table was created to key to systems and mappable US-NVC alliances in an ecologically-related geographic area, utilizing the MRLC map zones. There are 66 map zones for the conterminous US. NatureServe developed 26 sequence tables for these 66 map zones (Figure 1).
3. LANDFIRE also contracted with NatureServe to have dichotomous field keys written for all of the U.S. map zones. These keys were developed to cover the same map zones clusters as the sequence tables, and are available in MS Word documents for all of the U.S.
4. From a data processing standpoint, the vegetation samples first had to be formatted to match the specifications of the auto-key program created by USFS Missoula Fire Lab staff. We do not detail these formatting requirements here, as they are rather complex, and are completed by LANDFIRE contractors.
5. The sequence tables and vegetation samples are run through an automated Python application, developed by staff at the Missoula Fire Lab, called the "auto-key". The auto-key program sequentially compares each vegetation sample against criteria contained in the sequence table. Each ecological system type is represented in the sequence table via a set of vegetation composition criteria, which are organized in a particular order, or "sequence" (hence Sequence Table, or SQT). Each plot or point must meet all of the criteria for a particular ecological system, as represented by one sequence. If the sample meets all the criteria, the auto-key attributes the plot with the ecological system code and name. Samples which do not meet the criteria for a system can be attributed either with a more generic label, such as "unclassified forest and woodland", or else go through the entire SQT without keying and are attributed with "none".

Other land cover classes, such as introduced annual grasslands, or introduced riparian woody vegetation, are also included in a SQT to appropriately attribute any vegetation samples representing those land cover classes.

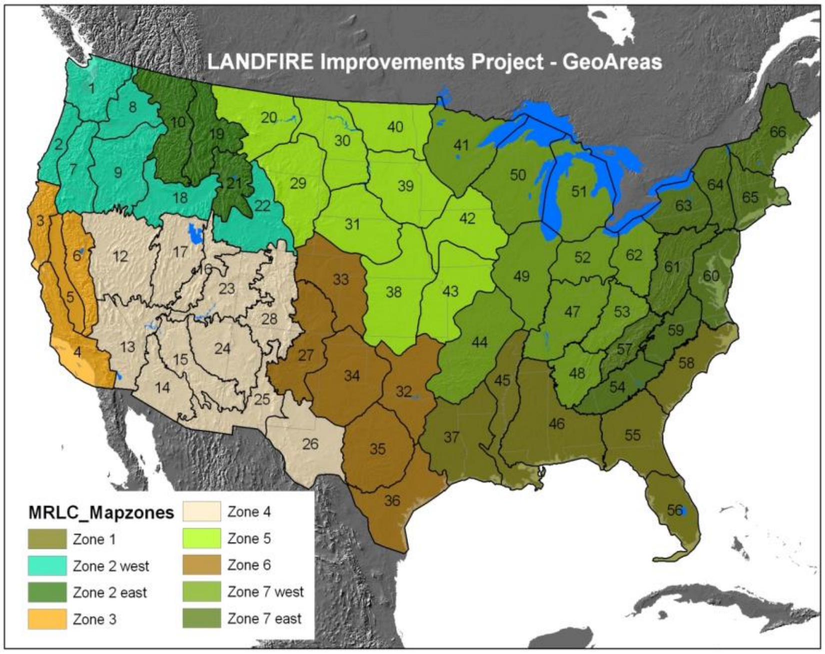
Figure 1. Groups of MRLC map zones that were the analysis units for the LANDFIRE sequence tables in the coterminous U.S.



Methods

For the LANDFIRE effort, both dichotomous field keys and auto-keys were developed for map legend classes and organized in a series of 17 map zone groupings that spanned the nation. For ongoing maintenance of national map products, the map zone groups have been further aggregated by LANDFIRE into larger geographic areas (GeoAreas). This project was organized around a modified form of these LANDFIRE GeoAreas (Figure 2). Within each GeoArea, project ecologists were provided with a subset of sample data for each relevant LANDFIRE map class (up to 30 sample plots). Using sample data on vegetation composition and structure, along with limited mapped ancillary data (for general orientation and ecological context), ecologists applied a map legend label to each sample. They documented their expert process for making label assignments, highlighting key pieces of information they used to arrive at their determination. The expert assignments were then compared to those previously applied through the LANDFIRE auto-keys assignments on spatially located field plots. Contingency tables were developed, analyzed, and documented. Key outcomes from each expert analysis include the contingency table, systematic discrepancies between expert and auto-key labels, and recommended changes to the auto-keys and technical procedures.

Figure 2. Modified LANDFIRE GeoAreas in the conterminous U.S. for use in this project.



Sample data were segmented by those that were used directly in LANDFIRE map production versus those that were held aside for use in accuracy assessment. Therefore, an expert-reviewed, independent sample data set for accuracy assessment was an additional project outcome. Expert ecologists were also be well-positioned to evaluate the results of auto-key assignments for LANDFIRE map legend classes in light of the related NVC Group and Macrogroup vegetation concepts that have been established and described.

For the expert reviews, the team needed to first determine the plot data available for use in the project and the sample design for selecting a subset of those plots. Secondly an evaluation was required of what kinds of data are contained in the plots that could be used for the expert review. The analysis team obtained counts of plots by map zone, GeoArea and system or land cover type, as well as counts of how many were used as training data in the mapping effort, or were withheld and used as the initial accuracy assessment plots. Additional counts were obtained for the number of plots acquired after the LANDFIRE mapping effort was completed in each GeoArea. A series of calls were held to discuss the number and distribution of plots by system type to be used in a "sample draw" for the expert review. Once the number of plots by system type by GeoArea was decided upon, the sample draw was completed by TNC and EROS team members, by selecting plots for each system randomly across all map zones in the GeoArea, with "independent" plots (not used in the original mapping effort) given selection priority.

The analysis team then reviewed in detail the available data tables and fields that are stored and managed in the LANDFIRE Reference Database (LFRDB). The data in the LFRDB is derived from many source datasets of varying quality and completeness. In addition, many plots in the LFRDB for forest types were provided by the Forest Inventory and Analysis (FIA) program, which has restrictions on sharing of their data. The discussions about what data to provide the experts for use in the labeling centered around:

1. Providing the same data as are used in the auto-key procedures
2. Providing additional data that were not originally used in the auto-keys, and
3. Maintaining the "privacy" of the FIA data, ensuring the experts could not determine which plots were FIA vs not

Table 1 is a list of the general categories of data that were extracted from the LFRDB and provided to the experts for use in their review. After much discussion, it was also determined to provide a remotely-sensed image clip for each plot, as well as between 1 and 3 on-the-ground photos for the plot if such were available from the original data providers. These images provide some context for the expert reviewer, without revealing the exact location of the plot. The image clips were created automatically from the plot coordinates, and in the lower 48 were from NAIP imagery. All images were of the same scale, with the plot location a dot in the center of the image (Figure 3 is an example).

Table 1. Categories & fields of data provided to expert during review process

Data category	Fields	Notes
Vegetation Structure	% cover of trees, shrubs, herbs, trees per acre, height of trees or shrubs	Values are calculated from source data & stored in LFRDB
Floristic composition	complete species list, % cover by species, nativity, height if available	Species list & % cover values are from the original source data, but other fields were derived by LANDFIRE
Dominant species	the 2 most dominant species within the major lifeform of the plot	The dominant and codominant species are provided, with % cover; the species are drawn from the dominant lifeform category of the plot (e.g. shrub dominated plots will have shrub species listed)
Geographic setting	map zone, USFS subsection, TNC ecoregion	These are derived by LANDFIRE from the coordinates of the plot
Landscape setting	elevation, aspect, slope	Values are derived form a DEM for the coordinates of the plot
Field notes	comments from field crew	Original field crew comments, if available
Image clips	Single image, same areal extent/scale for all plots	NAIP imagery was used for coterminous U.S. plots; coordinates in center of the image; no other locational information provided.

Figure 3. Example of an image clip for one plot in GeoArea 1

NatureServe developed a MS Access 2007 relational database (the Expert Attribution Database, EADB) for use in the project. A user interface was designed to link to the above LFRDB data (provided by EROS in a separate LFRDB), the image clip, and any ground-photos in easily navigated forms for review by the expert. An additional form allowed the expert to select from a subset of system types when labeling plots. The reviewer was required to select from the ecological systems known or highly probable to occur in the GeoArea. If the expert could not label the plot with a system type, then "can't assign" was an additional option. All plots also required a confidence in label assignment (high, medium, low) and the expert was asked to document in comments why they assigned that confidence, or why they could not assign it to an ecological system.

After the expert reviews were completed for a particular GeoArea, the results were run through several quality control procedures to check for plots missing labels, or other discrepancies in the resulting data. Then a number of queries were run in the Access database, to generate summary statistics for each GeoArea, comparing labels on plots from the auto-keys and the experts.

Analysis Team

- Patrick Comer, NatureServe

- NatureServe Regional Ecologists (Marion Reid, Kristin Snow, Mary Harkness, Gwen Kittel, Keith Schulz, Mark Hall, Milo Pyne, Carl Nordman, Judy Teague, Lesley Sneddon, Jim Drake, Shannon Menard)
- Anne Davidson, GAP
- Don Long, USFS RMRS
- Brenda Lundberg, EROS
- Chris Toney, USFS FIA
- Alexa McKerrow, GAP
- Gretchen Meier, EROS
- Chris Lea, NPS
- Jim Smith, TNC, Overall Coordinator

Intended Products of this Effort

2.1 Tabular comparisons (as contingency tables) between LANDFIRE auto-key assignment and expert assignment for each GeoArea data set with an associated interpretation of the outcomes (systematic discrepancies between expert and auto-key labels, and recommended changes).
2.2 A report by each GeoArea detailing processes and results, specifically identifying how they made individual assignments.
2.3 A report that documents procedures and data elements to improve the auto-key process in each GeoArea.
2.4 A report that documents technical procedures to adapt auto-keys for labeling NVCS group, Macrogroup, and Division concepts.
2.5 Full data sets with independent assignments for each GeoArea in standard LFRDB format.
2.6 A single overall report with recommendations for all GeoAreas, including commonalities and unique issues.

Results

The following results for GeoArea 1 are organized according to these primary product deliverable categories:

2.1 Tabular comparisons (as contingency tables) between LF auto-key assignment and expert assignment for each GeoArea data set with an analysis and reports document (identified, systematic discrepancies between expert and auto-key labels, and recommended changes).
2.2 A report by each GeoArea detailing processes and results, specifically identifying how they made individual assignments.
2.3 A report that documents procedures and data elements to improve the auto-key process in each GeoArea.
2.4 A report that documents technical procedures to adapt auto-keys for labeling NVCS Group, Macrogroup, and Division concepts.

GeoArea 1: Southeast

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 (Figure 2, 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 (Figure 1). 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

2.1 Tabular comparisons (as contingency tables) between LF auto-key assignment and expert assignment for each GeoArea data set with an analysis and reports document (identified, systematic discrepancies between expert and auto-key labels, and recommended changes).

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 2). 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 2. Under-sampled types within GeoArea 1

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

EVTCode	EVT Name	Ecological System elcode	Total Plots
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 3 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 3. 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
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

				Plots with Expert Matches				
EVT Code	**EVT Name**	**System Elcode**	**Total Plots**	**Total**	**%**	**High conf**	**Med conf**	**Low conf**
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

2.2 A report by each GeoArea detailing processes and results, specifically identifying how they made individual assignments.

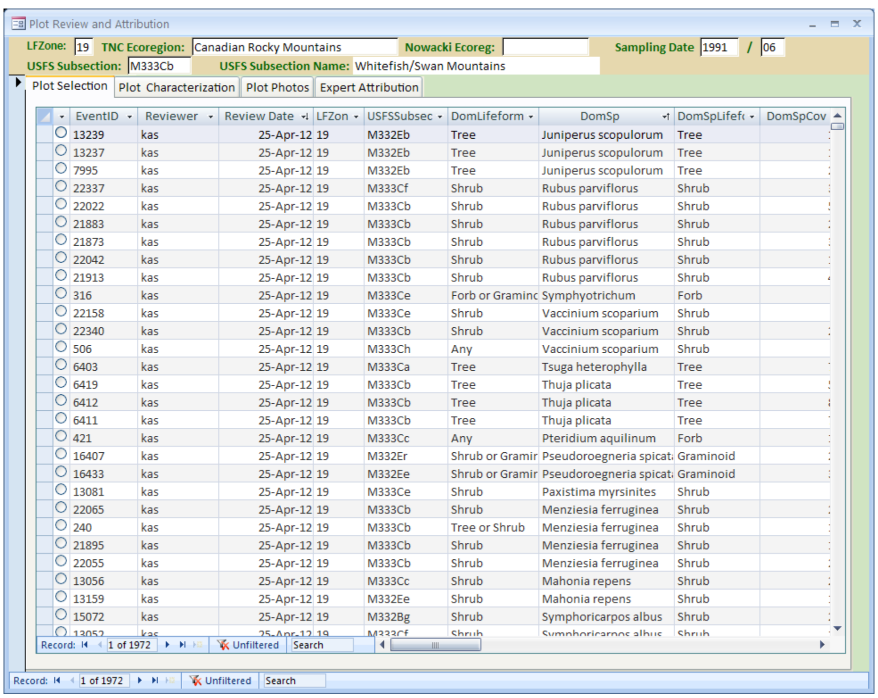
As described in the methods section above, the expert reviewers worked directly in the expert attribution database (EADB). Since GeoArea 1 had over 1,000 plots to review, a systematic, efficient process for reviewing and labeling plots was required. The forms provided in the EADB allowed the reviewer 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. Figure 4 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.

Figure 4. Screen shot of EADB form, showing some of the data the expert reviewer could select from or sort on to efficiently review similar plots


Plot Review and Attribution

LFZone: 19 TNC Ecoregion: Canadian Rocky Mountains Nowacki Ecoreg: Sampling Date 1991 / 06

USFS Subsection: M333Cb USFS Subsection Name: Whitefish/Swan Mountains

Plot Selection | Plot Characterization | Plot Photos | Expert Attribution

EventID	Reviewer	Review Date	LFZon	USFSSubsec	DomLifeform	DomSp	DomSpLifefo	DomSpCov
13239	kas	25-Apr-12	19	M332Eb	Tree	Juniperus scopulorum	Tree	
13237	kas	25-Apr-12	19	M332Eb	Tree	Juniperus scopulorum	Tree	
7995	kas	25-Apr-12	19	M332Eb	Tree	Juniperus scopulorum	Tree	
22337	kas	25-Apr-12	19	M333Cf	Shrub	Rubus parviflorus	Shrub	
22022	kas	25-Apr-12	19	M333Cb	Shrub	Rubus parviflorus	Shrub	
21883	kas	25-Apr-12	19	M333Cb	Shrub	Rubus parviflorus	Shrub	
21873	kas	25-Apr-12	19	M333Cb	Shrub	Rubus parviflorus	Shrub	
22042	kas	25-Apr-12	19	M333Cb	Shrub	Rubus parviflorus	Shrub	
21913	kas	25-Apr-12	19	M333Cb	Shrub	Rubus parviflorus	Shrub	
316	kas	25-Apr-12	19	M333Ce	Forb or Graminc	Symphyotrichum	Forb	
22158	kas	25-Apr-12	19	M333Ce	Shrub	Vaccinium scoparium	Shrub	
22340	kas	25-Apr-12	19	M333Cb	Shrub	Vaccinium scoparium	Shrub	
506	kas	25-Apr-12	19	M333Ch	Any	Vaccinium scoparium	Shrub	
6403	kas	25-Apr-12	19	M333Ca	Tree	Tsuga heterophylla	Tree	
6419	kas	25-Apr-12	19	M333Cb	Tree	Thuja plicata	Tree	
6412	kas	25-Apr-12	19	M333Cb	Tree	Thuja plicata	Tree	
6411	kas	25-Apr-12	19	M333Cb	Tree	Thuja plicata	Tree	
421	kas	25-Apr-12	19	M333Cc	Any	Pteridium aquilinum	Forb	
16407	kas	25-Apr-12	19	M332Er	Shrub or Gramir	Pseudoroegneria spicat	Graminoid	
16433	kas	25-Apr-12	19	M332Ee	Shrub or Gramir	Pseudoroegneria spicat	Graminoid	
13081	kas	25-Apr-12	19	M333Ce	Shrub	Paxistima myrsinites	Shrub	
22065	kas	25-Apr-12	19	M333Cb	Shrub	Menziesia ferruginea	Shrub	
240	kas	25-Apr-12	19	M333Cb	Tree or Shrub	Menziesia ferruginea	Shrub	
21895	kas	25-Apr-12	19	M333Cb	Shrub	Menziesia ferruginea	Shrub	
22055	kas	25-Apr-12	19	M333Cb	Shrub	Menziesia ferruginea	Shrub	
13056	kas	25-Apr-12	19	M333Cc	Shrub	Mahonia repens	Shrub	
13159	kas	25-Apr-12	19	M332Ee	Shrub	Mahonia repens	Shrub	
15072	kas	25-Apr-12	19	M332Bg	Shrub	Symphoricarpos albus	Shrub	
13052	kas	25-Apr-12	19	M333Cf	Shrub	Symphoricarpos albus	Shrub	

Record: 1 of 1972 Unfiltered Search

Record: 1 of 1972 Unfiltered Search

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

2.3 A report that documents procedures and data elements to improve the auto-key process in each GeoArea.

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 4.

Table 4. 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 Forest	Hard to tell if this is a large river, small stream, or what. Presence of *Taxodium ascendens* is questionable 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.

Adapting auto-keys for NVC Groups, Macrogroups, and Divisions

2.4 A report that documents technical procedures to adapt auto-keys for labeling NVCS Group, Macrogroup, and Division concepts.

US-NVC Groups

In an effort to understand the potential implications of adapting LANDFIRE auto-keys for use with the revised US-NVC, we first compared the mapped ecological system types within this GeoArea to their related US-NVC Group concepts. These two classification concepts, with the NVC designed solely using existing vegetation, and ecological systems combining existing vegetation and biophysical factors, are most closely related at the Group level of the revised US-NVC hierarchy. Since these two classifications have been thoroughly related to each other, these relationships should provide insight for the task of updating auto-keys for use with the US-NVC.

Within this GeoArea, some 167 terrestrial ecological system types could occur. Of these, 7 ecological system concepts have a practical 1:1 relationship with NVC Group concepts, and 157 of the remaining ecological system concepts nest cleanly within 42 NVC Group concepts. Three ecological systems had not been assigned an NVC Group. Those include South-Central Interior Small Stream and Riparian (CES202.706), South-Central Interior/ Upper Coastal Plain Wet Flatwoods (CES203.480), and South-Central Interior / Upper Coastal Plain Flatwoods (CES203.479). There is some potential for slight differences among floristic elements among these NVC Groups relative to ecological systems. For example, one or more associations linked to a given terrestrial ecological system type may now be linked to a different NVC Group concept. There is some limited potential that the floristic information found within the auto-key would need to be revisited to account for this, but within this GeoArea, we believe that this instance is quite limited.

Where the relationship between ecological systems and NVC Groups is more complex, there is potential need for substantive changes to existing auto-keys. Within this GeoArea, no ecological system types have a more complex relationship with NVC Group concepts (Table 5).

In GeoArea1 the ecological systems concepts are finely tessellated, making the relationship to the newly defined NVC Groups straightforward, avoiding the many to many relationships that would occur with more generalized ecological systems. The trade off however is the difficultly in classifying plots to the numerous types with the limited information available through most of the existing datasets. For other parts of the country the ecological systems to Group crosswalks are more complex, making an analysis of the improvement in the auto-key process at the Group level less relevant, therefore we do not include that summary here.

Table 5. Ecological Systems of GeoArea 1 that have complex relationships with US-NVC Groups.

There are no GeoArea 1 Ecological Systems that have complex relationships with US-NVC Groups.

US-NVC Macrogroups

Ecological Systems can be fairly comfortably rolled up to broader US-NVC Macrogroups, which cover the existing-vegetation component of their related ecological systems. Using LANDFIRE auto-keys for US-NVC Macrogroups instead of ecological systems could potentially resolve disagreements between experts and auto-keys found at the ecological systems level. To evaluate the potential effect of using the auto-key for Macrogroups, we arranged the ecological system types by US-NVC Macrogroup in the expert-auto-key contingency table (Results Workbook), and also compared the percent of expert to auto-key matches at the ecological system level versus the Macrogroup level (Table 6).

There are 13 US-NVC Macrogroups represented among natural mapped classes in this GeoArea. While the results in Table 6 suggest rolling up to Macrogroup would yield improved results, consideration must be given to the fact that many of these Macrogroups are in fact very broad concepts, and include diverse ecological system types. For example, three very broad Macrogroups together encompass 19 ecological systems and a large proportion of the natural upland forest acreage of GeoArea 1. These are:

- M007 Longleaf Pine & Sand Pine Woodland
- M008 Southern Mixed Deciduous-Evergreen Broadleaf Forest
- M016 Southern Hardwood & Pine Forest

Since these Macrogroups are broad regional units, they do not allow for many of the advantages of accurate ecological system assignments. At the scale of a regional mapping effort, distinguishing amongst the ecological systems is a desirable outcome; oftentimes outweighing the disadvantage of less accurate mapping results. More investment in field data collection, meeting minimum criteria of complete species composition, structural data, and environmental parameters would provide improve results in the auto-key. These field data then also lead to a better understanding of floristic and biogeographic patterns overall for individual systems which can then be incorporated into the sequence tables.

Auto-key results to Macrogroup and use in mapping would leave a lot of unanswered questions about the auto-keyed forest vegetation, but might be more appropriate for more extensive mapping efforts, or where the desired outcome does not require more detailed understanding of vegetation patterns in a landscape.

Some examples of how generalizing up from the ecological system to Macrogroup level would improve the agreement between the auto-key and expert assignments include:

For the upland longleaf pine types, rolling up to the Macrogroup level with the current auto-key assignments would increase the assignment agreement by 13%. This change would mean the primary diagnostics for assigning the plots would be the dominance of longleaf pine, the upland environment or indicators. The need to understand the biogeographic context would be reduced. At the Macrogroup level, it would still be important to distinguish between the Longleaf Pine & Sand Pine Woodland (M007), Wet Longleaf Pine & Southern Flatwoods (M161), as well as planted or ruderal pine types.

Generalizing the classification to the Loblolly & Shortleaf Pine – Oak Forest & Woodland Macrogroup would improve the agreement from the current auto-key assignments by 16% by removing the need to distinguish between West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland (CES203.056) and West Gulf Coastal Plain Pine-Hardwood Forest (CES203.378). In order for the disagreement at the Macrogroup level to be reduced further, it would require refinement of the keys relative to ruderal, unclassified and planted forest classes.

Southern Mixed Deciduous – Evergreen Broadleaf Forest (M008) improves slightly over the component ecological systems agreement.

Agreement in the Southern Coastal Plain Evergreen Hardwood & Conifer Swamp (M032) increases only slightly over the member ecological systems. Real improvement in the assignment will require making the distinction between the concepts underlying the seepage swamps and baygall systems, specifically the Atlantic Coastal Plain Streamhead Seepage, Swamp, Pocosin and Baygall (CES203.372; M032) and the Atlantic Coastal Plain Peatland Pocosin and Canebrake (CES203.267; M065) clearer.

Comment [AM1]: I am not sure how the math works on this – in order to go to 38% at the macrogroup level – 40 plots have to be correct. In the contingency table – there are 34 correct and 1 that would become correct if the three systems are combined into M032.

Comment [kls2]: There are an additional 5 systems with expert attributions to CES203.501 which is in MG032 but not an autokey system (an "other" system).

Table 6. Comparison of auto-keyed results when plots keyed to systems are rolled up to Macrogroups, showing percent of matches at the system level compared to Macrogroup level

Macrogroup	# auto-keyed systems	# plots	% expert matches at system level	% expert matches at MG level
M007 Longleaf Pine & Sand Pine Woodland	7	293	68%	81%
M008 Southern Mixed Deciduous-Evergreen Broadleaf Forest	6	152	14%	26%
M157 Loblolly & Shortleaf Pine - Oak Forest & Woodland	2	77	62%	78%
M016 Southern Hardwood & Pine Forest	6	130	45%	48%
M153 Central Mesophytic Hardwood Forest	3	75	13%	16%
M032 Southern Coastal Plain Evergreen Hardwood & Conifer Swamp	3	106	32%	38%
M033 Southern Coastal Plain Basin Swamp	2	57	9%	9%
M161 Wet Longleaf Pine & Southern Flatwoods	2	41	46%	46%
M309 Southeastern Coastal Plain Patch Prairie [Placeholder]	1	2	50%	50%
M057 Eastern North American Coastal Grassland & Shrubland	1	1	0%	0%
M065 Atlantic & Gulf Coastal Plain Bog & Fen	1	1	0%	0%
M067 Atlantic & Gulf Coastal Plain Pondshore & Wet Meadow	1	2	0%	0%
M079 Eastern North American Atlantic Salt Marsh	1	12	0%	42%

US-NVC Divisions

NVC Divisions are substantially simplified vegetation concepts relative to terrestrial ecological system types, so auto-keys designed for these concepts would be relatively simple to develop. Within GeoArea 1, we would recommend starting from a new baseline starting point in order to adequately design one auto-key to encompass the 10 natural US-NVC Division concepts that occur here.

Discussion

Comment [AM3]: There probably needs to be a section on semi-natural types – and disturbance regimes and handling those in the keys – standardizing the concepts of ruderal and managed types.

Comment [AM4]: There might be a place for a recommendation related to the fact that the autokeys or the screening process prior to subjecting plots to the autokeys need to be sensitive to rapid land use change. This will vary widely across the u.s.

The LANDFIRE reference database is the first attempt by a single agency to compile comprehensive georeferenced vegetation data for the United States. As such it is a powerful tool for use in many different applications, but there are caveats that must be clearly understood by the user(s) of the data and the results. Sequence tables are an innovative method for rapidly and efficiently keying thousands of vegetation samples; for LANDFIRE they were developed to key to ecological systems and land cover classes, but could be modified to key to any floristically-based vegetation types, such as the Group level of the NVC hierarchy.

Fundamentally, a sequence table as used by LANDFIRE is a set of criteria. Each vegetation sample has to meet some combination of criteria in the SQT to be labeled with an ecological system, or some other land cover class. Simply put, if the plot doesn't meet any criteria contained in the sequence table, then it may be mis-keyed, or not key to anything. Given our incomplete knowledge of the structural and floristic variability of each classification unit, it is nearly impossible to establish criteria in a sequence table - for regional application - to successfully and accurately key 100% of vegetation samples. However, with new field-based inventory and increasing ecological understanding, over time sequence tables can be revised and improved so as to accurately key increasing percentages of vegetation samples.

There are a number of reasons why a sequence table may not successfully key all samples run through it:

a) the unknown floristic quality of the vegetation data (how complete, how well collected, does it accurately represent the vegetation concept being keyed);
b) our limited knowledge of the variability in species composition, vegetation structure, and the distribution of ecological systems; and
c) the comprehensiveness (or lack thereof) in field inventory for any particular system (e.g., many from one small area, few to none from elsewhere in the region).

Each of these is discussed below.

A. Quality of vegetation data

First and foremost, the completeness and quality of the data as collected in the field, as well as the documentation of how the data were collected (the metadata) are primary issues for how well the sequence table process works. There are many different kinds of issues with the data collection, only a few of which are listed here as possible sources of problems:

- Was the species composition adequately sampled (complete species list)?
- Were only trees recorded (e.g., some FIA plots)? Only "dominant" or "most characteristic" species (e.g., SWReGAP training data)?
- Was the sample plotless, or within a plot or some other measured area?
- Or were the samples derived along transects?
- How was the cover or abundance data collected, or was it presence/absence?
- Was the sample area across an ecotone (for example across the transition from a wet valley bottom into the adjacent upland slope)?
- Does the sample adequately represent an occurrence of the vegetation type being sampled?
- Was the species taxonomy accurately recorded (many species are difficult for untrained crews to identify, such as *Carex* spp., or *Salix* spp.)?
- Were difficult species "lumped up" into broader taxon, such as genus, or even family?
- Was the sample location heavily or recently disturbed?

Many datasets obtained by the LANDFIRE team had inadequate metadata associated with them. Inadequate documentation of the sampling design or of what the values in the data tables represented, could result in incorrect processing of the data for use in the sequence tables.

The sampling design under which vegetation data was collected is an often neglected piece of metadata. A particular dataset could have many hundreds of plots in it, but the purpose(s) for which they were collected could be such as to negate their value for identifying floristically distinct vegetation types. For example, samples collected in a systematic grid without regard for sampling distinct vegetation types will often cross multiple ecological systems, and hence result in data that give erroneous results in an auto-key process.

An example of poor documentation of the collection protocols would include species names collected and provided as 4- or 6-letter acronyms, without a complete list of what species each acronym represents. The processing of the data into the LFRDB converts acronyms to full species utilizing the current NRCS PLANTS 'symbols'. So, POTR could be *Populus tremuloides*, *Poa tracyi,* or *Poa trivialis*, all valid species. But using PLANTS, POTR = *Poa tracyi*, while *Populus tremuloides* is POTR5. Each dataset has to be reviewed for its species taxonomy to ensure any acronyms are converted to the correct taxa, but without adequate metadata errors can creep in.

Another example would be where the species abundance data were collected in generalized "cover classes", and these had to be converted to "real cover" by using the mid-point of the class. If the metadata did not include documentation of what the classes represent, then the mid-points could be incorrectly converted, or even unobtainable. For example, cover class 3 could mean 5-25% cover (mid-point of 15%), or it could mean 25-35% cover (mid-point 30%). The sequence table process utilizes cover criteria for indicator species extensively, so incorrectly interpreted cover classes will lead to errors in the results.

B. Constraints within sequence table

Ecological systems are classified using a multi-factorial approach, including environmental factors, ecological processes and vegetation structure and composition. However, the sequence table process as currently developed and used by LANDFIRE does not allow use of local-scale environmental factors which might assist with distinguishing among floristically similar ecological systems. For example, how would one use avalanche slopes in an automated plot keying process? Or high-gradient vs. low gradient stream flow-regime? These are diagnostic features of one or more ecological systems that facilitate ready recognition in the field, but if floristic information is limited there may be no way to identify individual plots that occur on these features.

The early versions of the auto-key only allowed use of vegetation structure and composition data. The most recent auto-key does allow the use of elevation data which is helpful in accurately labeling plots to ecological systems that can be readily distinguished by elevation zones. The auto-key allows use of regional-scale variables, such as occurrence in a TNC ecoregion, or a USFS Section. Beyond these 2 variables (elevation and general geographic location) the auto-key does not currently allow use of any other more local-scale environmental variables, such as aspect, slope, landforms, soils conditions, etc.

Over time, as our knowledge of the floristic composition and structure of vegetation in the United States becomes more complete, local-scale variables may not be needed. If the plot data themselves are complete (meaning the species composition has been adequately sampled and recorded for the plot) we can infer environmental setting and characteristic ecological dynamics through the use of indicator species. For example, *Heracleum maximum* to indicate mesic or wet understory conditions for wetland and riparian ecological systems or *Juncus drummondii* and *Caltha leptosepala* to indicate alpine wetland sites, or the predominance of *Festuca idahoensis* as a montane or subalpine grassland indicator. However, it's generally the combination of multiple species in varying abundance that are used in a sequence table to key plots; hence incomplete or poorly collected species compositional data generate poor results from the auto-keying process.

In comparison, dichotomous field keys to the ecological systems of a region do allow incorporation of the environmental or ecological "context" of a vegetation sample. In a field key, you can explicitly state "if you are in a marsh, then go to this part of the key...." or "if you are in the alpine, go here…", or "if this place is in the path of regular avalanches, go to this part of the key…". One of the LANDFIRE products is a set of dichotomous keys to be used in the field, for all ecological systems and land cover classes in groups of MRLC map zones.

C. Developing automated keys for large geographic areas

Each sequence table was constructed to work across relatively large geographic areas, on the order of 2-5 USFS Sections (Figure 1). Hence each sequence table/auto-key included tens of ecological system types, and each system has some degree of compositional and structural variability across that region.

It's difficult to account for all compositional or structural variability that might occur in a single system type across a large geographic area. For example, western coniferous forests can vary from 25% tree cover to well over 90% cover, but in some patches may be less than 25%. Montane coniferous forests and woodlands on the Colorado Plateau are highly variable, with total tree cover ranging from 15% to >75%, with a diverse array of shrub associates, or sometimes no shrubs, and with little to no herbaceous component, or very high herbaceous cover. There are at least 4 different ecological systems for these montane forests; while the tree species are not particularly diverse, the possible shrub or herbaceous indicators are highly diverse. So, in this case the trees are not good indicators of the different ecological systems, and the shrubs are also only partially adequate. It is the herbaceous component that is particularly useful to key these systems, but when the plots are lacking in herbaceous data the task becomes much more difficult.

Another example is montane riparian shrublands of the southern Rocky Mountains, which are primarily placed into one ecological system. But to correctly key plots to the riparian system, the auto-key needs to account for every possible dominant shrub that might be found in a plot in the riparian zone (e.g., *Salix bebbiana, Salix geyeriana, Crataegus rivularis, Forestiera pubescens, Prunus virginiana, Rhus trilobata, Salix irrorata, Salix lucida, Shepherdia argentea, Betula occidentalis, Alnus incana, Salix exigua, Salix lasiolepis, Salix lutea, Salix ligulifolia,* etc.).

D. Cost/benefit & efficiency

The purpose of the auto-key process is to accurately key many hundreds of vegetation samples for each desired map class (ecological system or land cover) to feed into a mapping process. While a single georeferenced sample may be lacking in the complete floristics of an occurrence of an ecological system, the sequence table process aims to attribute many dozens to hundreds of plots to each ecological system or land cover class.

Auto-keys take a significant amount of time to develop for a region, and then to test, review, refine, and test again. A single auto-key for LANDFIRE typically took somewhere between 4 and 7 person days to create and refine. And, that assumes an agency such as SEM has already completed data compilation and processing for use. Some auto-keys for regions with large numbers of samples (for example map zones 1, 2, and 7 in the Pacific Northwest had over 100,000 plots) probably took closer to 10 person days to develop.

However, sequence tables can be refined over and over. The identification of combinations of species indicative of particular geographic or ecological settings is an ongoing effort amongst vegetation ecologists, and a repeatable and refine-able method such as this has distinct advantages. As we become more knowledgeable, field data becomes more comprehensive, and well collected datasets become more numerous, sequence tables can be improved until they successfully key 95% or more of the plots fed through them. This is a huge advantage for regional and national classification and mapping efforts, especially when it is desired to repeat them over some specified time frame with new imagery or new mapping methods.

Recommendations (draft)

This report section requires further development and interpretation; this is preliminary material. After other GeoAreas have been analyzed this section will be more completely written up. Recommendations may vary somewhat across the country, but we anticipate some general patterns relevant to all sequence tables and GeoAreas.

Adjustments to Auto-key procedures – inclusion of locational/biophysical information for pre-processing plots and/or inclusion of features in auto-keys

Narrowing vs. broadening the geographic application of the auto-key – FS Sections? In certain areas? Would this likely lead to greater accuracy?

Adjustment to auto-keys – additional requirements for vegetation sample data; primarily ground cover data

Expert review and labeling of plots for types of low confidence from auto-key.

Adjustments to Map Legends – moving to Group/Macrogroup concepts where systems level remains challenging – which ones?

Coping with uncertainty; what proportion of types could NOT be adequately handled through any of the above adjustments?

Careful review of the dominant tree, shrub, or grass elements shared among related types, should be the focus of auto-key improvements for these types.

In the southeast U.S., rapid land use change and past management are huge drivers of vegetation. There are instances where land use change had occurred between the date of the plot data collection and the taking of the aerial photograph.

There is a need to standardize the concepts for ruderal and managed types.