

Developing Auto-Keys for LANDFIRE Vegetation Mapping: 2014-2015 CONUS Project Report

The NatureServe Conservation Science Division

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To BLM and the Inter- Agency LANDFIRE Program

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*Photos: Spruce-Fir Forest on Sandia Mountains, NM (left);
Basalt Pothole Pond, Eastern WA (right)*

Acknowledgements

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Sue Gawler, Maine; Laurentian-Acadian Freshwater Marsh

We are very sad to note the recent passing of our dedicated and accomplished colleague, Sue Gawler, to ALS. Before her diagnosis in 2010, Sue spent many weeks and months in the field with us, knew the natural communities of Maine like the back of her hand, and worked on the ecological systems classification and first round of LANDFIRE keys. Her expertise, friendship, and warmth will be greatly missed.

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Introduction and Background

The Inter-agency LANDFIRE Program produces dynamic models and map products related to vegetation and fire regime that are of broad benefit to the public for addressing a wide variety of questions, including natural resource inventory, assessment, planning, and monitoring. LANDFIRE has implemented a series of new procedures and tools for processing vegetation sample plot data for dynamics modeling and vegetation mapping. Since 2005, this effort has made substantial advances in compiling and 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.

LANDFIRE was initiated using the NatureServe terrestrial ecological systems classification (Comer et al. 2003) as the basis for conceptual and spatial modeling of fire regime. LANDFIRE map products include biophysical settings (potential/historical distributions of each ecological system type), existing vegetation type (EVT), vegetation structure, and other fire regime derivatives. Auto-keys are used to automatically apply labels to georeferenced sample data according to the map classification, and these samples then feed into spatial modeling of these types. Previous evaluations of the LANDFIRE Auto-Keys (A-Ks) (Comer et al. 2012; hereafter “Improvements #1” LANDFIRE project) resulted in recommendations for how A-K performance could be enhanced through redesign. Additionally, since the first iteration LANDFIRE map products were completed prior to adoption of the revised U.S. National Vegetation Classification (USNVC, or NVC) (FGDC 2008), LANDFIRE may now choose to map existing vegetation types (EVT) using the new NVC standard. Therefore, this project was designed to update and redesign A-Ks for labeling georeferenced samples to both terrestrial ecological systems and NVC units that could be mapped by LANDFIRE, BLM, and other users.

LANDFIRE is now moving into a remapping effort for the U.S. and its insular areas. In 2013, LANDFIRE identified the need to revise the original sequence tables, and the desire to develop a new map legend that utilizes the Group level of the USNVC. In the 2014 LANDFIRE Program business plan (LANDFIRE 2014)¹, a suite of new mapped products was identified as desirable, and the goals, requirements and production strategies for this next mapping effort are now under development with mapping partners.

The work discussed in this document is in support of this new mapping effort by the LANDFIRE Program. Under this project, additional analysis was completed and suggested improvements to the LANDFIRE Auto-Keys were implemented, and a set of A-Ks were delivered that are fully functional with labels on georeferenced samples for LANDFIRE mapping of Terrestrial Ecological Systems and NVC Groups. An attribute table enables labeling of all plots to the NVC hierarchy units above the Group, including Macrogroup, Division, Formation, Subclass, and Class (FGDC 2008) along with cultural land use classes in the United States. Semi-natural vegetation was treated as feasible using USNVC concepts (e.g., Macrogroup or Group).

Background on LANDFIRE Legend and Auto-keys

LANDFIRE 2001

A major need of LANDFIRE was to compile georeferenced vegetation data for the entire United States. These data needed to be combined into one database and attributed in a consistent, repeatable fashion to a standardized classification of vegetation types or to standardized of land use or land cover classes. Since at the time it was the only classification that had been successfully applied to regional scale vegetation mapping at relatively high thematic resolution, the chosen classification system and map

¹ http://landfire.gov/documents/LF_Program_Business_Plan_2014.pdf

legend for LANDFIRE was the classification of Terrestrial Ecological Systems developed by NatureServe (Comer et al. 2003). Once attributed with ecological systems, the georeferenced samples were used as training data in a mapping effort that utilized remotely sensed imagery and other mapped geophysical data for spatial modelling. 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, georeferenced vegetation samples (also called “plots” for sample 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 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 (the “key”); 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 were originally called Sequence Tables, and the software application called the Auto-key. Hereafter, the term sequence tables is used interchangeably with auto-keys.

One of the main requirements for LANDFIRE map units was that they be floristically distinct, and could be differentiated floristically. Since abiotic variables were not consistently available for every plot, only a few abiotic attributes could be used to differentiate vegetation types represented by the plots. In addition, sequence tables were intended to work regional-scale patterns, as opposed to more local-scales.

LANDFIRE’s short-term needs, and long-term plans, required a repeatable methodology, with 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 georeferenced vegetation data to a land cover class, whether it’s an ecological system type or some other classified vegetation type.

The initial set of products, LANDFIRE National, were completed by LANDFIRE in December of 2009. Hereafter, the first LANDFIRE effort is referred to as LANDFIRE 2001 reflecting the time of the imagery used in the mapping (rather than using 2009 as the date of completion). Every two years LANDFIRE releases updates to the 2009 products to reflect change (typically, large wildfire scars) in the landscape over time.

LANDFIRE 2001 Legend

An additional role played by NatureServe during the LANDFIRE 2001 effort was the development of a standardized map legend, using the Terrestrial Ecological Systems as the base units, but then including other land cover classes that reflected common types of altered vegetation and human land uses. This process required a detailed review of the ecological system types and identification of those that occur at such fine spatial scales as to be generally un-mappable in regional mapping efforts. In addition, for LANDFIRE’s purposes, wetlands, riparian vegetation, and sparsely vegetated ecological systems (e.g., dunes, alpine bedrock, desert pavement, badlands, and cliffs) were aggregated into thematically broader units for use in the LANDFIRE mapping and modeling processes.

The other land cover classes in the master legend included such things as developed areas, agriculture, tree plantations, categories of vegetation dominated by exotic species or invasive plants, open water, and so on.

The resultant national LANDFIRE legend, as of 2009, for the conterminous US (CONUS), Alaska and Hawai’i included 552 natural ecological systems or aggregates of systems; 52 other land use and land cover types; and 32 NVC Alliances. An additional 149 individual ecological systems were not included in

the LANDFIRE map legend; instead they were included in one of the wetland/riparian/sparsely vegetation aggregates. Lastly, there were 119 ecological systems not mapped or included in any of the aggregates; most of these are small patch in character, occurring in such local, fine-scale spatial patterns as to be not mappable (e.g., seepage fens, vernal pools, aquatic beds, small rock outcrop types). However, this group also included types not of interest to LANDFIRE, such as systems dominated by algae (e.g. tidal flats, cobble shorelines, seagrass bed).

LANDFIRE 2001 Auto-Keys

For the LANDFIRE 2001 effort, each sequence table (now called auto-key) was created to key to ecological systems and NVC alliances presumed to be mappable in an ecologically-related geographic area, utilizing the MRLC map zones. There are 66 map zones for CONUS (**Figure 1**). NatureServe developed 26 sequence tables for these 66 map zones (**Figure 1**). Additionally there are 12 map zones in Alaska (**Figure 2**); 4 sequence tables were written for those map zones. Hawai’i had one sequence table written. In total, 31 sequence tables were written for the LANDFIRE 2001 effort. The section **What is an Auto-Key?** describes how auto-keys work (the Python program and the criteria used). The section below, **Design and Refinement of Auto-Keys**, describes the process for refining the LANDFIRE 2001 keys in support of the upcoming LANDFIRE ReMap.

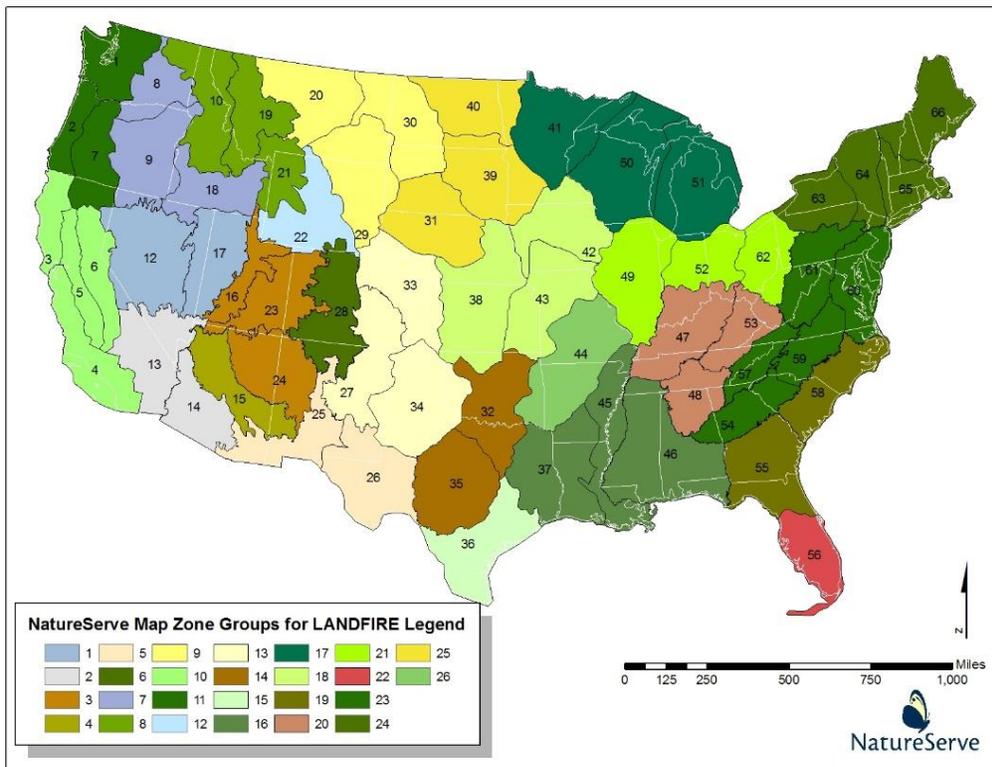


Figure 1. Groups of MRLC map zones that were the analysis units for the LANDFIRE sequence tables in the coterminous U.S.

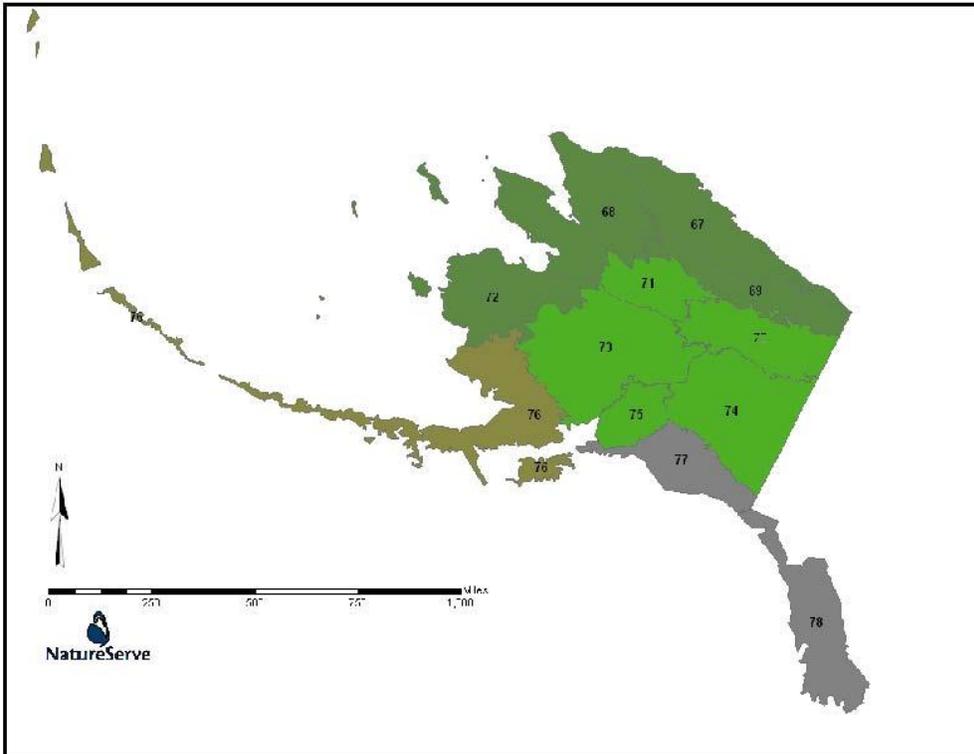


Figure 2. Map zones (numbers) and clusters (grouped by color) for sequence tables in Alaska.

LANDFIRE Improvements # 1

For LANDFIRE 2001, both dichotomous field keys and auto-keys were developed for map legend classes and organized in a series of 31 map zone groupings that spanned the nation. For ongoing maintenance of national map products, the map zone groups were further aggregated by LANDFIRE into larger geographic areas (Geo Areas, **Figure 3**). The Improvements #1 effort was organized around a modified form of these LANDFIRE Geo Areas (**Figure 4**). Within each Geo Area, project ecologists were provided with a subset of sample data for each relevant LANDFIRE map class (up to 30 sample plots per type). Using sample data on vegetation composition and structure, an image from NAIP imagery, along with limited mapped ancillary data (for general orientation and ecological context), ecologists applied an ecological system 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 (Comer et al. 2012). Key outcomes from each expert analysis included the contingency table, systematic discrepancies between expert and auto-key labels, and recommended changes to the auto-keys and technical procedures.

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 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.

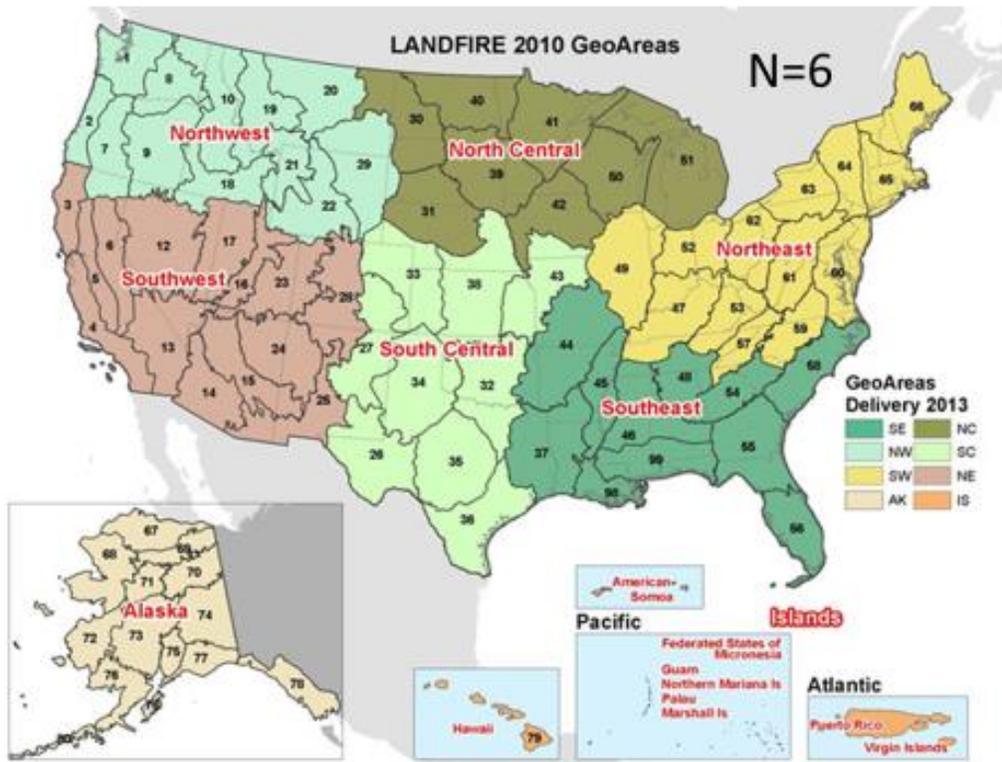


Figure 3. National LANDFIRE Geo Areas for ongoing management and maintenance of LANDFIRE products.

NatureServe developed a MS Access 2007 relational database (the Expert Attribution Database, EADB) for use in the project. The EADB is a user interface (i.e., front-end database) designed to link to the above LFRDB data (provided by EROS in a separate LFRDB), an image clip, and any ground-photos, in easily navigated forms for review by the expert. The reviewer was required to select from the ecological systems known or highly probable to occur in the Geo Area. 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.

A number of queries were run in the Access database, to generate summary statistics for each Geo Area, comparing labels on plots from the auto-keys and the experts. Contingency tables were created and reviewed for each Geo Area. In total, over 19,000 plots were reviewed for expert labeling (including Alaska and Hawai’i); of those, 17,293 received a label to ecological system. Disagreement between expert and A-K labeling was evaluated by regional Geo Area in the conterminous USA to identify sources of potential error in the A-Ks. All of the work and results were documented in a series of reports for each Geo Area (Comer et al. 2012).

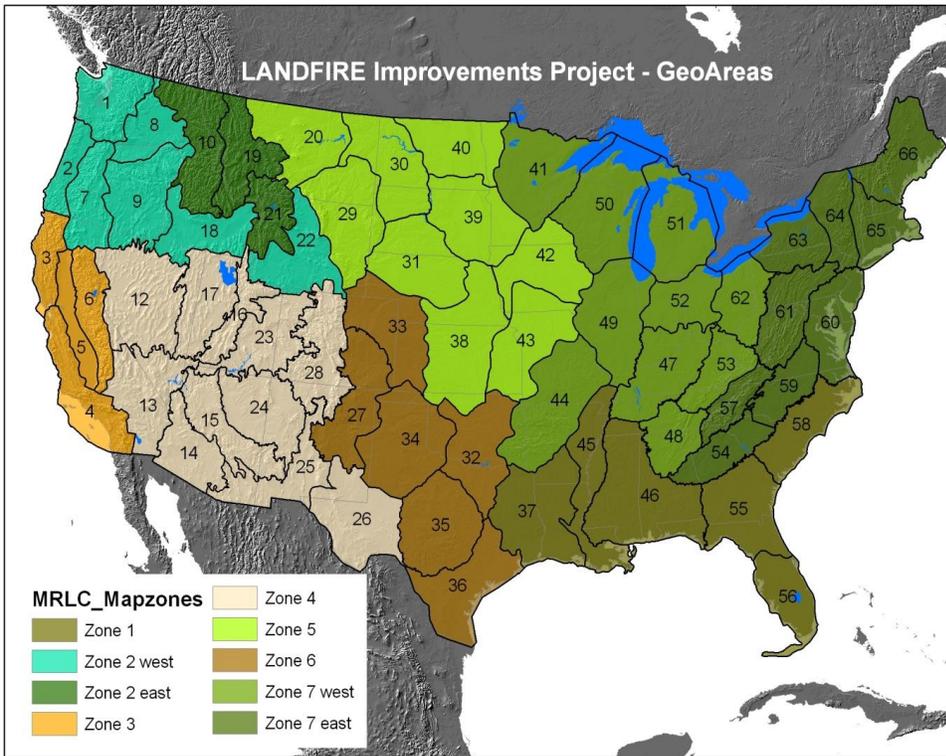


Figure 4. Modified LANDFIRE Geo Areas in the conterminous U.S. for use in the LANDFIRE Improvements #1 project.

Purpose and Objectives

The purpose of the current project reported on here was to further evaluate the Improvements #1 results and then redesign A-Ks to address errors. Previous evaluations of the LANDFIRE Auto-Keys (A-Ks) (Comer et al. 2012) resulted in recommendations for how A-K performance could be enhanced through redesign, and there are new opportunities for LANDFIRE to map EVT using the new USNVC standard. Therefore, the current need was to update and redesign previously completed A-Ks for labeling georeferenced samples to both terrestrial ecological systems and NVC units that could be mapped by LANDFIRE, GAP, BLM, and other users. This effort was initiated with two regional pilot projects, and then followed by full project implementation in other mapping regions across the nation.

Objectives of this project

This project aimed to complete the analysis and implement suggested improvements to the LANDFIRE Auto-Keys (A-Ks), and then deliver a validated set of A-Ks that are fully functional, i.e., to be able to key samples to Terrestrial Ecological Systems, NVC Groups and other map legend classes. Once samples are treated by finalized A-Ks, an attribute table allows subsequent labeling of all plots to the NVC hierarchy units above the Group, including Macrogroup, Division, Formation, Subclass, and Class (FGDC 2008, Faber-Langendoen et al. 2014) along with cultural land use classes in the United States. Ruderal (also called semi-natural) vegetation was treated using only USNVC concepts (e.g., Group), because Ecological System concepts are not applied to ruderal vegetation.

In each region, existing georeferenced sample data were used, along with the subset of expert attributed samples from the Improvements #1 effort, and existing A-Ks to:

1. further evaluate regional outputs and recommendations from the LANDFIRE Improvements #1 effort, and update A-Ks for ecological systems by
 - a. establishing which additional factors should be included in the A-K to improve performance (e.g., use of geophysical or geographic bounding information, minimum vegetation data requirements), and
 - b. revising how to sequence them in the A-K;
2. identify the minimum sample plot requirements for using an Auto-Key on particular ecological system and NVC Group concepts. For example, there are some types that must have the top 3-5 species, in terms of cover, listed from each canopy layer or one cannot presume that the A-K will label correctly;
3. determine which map classes, if any, should NOT be addressed through A-Ks; i.e., types that cannot be reliably auto-keyed and should go directly to a separate 'expert' labeling step.

In order to maximize accuracy in sample labeling, A-K redesign considered:

- a) re-ordering the sequence of vegetation characteristics,
- b) adding individual species to the criteria,
- c) inclusion of mapped geographic and geophysical variables in the A-K sequence,
- d) redesigning A-Ks to apply to different geographic areas that better match vegetation distributions, and
- e) use of expert-reviewed sample plots for validation and analysis of A-K performance.

The remainder of this report describes the team, the technical preparation for the project, the process and work flow used to achieve the above objectives, and provides a number of tables and text summarizing the results. Some of the issue encountered are described, and recommendations for future work are made.

Partnerships

There were two teams for the project, related to type and level of effort. The first, Coordinating Group, represents LANDFIRE, USGS, FIA, BLM, and NatureServe leadership, and provided project oversight and documented project effectiveness. The Development Group, made up of NatureServe regional ecologists, completed and reported on the pilot efforts, following agreed-upon protocols established by the Coordinating Group. The Development Group then fully implemented design of auto-keys for the coterminous U.S. The relative roles for the teams were as follows:

Team 1 (Coordinating Group). This team planned and coordinated the project, developed protocols for review, determined what types of Auto-Key modifications can be pursued, identified appropriate experts, reviewed and revised geographic boundaries for each Auto-Key, reviewed results from Team 2, identified commonalities and differences among the A-Ks, and wrote and distributed final reports. NatureServe was engaged in meetings and calls of this group, which was organized and convened for LANDFIRE by The Nature Conservancy's Fire Initiative.

Team 2 (Development Group). This team included regional experts to complete additional review of each of the Geo Area reports, identify proposed Auto-Key changes within the defined constraints, modify each A-K, develop new A-Ks for NVC types, and deliver the final Auto-Key to Team 1 along with a summary of the final Auto-Key modifications. The LANDFIRE A-K team #2 applied a QA process that examined plots labeled to different types (ecological systems or NVC types), working iteratively to arrive at the most complete and accurate sample labeling possible. They also iteratively tested the revised A-K

against the plots previously attributed by experts, to achieve at minimum 65% overall agreement between the Auto-Key and expert attributes.

Project Information & Design

Scope

The geographic scope of the project being reported on here is the coterminous U.S., not including the southern tip of Florida. That area will be treated with the Caribbean territories of Puerto Rico and the U.S. Virgin Islands. Future work not reported on here will include the Caribbean, Hawai'i and Alaska.

List of Products

- Final report summarizing methods and accuracy assessment of new A-Ks (this document);
- Updated A-Ks for Terrestrial Ecological Systems and land use classes;
- Newly developed A-Ks to NVC Groups;
- New A-Ks to semi-natural (hereafter called ruderal) and cultural vegetation;
- Legends (lists of vegetation types) organized by:
 - a. Ecological systems
 - b. NVC Groups
 - c. Ruderal, Cultural, other "land cover" classes
- Crosswalks within the mid-level of the NVC hierarchy from Group to Macrogroup, to Division that are fully functional and ready for vegetation mappers to attribute LANDFIRE deliverables at the Group, Macrogroup, and Division level;
- Crosswalk between Ecological System and NVC Group and thence to NVC Hierarchy (Macrogroups up to Division);
- Plots with expert labels to ecological system and NVC Groups;
- Boundaries of auto-key regions defined for this effort (shapefile).



Schedule

For the complete effort, including all US states and territories, a project totaling 2.5 years was estimated. The work began in the fall of 2013 and the coterminous U.S. auto-keys were completed in spring of 2015, 18 months. An additional 4-6 months was needed for final review of the products, and issuance of this report. Work extending into the Caribbean, Hawai'i and Alaska, requires an additional year to complete. If possible, additional time for external review would be beneficial to improve engagement and potentially product quality.

Fred Harris, Hole-in-the-Mountain Prairie, MN; Northern Tallgrass Prairie

Budget

The work reported on here was completed by NatureServe's Ecology Department in collaboration with the members of the coordinating team and with plot data management handled by the LANDFIRE Reference Database Manager. Within NatureServe, fourteen individual ecologists were involved with varying roles, including project management and oversight, advice and review, spatial data visualization, database development and data management, and development of the auto-keys and auto-key region reports.

Funding resources for the work were provided by Inter-agency LANDFIRE via an Assistance Agreement between the Bureau of Land Management and NatureServe over two federal fiscal years: FY14 and FY15.

From the FY14 funds, 3,407 person hours were required for the work; the FY15 funding covered 2,402 person hours. These hours include time for the ecology, data management and operations staff.

Communications

Representatives from the LANDFIRE Program, Bureau of Land Management and NatureServe served as a steering committee (the Coordinating Group) for the project, with Jim Smith (The Nature Conservancy LANDFIRE Project Lead) facilitating conference calls, notes, reports and other communications. Regular conference calls were held (primarily monthly). An agenda for each call was planned and notes were taken and distributed after each call, along with specific action items. Calls primarily focused on technical or methodological issues and decisions. *Ad hoc* calls for small groups or between individuals were also held to discuss or resolve issues or exchange information as needed. No in-person meetings were held, and no external communications were planned to occur during the production processes. A final report of the project will be developed, posted online and promoted. A journal article describing the project, results and recommendations may also be written if resources are available, and a General Technical Report is being considered for development in coordination with members of the mapping team.

Change Management

As described above, a team composed of individuals from the LANDFIRE Program, Bureau of Land Management and NatureServe served as the "steering committee" for the project. This team created and reviewed all project plans, and submitted them for approval to the funding partners (LANDFIRE and BLM). Changes to plans and schedules were reviewed by this group, discussed and modified where necessary and then submitted to LANDFIRE and BLM for approval.

For example, the original project plan was to create Ecological Systems Auto-Keys for all auto-key regions, and then in a second phase create NVC Group Auto-Keys for all auto-key regions. While testing and evaluating the processes in the Colorado Plateau and North Woods auto-key regions, NatureServe staff indicated that it would be more efficient to create Ecological Systems and NVC Group keys for an each auto-key region sequentially. The steering committee discussed the costs and benefits of the proposal, adjusted the plan accordingly and requested approval from the funding partners. After approval, the steering group implemented the new plan and developed a revised schedule.

Prior to initiating work on all of the AKRs, the Coordinating Team elected to prototype the steps for completing any individual AKR within two pilot areas. The pilot AKRs selected were the Colorado Plateau and the North Woods. The purpose of the pilot project areas was to help solidify the new auto-key regions, work thru the methods for preparing and managing the plot data, prototype the use of additional attributes for each plot in the key (the GEOSS bioclimate and landform values), develop the outline for reporting on individual AKR results.

Data

Vegetation data is the basis for all of the work reported on here. Spatial data were used to derive some attributes for the plots, such as ecoregion of occurrence or elevation. This section describes the vegetation data compiled by the LANDFIRE partners for use with the auto-keys and which is a major input to LANDFIRE's mapping process.

Major Sources of Vegetation Data

The LANDFIRE Reference Database (LFRDB) provided the plot data that was used for this project. The LFRDB is a compilation of geo-referenced field data describing vegetation and fuel attributes. The current LFRDB contains 759,142 geo-referenced plots in CONUS and 84,889 in Alaska and Hawaii. These data were collected from 631 different sources and were contributed by federal, state, local, and private entities. LANDFIRE collects data from multi-agency data calls and from LANDFIRE personnel searching web based data clearing houses and agency/corporate database systems.

Vegetation data from the LFRDB that had species composition information were used to help revise the auto-keys. Some of the major national sources of data used in this project included the following:

- ✓ **USFS Forest Inventory and Analysis Data (FIA):** USFS continuous forest census program that collects data on forested public and private lands throughout the United States.
- ✓ **USFS Natural Resource Information Systems (NRIS) Field Sampled Vegetation (FSVeg):** NRIS FSVeg is a cooperate database that is used by the USFS to store plot data from field surveys such as stand exams, inventories, and regeneration surveys.
- ✓ **USGS/NPS Vegetation Inventory and Monitoring Program:** Natural resource inventories of National Park lands throughout the United States, which includes plots collected for vegetation mapping.
- ✓ **NPS FFI (Feat/Firemon Integrated):** FFI is a database system used by the National parks to store Fire Effects Monitoring data.
- ✓ **USGS Gap Analysis Program:** Nationwide program in the United States that provides data and tools for science-based analysis of biological diversity.
- ✓ **NRCS National Resources Inventory (NRI):** A statistical survey of land use and natural resource conditions and trends on U.S. non-Federal lands
- ✓ **BLM Assessment, Inventory, and Monitoring (AIM) Data:** Information on status, condition, and trends of natural resources on BLM lands throughout the United States.

The LFRDB contains numerous other data sources many of which were used to revise the auto-keys. In addition, LANDFIRE also has data contributions that are currently being processed and will be added to the LFRDB for the upcoming remap. For a complete list of data sources see the "Compiled Data" spreadsheet at http://www.landfire.gov/participate_refdata_sub.php.

Data Sharing Agreements

LANDFIRE has signed data sharing agreements with several different data contributors. The purpose of the agreements is to protect proprietary or otherwise sensitive data and to ensure that these data are not released to the public. LANDFIRE has entered into data sharing agreements with USFS Forest Inventory Analysis (FIA) and NRCS National Resource Inventory (NRI). The agreement with FIA and NRI allows LANDFIRE to use these data in the LANDFIRE internal production process while maintaining the strict confidentiality of plot locations. LANDFIRE has also entered into data sharing agreements with other data contributors including the BLM Assessment Inventory and Monitoring (AIM) Strategy, State Natural Heritage programs, and various Native American Tribes. These types of data are also carefully managed by LANDFIRE and only used for internal product development.

Non-disclosure Agreements

In order to use some of the proprietary and sensitive data stored in the LFRDB for auto-key revisions, non-disclosure agreements had to be signed by pertinent staff. Both the Forest Inventory and Analysis program (FIA) of the USDA Forest Service and the Natural Resources Conservation Service (NRCS) required all project staff who would be handling plot data from the LFRDB to sign non-disclosure or confidentiality agreements. These agreements were provided to NatureServe staff, as well as LANDFIRE and TNC staff, were signed by them and then returned to the relevant agency representative.

The agreement with FIA ends December 31, 2015; while that with NRCS extends to the end of the MOU between NRCS and LANDFIRE, which is September 30, 2019.

Preparation of Plot Data and Data Management

The vegetation samples (plot data) are stored in a series of MS Access databases, collectively called the LANDFIRE Reference Database (LFRDB). The auto-key itself is also a MS Access table.

Vegetation and fuel data submitted to LANDFIRE are evaluated for inclusion into the LANDFIRE Reference Database (LFRDB). Each sampling unit must meet the following minimum requirements to be included in the LFRDB:

1. The sampling unit must have a georeference and a defined spatial coordinate system.
2. The sampling unit must contain a portion of the attributes needed by LANDFIRE, and the attributes must contain an acceptable level of detail.
3. Necessary supporting information, including definitions of the fields and any codes in the data tables, should accompany the data to ensure the data can be interpreted.

Some examples of acceptable level of detail for attributes include but are not limited to the following:

- ✓ Data containing only vegetation cover type labels must have labels that are detailed enough to be cross walked to LANDFIRE Existing Vegetation Types (EVT).
- ✓ Data containing species composition information must contain enough detail and a large enough species list to be able to run plots through a sequence table to key to LANDFIRE EVT.
- ✓ Species should be attributed with scientific names and canopy cover values must be included or be able to be derived from the information provided.
- ✓ All data meeting LANDFIRE minimum requirements are converted to the standard LANDFIRE LFRDB format. Digital photos of the sampled units are also archived, when available.

Once the data are in the LFRDB format, plots with species composition information are used develop the Auto-Key Region (AKR) databases which work with the auto-key program. In order to generate the key databases several steps were required.

- A. The plant species nomenclature had to be updated to the standard used by LANDFIRE, from the NRCS Plants² database. The original A-Ks used a fixed list from 2004 Plants, the taxonomy was updated to a fixed list from December 2013 Plants names. This was completed by the LFRDB Data Manager. A few taxa were difficult to crosswalk from the 2004 to the 2013 names; these were sent to the NatureServe Ecology Data Manager (who is a wizard with plant nomenclatures) and she was able to resolve most of these.
- B. Each plant taxon was assigned a lifeform; the term 'taxon' is used because in some cases the plant is identified only to Genus or even only to Family; there are also subspecies and varieties represented in the plot data, as well as such taxa as "unknown grass", "unknown perennial

² <http://plants.usda.gov/>

forb”, “unknown shrub”, etc. This is a necessary step in that simple structural characteristics (percent cover by lifeform) for each plot are calculated, and also relative cover for each taxon is calculated as a percentage of the lifeform total cover. LFRDB Data Manager sent NatureServe a list of species found in the plots within each multi-region. Many taxa already had lifeform assigned, but taxa from newer plots did not. These were reviewed by the ecologists, and lifeforms assigned.

- C. Plot attributes for structure and composition were calculated for each plot by the LFRDB Data Manager, once the taxonomy and lifeform assignments were completed: total absolute cover by lifeform, and relative cover for each species- calculated as percent absolute cover of the species divided by total cover of the lifeform to which it was assigned x 100 to achieve % relative cover.
- D. Other attributes for each plot were derived from a DEM and the plot geo-referencing: elevation, aspect, slope, ECOMAP subsection, EPA ecoregion, map zone, and TNC ecoregion. Additionally, landform and bioclimate values were derived from data produced by the USGS Group on Earth Observations³ program (Sayre et al. 2009).
- E. Other attributes stored in the LFRDB and included in the AKR databases were the expert labels from the LANDFIRE Improvements #1 project, along with the confidence of assignment and any comments the expert provided.
- F. Once the plots and attributes were prepared by the LANDFIRE Data Manager, and the boundaries of the AKRs determined and made available, then for each AKR all the plots occurring within the boundary were selected and exported into a “key database”. This key database has the necessary table and field structure required to work with the auto-key program. Each AKR key database was zipped and posted on an FTP site for NatureServe to download and use in the development of the auto-keys.
- G. NatureServe staff installed the Python program and scripts required to run the auto-key application. Once the auto-key is written it is used by the Python application along with the plots contained in the key databases to assign labels to the plots in the database.
- H. NatureServe kept copies of all the AKR key databases for use during creation of the auto-keys. After the work was completed for the 16 AKRs, these databases also contain the results of running the auto-key. The python program creates a series of output tables to help with interpretation of the results from running the key. These tables provide: a label for each plot, the descriptive data for each plot with its label, a table summarizing species composition and cover from all of the plots that keyed to individual vegetation type (these are known as ‘stand tables’), another table listing the 2 most dominant species in each plot with their absolute and relative cover, tables documenting which species were the indicators for the plot and which row of the key resulted in the label applied to the plot. See Appendix C: **LANDFIRE Documentation: Working Of Auto-Keys & Output Tables** for documentation of all the output tables.

³ <http://rmgsc.cr.usgs.gov/ecosystems/index.shtml>

Technical Elements

This section of the report describes the technical elements of the work. Topics include an explanation of how auto-keys are structured and work, how the spatial framework for auto-key regions was derived, the process for determining vegetation types to include in each auto-key, how the legend of the ruderal and cultural types was developed, how the ecologists wrote and refined the auto-keys, and how the expert labels on plots were used in the work.

What is an Auto-Key?

Below is a description of the structuring of the LANDFIRE 2001 effort, and how ‘sequence tables’ work, including the criteria used in the sequence tables. The section below, **Design and Refinement of Auto-Keys**, describes the process for refining the LANDFIRE 2001 keys. Appendices B and C provide LANDFIRE’s documentation of Plot data processing, auto-key format rules, and the data inputs required for the auto-key.



Keith Schulz, Buenos Aires National Wildlife Refuge, AZ; Chihuahuan Succulent Desert Scrub

1. Each sequence table was created to key to systems and mappable alliances in an ecologically-related geographic area, utilizing the MRLC map zones. There are 66 map zones for the coterminous US (**Figure 1**). NatureServe developed 26 sequence tables for these 66 map zones (**Figure 1**). Additionally there are 12 map zones in Alaska (**Figure 2**); 4 sequence tables were written for those map zones. Hawai’i had one sequence table written. In total, 31 sequence tables were written for the LANDFIRE 2001 effort.
2. The key contains fields for plot-level and species-level criteria. The plot-level criteria denote requirements for total cover on the plot, the amount of cover distributed by lifeform, planted stand origin, and spatial criteria including elevation, ECOMAP Subsection, EPA Ecoregion, TNC Ecoregion, and MRLC Map Zone.
3. The sequence table and vegetation samples are run through an automated Python application, developed by staff at the Missoula Fire Lab, called the “auto-key”. The program tests plots against these criteria row by row in the key, in the order denoted by the “Row_No” field. A plot is tested against each row until it satisfies all the criteria required by that row of the key, and will return with either an EVT [ecological system or other land cover/land use] assignment or a lack thereof if it failed the criteria of all rows. Each column that is populated with a criterion in the key is tested using AND logic, such that all conditions specified by columns in that row must be met by a given plot.
4. Within a given row in the key, the plot is first tested against the plot-level criteria. If the plot passes those criteria, it is then tested against the species-level criteria. The species-level criteria are a series of pairs of an indicator species list and cover conditions. Each indicator species can be denoted by genus (e.g., “*Artemisia*” or “*Artemisia* spp.”), species (e.g., “*Artemisia*

tridentata”), species-subspecies (e.g., “*Artemisia tridentata* ssp. *wyomingensis*”), species-variety (e.g., “*Clematis columbiana* var. *tenuiloba*”, or species-subspecies-variety (in that order only). The key classifier supports genus abbreviations in the species list where there is no ambiguity of the genus being referred to (e.g., “*Antennaria racemosa*, *A. rosea*, *Bupleurum americanum*”).

5. Each species in the species list is tested against the species present on a plot using regular expression searching. This means that if the case-sensitive text of the indicator species is found in the name of a species on the plot, that species is considered found and its cover is added to the tally that will be tested against the condition specified for the species list to which this indicator belongs. For example, if the species list includes “*Clematis columbiana*”, then a plot that records “*Clematis columbiana* var. *tenuiloba*” with 10% cover will be added to the total cover tested against the condition of that species list. The cover is summed across all species in the species list that were found on the plot. A cover condition can specify a cover value that the species list must be greater than, less than, or equal to. It can specify a range of covers (e.g., “10-25%”). It can also specify “present” or “absent” if the actual cover values of the species are unimportant for keying a plot. To test against this criterion, the relative cover value of each species within the species list that is found on a given plot is added together. This total is then compared to the criterion. If this value is nonzero, the “present” criterion is satisfied. If this value is zero, the “absent” criterion is satisfied.
6. The auto-key program sequentially compares each vegetation sample against the criteria contained in the sequence table, as described above. Each plot must meet all of the criteria for a particular ecological system; if the sample meets all the criteria, the auto-key attributes the plot / point with the ecological system, or other land cover type, 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”.
7. The auto-key program generates a number of output tables to enable the user to evaluate the results, both to determine if plots were keyed accurately to a system, but also to allow rapid and efficient review of plots that key to one of the more generic “land cover” labels. The output tables, among other things, list the labels assigned to each plot, summarize how many plots were assigned to each land cover type, and provide tables summarizing the species composition and cover data across all plots labeled to an individual vegetation type.

Design of Auto-key Regions and Multi-Regions

LANDFIRE 2001 was oriented around the MRLC map zones (**Figure 1-3**). Map zones are designed to efficiently organize image-based mapping efforts by delineating contiguous areas that follow general pattern in land cover coincident with clusters of satellite image scenes. Map production oriented around these map zones should tend to minimize effort when combining map products from adjacent map zones; as is the case for the National Land Cover Data, for which these map zones were originally designed. However, while map zones do acknowledge generalized pattern in land cover, there is considerable overlap of finer-scale vegetation classification units across map zones created for national mapping purposes. From the perspective of labeling vegetation samples, the use of map zones results in a large proportion of samples from types that are relatively “peripheral” to the map zone geography. Therefore, any auto-key designed to be applied within the spatial context of map zones must include these many peripheral types, and this fact introduces potential error in sample labeling.

In this effort, it was recognized that the processes of assigning labels to field samples is independent of the mapping process, and so alternative spatial frameworks could be used if they would result in improved accuracy in label assignments to sample plots. The subsequent mapping effort could still be organized around map zones, but the auto-key process would deliver more accurate labels regardless of where the sample plot occurred.

The task, therefore, was to establish alternative spatial frameworks for use in the design of auto-keys. They would need to more closely align with the natural distribution of terrestrial ecological system types and USNVC group types, maximizing similarity among types within an auto-key region, and minimizing overlap among adjacent auto-key regions. Auto-key regions that cover more extensive land area tend to include treatment of more types and potential for error introduced through complexity in auto-key design. Conversely, auto-keys treating a smaller area might be simpler, but would necessarily include more overlap in types with surroundings and result in a larger number of auto-keys for the country. Therefore, total area encompassed by each auto-key was a factor in the selection and design of alternative spatial frameworks.

Several approaches to mapping “ecoregions” have been applied throughout the United States and beyond. Most intend to integrate patterns of climate, physiography, and vegetation pattern to delineate relatively similar regional landscape unit. All of the several common approaches delineate ecoregions at several spatial scales; with “broader” ecoregions encompassing “narrower” subset ecoregions. These include the Forest Service-led ECOMAP approach (Cleland et al. 2007), the NRCS/BLM Major Land Resource Areas (MLRAs)⁴, and the multi-level EPA ecoregions⁵. While the ECOMAP and MLRA approaches delineate each ecoregion as just one polygon and apply a strict spatial nesting in the relationship among different levels of ecoregions (e.g., in ECOMAP, several Provinces cleanly nest within one Division, and several Sections nest within each Province), the EPA approach allows for multiple polygons to describe a given ecoregion, so spatial nesting falls within each of the 1-several polygons per ecoregion. The EPA approach contrasts most strongly with the other approaches in mountainous regions of the country, where EPA level IV ecoregions appear to reflect traditional “life zones” along major elevational gradients.

National map products from 2009-2011 efforts of LANDFIRE, GAP, and NatureServe were overlaid to summarize the number and extent of ecological system types found in varying clusters of adjacent ecoregions, as depicted by ECOMAP Provinces, MLRAs, and EPA Level IV. Pilot efforts concentrated on two representative portions of CONUS, in the Colorado Plateau of CO, UT, AZ, and NM; and in the upper Great Lakes Region including MN, WI, and MI. In general, overlays with ECOMAP provinces or EPA Level IV ecoregions tended to result in the least amount of “peripheral” type inclusions as compared with the other ecoregions.

Given this result, and using expert input from NatureServe regional ecologists, ECOMAP provinces were relied upon to establish auto-key regions throughout much of CONUS. However, EPA Level IV ecoregions were used throughout southern portions of CONUS to modify boundaries and finalize the auto-key regions. **Table 1** and **Figure 5** include results for 17 auto-key regions in CONUS.

⁴ http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053624

⁵ http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm

Table 1. Final list of the seventeen CONUS auto-key regions (AKRs), their names, and the number of LFRDB plots available for use with testing the auto-keys. Note that for the Caribbean AKR, the LFRDB does not yet contain plots for Puerto Rico or the Virgin Islands, so the number reflects only plots from South Florida.

AKR #	Auto-Key Region (AKR) Name	# of plots in the database for keying
1	North Pacific Coast	44,929
2	California	37,862
3	Intermountain Basins	50,034
4	Rocky Mountains	80,478
5	Warm Desert	17,338
6	Colorado Plateau	23,735
7	Western Great Plains	27,337
8	Eastern Great Plains	5,691
9	Texas Louisiana Coast	7,087
10	Texas Oklahoma Hill Prairie	4,043
11	Mississippi Alluvial	5,822
12	Central Interior	26,021
13	North Woods	50,195
14	Appalachian	22,999
15	Northeast Coast	3,517
16	Southeast Coastal Plain	20,221
17	Caribbean (inc. S. Florida)	812
	Total Plots, All AKRs	428,121

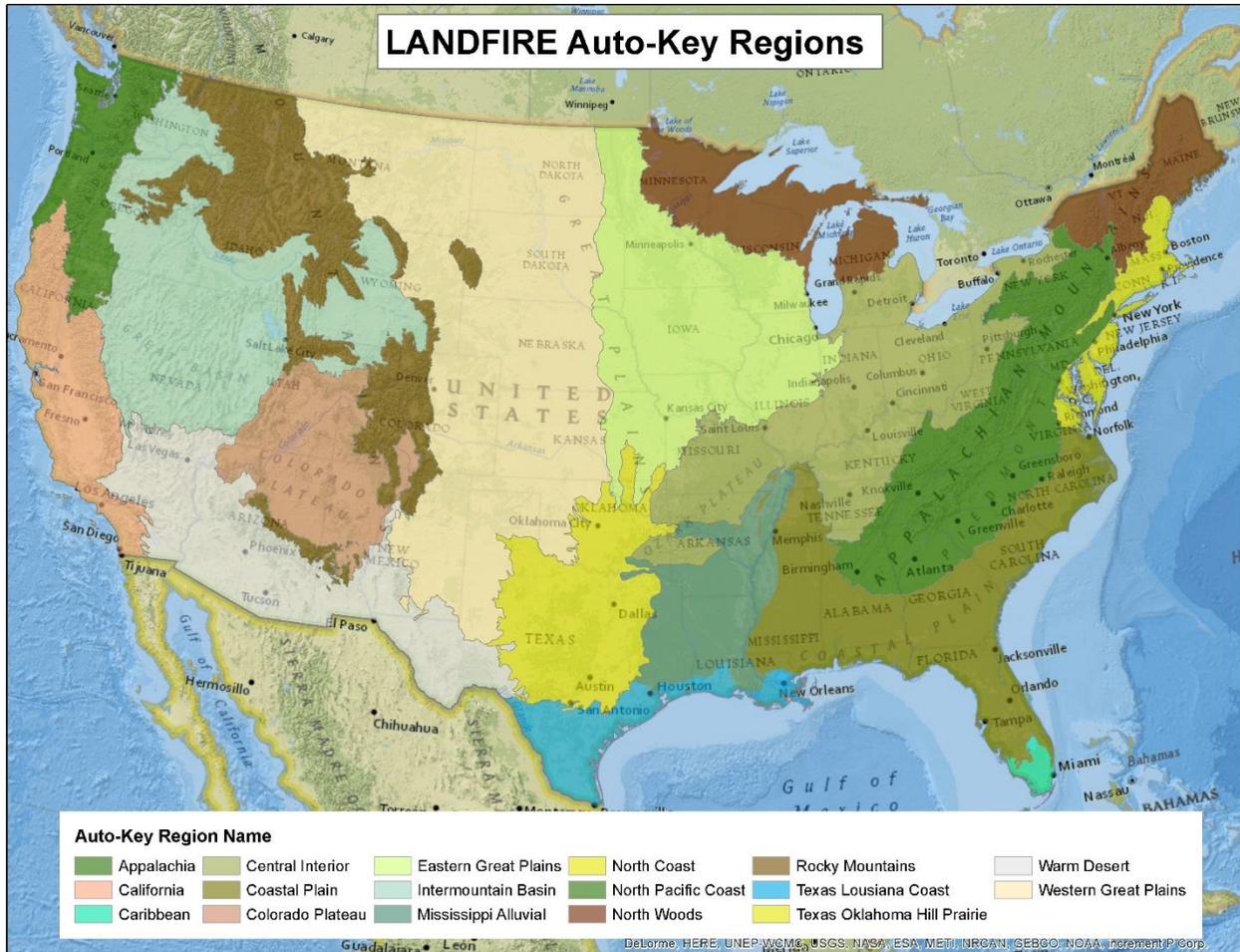


Figure 5. Auto-key regions as defined for this effort in 2015.

In addition to defining new regions for use with auto-keys to natural ecological systems and USNVC Groups, it was desirable to develop geographically larger regions within which keys would be developed for the ruderal, as well as cultural, vegetation types that would be found among field samples. Conceptually, ruderal and cultural vegetation is classified more broadly in the USNVC than the ecological systems or Groups, because the species dominating or characterizing these ruderal/cultural types tend to have wide ecological amplitude in where they occur or are present in areas because humans have introduced or planted them there.

Since one source of error in the first generation auto-keys for LANDFIRE 2001 was confusion between natural and ruderal types, new auto-keys designed for the ruderal-to-cultural spectrum of vegetation could be implemented in sequence prior to auto-keys designed for labeling samples of natural vegetation.

Once the initial 17 CONUS AKRs were defined, and the ruderal legend was finalized (see Section **Legend of Ruderal and Cultural Types**), then multi-regions were based on grouping the individual AKRs into four “multi-regions” (Table 2 and Figure 6): the Mountain West, California-Intermountain Basins-Warm Desert, the Cool Temperate East, and the Warm Temperate East. The same plots used for work on the individual AKRs were used for work on the keys for the multi-regions, but they were organized into 4 key databases corresponding to the multi-regions.

Table 2. Multi-regions defined for use with the ruderal and cultural auto-keys.

Multi Region	Auto-key regions included	# of plots
California and Interior West Multi-Region	California, Intermountain Basin, Warm Desert, Colorado Plateau	122,599
Mountain West Multi-Region	Rocky Mountains, North Pacific Coast	125,407
Cool Temperate Eastern Multi-Region	Western Great Plains, Eastern Great Plains, Central Interior, Appalachia, North Woods, North Coast	127,108
Warm Temperate Eastern Multi-Region	Texas-Oklahoma Hill Prairie, Texas-Louisiana Coast, Mississippi Alluvial, Coastal Plain, South Florida	35,632

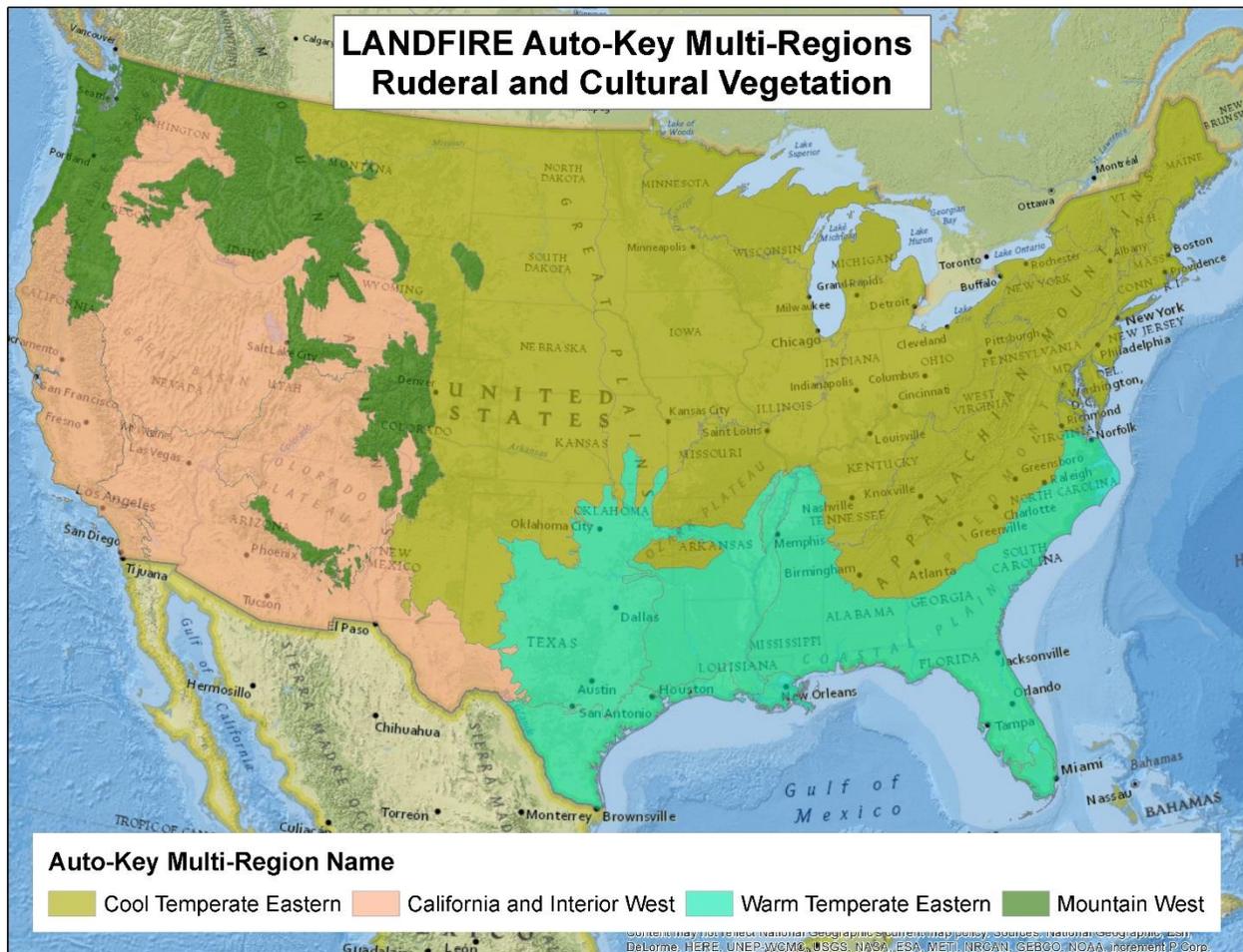


Figure 6. The multi-regions used for developing auto-keys to ruderal and cultural vegetation.

Legends by Auto-Key Regions

While this project is largely in support of LANDFIRE mapping, the National Gap Analysis Program will make use of the labeled plot data and the auto-keys developed for LANDFIRE. It was agreed prior to beginning the work described here that the keys should include most, if not all, of the ecological systems and NVC Groups found in CONUS; and that they should not be aggregated into conceptually broader units as was done for LANDFIRE 2001.

Hence, prior to developing keys to either ecological systems or NVC Groups, it was necessary to assemble a complete list of each of these for the lower 48 US states, the current geographic scope. While the ecological systems classification has changed little since the completion of LANDFIRE 2001, the NVC has changed significantly, with the development of the new Macrogroup and Group levels within the hierarchy (Faber-Langendoen et al. 2012, FGDC 2008, Franklin et al. 2012). In addition, during the revision of the NVC hierarchy, every effort was made to comprehensively crosswalk the individual ecological systems to one or more Groups. In some cases the ecological system is nearly equivalent in its core concept to an NVC Group, in other cases several systems crosswalk conceptually to the same Group; still others have a more complex relationship (but these are the minority of system types).

EVT Look-Up Table and EVT Codes

Data for both the ecological systems and the Groups were queried and downloaded from NatureServe's database, including these cross-walked relationships. For the systems, the data included whether or not it was previously included in the LANDFIRE 2001 legend, along with the various codes used by LANDFIRE and NatureServe to track these types. These lists became the source of a look-up-table (LUT) for all of the types that would be included in one or more AKR auto-keys. This LUT, called the EVT_LUT, is required by the auto-key program.

Each vegetation type included in one or more A-Ks is required to have a unique 4-digit code, called the EVT_code. These codes are used as attributes in the mapping process, but are also required in the A-K itself. In addition, for the mapping and modeling of biophysical setting (BpS) and environmental site potential (ESP), a second unique code was assigned to all types, the ESP_code. EVT_codes were assigned to all legend types for the LANDFIRE 2001 effort, but now many more vegetation types, both systems and Groups, were added to the EVT_LUT.

In addition, it was decided that the original 2001 EVT_codes for ecological systems should be "retired" and not used in this new ReMap effort. The reasoning for this decision is that the new keys will result in different plots being assigned to the systems than might have been assigned in the 2001 keys, and hence the mapped concept could be different. This will also avoid any possible confusion between the LANDFIRE 2001 products and the ReMap products. Accordingly all types tracked in the EVT_LUT received a new, unique set of EVT and ESP codes for use in the new A-Ks and all ReMap products. The 2001 codes are also tracked for relevant types so that a crosswalk exists and can be referenced as needed. The 2015 ReMap EVT_codes are provided in the various tables presented in this report.

NatureServe has maintained the master EVT_LUT throughout this project, and periodically provides it to the LFRDB Data Manager.

Lists by AKR

Once the new AKRs were defined, the next step was to assemble an initial list of all the ecological systems that might occur in each AKR. This was a necessary step for two reasons:

- a) The geography for the LANDFIRE 2001 auto-keys was different than what would be used for the revised auto-keys. Each new AKR overlaps with 2 or sometimes as many as 5 LANDFIRE 2001 map-zone-based keys.

- b) In addition, as described in section **LANDFIRE 2001 Legend**, many individual ecological systems were grouped into thematically broader ‘aggregates’ for the LANDFIRE legend. For the work reported on here, all ecological systems occurring in the U.S. are included in the revised auto-keys, regardless of whether they were part of the LANDFIRE 2001 project.

An obvious way to determine what ecological systems occur in each AKR is mapped spatial distribution; however, many systems are not mapped for a variety of reasons. So lists of systems by AKR were assembled from three different sources.

1. The GIS shapefile containing the AKR boundaries was used with the NatureServe Terrestrial Ecological Systems map (NatureServe 2013) to generate a list of the ecological systems that have been previously mapped within each AKR boundary. This list included calculation of areal extent (square kilometers) of each ecological system and other land cover classes (e.g. developed, ruderal vegetation, etc.) within the AKR.
2. The boundaries shapefile was provided to the LFRDB Data Manager, who queried the LFRDB and provided a listing of all of the plots within each AKR, along with their labels from the LANDFIRE 2001 keys to ecological system or other land cover class. A tally of the plots was created for each ecological system, i.e. how many plots were labeled to that ecological system in that AKR. These tallies were added to the above list generated from the mapped distributions.
3. A third data query was to count how many ECOMAP sections in which the ecological system was known or thought to occur, utilizing NatureServe’s tabular data in Biotics. Many wetland, riparian and sparsely vegetated systems are not mapped, nor do they have plots labeled in the LFRDB, but their approximate distribution is represented via the ECOMAP sections. NatureServe ecologists develop and maintain such distribution data for all terrestrial ecological systems.

These three sources of information about distribution were assembled into a MS Access DB, and queries generated a list of potential ecological systems for each AKR with mapped area, # of plots, and # of ECOMAP sections. The end result was a table, an example of which is shown in **Table 3**. The list for each AKR was then reviewed by the ecologists who are knowledgeable of the vegetation within that region. The purpose of the review was two-fold:

- ✓ Ensure all ecological systems that occur in the AKR would be represented in the auto-key
- ✓ Eliminate ecological systems that may have been erroneously mapped within the AKR, or that were so peripheral to the AKR they shouldn’t be included in the key

Table 3. Partial list of ecological systems for the Appalachia AKR, generated for review by the ecologist prior to working on the auto-key. Systems with 2001 EVT_CD (EVT codes) were part of the LANDFIRE 2001 legend; those lacking 2001 EVT_CD were either lumped within an aggregate for that legend, or were not treated at all. The “ESLF_CD” is another unique 4-digit code used by NatureServe in their spatial map of ecological systems.

ESLF_CD	2001 EVT_CD	ELCODE	GLOBAL_NAME	Mapped Sq Km	# of USFS Sections	# of LF plots
4256	2353	CES202.332	Southern Appalachian Low-Elevation Pine Forest	6,866.6	9	432
9312		CES202.323	Southern Piedmont Small Floodplain and Riparian Forest	4,494.3		
4308	2366	CES201.563	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	2,942.0	1	194

ESLF_CD	2001 EVT_CD	ELCODE	GLOBAL_NAME	Mapped Sq Km	# of USFS Sections	# of LF plots
4320	2377	CES202.600	Central Appalachian Pine-Oak Rocky Woodland	2,682.9	4	381
4126	2320	CES202.596	Central and Southern Appalachian Montane Oak Forest	2,431.2	4	937
9185		CES202.701	North-Central Interior Wet Meadow-Shrub Swamp	1,793.6		
9335		CES202.706	South-Central Interior Small Stream and Riparian	1,703.1		
9328		CES201.587	Laurentian-Acadian Floodplain Forest	1,514.8		
5416	2400	CES202.602	Central Appalachian Alkaline Glade and Woodland	849.9	4	44
9177		CES103.724	Boreal-Laurentian Conifer Acidic Swamp and Treed Poor Fen	754.6		
4111	2305	CES202.898	Southern Interior Low Plateau Dry-Mesic Oak Forest	720.9	1	69
4115	2309	CES202.029	Southern Appalachian Northern Hardwood Forest	650.8	6	465
9356		CES202.069	High Allegheny Wetland	549.1	1	
4147	2340	CES202.598	Appalachian Shale Barrens	547.9	2	52
4255	2352	CES202.331	Southern Appalachian Montane Pine Forest and Woodland	521.4	1	424
9160		CES202.018	Central Interior Highlands and Appalachian Sinkhole and Depression Pond		10	
4149	2342	CES202.268	Piedmont Hardpan Woodland and Forest		8	47
9307		CES202.604	North-Central Appalachian Acidic Swamp		7	
9308		CES202.298	Piedmont Seepage Wetland		4	
9198		CES201.585	Laurentian-Acadian Alkaline Fen		3	
9160		CES202.018	Central Interior Highlands and Appalachian Sinkhole and Depression Pond		10	

Once the list for the AKR had been created and reviewed by the ecologist, the next steps were to begin developing the new auto-key to ecological systems. That work is described in section **Design and Refinement of Auto-Keys**.

Subsequent to completing the auto-key to ecological systems, a further step required determining which NVC Groups occur in the relevant AKR. As described above, NatureServe has developed and maintains a crosswalk between all of the ecological systems and the NVC Groups. This relationship is available as a look-up table, wherein each ecological system is related to one, or more, Groups.

Once the auto-key to ecological systems was completed, a relatively simple query pulled from the systems-to-Groups look-up table to create an initial list of NVC Groups for the relevant AKR. The query also generated draft criteria for each Group, using the criteria for the ecological system related to that Group; in essence the query resulted in a draft auto-key to the NVC Groups based on the ecological systems auto-key. This list of Groups and associated criteria were then further modified as the ecologist worked through the new auto-key to NVC Groups for the relevant AKR. These modifications would include removing Groups that were very unlikely to occur in the AKR, but also to add any Groups that may not have been included by the crosswalk-based query.

Legend of Ruderal and Cultural Types

LANDFIRE 2001 had a list of land cover classes expanding beyond natural types (ecological systems and NVC alliances) that were developed for the legend and were used in the auto-keys (see section **Ruderal and Cultural Vegetation in the Auto-Keys** for further explanation). The types included both more recent, naturalized, or semi-natural ecosystems (what are now called “ruderal” ecosystems) as well as agricultural and developed types (what are now called “cultural” types). “Ruderal” vegetation includes spontaneously established vegetation composition that develops after distinct human disturbance (e.g., exotic dominated, natives in non-natural combinations, native overstory/exotic undergrowth, etc.). The essential determination must be that the composition has no natural analog and thus, the type can be distinguished from other native vegetation types. “Cultural” vegetation requires distinct human effort for its establishment and maintenance, so agricultural fields, urban and recreational landscapes (maintained parks, golf courses, lawns, gardens, etc.) are addressed under cultural vegetation categories.

The USNVC includes all vegetation types, but until 2008 (FGDC 2008), the USNVC had not fully addressed how to classify native, ruderal and cultural types. In recent years, the development of the revised NVC now includes identification of both ruderal and cultural portions of the hierarchy, with a set of standard units. Ruderal types are now included within a broadly defined “Natural Vegetation” category, and native and ruderal types are distinguished lower within that part of the hierarchy (typically at the macrogroup level). A list of the ruderal types and the cultural (Agricultural & Developed) types needed for the LANDFIRE 2015 Legend is presented in **Table 4**. For context, the upper levels of Cultural Vegetation are presented in **Table 5**.

For this effort, LANDFIRE 2001 map legends were compared with Regional GAP map legends (SW, SE, NW, and California regional efforts) to identify a robust set of ruderal and cultural map classes that might be treated by LANDFIRE 2015. These earlier concepts were compared to draft USNVC listings for cultural and ruderal vegetation to determine the subset of USNVC units that were likely to be considered mappable. **Table 4** provides a listing of desired LANDFIRE 2015 map classes for the ruderal portion of the overall map legend. In most cases, the Group level of the NVC was suitable for describing these map classes. The only cultural types included in the auto-keys are plantations and a very general class for “cultivated crops and irrigated agriculture”. This is because plot data collected within cultural vegetation generally is in forested plantations (e.g. FIA data), or in a few cases within something such as alfalfa fields. It is very unusual to have species composition from agricultural crops or lawns, for example, so there was no purpose to including such things in the keys.

These units were organized in terms of auto-key regions where they were likely to occur. This led to a grouping of AKRs as depicted in **Figure 6** as the practical framework for developing auto-keys specifically for ruderal and cultural map classes.

Table 4. List of ruderal and cultural vegetation types identified for the new LANDFIRE 2015 legend and keys. The types are organized by the USNVC Formation.

NVC Formation and Ruderal Groups		Notes
1.A.1 Tropical Dry Forest & Woodland		
G683	Caribbean Ruderal Dry Forest	Occurs in southern Florida
1.B.1 Warm Temperate Forest & Woodland		
G031	Southeastern Native Ruderal Forest	
G029	Southeastern Exotic Ruderal Forest	
G678	California Ruderal Forest	
1.B.2 Cool Temperate Forest & Woodland		
G030	Northern & Central Native Ruderal Forest	
G032	Northern & Central Exotic Ruderal Forest	
G685	Rocky Mountain Ruderal Forest	
G801	Vancouverian Ruderal Forest	
1.B.3 Temperate Flooded & Swamp Forest		
G552	Northern & Central Native Ruderal Flooded & Swamp Forest	
G763	Northern & Central Exotic Ruderal Flooded & Swamp Forest	
G553	Southeastern Native Ruderal Flooded & Swamp Forest	
G762	Southeastern Exotic Ruderal Flooded & Swamp Forest	
G510	Interior West Ruderal Riparian Forest & Scrub	
2.A.1 Tropical Lowland Grassland, Savanna & Shrubland		
G684	Caribbean & Mesoamerican Lowland Ruderal Grassland & Shrubland	Occurs in southern Florida
2.B.1 Mediterranean Scrub & Grassland		
G802	Californian Ruderal Scrub	
G497	California Ruderal Grassland & Forb Meadow	
2.B.2 Temperate Grassland & Shrubland		
G679	Northern & Central Plains Ruderal Grassland & Shrubland	
G059	Northern & Central Ruderal Meadow & Shrubland	
G680	Southern Plains & Texas Ruderal & Planted Grassland & Shrubland	
G583	Southeastern Ruderal Grassland & Shrubland	
G624	Interior Western North American Ruderal Grassland & Shrubland	
G648	Southern Vancouverian Lowland Ruderal Grassland & Shrubland	
2.B.4 Temperate to Polar Scrub & Herb Coastal Vegetation		
G647	North Pacific Maritime Coastal Ruderal Shrub & Grass Dune	
2.C.4 Temperate to Polar Freshwater Marsh, Wet Meadow & Shrubland		
G556	Northern & Central Ruderal Wet Meadow & Marsh	

NVC Formation and Ruderal Groups		Notes
G557	Southeastern Ruderal Wet Meadow & Marsh	
G524	Western North American Ruderal Wet Shrubland, Meadow & Marsh	
3.A.2 Warm Desert & Semi-Desert Scrub & Grassland		
G677	North American Warm Desert Ruderal Scrub & Grassland	
3.B.1 Cool Semi-Desert Scrub & Grassland		
G600	Great Basin & Intermountain Ruderal Dry Shrubland & Grassland	split into 4 subtypes for LF purposes
Subgroup	<i>Great Basin & Intermountain Introduced Annual and Biennial Forbland</i>	
Subgroup	<i>Great Basin & Intermountain Introduced Annual Grassland</i>	
Subgroup	<i>Great Basin & Intermountain Introduced Perennial Grassland and Forbland</i>	
Subgroup	<i>Great Basin & Intermountain Ruderal Shrubland</i>	
5.B.2 Temperate & Boreal Freshwater Aquatic Vegetation		
G595	Eastern North American Ruderal Aquatic Vegetation	
NVC Cultural Formation and Cultural Groups		Notes
7.A.2 Forest Plantation & Agroforestry		
G682	Caribbean Forest Plantation	
G779	Eastern North American Temperate Forest Plantation	split into 2 subtypes for LF purposes
Cultural Subgroup	<i>Northeastern North American Temperate Forest Plantation</i>	
Cultural Subgroup	<i>Southeastern North American Temperate Forest Plantation</i>	
G780	Western North American Temperate Forest Plantation	probably not mappable as distinct from natural forests
7.B Herbaceous Agricultural Vegetation (SubClass)		
	Cultivated Crops and Irrigated Agriculture	This was a generalized category for all agriculture and pasture / hay.

Table 5. A summary of the upper 3 levels of the USNVC Cultural Types.

Cultural Class	Cultural Subclass	Cultural Formation
7. Agricultural & Developed Vegetation [Anthromorphic Vegetation]		
	7.A. Woody Agricultural Vegetation	7.A.1. Woody Horticultural Crop
		7.A.2. Forest Plantation & Agroforestry*
		7.A.3. Woody Wetland Horticultural Crop

Cultural Class	Cultural Subclass	Cultural Formation
	7.B. Herbaceous Agricultural Vegetation**	7.B.1. Row & Close Grain Crop
		7.B.2. Pasture & Hay Field Crop
		7.B.3. Herbaceous Horticultural Crop
		7.B.4. Fallow Field & Weed Vegetation
		7.B.5. Herbaceous Wetland Crop
	7.C Herbaceous & Woody Developed Vegetation	7.C.1. Lawn, Garden & Recreational Vegetation
		7.C.2. Other Developed Vegetation
		7.C.3. Developed Wetland Vegetation
	7.D. Agricultural & Developed Aquatic Vegetation	7.D.1. Agricultural Aquatic Vegetation
		7.D.2. Developed Aquatic Vegetation
	✱	7.A.2. Forest Plantation & Agroforestry was split into 4 plantation types for the legend
**	7.B. Herbaceous Agricultural Vegetation was treated as 1 type in the keys; several different kinds of agriculture are likely to be on the legend and mapped.	

Design and Refinement of Auto-Keys

The work being reported on here had the objectives of redesigning A-Ks for ecological systems written during the LANDFIRE 2001 project, and secondly to write new A-Ks to natural NVC Groups. In addition, keys to ruderal and cultural vegetation were desired. As described previously, multiple technical steps were necessary before the work on the keys themselves could begin. To summarize, prior steps included:

1. Preparing plot data to be used with the keys
2. The redefining of new auto-key regions (AKRs) for the keys to natural types
3. Defining new multi-regions to use for the keys to ruderal & cultural types
4. Developing the draft legend of ecological systems for each AKR, followed by the legend of NVC Groups for each AKR
5. Revisiting the non-natural land cover types on the LANDFIRE 2001 legend and establishing a new legend for those ruderal & cultural types
6. Creating and maintaining a master EVT_LUT
7. Developing procedures for using the expert labels on plots for evaluating and validating the keys
8. Developing expert labels to Groups

A-Ks to Ecological Systems

Since the LANDFIRE 2001 work completed keys to ecological systems, and the system types have changed little in concept since 2009, the logical first step was to begin with refining the criteria to the 2001 keys to systems. Once the ecologist began work on refining the A-Ks to ecological systems for a particular AKR, generally the same steps were followed for each AKR as outlined below:

- A. Review the results from the Improvements #1 project, including the contingency tables and report for the relevant Geo Area(s).
 - a. The purpose of this step was to identify particular ecological systems that did not key well with the LANDFIRE 2001 keys and that tended to be confused with each other

- B. Review the original LANDFIRE 2001 keys to identify which key or keys would be the most useful to use as the starting point for the new AKR-based key
 - a. Most AKRs had at least 2 overlapping LANDFIRE 2001 keys (**Table 6**); the ecologist would select one, generally the one with the most types in it that would be in the new AKR
- C. Remove from the selected map-zone-based key any NVC alliances; also any individual ecological systems deemed to not occur in the AKR
- D. Add to the selected key any individual ecological systems that were treated in the LANDFIRE 2001 effort as members of an aggregate;
 - a. Copy and edit criteria for the aggregate to the added ecological systems.
 - i. The editing would then be to split the criteria (i.e. structure, species composition and distribution) for the aggregate into criteria relevant to the individual ecological system. For example the aggregate *Rocky Mountain Subalpine/Upper Montane Riparian Systems* has 2 member ecological systems (**Table 7**): *Rocky Mountain Subalpine-Montane Riparian Shrubland* and *Rocky Mountain Subalpine-Montane Riparian Woodland*. Criteria for the aggregate would need to be edited to exclude tree-dominated plots for the Shrubland system, and exclude shrub-dominated plots with no trees for the Woodland system.
 - b. Then delete the aggregate once individual systems were added and criteria edited
- E. Add to the selected key any individual ecological systems that were not in the selected key
 - a. Generally these additional ecological systems were in one of the other map-zone-based keys, so the ecological system along with its original criteria were copied to the new AKR key
 - b. Some ecological systems were never treated in one of the LANDFIRE 2001 keys, even as members of an aggregate; these would be added and new criteria for them drafted
- F. Once these steps were completed (see **Table 7** for examples of revisions) the new draft AKR key would be ready to run through the auto-key program for an initial test.
- G. This first run through the auto-key program usually resulted in the identification of taxonomic changes in the plant species names that would need to be corrected (see the section **Preparation of Plot Data and Data Management** above). This was because the LANDFIRE 2001 keys used nomenclature from 2004; while the new nomenclatural standard was 2013. The LFRDB data manager provided a crosswalk from the 2004 to 2013 names; the ecologist would consult this and correct plant names in the A-K.
- H. Following this initial test, assuming there were no further errors with the draft key, the ecologist would proceed with multiple, iterative refinements to the criteria in the key.
- I. These refinements could include any or all of:
 - a. Changing the order or ‘sequencing’ of the rows of criteria
 - b. Removing or adding species as diagnostic species
 - c. Changing the cover criteria, either the total cover by life-form or total relative cover of a suite of species
 - d. Adding, removing or revising the geographic/geophysical criteria, such as elevation or ECOMAP section.
- J. After each set of refinements, the ecologist would run the key through the program again, and review the results, as represented by a suite of output tables generated by the auto-key program [Note: See Appendix C: **LANDFIRE Documentation: Working Of Auto-Keys & Output Tables** which documents the output tables].
- K. When the ecologist was satisfied with the key results, the AKR report was populated (see section **AKR reports** below for a description of the reports).

Table 6. List of auto-key regions (AKRs) and their corresponding LANDFIRE 2001 auto-keys; the number of 2001 keys is provided. The 2001 keys are all named starting with “EVT_” followed by the MRLC map zones included in the key (e.g. z01 is map zone 1 in the Pacific Northwest). The 2001 keys that were most relevant to the new AKR are bolded. See **Figure 1** for a map of the zones and 2001 key clusters.

AKR_ID	Auto-key Region Name	LANDFIRE 2001 Map Zone Keys	# of 2001 Keys
1	North Pacific Coast	EVT_z01_z02_z07 , EVT_z03_z04_z05_z06, EVT_z08_z09_z18	3
2	California	EVT_z01_z02_z07, EVT_z03_z04_z05_z06 , EVT_z13_z14	3
3	Intermountain Basins	EVT_z08_z09_z18 , EVT_z12_z17 , EVT_z16_z23_z24, EVT_z20_z22	4
4	Rocky Mountains	EVT_z08_z09_z18, EVT_z10_z19_z21 , EVT_z15, EVT_z16_z23_z24, EVT_z28 , EVT_z29_z30	6
5	Warm Desert	EVT_z13_z14 , EVT_z15, EVT_z25_z26 , EVT_z27_z33_z34	4
6	Colorado Plateau	EVT_z12_z17, EVT_z15, EVT_z16_z23_z24	3
7	Western Great Plains	EVT_z20_z22, EVT_z25_z26, EVT_z27_z33_z34 , EVT_z29_z30 , EVT_z31_z39_z40	5
8	Eastern Great Plains	EVT_z38_z42_z43 , EVT_z41_z50_z51, EVT_z49_z52_z62	3
9	Texas-Louisiana Coast	EVT_z36 , EVT_z37_z45_z46_z98_z99,	2
10	Texas-Oklahoma Hill Prairie	EVT_z27_z33_z34, EVT_z32_z35 , EVT_z37_z45_z46_z98_z99	3
11	Mississippi Alluvial	EVT_z37_z45_z46_z98_z99 , EVT_z44	2
12	Central Interior	EVT_z41_z50_z51, EVT_z44 , EVT_z47_z48_z53, EVT_z49_z52_z62 , EVT_z63_z64_z65_z66	5
13	North Woods	EVT_z41_z50_z51 , EVT_z63_z64_z65_z66	2
14	Appalachia	EVT_z47_z48_z53, EVT_z54_z57_z59_z60_z61 , EVT_z63_z64_z65_z66	2
15	North[east] Coast	EVT_z54_z57_z59_z60_z61, EVT_z63_z64_z65_z66	2

Table 7. Example of revisions made to the Rocky Mountain AKR auto-key for ecological systems. Classes in blue font were removed from the LANDFIRE 2001 auto-key, and replaced with the classes shown below each removed class. This list does not include all of the revisions made.

	Action Taken
Removed criteria for alliances and keyed samples to appropriate system	
<i>Abies concolor</i> Forest Alliance	removed
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	kept as-is
<i>Artemisia tridentata</i> ssp. <i>vaseyana</i> Shrubland Alliance	removed
Inter-Mountain Basins Montane Sagebrush Steppe	kept as-is
<i>Quercus gambelii</i> Shrubland Alliance	removed
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	kept as-is
Added component systems and criteria for sparse and riparian system aggregates	
Rocky Mountain Alpine/Montane Sparsely Vegetated Systems	removed
Rocky Mountain Alpine Bedrock and Scree	added
Rocky Mountain Cliff, Canyon and Massive Bedrock	added
Rocky Mountain Montane Riparian Systems	removed
Rocky Mountain Lower Montane - Foothill Riparian Woodland and Shrubland	added
Rocky Mountain Subalpine/Upper Montane Riparian Systems	removed
Rocky Mountain Subalpine-Montane Riparian Shrubland	added
Rocky Mountain Subalpine-Montane Riparian Woodland	added
Added lumped small patch and linear systems excluded from LANDFIRE 2001 legend	
Unclassified Wetland-Riparian Herbaceous	removed
Rocky Mountain Alpine-Montane Wet Meadow	added
Rocky Mountain Subalpine-Montane Fen	added
North American Arid West Emergent Marsh	added

A-Ks to NVC Groups

The process for developing an auto-key to Groups for an AKR followed much the same procedures as described above. The first difference was how the key was initiated. Rather than making use of LANDFIRE 2001 keys to start, the draft Groups key was generated by use of a query that used two inputs: 1) the look-up table cross-walking each ecological system to one or more NVC Groups, and 2) the criteria in the key to ecological systems. The query generated a draft Groups key, with the criteria from the related ecological system(s).

In some cases, an individual Group was related to 2 or more ecological systems, and the criteria would then need to be combined. In other cases an individual ecological system was related to two different Groups; in this case, the criteria would need to be edited to reflect which Group.

The final list of Groups for the particular AKR then needed careful review by the ecologist. The relationship between ecological systems and Groups is not a perfect one-to-one, and creating the key using the above query process could result in inclusion of Groups that don't occur in a region. Conversely, additional Groups would need to be added to the key (e.g. those with no related ecological systems).

Once the expected Groups were included in the draft key, along with the structural and species criteria, the key would be iteratively run through the program and revised, as was done for the ecological systems key. When the ecologist was satisfied with the key results, the AKR report was populated.

Ruderal and Cultural Vegetation in the Auto-Keys

Once the legend for ruderal and cultural vegetation was identified (**Table 4**), discussion by the steering committee determined that it would be most efficient in the work flow of handling plots for mapping to use the keys in a step-wise fashion:

1. First, key plots to ruderal or cultural types,
2. then remove those plots labeled to ruderal or cultural from the plot dataset,
3. run the remaining plots through the keys to ecological systems or NVC Groups to obtain labels to systems or Groups

The decision was to create four individual keys for the ruderal and cultural vegetation types (see map in **Figure 6** and list in **Table 2**). These keys were developed in much the same way as the keys for systems or Groups; draft criteria were available for similar ruderal types from the LANDFIRE 2001 keys (see **Table 8**) and were used as the starting point for the criteria for the types identified for the 2015 keys. The process was iterative: develop the draft of the key and criteria, test the plots with the auto-key program, evaluate the results, revise the criteria, test the plots again, and so on. Since the datasets for the multi-regions were so large for three of the multi-regions, running the plots and key thru the program was very slow and would often take several hours.

However, in the process of developing keys for the individual AKRs for the natural ecological systems or NVC Groups, the ecologists needed to retain ruderal and cultural land cover classes in their keys, even though the focus of those keys was on the natural systems or Groups. There are two reasons for this: while the three step process above is desirable, in practice it was not implemented for this project; and the work on the keys for the AKRs treating systems and Groups started well before the final legend of ruderal and cultural types was determined. Therefore, the AKR keys to systems or Groups used the list of types shown in **Table 8**, which are the same classes used in the 2001 keys. While these land cover classes are related to the final ruderal & cultural types treated in the 2015 ruderal/cultural keys, in some cases the criteria for keying to “ruderal” was different across the keys.

In sum:

1. The new 2015 ecological system and NVC Groups keys organized into the auto-key regions used the list of land cover classes found in **Table 8**, which were also used in the 2001 keys.
2. The new 2015 keys to ruderal & cultural types, organized into 4 multi-regions, used the list of types found in **Table 4**.

The differences in how the 2015 keys treat ruderal and cultural vegetation is evaluated in the **Quality** section of the results.

Table 8. Land use and land cover classes used in the 2001 LANDFIRE keys, and in the 2015 AKR-based keys.

LAND USE
Cultivated Crops and Irrigated Agriculture
SEMI-NATURAL / ALTERED VEGETATION
Ruderal Vegetation
Ruderal Upland - Old Field

Ruderal Forest - Northern and Central Hardwood and Conifer
Ruderal Forest - Southeast Hardwood and Conifer
Ruderal Upland-Treed
Ruderal Wetland
Transitional Herbaceous Vegetation
Transitional Shrub Vegetation
Introduced Vegetation
Introduced Upland Vegetation - Treed
Introduced Upland Vegetation - Shrub
Introduced Upland Vegetation - Annual and Biennial Forbland
Introduced Upland Vegetation - Annual Grassland
California Annual Grassland
Introduced Upland Vegetation - Perennial Grassland and Forbland
Introduced Riparian Vegetation
Introduced Wetland Vegetation - Mixed
Introduced Wetland Vegetation - Tree
Introduced Wetland Vegetation - Shrub
Introduced Wetland Vegetation - Herbaceous
Introduced Coastal Wetland Vegetation - Tree
Introduced Coastal Wetland Vegetation - Shrub
Introduced Coastal Wetland Vegetation - Herbaceous
Recently Burned Vegetation
Recently Burned-Tree Cover
Recently Burned-Shrub Cover
Recently Burned-Herb and Grass Cover
Modified/Managed Vegetation
Recently Logged-Herb and Grass Cover
Recently Logged-Shrub Cover
Recently Logged-Tree Cover
Managed Tree Plantation - Northern and Central Hardwood and Conifer Plantation Group
Managed Tree Plantation - Southeast Conifer and Hardwood Plantation Group
Modified/Managed Northern Tall Grassland
Modified/Managed Southern Tall Grassland

Assessment, Inventory and Monitoring (AIM) Plot Review for BLM

In 2014, the Bureau of Land Management (BLM) provided plot data from their Assessment, Inventory and Monitoring (AIM) program to the LANDFIRE reference database manager for incorporation into the LFRDB. BLM also contracted with NatureServe to conduct a review of their AIM data, test using it with the auto-keys, and assign expert labels to a subset of the plots.

NatureServe completed this work in the spring of 2015, working with AIM plots in both the Intermountain Basin and Western Great Plains AKRs. All of the AIM plots in these 2 regions were run through both the ecological systems and NVC Groups auto-keys. A subset of the AIM plots were selected

for review by an ecologist, and assignment of expert labels. A report was developed and delivered to BLM (Reid and Schulz 2015), as were all of the expert labels assigned to AIM plots.

In the Intermountain Basin AKR, there were 3,691 AIM plots, and 200 in the Western Great Plains. In the IMB, 240 were reviewed by the ecologist for expert labeling, a small subset of the total; while in the WGP, all 200 AIM plots were reviewed and assigned expert labels. Labels for each plot were to ecological system and NVC Group. These AIM plots and expert labels are included in the **Results** section below.

Handling of Expert Labels

As described in section **LANDFIRE Improvements # 1**, some 19,000 plots were reviewed by experts to apply an expert label to ecological system for as many plots as possible. An additional 440 plots from the BLM AIM dataset were also reviewed and assigned expert labels (see the **Assessment, Inventory and Monitoring (AIM) Plot Review for BLM** section). This expert labeled dataset has value in several ways:

1. The expert can use his or her judgement to assign a label, making use of information beyond what the auto-key can use
2. It provides an independent dataset for use in validation or accuracy assessment of maps
3. It provides a dataset that can be compared, plot-by-plot, to the labels applied by the auto-key program, to assess problem areas within a key
4. Queries can provide simple statistics comparing auto-key and expert labels by type in order to evaluate how well the auto-key is working overall and for individual types.

The expert attributions were provided as part of each AKR key database (see section **Preparation of Plot Data and Data Management** for more details). The front-end expert attribution database (EADB) designed for use in the Improvements #1 project was adapted for this new effort. The original EADB was designed to assign expert labels; the adaptation of it compares labels assigned by the newly revised auto-keys (see section **Design and Refinement of Auto-Keys** above) with the expert labels from the Improvements #1 project. Additional queries and a revised form for viewing the plot data for the expert-labeled plots were developed.

An additional modification was to add the capability of assigning a new expert label to the plot. This re-assigning of an expert label was done when it was obvious the plot had been mis-labeled in the Improvements #1 project. In that effort, the experts were often reviewing several hundreds of plots very rapidly, typically with less than 5 minutes per plot for review and assigning of a label.

The implementation of using the expert labels from the Improvements #1 project and potentially revising the labels required adding a table to the key database for each AKR, and then populating that table with the original expertly labeled plots from the data provided by the LRDB Data Manager. This was necessary so that the original expert labels would not be modified in any way. An additional requirement was that any revised expert labels would be the basis for the queries used to compare auto-key labels to the expert labels. In other words, the original expert labels were not used in the queries described here, only the labels contained in the new table which stored the original labels + any changed labels.

A series of queries were developed to report on the results of the auto-key, as compared to expert labels on plots. See section **AKR reports** below for further documentation of the content of these reports.

Expert Labels to NVC Groups

The LANDFIRE Improvements #1 project resulted in expert labels on plots to ecological systems, which provided a robust dataset for evaluating and reporting on the auto-keys to ecological systems. However,

the second major objective of this current effort was to develop new auto-keys to the NVC Groups. It was also desirable to have Group labels on the same expert labeled plots, so that comparisons could be made between the expert labels and auto-key labels to Groups.

Utilizing the same crosswalk between ecological systems and NVC Groups described in **Legends by Auto-Key Regions** above, a query was used to populate an 'expert' label to Group for each of the expert plots, in the same MS Access table where all of the expert plot labels were being managed for each AKR. Since some ecological systems are cross-walked to more than one Group, this pre-population of the Group expert label was only done where the system is related to one, and only one, Group. This meant a number of expert plots with an expert label to ecological system did not have a Group expert label.

In subsequent steps, the ecologist working on the keys for a particular AKR reviewed the expert assignments to Group, and as time allowed assigned a Group label for plots with no label. In some cases the crosswalk of ES to Group resulted in plots being assigned to a Group that was incorrect. The ecologists tried to identify these problematic system-to-Group crosswalks, and then explicitly reviewed plots assigned to those systems or Groups to correct the Group label. Resources were not sufficient to review all >17,000 plots for the Group labels, but a significant percentage of them were reviewed.

Hence the expert labels to NVC Groups should be considered as preliminary assignments. Still, they represent a useful dataset for evaluating the auto-keys to Groups, and over time if resources allow further review of them, would result in a robust independent dataset for validating or assessing future maps of NVC Groups.

Table 9. Numbers of expert plots by auto-key region, with numbers actually assigned to an ecological system or NVC Group. Any individual plot can have an expert label for both ecological system and NVC Group, could only have one label, or in some cases no label.

AKR #	Name of Auto-key Region	# Expert Plots	# Expert Plots with System Label	# Expert Plots with NVC Group Label
1	North Pacific Coast	1,722	1,701	1,637
2	California	1,965	1,922	1,844
3	Intermountain Basins	1,992	1,868	1,666
4	Rocky Mountains	3,390	3,193	2,730
5	Warm Desert	705	684	680
6	Colorado Plateau	527	498	512
7	Western Great Plains	1,686	1,540	1,525
8	Eastern Great Plains	513	425	421
9	Texas-Louisiana Coast	259	167	167
10	Texas-Oklahoma Hill Prairie	552	412	375
11	Mississippi Alluvial	442	399	399
12	Central Interior	756	591	564
13	North Woods	1,058	795	771
14	Appalachia	1,171	1,027	1,022
15	North[east] Coast	259	237	237
16	Coastal Plain	937	797	797
	Total for all 16 AKRs	17,934	16,256	15,347

Comparison of Auto-Key and Expert Labels

- Once an auto-key has been run for an AKR key database, all of the plots are labeled to one of the ecological systems, NVC Groups or other land cover types included in the keys. Some of these plots also have an expert label to either ecological system or Group. The advantage of this 2-step process is that comparisons can be done between what the auto-key labeled an individual plot and what the expert labeled the same plot. [Note: the number of plots with expert labels in any single AKR is generally <5% of the total plots for that AKR.]
- Comparisons can also be done by vegetation type to simply count how many “matches” or “mismatches” there are between auto-key and expert labels, which can then be expressed as percentages of all plots labeled to that vegetation type.
- NatureServe’s Expert Attribution DB was programmed with a series of queries to generate a tabular report showing these comparisons. The comparisons are done from the perspective of the “expert”, under the assumption the expert will be correct more often than the auto-key, which is limited by the criteria that can be used. In other words, if the auto-key label is different from the expert label, it is a mismatch.
- Following the auto-key labeling step for each AKR in this study, the tabular reports were generated to compare the expert labels to auto-key labels. The reports could be generated for either the ecological systems key or the one for NVC Groups.
- These reports were then iteratively evaluated by the ecologist to determine if there were particular vegetation types for which the auto-key was not working well; refinements were made to the criteria in the key, and the report run again. In some cases these comparisons highlight where there are too few plots for a particular type.
- These reports became the basis for a final report for each AKR, as described below.



Marion Reid, San Rafael Swell UT; Colorado Plateau Pinyon-Juniper Woodland

AKR reports

Before presenting the results below, this section documents the reports developed for each AKR, after the A-Ks to ecological systems and NVC Groups were completed. As described in the **Handling of Expert Labels** section above, expertly labeled plots were available for each AKR, and those labels were compared to labels assigned by the auto-key program to aid the ecologist in evaluating the effectiveness of the key itself.

However, a second major value in the expert labels is to provide by-type validation information for a particular key/AKR. Queries were developed within the NatureServe EADB to make use of this expert-to-auto-key comparison. The results from queries were then added to an excel workbook, the “AKR Report”, one for each AKR, with a tab for the ecological systems results and a second for Groups results. The report provides a by-type summary of results (**Table 10** and described below) and columns for the ecologist to populate information about each type within the key. Using the by-type results, the AKR report also includes summary data for the key to ecological systems (**Table 11**, and described below) and a separate summary for the key to Groups. The two tables below provide an example of the results for ecological systems for the Appalachia AKR. All of the AKR reports are provided in Appendix D.

By-Type AKR Report Content

For each vegetation type in the report (system or Group), queries provided counts of the total number of plots labeled to it by the auto-key program (column: # AK labeled plots), the number of expert labeled plots for the type (column: # of expert labeled plots), and for ecological systems the square kilometers of mapped extent in the AKR, drawn from the NatureServe map of ecological systems (NatureServe 2013).

A plot-by-plot comparison was made via queries of the expert label on each individual expert plot and the auto-key label on the same plot. These were then summed to how many expert labels for the ecological system or Group were matched by the auto-key label (see # Matched column in **Table 10**) and how many did not match (column: # Mismatched). Percentages matched or mismatched were calculated by the query, by dividing the number matched by the total number of expert plots for the type, or the total mismatched by total expert plots for the type, multiplied by 100 to show percent (% mismatched and % matched columns in **Table 10**).

Because the total number of expert plots was small (or zero) for many types, and hence the % of matches should be considered carefully, additional queries were used to express the following:

- ✓ Categorize the number of expert plots (column: Relative Quantity of Expert Attributions in **Table 10**) into High (20 or more expert plots), Moderate (10 to 19 expert plots) and Low (1 to 9 expert plots).
- ✓ The percent matches were also categorized (column: Level of Agreement in **Table 10**) into High (70% matches or higher), Moderate (40% to 70% matches), and Low (0% to 40% matches).
- ✓ Whether there were an adequate number of expert plots (at least 10 expert plots) with the High, Moderate, or Low level of agreement (column: Level of Agreement w Adequate Expert Plots in **Table 10**).

All of the above information was generated by queries, and copied/pasted into the excel report table. Additional content in the report table was developed by the ecologist who wrote the auto-key for the relevant AKR, and hence was familiar with the workings of the key, as well as the plot data itself. Three additional columns were added to the report, and were populated by the ecologist. The “Notes on auto

key performance and type” column was the only place where the ecologist wrote their observations on the key and the type in relation to the key or the plots.

The Mapping Considerations column was a list of options from which the ecologist selected to categorize the type relevant to mapping methods; this column provides to the mapping team the ecologist’s perspective on mapping methods that would best be employed for the type. Options to select from are listed below along with the reasoning for each:

1. *Suitable for LANDFIRE modeling methods*: lots of plots, both expert and auto-keyed; distribution well-understood.
2. *Few samples, but occurs with distinct spectral signature*: may not have a lot of plots representing it, but is easily mapped due to spectral signature & distribution.
3. *Requires deductive modeling or custom methods*: applies to many riparian, wetland and sparsely vegetated types that often have a distinct biophysical setting but are small patch or linear in the landscape and may not be clear spectrally; often they don’t have a lot of plots either.
4. *Minor, very peripheral. Much of this type occurs in adjacent AK region*: the type occurs in this AKR, but may not have many plots (or none); the bulk of plots representing this type are most abundant in an adjacent AKR.
5. *Unmappable with modeling, only heritage element occurrence data would suffice to represent this type*: very poorly sampled types, often rare to uncommon, and occurring with a small patch spatial pattern.

The last column “Sufficiency of Samples” was another pick-list (high, medium, low) to capture the ecologist’s perspective on whether the type has an adequate number of plots to represent it. This include several aspects of sufficiency:

1. Number of plots that auto-key to the type
2. Number of plots with expert labels to the type (i.e. should there be more?)
3. Quality of the plot data, e.g. are most of the plots lacking shrub and herb compositional data, so are difficult to key
4. Are the plots accurately keyed to the type

Table 10. Example by-type report for ecological systems in the Appalachia AKR. Contents of the report are described above in the By-Type Report Content section.

NatureServe Elcode	EVT Code	Type Name	Mapped Extent (km2)	# AK labeled plots	# of expert labeled plots	# Mismatched	# Matched	% Mismatched	% Matched	Relative Quantity of Expert Attributions	Level of Agreement	Level of Agreement w Adequate Plots	Notes on auto key performance and type	Mapping Considerations	Sufficiency of Existing Samples (H, M, L)
CES202.373	7318	Southern and Central Appalachian Cove Forest	16,683	2255	141	68	73	48.23	51.77	High	Moderate	Moderate	Confusion with successional / ruderal (e.g. Liriodendron); aspect and landform (concave) would help with this. Many plots (FIA) lack shrub and herb data.	Requires deductive modeling or custom methods	H
CES202.359	7317	Allegheny-Cumberland Dry Oak Forest and Woodland	37,817	1605	100	35	65	35.00	65.00	High	Moderate	Moderate	Too much confusion with ruderal / successional (Pinus); and with other oak types. Many plots (FIA) lack shrub and herb data.	Requires deductive modeling or custom methods	M
CES202.591	7369	Central Appalachian Dry Oak-Pine Forest	21,434	375	90	76	14	84.44	15.56	High	Low	Low	This is a matrix type within a distinct region.	Suitable for LANDFIRE modeling methods	H
CES202.593	7370	Appalachian (Hemlock)-Northern Hardwood Forest	42,546	1375	67	34	33	50.75	49.25	High	Moderate	Moderate	Possible confusion with Cove forests, ruderal forests, and dry-mesic oak. Many plots (FIA) lack shrub and herb data.	Suitable for LANDFIRE modeling methods	H
CES201.564	7302	Laurentian-Acadian Northern	19,957	440	47	24	23	51.06	48.94	High	Moderate	Moderate	Confusion with hemlock-hardwoods. Many plots (FIA) lack shrub and herb data.	Suitable for LANDFIRE modeling methods	M

		Hardwood Forest													
CES202.332	7353	Southern Appalachian Low-Elevation Pine Forest	6,867	403	44	19	25	43.18	56.82	High	Moderate	Moderate	Confusion with Piedmont Oak-(Pine), hardwood types, montane pine. Elevation a very rough indicator compared with montane pine. Many plots (FIA) lack shrub and herb data.	Requires deductive modeling or custom methods	M
CES202.596	7320	Central and Southern Appalachian Montane Oak Forest	2,431	961	37	17	20	45.95	54.05	High	Moderate	Moderate	Confusion with oak-pine types, lower elevation oak, and some mesic forests. Many plots (FIA) lack shrub and herb data.	Suitable for LANDFIRE modeling methods	H
CES201.568	7389	Acadian-Appalachian Subalpine Woodland and Heath-Krummholz		3								Moderate	peripheral	Minor, very peripheral. Much of this type occurs in adjacent AK region	L
CES202.598	7340	Appalachian Shale Barrens		0								Low	very specific type in a limited region; need expert plots	Unmappable with modeling, only heritage element occurrence data would suffice to represent this type	L

Summary AKR Report Content

A summary report was developed for each AKR, for the systems key and for the Groups key. The by-type comparison of auto-key labels to the expert labels was summed up for the entire AKR, by adding the total number of matches of labels, then dividing the number of matches by the total number of expert plots. This is the Percent Overall Validation Agreement in the summary.

Additional numbers provided include the number of natural types in the key (either ecological systems or NVC Groups) and how many of those types have expert plots. For example in **Table 11** there are 77 ecological systems in the key, but only 37 of them have expert plots. For the 37 types with expert plots, the summary provides further details of how many have more than 20 expert plots (n=16), how many between 10 and 19 expert plots (n=4), and how many have 9 or fewer (including none) expert plots (n=17).

Additional summary statistics provided are as follows:

1. *# Types with High (70-100%) expert plot agreement with adequate #plots (10-59):* a count of the natural types in the key with at least 10 expert plots and where the percent of matches between the expert label and auto-key label is at least 70%.
2. *# Types with Moderate (40-70%) expert plot agreement with adequate #plots (10-59):* a count of the natural types in the key with at least 10 expert plots and where the percent of matches between the expert label and auto-key label is between 40% and 70%.
3. *# Types with Low (<40%) expert plot agreement with adequate #plots (10-59):* a count of the natural types in the key with at least 10 expert plots and where the percent of matches between the expert label and auto-key label is considered low, less than 40%.
4. *# Types: AK developer's judgement of High agreement for types with inadequate # [expert] plots (0-9):* a count of the natural types in the key with either zero expert plots or 9 or fewer (which is considered to be an inadequate number of expert plots) and for which the ecologist who developed the auto-key thinks the key is working well and most plots are keyed accurately.
5. *# Types: AK developer's judgement of Moderate agreement for types with inadequate # [expert] plots (0-9):* a count of the natural types in the key with either zero expert plots or 9 or fewer and for which the ecologist who developed the auto-key thinks the key is working moderately well.
6. *# Types: AK developer's judgement of Low agreement for types with inadequate # [expert] plots (0-9):* a count of the natural types in the key with either zero expert plots or 9 or fewer and for which the ecologist who developed the auto-key thinks the key is working poorly and most plots are not keyed accurately.

Table 11. Summary results for the Appalachia AKR, ecological systems key. A similar summary of results was completed for the NVC Groups key for each AKR.

Auto-Key region: AKR14 – Appalachia		Legend type: Ecological Systems
Summary Statistic		Result
Percent Overall Validation Agreement		49.21
Total number of natural types in AKR		77
Total number of natural types with expert plots		37
# Types with High # (20-59, or more) of expert plots		16
# Types with Moderate # (10- 19) of expert plots		4

Auto-Key region: AKR14 – Appalachia	Legend type: Ecological Systems	
Summary Statistic		Result
# Types with Low # (1-9) of expert plots		17
# Types with High (70-100%) expert plot agreement with adequate #plots (10-59)		2
# Types with Moderate (40-70%) expert plot agreement with adequate #plots (10-59)		14
# Types with Low (<40%) expert plot agreement with adequate #plots (10-59)		4
# Types: AK developer's judgement of High agreement for types with inadequate # [expert] plots (0-9)		1
# Types: AK developer's judgement of Moderate agreement for types with inadequate # [expert] plots (0-9)		35
# Types: AK developer's judgement of Low agreement for types with inadequate # [expert] plots (0-9)		21

Report Content for Ruderals Keys

Excel spreadsheet reports were also developed for each of the four multi-region keys to ruderal and cultural vegetation types. Because expert plots were not labeled to ruderal/cultural vegetation, no comparisons could be made between the auto-key and expert labels. The reports are provided in Appendix D.

For each type, the report contains:

- ✓ a count of the number of plots keyed to the type,
- ✓ a rating by the ecologist of how well the key is working (high, medium, low),
- ✓ a simple ‘concept summary’ for the type,
- ✓ a notes column reflecting on the auto-key performance for the type,
- ✓ a mapping considerations pick-list, as was used for the systems and Groups reports,
- ✓ and sufficiency of sample data, as was used for the systems and Groups report.

Results

This section of the report provides a summary of the results of this effort. It is organized into subsections describing results for the legends of types, followed by results for the individual auto-key regions (e.g. numbers of plots, expert plots, overall validation numbers), and the keys to ruderal/cultural types (e.g. numbers of plots by type). Additional results can be found in Appendix A (the LANDFIRE 2015 Legend), Appendix D (reports for each of the 16 AKRs), and Appendix E (counts of plots and expert plots for each ecological system and NVC Group). Some interpretation of these results is also provided.

The **Project Analysis and Effectiveness** section below provides more in-depth analysis comparing the 3 different sets of keys (systems, Groups and ruderals) and also comparing across the two timeframes of keys (2001 to 2015). Several tables summarize numbers of plots by Geo Area across the types and time frames of keys. Some discussion and interpretation of these analyses is provided. In addition, in the **Case Studies: Rocky Mountains, Western Great Plains, Appalachia** section, an example contingency table is presented, with an explanation of how to interpret it and then the contingency tables from three AKRs are discussed. Appendix G provides those tables.

Final Legends

The master LANDFIRE 2015 legend is being tracked in a MS Excel workbook which has been provided to LANDFIRE and the coordinating team (and see Appendix A). Data for each vegetation type is included, such as all the different codes for it, whether it was on the LANDFIRE 2001 legend, its distribution, or for NVC Groups how they relate to the upper levels of the NVC hierarchy.



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There are six hundred and thirty one (631) ecological systems in the lower 48; of these, 541 are recommended to be on the LANDFIRE legend for the ReMap effort (**Table 12**). Ninety eight (98) systems represent wetlands or cliffs, talus, shorelines, and other sparsely vegetated types that are unlikely to be mappable due to a variety of reasons (too few plots, very small patch in typical spatial pattern, not relevant to LANDFIRE objectives e.g., seagrass or other aquatic beds). In the 2001 legend and keys (**Table 12**), 391 systems were treated, along with 36 aggregates and 32 alliances. For the 2015 legend and keys 150 systems were added.

In both 2001 and 2015, land use and ruderal types were treated in the keys; those types carried over to the 2015 AKR keys. A new set of Ruderal and Cultural types was defined for the ReMap effort making use of the NVC Group level for the most part, and a separate set of keys were written specifically for those types.

Table 12. Comparison of the LANDFIRE 2001 and 2015 legends.

Land Cover Category	2001 Legend	2015 Legend	Notes
Ecological Systems	391	541	150 types not in 2001 added to 2015
Aggregates of ecological systems	36	n/a	aggregates were replaced by individual ecological systems
NVC alliances	32	n/a	alliances are no longer part of the legend
Land use & ruderal types (Table 8)	32		Of necessity, these types were included in the 2015 AKR keys, but separate keys to ruderal/cultural types were also developed.
Ruderal & Cultural types (Table 4)		35	
Systems included in aggregates	156	n/a	these 156 systems are now included in the 2015 keys
Systems considered to be not-mappable	112	98	in 2015, these are in the keys; in 2001 they weren't included in the keys

There are three hundred and twenty (320) NVC Groups in the lower 48; of these, 278 are recommended to be on the LANDFIRE legend for mapping of NVC concepts. Forty two (42) Groups represent wetlands or cliffs, talus, shorelines, and other sparsely vegetated types that are unlikely to be mappable due to similar reasons for un-mappable ecological systems.

Thirty one (31) ruderal vegetation types were identified; of these 27 are NVC Groups; the other 4 are thematically finer than Groups. The NVC Group Great Basin & Intermountain Ruderal Dry Shrubland & Grassland (G600) was split into 4 ruderal types, because there is a need to map and understand the distribution of exotic annual grasslands in the interior western US, along with other interior west ruderal vegetation.

Four (4) forest plantations represent most of the cultural types. A generalized category for cultivated crops and irrigated agriculture makes up the fifth cultural type. Two additional cultural types – Tropical Open Lawn and Tropical Tree Developed Vegetation – were included in the Warm Temperate Southeastern Ruderals key, but no plots keyed to either type.

Summary by AKRs: Plots, Expert Plots, Keys

Sixteen individual auto-key regions were identified for this project, excluding the southern tip of Florida, which will be included with a future Caribbean AKR. Since two auto-keys were written for each AKR (one for ecological systems, another for NVC Groups) a total of 32 keys were developed and tested with the plot data for each relevant AKR and against the expert labeled plots as well. **Table 13** and **Table 14** provide the summaries from each AKR report, as explained in the above section **Summary AKR Report Content**.

A total of 427,309 plots were included in the key databases across these 16 AKRs; of these, 17,934 were reviewed by experts during the LANDFIRE Improvements #1 effort, and most of these had a label applied (**Table 9**). In sum, 4.2% of the total plots were also expert-reviewed plots.

The total number of plots for each AKR varied greatly, from a high of 80,148 in the Rocky Mountains (Table 13) to a low of 3,517 in the North Coast AKR (Table 14). Some of this variation in plot numbers has to do with the relative size of the individual AKRs, but the variation also relates to the amount of field-based samples available in any particular region. For example the Rocky Mountains AKR has a large number of plots sampled by National Forest staff and the USFS FIA program, as it is a forested region dominated by public land. In addition there are several large national parks with plot data that have been contributed to the LFRDB and a number of other inventory efforts have occurred across the region. This AKR stretches north-to-south from northeastern Washington into the Mogollon Rim area of Arizona - a large geographic extent (Figure 5). In contrast, the North Coast is smaller in extent, and also is a heavily urbanized portion of the country, with concomitantly less natural vegetation and far fewer inventory efforts resulting in samples. Several other AKRs have low numbers of total plots: Texas-Oklahoma Hill Prairie (4,043), Eastern Great Plains (5,691), Mississippi Alluvial (5,833), and Texas-Louisiana Coast (7,087). Most of the AKRs in the western half of CONUS have well over 15,000 plots.

The number of expert-reviewed plots by AKR also varied, not unexpectedly, from 259 each in the Texas-Louisiana Coast and North Coast AKRs (Table 14), to 3,390 in the Rocky Mountains AKR (Table 13). Proportionally the expert plots varied from only 2% of the total plots in the Colorado Plateau and North Woods AKRs to 14% of the total plots in the Texas-Oklahoma Hill Prairie. For most of the AKRs, the proportion of expert plots was 4% to 8%. Part of the variation in the number of expert plots can be explained by how the plots were selected for the Improvements #1 project (more plots were selected for the more abundant ecological systems, but spread across Geo Areas where they occurred). An additional factor was that the expert plots are all samples that were not used in the original LANDFIRE mapping effort- they represent an independent dataset. However, this constraint meant that in some regions of the country far fewer samples were available to become 'expert' plots.

A measure of the complexity of a key in an auto-key region is the number of natural vegetation types in the key. When the number of types is high, the key itself becomes a complex set of criteria to be thought through carefully by the developer. The number of ecological systems by AKR key varied from 114 in the Intermountain Basins (IMB) AKR (Table 13) to only 28 in the Eastern Great Plains (Table 14). The IMB has a lot of types that are peripheral to the AKR- the bulk of their distribution lies outside of the IMB, but they do occur and hence are included in the key. The IMB is a good example of this issue of "periphery". It is a large area, with isolated mountain ranges, and borders the California, Warm Desert, Rocky Mountains, and North Pacific Coast AKRs. A number of ecological systems were included in the key, and plots were assigned to them by the auto-key, but the extent of the individual type within the AKR is very small.

The auto-keys to NVC Groups overall have fewer types included in the key. This is to be expected, as Groups are somewhat coarser concepts than ecological systems and there are fewer of them in the U.S. Interestingly, the Western Great Plains had the highest number of Groups in the key (78) with the Intermountain Basins and Rocky Mountains each having 77. The Mississippi Alluvial had the fewest Groups in the key, only 21. The high number of Groups in the Western Great Plains key is perhaps explained by its very large extent, extreme north-south gradient, peripheral forest and woodland Groups from the Rocky Mountains AKR to the west, and the west-to-east transition from shortgrass prairies to the mixed grass prairies and then the hardwood woodlands and savannas of the Eastern Great Plains and Hill Prairie regions. In essence, the Western Great Plains AKR is a region of continental scale transitions in floristic patterns.

Table 13. Summary of results for AKRs in the western half of CONUS. The table provides total number of plots, number of expert labeled plots, percent of plots that have expert labels, overall percent agreement between expert and auto-key labels, how many natural types are in the key, how many of these have expert plots and how many expert plots, and how plots keyed overall to the natural types, land cover classes, or did not key at all. The bolded AKRs are used as case studies for tables and discussion.

AKR Name:	North Pacific Coast	California	Inter-mountain Basins	Rocky Mountains	Warm Desert	Colorado Plateau	Western Great Plains	Texas-Oklahoma Hill Prairie
REPORT SUMMARIES								
AKR Number:	1	2	3	4	5	6	7	10
# of Plots	44,929	37,862	50,034	80,478	17,338	23,735	27,337	4,043
# of Expert Attributed Plots	1,722	1,965	1,992	3,390	705	527	1,686	552
% of expert to total plots	4%	5%	4%	4%	4%	2%	6%	14%
SYSTEMS KEYS								
Percent Overall Validation Agreement	69.4%	70.0%	75.6%	65.0%	81.3%	85.4%	65.0%	67.0%
Total number of natural types in AKR	90	75	114	99	73	67	83	46
Total number of natural types with expert plots	72	62	71	80	50	52	59	21
# Types with High # (20-59, or more) of expert plots	26	28	23	40	15	8	17	8
# Types with Moderate # (10- 19) of expert plots	16	13	10	9	7	10	12	4
# Types with Low # (1-9) of expert plots	30	21	38	31	28	34	30	9
# of plots keyed to natural types	36,162	33,429	41,826	67,268	14,202	21,342	21,325	2,605
# of plots keyed to a non-natural land cover type	242	263	3,855	608	246	739	1,068	124
# of plots not keyed (unclassified or none)	8,525	4,170	4,353	12,602	2,890	1,654	4,944	1,314
Proportion not keyed (unclassified or none)	18.97%	11.01%	8.70%	15.66%	16.67%	6.97%	18.09%	32.50%

REPORT SUMMARIES	AKR Name: North Pacific Coast	California	Inter-mountain Basins	Rocky Mountains	Warm Desert	Colorado Plateau	Western Great Plains	Texas-Oklahoma Hill Prairie
GROUPS KEYS								
Percent Overall Validation Agreement	73.3%	76.0%	80.7%	69.8%	86.4%	88.3%	69.0%	90.0%
Total number of natural types in AKR	68	52	77	77	63	61	78	33
Total number of natural types with expert plots	54	41	56	67	44	49	54	12
# Types with High # (20-59, or more) of expert plots	23	16	20	31	14	9	17	3
# Types with Moderate # (10- 19) of expert plots	6	3	8	14	7	8	12	2
# Types with Low # (1-9) of expert plots	25	22	28	22	23	32	25	7
# of plots keyed to natural types	33,850	32,902	42,207	71,531	14,389	21,259	21,103	2,528
# of plots keyed to a non-natural land cover type	230	263	2,966	601	205	721	1,068	122
# of plots not keyed (unclassified or none)	10,849	4,697	4,861	8,346	2,744	1,755	5,166	1,393
Proportion not keyed (unclassified or none)	24.15%	12.41%	9.72%	10.37%	15.83%	7.39%	18.90%	34.45%

Table 14. Summary of results for AKRs in the eastern half of CONUS.

REPORT SUMMARIES	AKR Name: Eastern Great Plains	Texas-Louisiana Coast	Mississippi Alluvial	Central Interior	North Woods	Appalachia	North [east] Coast	Coastal Plain
AKR Number:	8	9	11	12	13	14	15	16
# of Plots	5,691	7,087	5,822	26,021	50,195	22,999	3,517	20,221
# of Expert Attributed Plots	513	259	442	756	1,058	1,171	259	937
% of expert to total plots	9%	4%	8%	3%	2%	5%	7%	5%
SYSTEMS KEYS								
Percent Overall Validation Agreement	80.0%	80.3%	77.8%	76.0%	70.0%	49.2%	77.4%	36.5%
Total number of natural types in AKR	28	59	42	35	46	77	38	72
Total number of natural types with expert plots	16	20	28	23	28	37	20	47
# Types with High # (20-59, or more) of expert plots	6	3	5	10	12	16	3	13
# Types with Moderate # (10- 19) of expert plots	1	1	7	5	5	4	3	14
# Types with Low # (1-9) of expert plots	9	16	16	8	11	17	14	20
# of plots keyed to natural types	4,403	5,568	3,510	18,952	43,552	15,297	2,280	10,497
# of plots keyed to a non-natural land cover type	452	85	1,720	708	570	5,834	704	7,691
# of plots not keyed (unclassified or none)	836	1,434	592	6,361	6,073	1,868	533	2,033
Proportion not keyed (unclassified or none)	14.69%	20.23%	10.17%	24.45%	12.10%	8.12%	15.15%	10.05%

AKR Name:	Eastern Great Plains	Texas-Louisiana Coast	Mississippi Alluvial	Central Interior	North Woods	Appalachia	North [east] Coast	Coastal Plain
REPORT SUMMARIES								
GROUPS KEYS								
Percent Overall Validation Agreement	80.0%	86.9%	78.2%	79.0%	68.0%	56.0%	78.0%	39.9%
Total number of natural types in AKR	32	32	21	30	39	48	28	35
Total number of natural types with expert plots	11	14	15	17	24	27	16	23
# Types with High # (20-59, or more) of expert plots	5	2	8	10	11	10	4	14
# Types with Moderate # (10- 19) of expert plots	0	3	0	2	5	3	2	2
# Types with Low # (1-9) of expert plots	6	9	7	5	8	14	10	7
# of plots keyed to natural types	4,387	5,600	3,602	19,397	42,753	15,768	2,299	10,442
# of plots keyed to a non-natural land cover type	455	85	1,720	703	559	5,394	704	7,385
# of plots not keyed (unclassified or none)	849	1,402	500	5,921	6,883	1,837	514	2,394
Proportion not keyed (unclassified or none)	14.92%	19.78%	8.59%	22.75%	13.71%	7.99%	14.61%	11.84%

The percent overall validation statistic is a useful measure of how well the key is working across all types. As described above it is the number of matches between expert and auto-key labels divided by the total number of expert plots x 100, and it was calculated for each of the two keys for an AKR (systems key and Groups key). As can be seen in **Table 13** and **Table 14**, the overall agreement varies greatly across the AKRs. For example, the overall agreement for ecological systems keys ranges from a high of 85% (Colorado Plateau) to a low of 36.5% (Coastal Plain). Overall agreement for the Groups keys similarly ranges from a high of 90% (Texas-Oklahoma Hill Prairie) to a low of 39.9% (Coastal Plain). For most of the AKRs, the key to NVC Groups has a higher overall agreement; only the North Woods had a lower overall agreement for the Groups key than the systems key. Again, this pattern was expected, given fewer types in the typical Groups key vs. that for ecological systems.

There are a number of factors that influenced the overall validation results across the 16 AKRs:

1. *The total number of expert plots is variable by AKR and by individual type*, whether system or Group. For some AKRs there may be a lot of expert plots, but they could be mostly for a few, easily auto-keyed types; or they might be mostly for Systems or Groups that are difficult to auto-key. Reviewing in detail the individual AKR reports, by type, will provide more understanding of why the overall agreement may be high or low for any particular AKR.
2. *The plot data for some AKRs does not lend itself to use in an automated keying process*. For example, forested plots lacking shrub and herb composition and abundance data don't key well, but the Improvements #1 expert review process facilitated putting an accurate label on many of these plots. FIA plots are an example of this, and for some AKRs make up the majority of plots for tree-dominated vegetation types.
 - ✓ This is the case in the North Woods, Coastal Plain, Central Interior, and Appalachia AKRs.
3. *Some AKRs have a preponderance of ruderal vegetation*, comprised of a mix of native and introduced plant species. These are difficult to separate from the natural types in a key, and when data for shrub & herb composition is also lacking, keying is even more challenging. The expert labeling process called these ruderal plots "can't assign", but the auto-key process might label them as a natural system.
 - ✓ The Coastal Plain AKR in the southeast is the best example of this difficulty- the region is predominantly ruderal vegetation, and has a high preponderance of FIA plots.
4. *Wetland and riparian vegetation can be difficult to auto-key* in regions where the dominant tree species occur across both wetland and upland gradients (e.g., the region is climatically wet or has a lot of lowland topography). This is compounded when shrub and herb compositional data are lacking, or when the species that could indicate it is a wetland or riparian/floodplain setting are not recorded for the plot. However, an expert review of the plot with photos and ancillary plot attributes that can't be used in the auto-key will often result in an accurate expert label.
 - ✓ Several AKRs have this difficulty – the North Pacific Coast (especially on the west side of the Cascades divide), the Coastal Plain, and Appalachia.
5. *Some vegetation types, both systems and Groups, are not good candidates for an automated keying process*. These could include types that are naturally very heterogeneous in the floristic composition at the level of the sample plot. For example, many open "glades" and other open woodland types can be readily recognized as a given recurring natural community, but individual plots can include only a small portion of the broader suite of species found across all the distribution of the type. Other cases include types that are naturally rare, with too few samples, or others where the full range of species composition is not yet well known or documented.

Another measure of the performance of the keys is to evaluate the numbers of plots that the auto-key assigns to types on the legend (natural ecological systems and NVC Groups) versus how many do not key. These numbers (proportion of plots that did not key) vary from a low of 6.97% for the ecological systems key of the Colorado Plateau AKR (**Table 13**), to a high of 34.45% for the NVC Groups Key of the Texas-Oklahoma Hill Prairie AKR (**Table 13**). Again, reasons vary for high percentages, but in most cases one can assume that source data for plot samples tends to lack sufficient information to allow the auto-key to attribute the plot. Some AKRs, such as the North Pacific Coast, Texas-Louisiana Coast, Central Interior, and Warm Desert, all consistently had high percentages of unclassified plots. Additional review of plot data within these areas could be investigated further to better understand common deficiencies in plot data for purposes of applying labels with auto-keys. This would provide insights for enhancing data collection protocols.

Results for Ruderal and Cultural Keys

The keys to Ruderal and Cultural types were completed in a separate process from the keys for systems or Groups, and for much larger areas than the AKRs (see **Figure 6** and section **Ruderal and Cultural Vegetation in the Auto-Keys**). Out of a total of 409,871 plots that were run through the Ruderals keys, 20,710 keyed to one of the ruderal or cultural types defined for the legend (**Table 15**). The table summarizes the number of plots by the six Geo Areas (**Figure 3**) rather than the four multi-regions used to develop the keys.

The Southeast (SE) and Southwest (SW) Geo Areas had the most plots keying to ruderal types (8,586 and 6,248, respectively). The South Central (SC) had the fewest plots, only 507. Four types had more than 1,000 plots, seven between 500 and 1,000, nine between 100 and 500 and thirteen with fewer than 100 plots.

The ruderal and cultural types with the most plots in the eastern U.S. were Southeastern [and Northeastern] North American Temperate Forest Plantation, Southeastern Native Ruderal Forest, and in the west were Great Basin & Intermountain Ruderal Shrubland, Introduced Annual Grassland and Introduced Annual and Biennial Forbland, along with Interior Western North American Temperate Ruderal Grassland & Shrubland and Western North American Temperate Forest Plantation.

Plantations were keyed primarily by use of a plot attribute that indicated the plot (at the time of sampling) was 'planted'. Plots keying to plantations should be reviewed carefully against some other spatial/spectral indication that they are indeed in managed plantations. For example in the Pacific Northwest AKR, many of these 'planted' plots were reviewed by the ecologist and determined to not be distinguishable floristically from the natural forest types of the region.

The patterns of plots by Geo Area for the ruderal and cultural types follows what could be expected. For example the SW and Northwest (NW) Geo Areas have high numbers of plots keying to Great Basin ruderal shrublands (generally sagebrush with cheatgrass or other exotic grasses) or Great Basin introduced annual grasslands. The Northeast (NE), North Central (NC) and Southeast Geo Areas have high numbers of plots keying to plantations.

Table 15. Numbers of plots keying to one of the ruderal or cultural types in the ruderal keys, by Geo Area, and total number of plots by type. The table is sorted from the most total plots to the least for individual types, with total plots keying to any ruderal or cultural types by Geo Area in the top row.

	LANDFIRE Geo Area						
	NC	NE	NW	SC	SE	SW	Total
Total Number of Plots that Keyed to a Ruderal Type	804	1,039	3,526	507	8,586	6,248	20,710
Southeastern North American Temperate Forest Plantation		396		3	6,447		6,846
Great Basin & Intermountain Ruderal Shrubland			745			2,152	2,897
Southeastern Native Ruderal Forest		113		11	1,847		1,971
Great Basin & Intermountain Introduced Annual Grassland			533			473	1,006
Northeastern North American Temperate Forest Plantation	598	368			23		989
Interior Western North American Temperate Ruderal Grassland & Shrubland			369	2		582	953
Western North American Temperate Forest Plantation			813			118	931
Great Basin & Intermountain Introduced Annual and Biennial Forbland			407	1		369	777
California Ruderal Scrub						610	610
North American Warm Desert Ruderal & Planted Scrub & Grassland				44		498	542
Rocky Mountain Ruderal Forest			311			227	538
Cultivated Crops and Irrigated Agriculture			12	124		233	369
Northern & Central Plains Ruderal & Planted Grassland & Shrubland	90		59	158		4	311
Californian Ruderal Forest			4			282	286
Northern & Central Ruderal Meadow & Shrubland	90	48		124	1		263
Interior West Ruderal Riparian Forest & Scrub			10	5		232	247
Great Basin & Intermountain Introduced Perennial Grassland and Forbland			122			121	243
California Ruderal Grassland & Forb Meadow			1			240	241

	LANDFIRE Geo Area						
	NC	NE	NW	SC	SE	SW	Total
Western North American Ruderal Wet Shrubland, Meadow & Marsh			76			105	181
Southeastern Ruderal Wet Meadow & Marsh		2			147		149
Southern Vancouverian Lowland Ruderal Grassland & Shrubland			63			1	64
Eastern North American Ruderal Aquatic Vegetation					59		59
Northern & Central Ruderal Wet Meadow & Marsh	10	46		1			57
Southeastern Ruderal Grassland and Shrubland		1		3	35		39
Northern & Central Native Ruderal Flooded & Swamp Forest	15	20			1		36
Southern Plains & Texas Ruderal & Planted Grassland & Shrubland				26			26
Northern & Central Native Ruderal Forest		24					24
Northern & Central Exotic Ruderal Forest	1	18		4			23
Southeastern Exotic Ruderal Forest				1	14		15
Southeastern Native Ruderal Flooded & Swamp Forest		1			9		10
Southeastern Exotic Ruderal Flooded & Swamp Forest					3		3
North Pacific Maritime Coastal Sand Dune Ruderal Scrub & Herb Vegetation			1			1	2
Northern & Central Exotic Ruderal Flooded & Swamp Forest		2					2
Total Number of Plots that did not Key to a Ruderal Type	50,474	38,066	132,070	13,335	45,849	109,367	389,161

Project Analysis and Effectiveness

The objective of this section is to evaluate the effectiveness of this current effort and the quality of the products produced (i.e. the auto-keys). Below several analyses are presented that highlight how the auto-keys produced under this effort performed in comparison to each other, as well as in comparison to the keys produced for LANDFIRE 2001. It reflects upon the results described previously, provides some additional tables and discussion, and presents interpretation of contingency tables developed for three AKR case studies.

Quality

Evaluation of the auto-key performance was a desired outcome of this project. The results summarized for each AKR in the reports described in the **AKR reports** section above provide one view of the key performance within an auto-key region (see Appendix D: **Auto-Key Reports by Auto-Key Region** for all of the individual AKR reports). Three auto-key regions were selected as case studies for this report to highlight different circumstances of data and key complexity across the country; the case studies are in the case studies section below.

The patterns of summarized results compared across all the AKRs (**Table 13** and **Table 14**) is another check on the performance of the keys and the variation across CONUS in the number of plots, quality of plot data, complexity of keys, and validation numbers from the expert plots.

Additional summaries can compare results across different types of keys (i.e. the keys to natural ecological systems or NVC Groups versus the keys to Ruderal types), or across different time frames of keys (i.e. comparing results from the LANDFIRE 2001 keys for systems to the LANDFIRE 2015 keys).

Comparison #1: Between Keys to Natural Types and Ruderal/Cultural

A first comparison was done between the keys for the Ruderal and Cultural types and the keys for natural ecological systems or NVC Groups (**Table 16**). Please see the section **Ruderal and Cultural Vegetation in the Auto-Keys** for an explanation of the key development for ruderal & cultural vegetation types. The comparison of the results was done using the following logic:

1. The auto-key label from the Ruderal/Cultural key was taken as the final label for the plot, even if in the system or Group key it was labeled as a natural type
2. The list of types or land cover classes found in the ecological systems keys were categorized as “natural”, “ruderal”, or “not labelled”. The ‘not labeled’ category includes both the generic “unclassified [structural type]” and plots with no label (i.e. the label is ‘none’).
3. The list of types or land cover classes found in the NVC Groups keys were categorized in the same way.
4. Counts were created by Geo Area (**Figure 3**), comparing how many plots labeled as Ruderal or Cultural in those keys received a natural label from the systems keys or Groups keys; or were not labeled.
5. The plots provided in 2015 by the BLM AIM program and the NRCS NRI program were not included in this analysis; nor were any plots from South Florida.

The results indicate that for many of the AKRs (as summed by Geo Area) the 3 types of keys treated the ruderal and cultural land cover classes very similarly, with the exception of the regions within the Southwest (SW) and Northwest (NW) Geo Areas. In 4 of the Geo Areas, the number of ruderal/cultural plots across the three sets of keys were very similar (see the top row of each of the systems or Groups portions of **Table 16**). For example, in the North Central (NC) Geo Area, 804 plots keyed as ruderal in the multi-region keys; while in the AKR keys for systems 642 plots were given a ruderal land cover class label, and 642 plots were labeled as ruderal in the Groups keys.

Table 16. Comparison across the 2 kinds of keys: the key to the ruderal/cultural legend is compared to the keys for natural ecological systems or NVC Groups, by counts of plots. If a plot keyed to a Ruderal or Cultural type in the “ruderal” key, then that label was assumed to be correct; all types in each of the systems or Groups keys were categorized as “ruderal”, “natural” or “not labeled” in order to compare to the ruderal key labels. Yellow highlighted cells indicate where the key to the ruderal/cultural legend labeled more plots as a ruderal type than did either the systems keys or Groups keys.

	LANDFIRE Geo Area						
	NC	NE	NW	SC	SE	SW	Total
Total Number Plots that Keyed to a Ruderal or Cultural Type	804	1,039	3,526	507	8,586	6,248	20,710
Summaries For Systems Keys							
# of Keyed Ruderal/Cultural Plots with a Systems Key Ruderal/Cultural label	642	892	1,373	423	7,471	1,868	12,669
# of Keyed Ruderal/Cultural Plots with a Systems Key Natural label	129	89	1,916	27	836	3,795	6,792
# of Keyed Ruderal/Cultural Plots Not labeled in the Systems Key	33	58	237	57	279	585	1,249
Summaries For Groups Keys							
# of Keyed Ruderal/Cultural Plots with a Groups Key Ruderal label	642	891	1,371	423	7,424	1,835	12,586
# of Keyed Ruderal/Cultural Plots with a Groups Key Natural label	131	93	1,859	19	853	3,744	6,699
# of Keyed Ruderal/Cultural Plots Not labeled in the Groups Key	31	55	296	65	309	669	1,425

However, in the NW and SW GAs, the number of plots that keyed to ruderal or cultural in the multi-region keys was 3,526 and 6,248, respectively. In contrast, in the systems and Groups keys, less than 40% of those same plots keyed to a ruderal or cultural land cover class (**Table 16**, see yellow highlighted cells). To explore this further, the ruderal/cultural plots for the NW that keyed to a natural system (n = 1,916) or Group (n = 1,859) and similarly in the SW (n = 3,796 for systems and n = 3,744 for Groups) were then summarized by which ecological system and NVC Group label they received. This summary is in Appendix F.

The results from those summaries indicate the following:

1. The plots with ruderal labels from the multi-region keys were labeled to any of the natural ecological systems or NVC Groups.
2. In the NW and SW Geo Areas, a large number of ruderal plots keyed to one of the many important forest types (either system or Group). In the ruderal/cultural key, a number of these would have been labeled as Western Temperate Forest Plantation, based on an attribute provided with the plots that indicate they were ‘planted’. A Plantation land cover class was not included in either the systems or Groups keys, so these planted plots would have keyed to a natural type in most cases.
3. In both the NW and SW, large numbers of the ruderal plots keyed to one of the major sagebrush systems or Groups, rather than to a ruderal land cover class. This is not surprising; invasive

annual grasses are now found in many plots of sagebrush types- in the systems or Groups keys, these were labeled to a natural type. However, in the ruderal keys many of them would be labeled as Great Basin and Intermountain Ruderal Shrubland (e.g. sagebrush with a cheatgrass understory).

4. A similar pattern is seen for the natural types of saltbush scrub, alkaline flats, and Intermountain Semi-desert Shrub Steppe, where greasewood (*Sarcobatus vermiculatus*), *Atriplex* and rabbitbrush (*Ericameria*) species are common. These areas are also prone to invasion by exotic annuals.

Comparison #2: Between Keys in Two Timeframes 2001 to 2015

Another comparison was done between the keys across time frames, specifically comparing the results for the LANDFIRE 2001 keys and the new 2015 keys. This comparison was only done for ecological systems, since Groups were not keyed in the 2001 effort (Table 17). This analysis used the following logic:

1. The auto-key label from the Ruderal/Cultural key was taken as the final label for the plot, even if in the system or Group key it was labeled as a natural type
2. The list of types or land cover classes found in the ecological systems keys were categorized as “natural”, “ruderal”, or “not labelled”. The ‘not labeled’ category includes both the generic “unclassified [structural type]” and plots with no label (i.e. the label is ‘none’).
3. Counts were created by Geo Area (Figure 3) for each time frame, comparing how many plots labeled as Ruderal or Cultural, natural system, or were not labeled
4. The plots provided in 2015 by the BLM AIM program and the NRCS NRI program were not included in this analysis; nor were any plots from South Florida.

The results of this comparison (Table 17) indicate that for the North Central (NC) and Northeast (NE) Geo Areas the 2015 keys have a higher number of plots that were not labeled as compared to the 2001 keys (right 2 columns, yellow highlight); and a smaller number of plots that keyed to a natural system (far left columns, green highlight). In the Southeast (SE), comparing from 2001 to 2015, fewer plots keyed to an ecological system but more plots keyed to a ruderal type (center 2 columns, yellow highlight).

Table 17. Comparison of the LANDFIRE 2001 keys with the LANDFIRE 2015 keys, of numbers of plots keying to an ecological system, ruderal/cultural types, or that were not labeled; counts of plots across the three categories of labels. Yellow highlighted cells indicate where there was a noticeable difference between the 2001 and 2015 keys, with more plots keying to that category in 2015 than in 2001. Green highlighting indicates the inverse- where more plots keyed to that category in 2001 than in 2015.

Geo Area	# Plots that Keyed to a Natural System		# Plots that Keyed to a Ruderal Type		# Plots that Keyed to None/Unclassified	
	LF 2001	LF 2015	LF 2001	LF 2015	LF 2001	LF 2015
NC	47,160	43,654	1,023	1,106	3,095	6,518
NE	31,373	29,777	4,813	4,928	2,919	4,400
NW	111,358	108,447	2,149	4,787	21,412	21,685
SC	9,438	9,524	1,515	1,530	2,889	2,788
SE	37,386	33,011	9,147	12,925	7,902	8,499
SW	94,072	96,285	3,469	7,795	17,783	11,244
Totals	330,787	320,698	22,116	33,071	56,000	55,134

The NW Geo Area had fewer plots keying to a natural system in 2015 than in 2001. It appears most of those plots shifted from having an ecological system label to having a ruderal label, but the number of plots that did not key is much the same across the 2 timeframes of keys. The pattern in the SW is not quite the same- as with the NW more plots were keyed to a ruderal type in 2015 than in 2001, but the number keying to ecological system was higher in 2015, and the number not labeled dropped by over 6,000 plots.

Comparison #3: Change in Ecological System labels from 2001 to 2015

A third comparison was made, again across the 2 timeframes of keys (2001 to 2015). In this only labels to individual ecological systems were included; plots labeled in 2001 to a ruderal type, NVC alliance, or one of the aggregates were excluded. The comparison then looks at whether those plots with an ecological system label from the 2001 keys had the same ecological system label from the 2015 keys (**Table 18**); counts and percent of same or different labels by Geo Area are provided. The change could have been to any of the following:

- ✓ A different ecological system
- ✓ A ruderal or cultural type
- ✓ Not labeled

The results are similar across all of the Geo Areas. Some 62% of plots retained the same label across the 2 timeframes of keys, while 38% changed label. The South Central (SC) Geo Area had the least amount of change (32.6%) while the Southeast (SE) had the most (44.5%).

Table 18. Comparison of the LANDFIRE 2001 keys to the 2015 keys, number and percent of plots that received the same ecological system label across the two timeframes. This comparison only included plots that keyed to an individual ecological system in the 2001 keys; all other labels were excluded (i.e. the aggregates, alliances and other land use/land cover labels).

	LANDFIRE Geo Area						Totals
	NC	NE	NW	SC	SE	SW	
# and % of plots with <u>same</u> ecological system assignment	25,738	15,332	57,685	6,187	17,336	55,575	177,853
	66.9%	56.5%	60.0%	67.4%	55.5%	65.4%	61.9%
# and % of plots with <u>different</u> ecological system assignment	12,757	11,793	38,468	2,988	13,906	29,465	109,377
	33.1%	43.5%	40.0%	32.6%	44.5%	34.6%	38.1%

Case Studies: Rocky Mountains, Western Great Plains, Appalachia

Elsewhere in this report and in appendices, one can find overall summaries of auto-key performance. Here, by preparing contingency tables to compare A-K label results against expert-labeled plots, results can highlight where there is agreement between expert-labels and those produced by the auto-key. Conversely, these brief summaries specify the types that tend to be confused with other related types in each auto-key. In each instance of the three case studies, interpretation is provided to help explain common patterns among the common errors associated with a given auto-key. The full contingency tables for each of these AKRs are found in Appendix G.

For orientation, **Table 19** includes a portion of a contingency table for the Appalachia AKR. The columns for each type represent the count of expert plots labeled to the type; the rows for each are a count of plots labeled by the auto-key to that type. One can see in the Total row at the bottom, the number of sample plots for each type (in each column) that have expert labels for use in this evaluation. Columns with the higher numbers of sample plots provide more reliable information for interpretation. From this subset, one can see where the Appalachian Oak / Chestnut Forest Group is represented by 209 sample plots labeled by the auto-key (Total column on the right). Of these, 81%, or 170 plots labeled by experts to the type were in agreement. Disagreement was most concentrated in expert and auto-keyed plots labeled to Northeastern Oak-Hickory Forest & Woodland, and to the Appalachian & Interior Mesic Forest (yellow highlighted cells). Sample plots from each of these Groups can be expected to share some species, and so some level of disagreement might be expected.

This same pattern is observed further down in the contingency table for rows of Northeastern Oak-Hickory Forest & Woodland and Appalachian & Interior Mesic Forest, with most substantial disagreement occurring with the Appalachian Oak / Chestnut Forest. This example indicates the potential need for future refinement of either/both the NVC Group classification (better differentiating these three types in terms of species composition, distribution, and site conditions) and/or refinements to this auto-key to better handle those differences.

Another highlighted example from this AKR is the Piedmont & Central Atlantic Coastal Plain Oak Forest, which occurs with an overlapping distribution in the adjacent Coastal Plain AKR. With 90 auto-key labeled sample plots available for evaluation in this contingency table, overall agreement with the expert labels was 64% (58 plots). Of those types with the most disagreement, Appalachian & Interior Mesic Forest and Appalachian Oak / Chestnut Forest groups also share some species composition and therefore, could be confused in the auto-key.

Table 19. Example section of a contingency table for NVC Groups from the Appalachia AKR. For presentation purposes, the right-hand 12 columns are not shown. Numbers in the cells are counts of sample plots; rows represent what the auto-key labeled the plots; columns what the expert labeled the plots. The blue-colored diagonal cells count the plots where both A-K and expert agree. The lowest rows and right-hand columns show totals of plots and % match between A-K and expert labels according to the perspective.

Expert Group Name -->		Appalachian Oak / Chestnut Forest	Northeastern Chinkapin Oak - Red-cedar Forest & Woodland	Northeastern Oak - Hickory Forest & Woodland	Pitch Pine Barrens	Virginia Pine & Table Mountain Pine Woodland & Barrens	Appalachian & Allegheny Northern Hardwood - Conifer Forest	Appalachian & Interior Mesic Forest	Central & Southern Appalachian Red Spruce - Fir - Hardwood Forest	Laurentian & Acadian Hardwood Forest			
Group Name - Auto-key	elcode	G015	G016	G650	G161	G162	G742	G020	G632	G743	Total A-	correct	% correct
Appalachian Oak / Chestnut Forest	G015	170		12	2	6	1	13			209	170	81%
Northeastern Chinkapin Oak - Red-cedar Forest & Woodland	G016	3	1	3			1	4			12	1	8%
Northeastern Oak - Hickory Forest & Woodland	G650	75	1	39	4	2	12	5		7	147	39	27%
Pitch Pine Barrens	G161	11			8		1				20	8	40%
Virginia Pine & Table Mountain Pine Woodland & Barrens	G162	3				7					13	7	54%
Appalachian & Allegheny Northern Hardwood - Conifer Forest	G742	2		1			42		2	1	49	42	86%
Appalachian & Interior Mesic Forest	G020	21		1			21	119			173	119	69%
Central & Southern Appalachian Red Spruce - Fir - Hardwood Forest	G632						1		25		26	25	96%
Laurentian & Acadian Hardwood Forest	G743									23	25	23	92%
Laurentian & Acadian Hemlock - White Pine - Hardwood Forest	G741									5	7	2	29%
Northern Appalachian & Acadian Red Spruce - Fir - Hardwood Forest	G744									1	1	0	0%
Laurentian & Acadian Pine - Oak Forest & Woodland	G025										1	0	0%
Chinkapin Oak - Shumard Oak - Blue Ash Alkaline Forest	G601	4	1	2							18	11	61%
Piedmont & Central Atlantic Coastal Plain Oak Forest	G165	10						15			90	58	64%
Shortleaf Pine - Oak Forest	G012	5					1	2			44	29	66%
Silver Maple - Sugarberry - Sweetgum Floodplain Forest	G673	1						2			15	12	80%
Central & Appalachian Seepage Swamp	G044										0	0	#DIV/0!
Bald-cypress - Tupelo Floodplain Forest	G033										1	0	0%
Oak - Sweetgum Floodplain Forest	G034							2			18	10	56%
Appalachian Mafic Glade	G180										1	1	100%
Eastern North American Boreal Alkaline Fen	G185										0	0	#DIV/0!
Central Shrub & Herb Depression Pond	G599										0	0	#DIV/0!
[no autokey assignment]		20		2	2		10	19	1	10	107		
Total Expert Plots		305	3	58	14	16	79	162	27	37	870	557	64%
% correct		56%	33%	67%	57%	44%	53%	73%	93%	62%			

Below are provided brief case studies of results and interpretation from auto-keys for both ecological systems and groups for three AKRs. The full contingency tables for each of these AKRs are provided in Appendix G.

Rocky Mountains AKR4 – Ecological Systems

With approximately 80 types in this AKR, overall performance was quite high (75%), with many types scoring above 70-80% agreement. Among those with lower proportions of agreement, and where there were sufficient samples to evaluate, types that commonly occur adjacent to each other, some with at least some floristic overlap, were among the most prevalent. For example, Rocky Mountain Subalpine-Montane Mesic Meadow tended to be confused with Northern Rocky Mountain Subalpine-Upper Montane Grassland, or other lower elevation grassland types. Types that the A-K labeled as Rocky Mountain Subalpine-Montane Riparian Shrubland tended to be confused with upland shrubland types commonly found immediately adjacent to riparian zones, such as Northern Rocky Mountain Montane-Foothill Deciduous Shrubland or Northern Rocky Mountain Subalpine Deciduous Shrubland. Types that the A-K labeled as Inter-Mountain Basins Semi-Desert Shrub-Steppe tended to be confused with Inter-Mountain Basins Big Sagebrush Shrubland. Unsurprisingly given floristic similarity, Inter-Mountain Basins Big Sagebrush Steppe tended to be confused with the most abundant types commonly located immediately adjacent, including Inter-Mountain Basins Big Sagebrush Shrubland and along an upper elevational gradient, Inter-Mountain Basins Montane Sagebrush Steppe. All of these latter cold-desert types, excluding the montane sagebrush steppe, are common throughout the periphery of this AKR.

Rocky Mountains AKR4 – NVC Groups

With some 68 types in this A-K, similar patterns are evident between this key and that for the ecological systems. Where the A-K labeled plots Rocky Mountain & Sierran Alpine Turf & Fell-Field, there was some confusion with Rocky Mountain Subalpine-Montane Mesic Herbaceous Meadow, Central Rocky Mountain Montane Grassland, and Vancouverian & Rocky Mountain Montane Wet Meadow & Marsh. Plots labeled Rocky Mountain & Great Basin Montane Riparian Forest were most often confused with adjacent upland forest types, such as the Rocky Mountain Subalpine Moist Spruce - Fir Forest & Woodland.

Western Great Plains AKR7 – Ecological Systems

With 60 types in this A-K, overall performance is high at 74%. Among the types scoring lower in agreement are several types typical of the western periphery of the AKR. For example, Southern Rocky Mountain Pinyon-Juniper Woodland tended to be confused with the floristically similar, and often adjacent, Southern Rocky Mountain Juniper Woodland and Savanna. Central Mixedgrass Prairie was most commonly confused with Northwestern Great Plains Mixedgrass Prairie. These two major grassland types tend to form a transition with each other in northern Nebraska. In the southern portion of the AKR, plots labeled Apacherian-Chihuahuan Mesquite Upland Scrub tended to be confused with the closely related Western Great Plains Mesquite Woodland and Shrubland.

Western Great Plains AKR7 – NVC Groups

This A-K performs quite similarly to the ecological systems key in the AKR. Of the types where performance appears to be lowest, and where there are sufficient numbers of plots to interpret results, several types are confused that are somewhat peripheral to the Western Great Plains and more common further west in the Intermountain Basins. For example, Intermountain Mountain Big Sagebrush Shrubland & Steppe is most commonly confused with Intermountain Mesic Tall Sagebrush Shrubland & Steppe, which occurs along its lower elevation margins throughout the northwestern periphery of this AKR. North American Desert Alkaline-Saline Shrub Wetland, which includes Greasewood and saltbushes,

is most commonly confused with Northern Great Plains Mixedgrass Prairie. Plots labeled by the A-K as Southern Plains Scrub Woodland & Shrubland were most commonly confused with Great Plains Shortgrass Prairie, which tends to occur immediately adjacent throughout the southern portion of this AKR.

Appalachia AKR14 – Ecological Systems

This A-K includes 34 types, but appears to perform somewhat poorly, with an overall agreement of 56%. For nearly all types where this A-K appears to perform least well are forest types. In many of the Appalachian forests, overstory tree diversity can be quite high, but some species show high constancy across multiple types. In most instances, plot data need to include the full complement of shrub and herbaceous taxa to confidently distinguish among similar types. The current reliance on FIA data that often lack understory composition likely explains much of the confusion among types in the AKR. For example, plots labeled Central and Southern Appalachian Montane Oak Forest were most commonly confused with Southern Appalachian Oak Forest, which occurs along a lower elevation transition. Northeastern Interior Dry-Mesic Oak Forest, which is concentrated in the northern reaches of this AKR, was confused with Central Appalachian Dry Oak-Pine Forest and Appalachian (Hemlock)-Northern Hardwood Forest, with which it shares red oak. Finally, Southern Piedmont Mesic Forest also shares some overstory taxa with Southern Piedmont Dry Oak-(Pine) Forest, a type for which it was most commonly confused.

Appalachia AKR14 – NVC Groups

Relative to the ecological systems key in this AKR, this key included fewer types (22 vs. 34), and performed somewhat better (64% vs 56%). One could expect a similar explanation here for confusion among forest types resulting in most cases from limited understory composition included in FIA sample plots. As noted previously, for plots labeled to Northeastern Oak - Hickory Forest & Woodland, most common confusion was with Appalachian Oak / Chestnut Forest and Appalachian & Allegheny Northern Hardwood - Conifer Forest. Piedmont & Central Atlantic Coastal Plain Oak Forest was most commonly confused with Appalachian & Interior Mesic Forest. Interestingly, Pitch Pine Barrens were most commonly confused with Appalachian Oak / Chestnut Forest. This might result from the fact that Pitch Pine Barrens occur within this AKR at the periphery of their natural distribution, and so samples may be skewed towards sites that are more transitional in character to oak-dominated forests of the Appalachia AKR.

Lessons Learned and Recommendations

The LANDFIRE reference database is the first attempt to compile comprehensive georeferenced vegetation sample data for the United States. Auto-keys are an innovative method for rapidly and efficiently labeling thousands of vegetation samples. For LANDFIRE they were developed to key to ecological systems and land cover classes, but through this most recent effort, were subsequently adapted to key the floristically-based Group level of the NVC vegetation classification hierarchy. 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 original vegetation sample data, and the labeled results.

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

Some specific reasons that an auto-key may not successfully key all samples include:

1. floristic quality or completeness of the vegetation data (how complete, how well collected, does it accurately represent the vegetation type being keyed at all levels of the vegetative canopy);
2. limited knowledge of the variability in species composition, vegetation structure, and the distribution of ecological systems or NVC Groups, as a function of field inventory effort;
3. comprehensiveness (or lack thereof) in field inventory for any particular vegetation type (e.g., many samples from one small area, few to none from elsewhere in the regional distribution).

All of these reasons can come into play with whole classes of vegetation types; such as naturally rare types or types with characteristics that otherwise introduce challenges to automated labeling. For example, sparsely vegetated types, including many common types in deserts, coastal uplands, or on rocky cliff and outcrops, can typically occur with a very high variability in species composition and canopy cover. An ecologist may be able to readily recognize recurrent pattern and describe the type, but is relying on many environmental cues in addition to vegetation composition. Field sampling is often limited in these types, and requires much intensive investment to fully capture natural variability. Practically speaking, these and similar types may never be adequately addressed using an auto-key, and should be targeted for direct labeling by expert ecologists.



Milo Pyne, Cherokee NF; Southern and Central Appalachian Cove Forest

Spatial Framework for Auto-Keys

Each auto-key was constructed to work across relatively large geographic areas, on the order of multiple USFS ECOMAP sections (**Figure 5**). The AKR framework developed for this effort more closely aligns with the natural distribution of terrestrial ecological system types and USNVC group types and maximizes similarity among types within an auto-key region. The intent was to also minimize overlap with adjacent auto-key regions, however the results above (**Table 13 and Table 14**) indicate that there will always be issues with types in an AKR that are peripheral to the region. This is unavoidable with these geographically large regions. Auto-key regions that cover more extensive land area tend to include treatment of more types (for efficiency in development time) but potential for error is introduced through increased complexity in auto-key design. Conversely, auto-keys treating a smaller area might be simpler, but would necessarily include more overlap in types with surroundings and result in a larger number of auto-keys for the country. Therefore, total area encompassed by each auto-key was a factor in the selection and design of alternative spatial frameworks.

The results evaluated above and in the individual AKR reports indicate that the new spatial framework for the development of auto-keys was successful. It might be useful to look more closely at the results within two or three AKRs to consider whether splitting them into smaller units would be helpful; e.g., the Rocky Mountains AKR and Appalachia are two in particular where splitting from north-to-south might result yield better results. The Coastal Plain is another AKR where smaller areal coverage might improve the results. However, it remains difficult to know with certainty in this area where the overwhelming issue is the quality of plot data (see below).

Expert Labeling

This effort incorporated results of having vegetation experts independently review and label sample plots. Regionally-expert ecologists had information about the floristics, vegetation structure, regional setting, and aerial imagery available to help them make a determination about the type likely represented in the sample. This was arguably the most important advancement of this effort over the original auto-key development process. It provided a crucial opportunity to evaluate the performance of each auto-key during its development; and then to summarize overall performance of the final auto-key. This compares with LANDFIRE 2001 auto-keys where no expert-labeled samples were available for use in development of validation. Developers were effectively “blind” as to the actual performance of the LANDFIRE 2001 auto-keys. Having these expert-reviewed samples enabled reporting of the performance for each auto-key as a whole, and for a large proportion of individual classification units. The results from this current effort now can provide a baseline on auto-key performance against which future revisions to keys can be evaluated.

On average some 5% of sample plots were used in the development and validation of these updated auto-keys. Moving forward, 5-10% of samples, representing all types listed within a given AKR, should be the goal for maintaining an independent expert-reviewed data set for evaluating and improving the performance of each auto-key. Evaluating existing data against this goal should provide a clear priority list of types in need of additional investment.

However, it is important to recognize that labels applied by experts cannot be guaranteed to be “correct.” In many instances, two experts could evaluate the same sample plot and not agree completely on the appropriate label. This can result when there are limitations in existing sample data, there is high relative similarity among types that can co-occur within a given AKR, and/or when classification effort remains to better describe and differentiate similar types. For most forest types, one of the issues in conflicting labels is likely to be the lack of understory shrubs and herbs species composition in the plot data.

For this reason, we recommend developing a process where multiple experts be presented with the opportunity to review samples, apply labels, and describe their rationale for applying each label. This information, derived from 2-4 regional vegetation experts, would provide a solid foundation for scoring confidence in the performance of each auto-key, and for prioritizing efforts to improve the classification within each AKR. Maintenance of this independent, expert-reviewed data set is essential to improving the performance of these auto-keys, and so ongoing investment in these data should be among the highest priorities.

Quality and Sufficiency of Vegetation Data

All acknowledge that investment in field data collection is the most costly, but also most essential ingredient to LANDFIRE map production. First and foremost, the completeness and quality of these field-collected data, as well as the documentation of how the data were collected (the metadata) are primary issues for how well the auto-key functions. There are many different kinds of issues with the data and metadata collection, some of which are listed here as possible sources of problems:

- Was the species composition adequately sampled (i.e., a relatively complete species list)?
- Were only trees recorded (e.g., many 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?
- Were the samples derived along transects as point-intercepts, then converted to percent cover?
- How was cover or abundance data was collected (e.g., with cover classes, and what scale of classes?), or was it presence/absence? Basal area and density of trees?
- Was the sample area across a major ecotone (for example across the transition from a wet valley bottom into the adjacent upland slope)?
- Does the sample adequately represent the variability 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 (perhaps introducing uncharacteristic taxa)?

Some 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 cause incorrect processing of the data for use in the auto-keys.

The results of this effort highlight vegetation types, and if spatially analyzed, geographic areas where plot data are lacking. It also highlights types for which there is an insufficiency of expert labeled plots and where the plot data have resulted in difficulties in the auto-key (e.g. many forested plots lacking shrub and herb compositional data). Targeted field inventories to “fill the gaps” in plot data for particular types or geographies should be considered.

Suggested Improvements to Python AK program

1. Add ways to indicate if % cover criteria for species (or groups of species) are absolute cover or relative cover; this would provide flexibility in how indicator taxa are used in the key; this could be as simple as the spp/cover pairs are relative cover for the first 4 or 5 pairs, and absolute cover for the remaining pairs.
2. Develop a user-interface that allows designating which of several “geographic constraints” you wish to use in the key; e.g., be able to select map zones + subsections for one key, or EPA Level 4 ecoregions somewhere else

3. Develop a user-interface to allow selection of the biophysical classes and variables to be used in a key (elevation in meters, aspect in degree ranges, bioclimate types, landform types, wetland or riparian type, substrate classes, or others)

Next Steps in Preparation for Mapping

- ✓ **Invest in additional expert-reviewed plots, for under-represented ES and for many NVC Groups.**
 - Facilitate further evaluation of AK performance
- ✓ **Complete contingency tables for all remaining AKRs.**
- ✓ **Develop database tool for managing map legends by place;** DB is likely to be complex, lots of codes and modifiers; relational DB with descriptions and tools is strongly recommended
 - Maintain current relationships between ES and NVC Groups and NVC hierarchy and BpS models, other Xwalks (FGDC 1998? SAF, SRM types? Cowardin?) and others.
- ✓ **Establishing desired map legend for mapping zones (as determined by mapping team)**
 - Finalize range maps of types (ecological systems, NVC Groups, ruderal types)
 - Compare AK results to finalize types only suitable for local-scale mapping
- ✓ **QC of plot data for types on desired legend**
 - Identification of distribution errors
 - Identification of geographic gaps for targeted data gathering
- ✓ **Synthesize and translate recommendations by ecologist to mappers by AKR/Mapping zone.**

Information Distribution

NatureServe has delivered to LANDFIRE all of the auto-keys, expert and auto-keyed labels on plots, the legends for both ecological systems and NVC Groups, and other miscellaneous tables and data. These products will be posted on the www.landfire.gov site at some future date.



Marion Reid, Jedediah Smith Redwood State Park, CA; California Coastal Redwood Forest

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Appendices

A. LANDFIRE 2015 Legend

See attached workbook:

LANDFIRE2015_LEGEND.xlsx

B. LANDFIRE Documentation: LFRDB Plot & Species Data

See attached files:

LFRDB_Plot_Data_Processing_2010.pdf

Auto-key_Input_Data_Explained_20070319.pdf

C. LANDFIRE Documentation: Working Of Auto-Keys & Output Tables

See attached files:

EVT_SeqTab_Format_Rules_20061020.doc,

EVT_Key_Data_Dictionary_20061031.pdf,

Auto-key_Input_Data_Explained_20070319.pdf

D. Auto-Key Reports by Auto-Key Region and Multi-Regions

See attached files:

AKR 1_NorthPacific_Standard AK Report Formats_Systs_Groups.xlsx

AKR 2_California_Standard AK Report Formats_Systs_Groups_April20_2015.xlsx

AKR 3_IntermountainBasin_Standard AK Report Formats_Systs_Groups- 3-18-2015.xlsx

AKR 4_RockyMtn_Standard AK Report Formats_Systs_Groups_4_17_2015.xlsx

AKR 5_Warm_Desert_Standard AK Report Formats_Systs_Groups.xlsx

AKR 6_coloradoPlat_Standard AK Report Formats_Systs_Groups.xlsx

AKR 7_WestGreatPlains_AK Report_Systs_Groups_3.31.2015.xlsx

AKR 8_Eastern Great Plains_Standard AK Report Format.xlsx

AKR 9_TexasLouisianaCoast_Standard AK Report Formats_Systs_Groups_Mar25.xlsx

AKR 10_TX_OK_HillPrairie_Report_Systs_Groups.xlsx

AKR 11_MississippiAlluvial_StandardReportFormat_Systs_Groups-4feb2015.xlsx

AKR 12_CentralInterior_AK Report_Systs_Groups.xlsx

AKR 13_northWoods_Standard AK Report Formats_Systs_Groups.xlsx

AKR 14_AppalachianStandard Report Formats_Systs_Groups.xlsx

AKR 15_NorthCoast_StandardReportFormat_Systs_Groups-4feb2015.xlsx

AKR 16_coastalPlain_StandardReportFormat_Systs_Groups.xlsx

Ruderal_CA_basin_summary report_12-23-2014.xlsx

Ruderal_EasternCoolTemperate_summary report_01_22_2015.xlsx

Ruderal_EasternWarmTemperate_summary report_02_25_2014.xlsx

Ruderal_Mtn_West_summary report_12-23-2014.xlsx

E. Counts of A-K and Expert Plots by Ecological System and NVC Group

Summary table showing # of AK plots, # of expert plots, mapped extent for each Ecological System

Below is a table showing counts of plots for each ecological system: those keyed to the systems by the auto-keys, the number of expert plots for the systems, and the mapped extent in square kilometers. The last column is a ratio of the number of auto-keyed plots per square kilometer, to provide a relative sense of sampling intensity for the types. Ratios of 0.2 or higher are uncommon; most systems have a ratio under 0.09. A few systems with very small mapped extent have very high ratios; these should be considered un-informative.

Table 20. Counts of auto-key plots, expert plots, and mapped extent (sq km) for ecological systems. A ratio of # of auto-key plots per sq kilometer is also provided. The table is sorted from most mapped extent to least; where mapped extent is zero, then it is sorted by most to least auto-keyed plots.

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7141	Northwestern Great Plains Mixedgrass Prairie	2,591	147	206,903	0.013
7125	Inter-Mountain Basins Big Sagebrush Steppe	3,890	176	186,083	0.021
7080	Inter-Mountain Basins Big Sagebrush Shrubland	8,897	285	167,581	0.053
7302	Laurentian-Acadian Northern Hardwood Forest	18,689	152	164,467	0.114
7149	Western Great Plains Shortgrass Prairie	2,924	163	147,740	0.020
7126	Inter-Mountain Basins Montane Sagebrush Steppe	8,269	192	98,058	0.084
7148	Western Great Plains Sand Prairie	381	28	96,484	0.004
7016	Colorado Plateau Pinyon-Juniper Woodland	8,619	91	93,286	0.092
7081	Inter-Mountain Basins Mixed Salt Desert Scrub	2,537	120	90,278	0.028
7304	Ozark-Ouachita Dry-Mesic Oak Forest	6,606	55	84,162	0.078
7087	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	2,058	71	83,562	0.025
7132	Central Mixedgrass Prairie	467	45	82,420	0.006
7095	Apacherian-Chihuahuan Mesquite Upland Scrub	671	68	73,422	0.009
7321	South-Central Interior Mesophytic Forest	2,509	89	69,209	0.036
7370	Appalachian (Hemlock)-Northern Hardwood Forest	1,975	94	69,042	0.029
7045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	5,567	190	58,846	0.095
7368	Southern Piedmont Dry Oak-(Pine) Forest	704	89	58,350	0.012
7082	Mojave Mid-Elevation Mixed Desert Scrub	1,736	37	53,785	0.032
7019	Great Basin Pinyon-Juniper Woodland	5,480	120	52,722	0.104
7055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	6,852	215	52,465	0.131
7054	Southern Rocky Mountain Ponderosa Pine Woodland	5,306	114	48,623	0.109
7371	West Gulf Coastal Plain Pine-Hardwood Forest	526	111	46,924	0.011
7074	Chihuahuan Creosotebush Desert Scrub	224	32	45,005	0.005

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7127	Inter-Mountain Basins Semi-Desert Shrub-Steppe	3,541	109	44,451	0.080
7383	Edwards Plateau Limestone Savanna and Woodland	514	66	44,365	0.012
7121	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	887	60	41,745	0.021
7519	East-Central Texas Plains Post Oak Savanna and Woodland	152	66	40,047	0.004
7317	Allegheny-Cumberland Dry Oak Forest and Woodland	2,020	123	39,717	0.051
7310	North-Central Interior Dry-Mesic Oak Forest and Woodland	2,342	143	39,652	0.059
7308	Crosstimbers Oak Forest and Woodland	155	56	39,559	0.004
7050	Rocky Mountain Lodgepole Pine Forest	6,189	283	39,390	0.157
7109	Sonoran Paloverde-Mixed Cacti Desert Scrub	1,048	20	39,055	0.027
7111	Western Great Plains Mesquite Woodland and Shrubland	479	42	38,809	0.012
7369	Central Appalachian Dry Oak-Pine Forest	564	114	38,658	0.015
9055	Boreal-Laurentian Bog	94	19	37,226	0.003
7079	Great Basin Xeric Mixed Sagebrush Shrubland	1,639	121	37,094	0.044
7303	Northeastern Interior Dry-Mesic Oak Forest	2,688	122	36,953	0.073
7305	Southern Interior Low Plateau Dry-Mesic Oak Forest	1,419	66	35,490	0.040
7135	Inter-Mountain Basins Semi-Desert Grassland	1,200	60	33,941	0.035
7393	Edwards Plateau Limestone Shrubland	9	9	31,949	0.000
7094	Western Great Plains Sandhill Steppe	531	91	31,491	0.017
7153	Inter-Mountain Basins Greasewood Flat	2,060	108	30,903	0.067
7423	Southeastern Great Plains Tallgrass Prairie	46	3	30,393	0.002
7481	Laurentian-Acadian Alkaline Conifer-Hardwood Swamp	5,394	166	30,379	0.178
7139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	1,121	191	29,616	0.038
7011	Rocky Mountain Aspen Forest and Woodland	3,578	174	29,566	0.121
7373	Acadian Low-Elevation Spruce-Fir-Hardwood Forest	1,315	53	28,718	0.046
7053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	2,304	149	26,987	0.085
7028	Mediterranean California Mesic Mixed Conifer Forest and Woodland	4,791	104	26,022	0.184
7372	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	43	26	25,406	0.002
7056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	3,129	124	23,990	0.130
9089	Laurentian-Acadian Sub-boreal Mesic Balsam Fir-Spruce Forest	2,847	27	23,642	0.120
9001	Colorado Plateau Mixed Bedrock Canyon and Tableland	1,067	24	23,629	0.045
7179	Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	7,305	149	23,374	0.313
7025	Madrean Pinyon-Juniper Woodland	2,095	59	23,319	0.090
7318	Southern and Central Appalachian Cove Forest	2,245	141	22,955	0.098
7314	North-Central Interior Maple-Basswood Forest	574	53	22,501	0.026

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7039	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	7,946	124	21,970	0.362
7100	Chihuahuan Mixed Desert and Thornscrub	659	35	21,668	0.030
7315	Southern Appalachian Oak Forest	954	75	21,659	0.044
7047	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	3,657	128	21,194	0.173
9179	North-Central Interior Floodplain	570	130	21,017	0.027
9008	Inter-Mountain Basins Playa	497	15	20,635	0.024
7376	Southern Ridge and Valley / Cumberland Dry Calcareous Forest	216	24	20,618	0.010
7390	Tamaulipan Mixed Deciduous Thornscrub	174	7	19,313	0.009
7347	Atlantic Coastal Plain Upland Longleaf Pine Woodland	301	44	19,216	0.016
7107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	1,541	45	19,021	0.081
9085	East Gulf Coastal Plain Small Stream and River Floodplain Forest	196	48	18,962	0.010
7367	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	2,928	54	18,832	0.155
7313	North-Central Interior Beech-Maple Forest	421	47	18,530	0.023
7027	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	3,421	98	18,252	0.187
7105	Northern and Central California Dry-Mesic Chaparral	1,435	54	17,619	0.081
7422	Texas Blackland Tallgrass Prairie	3		17,205	0.000
7166	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	4,261	141	17,085	0.249
7366	Laurentian-Acadian Pine-Hemlock-Hardwood Forest	2,001	87	16,939	0.118
7037	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	2,265	74	16,669	0.136
9150	North American Warm Desert Pavement	156	5	16,265	0.010
7421	Central Tallgrass Prairie	193	2	16,006	0.012
7114	California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna	1,036	71	15,962	0.065
9019	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	864	45	15,880	0.054
7104	Mogollon Chaparral	729	47	15,784	0.046
7017	Columbia Plateau Western Juniper Woodland and Savanna	1,341	103	15,737	0.085
7124	Columbia Plateau Low Sagebrush Steppe	1,641	114	15,279	0.107
7059	Southern Rocky Mountain Pinyon-Juniper Woodland	1,121	66	14,997	0.075
7503	Chihuahuan Loamy Plains Desert Grassland	123	16	13,453	0.009
9284	West Gulf Coastal Plain Small Stream and River Forest	174	35	13,439	0.013
9141	Mississippi River Riparian Forest	144	18	13,205	0.011
9015	Northwestern Great Plains Riparian	89	13	13,198	0.007
9247	Southern Coastal Plain Blackwater River Floodplain Forest	44	6	13,148	0.003

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7066	Inter-Mountain Basins Mat Saltbush Shrubland	274	66	13,026	0.021
7078	Colorado Plateau Blackbrush-Mormon-tea Shrubland	467	35	12,920	0.036
7311	North-Central Interior Dry Oak Forest and Woodland	519	32	12,735	0.041
9023	Western Great Plains Badlands	53	17	12,560	0.004
7335	Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	117	32	12,545	0.009
7123	Columbia Plateau Steppe and Grassland	736	49	12,543	0.059
9183	North-Central Interior Wet Meadow-Shrub Swamp	19	1	12,518	0.002
7097	California Mesic Chaparral	951	55	12,203	0.078
7043	Mediterranean California Mixed Evergreen Forest	3,862	143	12,027	0.321
7119	Southern Rocky Mountain Juniper Woodland and Savanna	290	100	11,576	0.025
7301	Laurentian-Acadian Sub-boreal Aspen-Birch Forest	1,221	7	11,190	0.109
9230	Southeastern Great Plains Floodplain Forest	31	27	11,088	0.003
7374	Acadian-Appalachian Montane Spruce-Fir Forest	1,147	38	11,040	0.104
7146	Southern Rocky Mountain Montane-Subalpine Grassland	490	48	10,959	0.045
7102	Colorado Plateau Pinyon-Juniper Shrubland	459	6	10,930	0.042
7072	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	186	44	10,781	0.017
7051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	2,486	83	10,358	0.240
7110	Southern California Dry-Mesic Chaparral	2,409	125	10,271	0.235
7031	California Montane Jeffrey Pine-(Ponderosa Pine) Woodland	1,259	28	10,267	0.123
7145	Rocky Mountain Subalpine-Montane Mesic Meadow	1,013	98	10,215	0.099
7174	North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	2,264	67	10,016	0.226
7032	Mediterranean California Red Fir Forest	2,033	108	9,811	0.207
7323	West Gulf Coastal Plain Mesic Hardwood Forest	367	36	9,679	0.038
9050	Atlantic Coastal Plain Small Blackwater River Floodplain Forest	276	14	9,295	0.030
9151	North American Warm Desert Playa	61	2	9,229	0.007
7144	Rocky Mountain Alpine Turf	252	35	8,956	0.028
9082	East Gulf Coastal Plain Large River Floodplain Forest	84	25	8,584	0.010
9120	Laurentian-Acadian Wet Meadow-Shrub Swamp	297	31	8,548	0.035
9028	Western Great Plains Riparian	202	23	8,526	0.024
9129	Mediterranean California Foothill and Lower Montane Riparian Woodland and Shrubland	427	49	8,457	0.050
7134	Columbia Basin Foothill and Canyon Dry Grassland	440	70	8,378	0.053
7098	California Montane Woodland and Chaparral	427	51	8,236	0.052
9041	Atlantic Coastal Plain Blackwater Stream Floodplain Forest	32	22	7,994	0.004

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km ²)	# Auto-key Plots / km ²
9034	North American Warm Desert Riparian Woodland and Shrubland	256	9	7,968	0.032
7488	Eastern Great Plains Wet Meadow-Prairie-Marsh	2		7,802	0.000
7015	California Coastal Redwood Forest	820	63	7,733	0.106
7052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	281	13	7,719	0.036
7029	Mediterranean California Mixed Oak Woodland	616	51	7,671	0.080
7092	Southern California Coastal Scrub	1,764	94	7,638	0.231
9154	North American Warm Desert Wash	407	39	7,547	0.054
7316	Southern Piedmont Mesic Forest	782	18	7,500	0.104
7362	Laurentian-Acadian Northern Pine-(Oak) Forest	1,830	56	7,494	0.244
7324	Northern Atlantic Coastal Plain Hardwood Forest	287	57	7,463	0.038
9004	Inter-Mountain Basins Active and Stabilized Dune	127	8	7,248	0.018
7349	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	613	59	7,244	0.085
9248	Southern Coastal Plain Hydric Hammock	130	9	7,137	0.018
9249	Southern Coastal Plain Nonriverine Basin Swamp	14	11	7,104	0.002
7106	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	1,253	205	6,990	0.179
7093	Southern Colorado Plateau Sand Shrubland	304	16	6,944	0.044
7353	Southern Appalachian Low-Elevation Pine Forest	393	45	6,926	0.057
7076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	82	23	6,897	0.012
9014	Northwestern Great Plains Floodplain	380	40	6,797	0.056
9016	Rocky Mountain Alpine Bedrock and Scree	45	12	6,725	0.007
7049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	496	74	6,606	0.075
7030	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland	1,422	97	6,512	0.218
7454	East Gulf Coastal Plain Near-Coast Pine Flatwoods	476	10	6,501	0.073
7014	Central and Southern California Mixed Evergreen Woodland	645	28	6,469	0.100
7091	Sonoran Mid-Elevation Desert Scrub	72	16	6,398	0.011
7062	Inter-Mountain Basins Curl-leaf Mountain-mahogany Woodland and Shrubland	903	159	6,361	0.142
7407	Laurentian Pine-Oak Barrens	1,176	16	6,307	0.186
7385	Great Plains Wooded Draw and Ravine	171	31	6,278	0.027
7115	Inter-Mountain Basins Juniper Savanna	152	26	6,267	0.024
9021	Rocky Mountain Subalpine-Montane Riparian Shrubland	2,336	109	6,256	0.373
7452	Atlantic Coastal Plain Peatland Pocosin and Canebrake	35	30	6,165	0.006
9282	West Gulf Coastal Plain Large River Floodplain Forest	176	19	6,105	0.029
9147	North American Warm Desert Bedrock Cliff and Outcrop	98	13	5,970	0.016

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7140	Northern Rocky Mountain Subalpine-Upper Montane Grassland	560	166	5,860	0.096
7346	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland	529	38	5,849	0.090
7420	Northern Tallgrass Prairie	227		5,637	0.040
7061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	1,023	59	5,632	0.182
7041	North Pacific Mountain Hemlock Forest	1,414	128	5,618	0.252
7046	Northern Rocky Mountain Subalpine Woodland and Parkland	2,603	129	5,590	0.466
9117	Laurentian-Acadian Floodplain Forest	824	34	5,530	0.149
7451	West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	14	2	5,419	0.003
7343	Southern Atlantic Coastal Plain Mesic Hardwood Forest	227	24	5,388	0.042
9026	Western Great Plains Floodplain	176	17	5,350	0.033
9140	Mississippi River Low Floodplain (Bottomland) Forest	168	10	5,232	0.032
7460	Southern Coastal Plain Nonriverine Cypress Dome	595	16	5,143	0.116
7075	Chihuahuan Mixed Salt Desert Scrub	55	23	5,125	0.011
9009	Inter-Mountain Basins Shale Badland	284	10	5,104	0.056
7501	Southern Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest	103	18	5,094	0.020
7147	Western Great Plains Foothill and Piedmont Grassland	222	8	5,008	0.044
9051	Atlantic Coastal Plain Small Brownwater River Floodplain Forest	103	17	5,008	0.021
9092	Edwards Plateau Floodplain Terrace	82	20	4,984	0.016
9170	North Pacific Lowland Mixed Hardwood-Conifer Forest	405	15	4,972	0.081
9017	Rocky Mountain Alpine-Montane Wet Meadow	1,302	51	4,896	0.266
7325	East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	58	18	4,891	0.012
7024	Madrean Lower Montane Pine-Oak Forest and Woodland	620	35	4,737	0.131
7023	Madrean Encinal	673	37	4,661	0.144
9259	Southern Piedmont Small Floodplain and Riparian Forest	118	21	4,654	0.025
7156	North Pacific Lowland Riparian Forest and Shrubland	508	29	4,652	0.109
9033	Inter-Mountain Basins Volcanic Rock and Cinder Land	98	2	4,595	0.021
9006	Inter-Mountain Basins Cliff and Canyon	219	23	4,586	0.048
7377	Central Appalachian Pine-Oak Rocky Woodland	459	17	4,537	0.101
7357	Southern Coastal Plain Mesic Slope Forest	112	14	4,505	0.025
7133	Chihuahuan Sandy Plains Semi-Desert Grassland	43	5	4,504	0.010
7077	Chihuahuan Succulent Desert Scrub	48	10	4,444	0.011
7018	East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	2,049	40	4,358	0.470

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7088	Sonora-Mojave Mixed Salt Desert Scrub	206	39	4,338	0.047
7065	Columbia Plateau Scabland Shrubland	275	52	4,237	0.065
7122	Chihuahuan Gypsophilous Grassland and Steppe	23	4	4,232	0.005
9018	Rocky Mountain Cliff Canyon and Massive Bedrock	664	77	4,136	0.161
7525	Edwards Plateau Riparian		12	4,021	
7169	Northern Rocky Mountain Subalpine Deciduous Shrubland	783	81	3,996	0.196
9012	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	1,010	124	3,799	0.266
7489	Floridian Highlands Freshwater Marsh	26	1	3,760	0.007
9121	Llano Estacado Caprock Escarpment and Breaks Shrubland and Steppe	102	12	3,741	0.027
7523	Edwards Plateau Dry-Mesic Slope Forest and Woodland	60	39	3,734	0.016
9071	Columbia Bottomlands Forest and Woodland	9	9	3,658	0.002
7307	East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	186	35	3,607	0.052
7085	Northwestern Great Plains Shrubland	175	20	3,545	0.049
7456	Northern Atlantic Coastal Plain Pitch Pine Lowland	28	4	3,531	0.008
7086	Rocky Mountain Lower Montane-Foothill Shrubland	748	16	3,486	0.215
9003	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	717	83	3,482	0.206
7504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	97	32	3,393	0.029
7410	Llano Uplift Acidic Forest-Woodland-Glade	17	19	3,385	0.005
7138	North Pacific Montane Grassland	25	10	3,383	0.007
7036	North Pacific Seasonal Sitka Spruce Forest	1,319	56	3,353	0.393
7453	Central Florida Pine Flatwoods	971	13	3,306	0.294
9243	Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh	19		3,299	0.006
9197	Northern Atlantic Coastal Plain Tidal Salt Marsh	136	4	3,288	0.041
7306	East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland	30	16	3,284	0.009
7035	North Pacific Dry Douglas-fir-(Madrone) Forest and Woodland	500	6	3,247	0.154
9056	Boreal-Laurentian Conifer Acidic Swamp and Treed Poor Fen	2,685	68	3,222	0.833
7143	Rocky Mountain Alpine Fell-Field	6	8	3,132	0.002
9035	North American Warm Desert Lower Montane Riparian Woodland and Shrubland	228	9	3,127	0.073
9029	Western Great Plains Saline Depression Wetland	52	9	2,936	0.018
9145	North American Warm Desert Active and Stabilized Dune	73		2,930	0.025
7165	Northern Rocky Mountain Foothill Conifer Wooded Steppe	258	22	2,926	0.088

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
9224	South-Central Interior Small Stream and Riparian	2	30	2,837	0.001
7013	Western Great Plains Dry Bur Oak Forest and Woodland	43	27	2,785	0.015
7167	Rocky Mountain Poor-Site Lodgepole Pine Forest	125	58	2,608	0.048
9223	South-Central Interior Large Floodplain	211	18	2,587	0.082
7467	Tamaulipan Floodplain	3		2,561	0.001
7517	Paleozoic Plateau Bluff and Talus	65	4	2,555	0.025
7309	Southern Appalachian Northern Hardwood Forest	192	22	2,504	0.077
9112	Laurentian Jack Pine-Red Pine Forest	2,880	30	2,494	1.155
9180	North-Central Interior Freshwater Marsh	45		2,457	0.018
9268	Tamaulipan Ramadero	5		2,454	0.002
7320	Central and Southern Appalachian Montane Oak Forest	960	37	2,431	0.395
7064	Colorado Plateau Mixed Low Sagebrush Shrubland	235	29	2,427	0.097
7334	Ozark-Ouachita Mesic Hardwood Forest	528	9	2,378	0.222
7150	Western Great Plains Tallgrass Prairie	33	4	2,301	0.014
9231	Southeastern Great Plains Riparian Forest	165	57	2,122	0.078
7482	Great Plains Prairie Pothole	46		2,121	0.022
7356	Florida Longleaf Pine Sandhill	1,131	41	2,116	0.535
7429	West Gulf Coastal Plain Southern Calcareous Prairie	1		2,107	0.000
7038	North Pacific Maritime Mesic Subalpine Parkland	150	27	2,093	0.072
9177	North-Central Interior and Appalachian Acidic Peatland	143		2,026	0.071
7446	South Florida Pine Flatwoods	74	4	2,008	0.037
9146	North American Warm Desert Badland	29	1	1,986	0.015
7329	East Gulf Coastal Plain Southern Loess Bluff Forest	25	4	1,972	0.013
9011	North American Arid West Emergent Marsh	343	14	1,968	0.174
7327	East Gulf Coastal Plain Northern Loess Bluff Forest	46	7	1,948	0.024
7129	California Central Valley and Southern Coastal Grassland	84	31	1,923	0.044
7008	North Pacific Oak Woodland	223	50	1,918	0.116
9022	Rocky Mountain Subalpine-Montane Riparian Woodland	1,823	61	1,886	0.967
7033	Mediterranean California Subalpine Woodland	877	40	1,804	0.486
7401	Central Interior Highlands Calcareous Glade and Barrens	312	1	1,803	0.173
9178	North-Central Interior and Appalachian Rich Swamp	173	28	1,763	0.098
7117	Southern Rocky Mountain Ponderosa Pine Savanna	143	24	1,754	0.082
7042	North Pacific Mesic Western Hemlock-Silver Fir Forest	3,213	55	1,676	1.917
9211	Red River Large Floodplain Forest	41	3	1,655	0.025
7118	Southern California Oak Woodland and Savanna	300	24	1,653	0.182
7348	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	104	37	1,577	0.066
9213	Sierra Nevada Cliff and Canyon	77	2	1,575	0.049

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7518	North-Central Interior Wet Flatwoods	92	33	1,514	0.061
7338	Central and South Texas Coastal Fringe Forest and Woodland	4	7	1,510	0.003
7060	East Cascades Oak-Ponderosa Pine Forest and Woodland	117	35	1,505	0.078
9250	Southern Coastal Plain Oak Dome and Hammock	117	17	1,473	0.079
7382	Southern Atlantic Coastal Plain Maritime Forest	50	4	1,421	0.035
7449	Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	222	13	1,417	0.157
9088	Laurentian-Acadian Sub-boreal Dry-Mesic Pine-Black Spruce-Hardwood Forest	700	1	1,394	0.502
9002	Columbia Basin Foothill Riparian Woodland and Shrubland	118	36	1,388	0.085
7063	North Pacific Broadleaf Landslide Forest and Shrubland	595	13	1,374	0.433
9025	Western Great Plains Closed Depression Wetland	234	2	1,374	0.170
7058	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	1,343	112	1,357	0.990
7012	Rocky Mountain Bigtooth Maple Ravine Woodland	218	29	1,291	0.169
7425	Florida Dry Prairie	418		1,256	0.333
9148	North American Warm Desert Cienega	95		1,213	0.078
7158	North Pacific Montane Riparian Woodland and Shrubland	170	17	1,208	0.141
7070	Rocky Mountain Alpine Dwarf-Shrubland	164	63	1,183	0.139
9032	Columbia Plateau Ash and Tuff Badland	50	2	1,170	0.043
7137	Mediterranean California Subalpine Meadow	368	20	1,136	0.324
9125	Mediterranean California Alpine Bedrock and Scree	5	2	1,122	0.004
7178	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	465	29	1,063	0.438
7513	Lower Mississippi River Flatwoods	19	3	1,019	0.019
7113	California Coastal Live Oak Woodland and Savanna	733	70	1,015	0.722
7151	California Central Valley Riparian Woodland and Shrubland	255	82	1,007	0.253
7364	Ozark-Ouachita Dry Oak Woodland	3,132	67	975	3.213
7116	Madrean Juniper Savanna	186	29	970	0.192
7173	North Pacific Wooded Volcanic Flowage	159	4	954	0.167
7010	Northern Rocky Mountain Western Larch Savanna	237	6	931	0.255
7108	Sonora-Mojave Semi-Desert Chaparral	346	26	925	0.374
7044	Northern California Mesic Subalpine Woodland	1,359	20	914	1.487
7330	Southern Coastal Plain Dry Upland Hardwood Forest	229	17	902	0.254
7071	Sierra Nevada Alpine Dwarf-Shrubland	49	18	896	0.055
9138	Mississippi River Bottomland Depression	128	23	872	0.147
9188	Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	44	15	863	0.051
7387	Florida Peninsula Inland Scrub	182		851	0.214

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7326	South-Central Interior / Upper Coastal Plain Flatwoods	27		845	0.032
9069	Central Texas Coastal Prairie River Floodplain	4	2	832	0.005
9152	North American Warm Desert Riparian Mesquite Bosque	64	4	828	0.077
9095	Florida Big Bend Salt and Brackish Tidal Marsh	2		800	0.002
7450	Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods	111	11	788	0.141
7662	Temperate Pacific Freshwater Emergent Marsh	55	1	782	0.070
7461	Southern Coastal Plain Seepage Swamp and Baygall	567	40	781	0.726
7022	Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland	121	1	778	0.155
7668	Temperate Pacific Tidal Salt and Brackish Marsh	220	43	754	0.292
7322	Crowley's Ridge Mesic Loess Slope Forest	21	9	749	0.028
7034	Mediterranean California Mesic Serpentine Woodland and Chaparral	207	46	740	0.280
7057	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	626	51	736	0.850
7436	Northern Atlantic Coastal Plain Dune and Swale	254	10	722	0.352
7020	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland	152	32	718	0.212
9241	Southern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh	1		689	0.001
7458	West Gulf Coastal Plain Pine-Hardwood Flatwoods	80	14	674	0.119
9077	East Gulf Coastal Plain Depression Pondshore	131	1	667	0.196
9027	Western Great Plains Open Freshwater Depression Wetland	31	18	640	0.048
7397	Nashville Basin Limestone Glade and Woodland		2	639	
7510	Crowley's Ridge Sand Forest		4	637	
9045	Atlantic Coastal Plain Embayed Region Tidal Salt and Brackish Marsh	19		616	0.031
7021	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	1,080	22	613	1.762
7506	West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods	48	8	601	0.080
7733	North Pacific Montane Massive Bedrock-Cliff and Talus	155	12	598	0.259
7128	Northern California Coastal Scrub	212	54	591	0.359
7412	North-Central Interior Sand and Gravel Tallgrass Prairie	119		580	0.205
7328	Southern Coastal Plain Limestone Forest	33	1	566	0.058
7355	Northern Atlantic Coastal Plain Pitch Pine Barrens	98	54	565	0.174
9106	High Allegheny Wetland	2	3	552	0.004
7083	North Pacific Avalanche Chute Shrubland	102	18	530	0.192
7352	Southern Appalachian Montane Pine Forest and Woodland	110	16	525	0.209

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km ²)	# Auto-key Plots / km ²
7663	North Pacific Shrub Swamp	32	8	524	0.061
7331	Eastern Great Plains Tallgrass Aspen Parkland	124	38	511	0.242
7171	North Pacific Alpine and Subalpine Dry Grassland	143	44	507	0.282
9104	Gulf Coast Chenier Plain Fresh and Oligohaline Tidal Marsh	1,165	25	506	2.301
7735	North American Glacier and Ice Field	8		499	0.016
9105	Gulf Coast Chenier Plain Salt and Brackish Tidal Marsh	151	11	492	0.307
9024	Western Great Plains Cliff and Outcrop	44	9	483	0.091
7455	East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods		4	478	
7466	Great Lakes Wooded Dune and Swale	18		478	0.038
7350	Central and Southern Appalachian Spruce-Fir Forest	93	28	454	0.205
9143	Mississippi Sound Salt and Brackish Tidal Marsh	1		453	0.002
7142	Columbia Basin Palouse Prairie	29	8	451	0.064
9272	Temperate Pacific Subalpine-Montane Wet Meadow	531	4	449	1.183
7379	Northern Atlantic Coastal Plain Maritime Forest	53	10	433	0.122
9030	Columbia Plateau Silver Sagebrush Seasonally Flooded Shrub-Steppe	310	48	408	0.760
7380	East Gulf Coastal Plain Maritime Forest	26	1	402	0.065
7378	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	131	31	391	0.335
9005	Inter-Mountain Basins Alkaline Closed Depression	298	3	386	0.773
7669	Temperate Pacific Intertidal Flat	9		360	0.025
9160	North Pacific Active Volcanic Rock and Cinder Land		1	352	
7101	Madrean Oriental Chaparral	11	1	342	0.032
7734	North Pacific Alpine and Subalpine Bedrock and Scree	1	5	333	0.003
7120	Willamette Valley Upland Prairie and Savanna	20		331	0.060
9165	North Pacific Hardwood-Conifer Swamp	165	40	302	0.547
7084	North Pacific Montane Shrubland	439	47	299	1.468
7351	Southeastern Interior Longleaf Pine Woodland	95	26	294	0.324
7170	Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral	33	6	280	0.118
9246	Southern California Coast Ranges Cliff and Canyon		6	276	
9245	Southern Atlantic Coastal Plain Tidal Wooded Swamp	7	2	263	0.027
7381	Lower Mississippi River Dune Woodland and Forest	5	4	254	0.020
7507	Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	65	6	249	0.261
7400	Central Appalachian Alkaline Glade and Woodland	39		238	0.164
7485	East Gulf Coastal Plain Savanna and Wet Prairie	23		237	0.097
9195	Northern Atlantic Coastal Plain Riparian and Floodplain	111	9	236	0.471

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7468	Atlantic Coastal Plain Streamhead Seepage Swamp-Pocosin-Baygall	920	28	236	3.902
7103	Great Basin Semi-Desert Chaparral	162	24	230	0.705
7444	Eastern Boreal Floodplain	230	23	225	1.021
9258	Southern Piedmont Large Floodplain Forest	111	6	223	0.498
9080	East Gulf Coastal Plain Freshwater Tidal Wooded Swamp	4		220	0.018
7068	North Pacific Dry and Mesic Alpine Dwarf-Shrubland or Fell-field or Meadow	239	71	219	1.089
9171	North Pacific Maritime Coastal Sand Dune and Strand	19	9	216	0.088
7388	Southern Atlantic Coastal Plain Xeric River Dune	2		212	0.009
9130	Mediterranean California Northern Coastal Dune	1		208	0.005
9059	Central Appalachian River Floodplain	325	26	201	1.620
9060	Central Appalachian Stream and Riparian	36	9	200	0.180
9068	Central Texas Coastal Prairie Riparian	1	1	200	0.005
7131	California Northern Coastal Grassland	34	9	194	0.175
7394	North-Central Interior Oak Savanna	20	3	193	0.104
7112	California Central Valley Mixed Oak Savanna	166	10	179	0.928
9020	Rocky Mountain Subalpine-Montane Fen	24	2	169	0.142
7363	Central Interior Highlands Dry Acidic Glade and Barrens	51	3	157	0.325
9166	North Pacific Herbaceous Bald and Bluff	1	2	154	0.006
7026	Madrean Upper Montane Conifer-Oak Forest and Woodland	248	7	154	1.612
7361	Central Atlantic Coastal Plain Maritime Forest	68	1	150	0.454
7358	Bastrop Lost Pines Forest and Woodland	8	4	146	0.055
9099	Great Lakes Acidic Rocky Shore and Cliff	6		144	0.042
7430	Southern Coastal Plain Blackland Prairie and Woodland	6	4	141	0.043
7426	Southern Atlantic Coastal Plain Dune and Maritime Grassland	162		141	1.150
9191	Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh	5		138	0.036
9239	Southern Atlantic Coastal Plain Depression Pondshore	2		138	0.014
7172	Sierran-Intermontane Desert Western White Pine-White Fir Woodland	476	47	134	3.544
7354	Northeastern Interior Pine Barrens	3	2	122	0.025
7514	Central Florida Herbaceous Pondshore	197		114	1.724
9283	West Gulf Coastal Plain Near-Coast Large River Swamp	2	2	112	0.018
7459	Atlantic Coastal Plain Clay-Based Carolina Bay Wetland	2	1	99	0.020
9110	Klamath-Siskiyou Cliff and Outcrop	14	1	82	0.172
9993	West Gulf Coastal Plain Flatwoods Pond	10		77	0.129
9010	Inter-Mountain Basins Wash	57	2	70	0.815

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
7414	Southern Appalachian Grass and Shrub Bald	14	5	69	0.203
9228	Southeastern Coastal Plain Interdunal Wetland	149		66	2.254
7386	Acadian-Appalachian Alpine Tundra	8		66	0.122
9044	Atlantic Coastal Plain Embayed Region Tidal Freshwater Marsh	4	1	62	0.064
7136	Mediterranean California Alpine Dry Tundra	33	1	54	0.610
7415	Arkansas Valley Prairie and Woodland	59	20	52	1.127
7457	South-Central Interior / Upper Coastal Plain Wet Flatwoods	35	4	49	0.709
7395	North-Central Oak Barrens	14	2	49	0.285
7161	Northern Rocky Mountain Conifer Swamp	86	15	48	1.776
7509	Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest	22	8	47	0.464
7337	Southeast Florida Coastal Strand and Maritime Hammock	1		47	0.021
7096	California Maritime Chaparral	211	4	46	4.610
7067	Mediterranean California Alpine Fell-Field	8	1	46	0.175
9161	North Pacific Bog and Fen	3	2	45	0.066
7130	California Mesic Serpentine Grassland	23		44	0.525
9240	Southern Atlantic Coastal Plain Florida Beach	1		42	0.024
7431	Southwest Florida Dune and Coastal Grassland	59		41	1.434
7522	Northern Atlantic Coastal Plain Heathland and Grassland	3		39	0.076
7521	West Gulf Coastal Plain Stream Terrace Sandyland Longleaf Pine Woodland		1	38	
9207	Ozark-Ouachita Riparian	60	21	36	1.660
7409	Great Lakes Alvar	1		35	0.029
7389	Acadian-Appalachian Subalpine Woodland and Heath-Krummholz	44		29	1.534
9072	Columbia Plateau Vernal Pool	1		28	0.036
9126	Mediterranean California Coastal Bluff	17	8	25	0.670
9257	Southern Piedmont Granite Flatrock and Outcrop	2		25	0.081
9134	Mediterranean California Southern Coastal Dune	1	2	22	0.045
9101	Great Lakes Dune	19		22	0.866
7435	East Gulf Coastal Plain Dune and Coastal Grassland	3		20	0.148
9167	North Pacific Hypermaritime Shrub and Herbaceous Headland		1	20	
9202	Northern Great Lakes Coastal Marsh	13	3	20	0.654
7462	West Gulf Coastal Plain Seepage Swamp and Baygall	89	10	18	5.040
9118	Laurentian-Acadian Freshwater Marsh	197	16	15	13.082
9133	Mediterranean California Serpentine Foothill and Lower Montane Riparian Woodland and Seep	48	4	14	3.413
7336	Southwest Florida Coastal Strand and Maritime Hammock	9		13	0.715

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km ²)	# Auto-key Plots / km ²
9062	Central California Coast Ranges Cliff and Canyon		15	12	0.000
7177	California Coastal Closed-Cone Conifer Forest and Woodland	20	3	10	2.098
9122	Louisiana Beach	21		9	2.218
9007	Inter-Mountain Basins Interdunal Swale Wetland	1		9	0.107
7375	Eastern Serpentine Woodland	2		7	0.268
7391	Tamaulipan Mesquite Upland Scrub (only in Mexico)		3	7	0.000
7524	Edwards Plateau Mesic Canyon		4	6	0.000
9236	Southern Appalachian Rocky Summit	2		6	0.336
9271	Temperate Pacific Freshwater Mudflat	6		5	1.268
9175	North-Central Appalachian Circumneutral Cliff and Talus		1	3	0.000
7664	Temperate Pacific Freshwater Aquatic Bed	14	1	2	5.708
7168	Northern Rocky Mountain Avalanche Chute Shrubland	265	38	2	115.695
9042	Atlantic Coastal Plain Brownwater Stream Floodplain Forest	2	6	1	1.864
7009	Northwestern Great Plains Aspen Forest and Parkland	9	8	1	12.407
9234	Southern Appalachian Granitic Dome	7		0.46	15.161
9173	North-Central Appalachian Acidic Cliff and Talus	3		0.39	7.628
9232	Southern and Central Appalachian Bog and Fen	14		0.37	38.220
9256	Southern Piedmont Glade and Barrens	27	2	0.13	215.827
7099	California Xeric Serpentine Chaparral	259	42	0.05	4,796.296
9087	Northern Dry Jack Pine-Red Pine-Hardwood Woodland	39		0.01	3,939.394
9136	Mississippi Delta Fresh and Oligohaline Tidal Marsh	1,752	37		
9137	Mississippi Delta Salt and Brackish Tidal Marsh	1,345	25		
9066	Central Interior Highlands and Appalachian Sinkhole and Depression Pond	393			
9185	Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp	255	11		
9288	Northeastern Interior Calcareous Oak Forest	236			
7048	Northwestern Great Plains Highland White Spruce Woodland	168	13		
9139	Mississippi River High Floodplain (Bottomland) Forest	155	9		
9174	North-Central Appalachian Acidic Swamp	121	7		
9039	Acadian-Appalachian Conifer Seepage Forest	120	14		
9057	Boreal-Laurentian-Acadian Acidic Basin Fen	120	11		
7341	Northwestern Great Plains Canyon	115			
9114	Laurentian-Acadian Alkaline Fen	112	6		
9204	Northern Gulf of Mexico Seagrass Bed	90	1		
9242	Southern Atlantic Coastal Plain Large River Floodplain Forest	82	19		

EVT Code	Ecological System Name	# of Auto-key Plots	# of Expert Plots	Mapped Extent (km²)	# Auto-key Plots / km²
9186	Northern Appalachian-Acadian Rocky Heath Outcrop	66	9		
9083	East Gulf Coastal Plain Northern Seepage Swamp	47	4		
9278	Texas-Louisiana Fresh-Oligohaline Subtidal Aquatic Vegetation	36			
9176	North-Central Appalachian Seepage Fen	34	3		
9187	Northern Atlantic Coastal Plain Basin Peat Swamp	29	9		
9098	Florida River Floodplain Marsh	20			
9113	Laurentian-Acadian Acidic Cliff and Talus	20			
9115	Laurentian-Acadian Calcareous Cliff and Talus	17			
9123	Lower Mississippi River Dune Pond	13	1		
7505	Ouachita Novaculite Glade and Woodland	9			
9119	Laurentian-Acadian Lakeshore Beach	5			
9209	Piedmont Seepage Wetland	5	2		
9214	Sonoran Fan Palm Oasis	5			
9182	North-Central Interior Shrub-Graminoid Alkaline Fen	4			
9233	Southern and Central Appalachian Mafic Glade and Barrens	4			
7090	Sonoran Granite Outcrop Desert Scrub	3	4		
7342	Piedmont Hardpan Woodland and Forest	3			
9038	Acadian Maritime Bog	3	1		
9201	Northern Columbia Plateau Basalt Pothole Pond	3			
9070	Colorado Plateau Hanging Garden	3			
9142	Mississippi Sound Fresh and Oligohaline Tidal Marsh	2			
9237	Southern Appalachian Seepage Wetland	1	1		
9189	Northern Atlantic Coastal Plain Brackish Tidal Marsh	1			
9058	California Central Valley Alkali Sink		14		
9124	Mediterranean California Alkali Marsh		5		
7073	Baja Semi-Desert Coastal Succulent Scrub		1		
9052	Boreal Depressional Shrub Bog		1		
9263	Southwest Florida Perched Barriers Tidal Swamp and Lagoon		1		

Summary table showing # of AK plots, # of expert plots, for each NVC Group

Below is a table showing counts of plots for each natural NVC Group: those keyed to the Group by the auto-keys and the number of expert plots for the Group.

Table 21. Counts of auto-key plots and expert plots for natural NVC Groups. The table is sorted from most auto-keyed plots to least; where auto-key plots equals zero, then it is sorted by most to least expert plots.

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6043	Laurentian & Acadian Hardwood Forest	18,448	148
6288	Intermountain Mountain Big Sagebrush Shrubland & Steppe	14,468	169
6085	California Montane Conifer Forest & Woodland	12,661	396
6056	South-Central Interior Oak Forest & Woodland	11,459	273
6089	North Pacific Maritime Douglas-fir - Western Hemlock Forest	9,771	193
6286	Intermountain Dry Tall Sagebrush Shrubland	7,484	140
6062	Northwestern Great Plains-Black Hills Ponderosa Pine Forest & Woodland	7,475	149
6079	Colorado Plateau Pinyon - Juniper Woodland	6,550	61
6070	Rocky Mountain Subalpine Dry-Mesic Spruce - Fir Forest & Woodland	6,453	222
6069	Rocky Mountain Lodgepole Pine Forest & Woodland	6,361	317
6059	Central Rocky Mountain Douglas-fir - Pine Forest	6,001	183
6106	Laurentian-Acadian-Allegheny Alkaline Swamp	5,640	201
6075	Southern Rocky Mountain Ponderosa Pine Forest & Woodland	5,442	113
6065	Central Rocky Mountain Mesic Grand Fir - Douglas-fir Forest	5,416	51
6157	Northern Great Plains Mixedgrass Prairie	5,285	164
6034	Appalachian & Interior Mesic Forest	5,070	254
6090	North Pacific Maritime Silver Fir - Western Hemlock Forest	5,057	118
6049	Laurentian & Acadian Pine - Oak Forest & Woodland	4,781	88
6161	Great Plains Shortgrass Prairie	4,778	207
6028	Appalachian Oak / Chestnut Forest	4,773	371
6285	Intermountain Low & Black Sagebrush Shrubland & Steppe	4,728	301
6072	Rocky Mountain Subalpine-Montane Aspen Forest & Woodland	4,489	232
6138	California Xeric Chaparral	4,433	184
6081	Great Basin Pinyon - Juniper Woodland	4,260	71
6055	Shortleaf Pine - Oak Forest	4,022	137
6061	Middle Rocky Mountain Montane Douglas-fir Forest & Woodland	4,018	116
6046	Northern Mesic Balsam Fir-Spruce-Hardwood Forest	3,980	36
6282	Intermountain Semi-Desert Shrubland & Steppe	3,962	115
6287	Intermountain Mesic Tall Sagebrush Shrubland & Steppe	3,932	98
6018	Californian Moist Coastal Mixed Evergreen Forest	3,739	129
6096	Sierra-Cascade Red Fir - Mountain Hemlock Forest	3,674	118
6078	Colorado Plateau - Great Basin Juniper Woodland & Savanna	3,674	107

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6258	North American Desert Alkaline-Saline Shrub Wetland	3,389	131
6145	Central Rocky Mountain Lower Montane Foothill & Valley Grassland	3,280	255
6117	Rocky Mountain & Great Basin Montane Riparian Forest	3,269	137
6071	Rocky Mountain Subalpine Moist Spruce - Fir Forest & Woodland	3,187	142
6016	California Broadleaf Forest & Woodland	3,171	278
6031	Northeastern Oak - Hickory Forest & Woodland	2,938	163
6036	North-Central Oak - Hickory Forest & Woodland	2,808	176
6077	Southern Rocky Mountain White Fir - Douglas-fir Dry Forest	2,719	88
6291	Intermountain Shadscale - Saltbush Scrub	2,543	137
6130	Eastern Black Spruce-Tamarack Poor Swamp	2,490	57
6068	Northern Rocky Mountain Whitebark Pine - Subalpine Larch Woodland	2,439	93
6060	Central Rocky Mountain Ponderosa Pine Woodland & Savanna	2,419	164
6064	Central Rocky Mountain Interior Western Red-cedar - Western Hemlock Forest	2,165	17
6220	Atlantic & Gulf Coastal Plain Freshwater Tidal Marsh	2,117	48
6044	Laurentian & Acadian Hemlock - White Pine - Hardwood Forest	2,088	86
6272	Mojave-Sonoran Bajada & Valley Desert Scrub	2,044	78
6092	North Pacific Western Hemlock - Sitka Spruce - Western Red-cedar Seasonal Rainforest	2,004	90
6320	Intermountain Basins Cliff Scree & Badland Sparse Vegetation	2,001	70
6113	Oak - Sweetgum Floodplain Forest	1,992	197
6239	Western Montane-Subalpine Riparian & Seep Shrubland	1,969	170
6149	Rocky Mountain Subalpine-Montane Mesic Herbaceous Meadow	1,958	208
6007	Mesic Longleaf Pine Flatwoods-Spodosol Woodland	1,946	22
6141	Central & Southern California Coastal Sage Scrub	1,944	87
6254	Atlantic & Gulf Coast High Salt Marsh	1,918	39
6047	Appalachian & Allegheny Northern Hardwood - Conifer Forest	1,854	115
6095	Sierra-Cascade Cold-Dry Subalpine Woodland	1,763	153
6152	Southern Rocky Mountain Gambel Oak - Mixed Montane Shrubland	1,709	42
6271	Mojave Mid-Elevation Mixed Desert Scrub	1,601	35
6006	Dry-Mesic Loamy Longleaf Pine Woodland	1,594	182
6088	East Cascades Mesic Grand Fir - Douglas-fir Forest	1,590	40
6240	Vancouverian & Rocky Mountain Montane Wet Meadow & Marsh	1,544	31
6281	Intermountain Semi-Desert Grassland	1,465	133
6155	Central Great Plains Mixedgrass Prairie	1,456	53
6331	Warm Southwest Riparian Forest & Woodland	1,374	159
6094	North Pacific Mountain Hemlock - Silver Fir Forest & Tree Island	1,372	161
6023	Madrean Pinyon - Juniper Woodland	1,338	35
6010	Xeric Longleaf Pine Woodland	1,325	40
6080	Columbia Plateau Western Juniper Woodland & Savanna	1,306	99

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6054	Piedmont & Central Atlantic Coastal Plain Oak Forest	1,297	115
6144	Central Rocky Mountain High Montane Mesic Shrubland	1,271	112
6084	Southern Rocky Mountain Pinyon-Juniper Woodland	1,251	80
6048	Great Lakes Pine Barrens	1,249	16
6147	Central Rocky Mountain Montane-Foothill Deciduous Shrubland	1,240	27
6045	Northern Appalachian & Acadian Red Spruce - Fir - Hardwood Forest	1,191	92
6276	Warm Semi-Desert Shrub & Herb Dry Wash & Colluvial Slope	1,164	44
6313	Rocky Mountain Cliff Scree & Rock Vegetation	1,150	91
6137	California Mesic & Pre-montane Chaparral	1,099	82
6274	Sonoran Paloverde - Mixed Cacti Desert Scrub	1,054	26
6101	Silver Maple - Green Ash - Black Ash Floodplain Forest	1,015	29
6153	Southern Rocky Mountain Mountain-mahogany - Mixed Foothill Shrubland	1,012	17
6035	North-Central Beech - Maple - Basswood Forest	993	99
6103	Silver Maple - Sugarberry - Sweetgum Floodplain Forest	981	76
6279	Colorado Plateau Blackbrush - Mormon-tea Shrubland	952	60
6261	Chihuahuan Creosotebush - Mixed Desert Scrub	950	67
6022	Madrean Juniper Savanna & Woodland	913	54
6265	Chihuahuan Mesquite Upland Scrub	905	70
6241	Vancouverian & Rocky Mountain Subalpine & Alpine Snowbed Wet Meadow & Dwarf-Shrubland	905	
6105	Laurentian-Acadian-Allegheny Acidic Swamp	899	20
6266	Chihuahuan Desert Foothill-Piedmont & Lower Montane Grassland	897	62
6183	Western Madrean Chaparral	890	73
6082	Intermountain Basins Curl-leaf Mountain-mahogany Scrub & Woodland	841	155
6181	Western North American Montane Sclerophyll Scrub	823	110
6086	California Coastal Redwood Forest	783	83
6011	Western Gulf Coastal Plain Pine - Oak Forest & Woodland	780	149
6019	Southern Plateau Dry Forest & Woodland	773	107
6111	Coastal Plain Mixed Evergreen Swamp	731	88
6160	Great Plains Sand Shrubland	715	80
6021	Madrean Encinal	689	39
6255	Atlantic & Gulf Coast Low Salt Marsh	679	14
6051	Northern Dry-Mesic Pine-Black Spruce-Hardwood Forest	663	1
6333	Southern Vancouverian Dry Douglas-fir - Madrone Woodland	629	15
6122	North Pacific Lowland Riparian Forest & Woodland	628	27
6108	Pond-cypress Swamp	618	17
6327	Ozark-Ouachitas Mesic Forest	596	7
6100	Northern & Central Great Plains Floodplain Forest	594	54
6159	Great Plains Sand Grassland	588	26

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6063	Rocky Mountain Foothill-Rock Outcrop Limber Pine - Juniper Woodland	579	88
6294	Rocky Mountain & Sierran Alpine Turf & Fell-Field	578	60
6102	Silver Maple - Green Ash - Sycamore Floodplain Forest	576	137
6123	North Pacific Maritime Hardwood - Conifer Swamp	574	14
6014	Southern Mesic Beech - Magnolia - Oak Forest	570	53
6032	Pitch Pine Barrens	566	73
6024	Madrean Lower Montane Pine - Oak Forest & Woodland	556	33
6073	Rocky Mountain Subalpine-Montane Limber Pine - Bristlecone Pine Woodland	550	49
6151	Southern Rocky Mountain Montane-Subalpine Grassland	545	50
6243	Rocky Mountain & Great Basin Lowland & Foothill Riparian Shrubland	499	68
6058	Southeastern Great Plains Post Oak - Blackjack Oak Forest & Woodland	493	132
6259	North American Desert Alkaline-Saline Herbaceous Wetland & Playa	490	21
6115	Southern Ash-Elm-Willow Floodplain Forest	476	28
6242	Arid West Interior Freshwater Emergent Marsh	468	10
6222	Atlantic & Gulf Coastal Plain Pondshore & Wet Prairie	464	1
6290	Intermountain Dwarf Saltbush - Sagebrush Scrub	461	70
6087	Cascadian Oregon White Oak - Conifer Forest & Woodland	459	92
6098	North-Central Flatwoods & Swamp Forest	453	38
6112	Bald-cypress - Tupelo Floodplain Forest	439	94
6184	Florida Dry Prairie	419	
6284	Columbia Plateau Scabland Shrubland	415	55
6083	Southern Rocky Mountain Juniper Woodland & Savanna	414	79
6074	Rocky Mountain Douglas-fir - White Fir - Blue Spruce Mesic Forest	404	16
6324	Southeastern Great Plains Floodplain Forest	392	118
6015	Southern Mesic Beech - Oak - Mixed Deciduous Forest	384	59
6278	Tamaulipan Dry Mesquite & Thornscrub	370	10
6109	Coastal Plain Hardwood Basin Swamp	357	29
6091	North Pacific Red Alder - Bigleaf Maple - Douglas-fir Forest	350	33
6025	Madrean Upper Montane Conifer - Oak Forest & Woodland	346	8
6175	Central Alkaline Open Glade & Barrens	330	3
6156	Northern Great Plains Dry Mixedgrass Prairie	327	12
6330	Northern Rocky Mountain Lowland & Foothill Riparian Forest	322	14
6319	North American Warm Semi-Desert Cliff Scree & Pavement Sparse Vegetation	293	20
6237	Great Plains Shrub & Herb Riparian	284	14
6249	North American Warm Desert Riparian Low Bosque & Shrubland	275	6
6146	Central Rocky Mountain Montane Grassland	274	105
6269	Chihuahuan Semi-Desert Lowland Grassland	274	48
6027	Southern Plains Oak - Juniper Scrub Woodland & Shrubland	274	19

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6164	Northern Great Plains Tallgrass Prairie	274	
6194	North Atlantic Coastal Shrub & Grass Dune	258	10
6038	Eastern Great Plains Tallgrass Aspen Parkland	257	38
6211	Eastern North American Boreal Acidic Bog & Fen	251	26
6163	Central Great Plains Tallgrass Prairie	247	2
6257	Temperate Pacific Tidal Salt & Brackish Marsh	243	42
6066	Central Rocky Mountain Montane White Spruce Forest	235	13
6140	California North Coastal & Mesic Scrub	234	63
6167	Southern Great Plains Tallgrass Prairie	233	3
6030	Northeastern Chinkapin Oak - Red-cedar Forest & Woodland	233	3
6118	Rocky Mountain & Great Basin Swamp Forest	228	6
6131	Eastern Boreal Hardwood Floodplain & Swamp	225	23
6295	North Pacific Alpine-Subalpine Dwarf-Shrubland & Heath	224	21
6232	Northern & Central Shrub Swamp	222	21
6053	Chinkapin Oak-Shumard Oak-Blue Ash Alkaline Forest	220	18
6104	Northern Atlantic Coastal Hardwood & Conifer Swamp	214	37
6136	California Maritime Chaparral	212	4
6040	Northern & Central Great Plains Mesic Woodland	206	31
6013	Live Oak - Hickory - Palmetto Forest	198	11
6228	Eastern North American Freshwater Marsh	192	19
6142	California Annual Grassland	182	13
6110	Hardwood & Loblolly Pine Nonriverine Wet Flatwoods	181	29
6012	Southern Evergreen Oak Forest	179	34
6289	Cool Semi-Desert Shrub & Herb Wash-Arroyo	173	1
6293	Rocky Mountain & Sierran Alpine Dwarf-Shrubland	171	70
6165	Sand & Gravel Tallgrass Prairie	170	
6026	Southern Plains Mesquite Scrub Woodland & Shrubland	169	7
6033	Virginia Pine & Table Mountain Pine Woodland & Barrens	167	16
6067	Intermountain Basins Subalpine Limber Pine - Bristlecone Pine Woodland	165	32
6195	South Atlantic & Gulf Shrub & Grass Coast & Dune	165	
6283	Intermountain Sparsely Vegetated Dune Scrub & Grassland	163	6
6076	Southern Rocky Mountain Ponderosa Pine Savanna	162	24
6252	Western Great Plains Saline Depression Wetland	156	8
6315	North Vancouverian Montane Massive Bedrock Cliff & Talus	154	13
6221	Atlantic & Gulf Coastal Interdunal Marsh & Prairie	151	
6219	Rocky Mountain Neutral-Alkaline Fen	149	
6263	Chihuahuan Desert Sand Scrub	148	28
6213	Eastern North American Sub-boreal Acidic Bog & Fen	144	
6253	Atlantic & Gulf Coast Brackish Tidal Marsh	134	2

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6185	Florida Xeric Scrub	131	
6230	Laurentian & Northeast Wet Meadow	128	17
6017	California Conifer Forest & Woodland	127	9
6042	Central & Southern Appalachian Red Spruce - Fir - Hardwood Forest	117	28
6212	Eastern North American Boreal Alkaline Fen	117	10
6325	Laurentian-Acadian Acidic Scrub & Grassland	117	
6143	California Native Perennial Grassland	116	37
6129	Balsam Fir-Black Spruce Eastern Boreal Rich Swamp	111	1
6238	Great Plains Wet Prairie Wet Meadow & Seepage Fen	97	14
6316	Southern Vancouverian Cliff Scree & Rock Vegetation	95	2
6305	Eastern North American Freshwater Aquatic Vegetation	95	
6235	Great Plains Playa & Rainwater Basin Wetland	90	5
6302	Widgeongrass	90	1
6210	Southeastern Coastal Plain Pocosin & Shrub Bog	78	30
6182	Eastern Madrean Chaparral	76	3
6273	North American Warm Semi-Desert Dunes & Sand Flats	72	
6246	Vancouverian Wet Shrubland	69	36
6039	Great Plains Oak Woodland	66	27
6008	Sand Pine Scrub Forest & Open Woodland	65	
6099	South-Central Flatwoods & Pond Forest	64	4
6173	Central Acidic Open Glade & Barrens	61	4
6154	Southern Vancouverian Shrub & Herbaceous Bald Bluff & Prairie	56	12
6223	Coastal Plain River & Basin Freshwater Marsh	55	1
6201	California Coastal Beach & Dune Scrub	54	2
6262	Chihuahuan Desert Lowland Basin Scrub	53	22
6029	North Atlantic Maritime Scrub Forest	53	10
6256	Atlantic & Gulf Coast Saline Flat & Panne	53	
6234	Great Plains Freshwater Marsh	49	4
6125	North Pacific Montane Riparian Woodland	48	15
6270	Baja Semi-Desert Coastal Succulent Scrub	46	3
6268	Chihuahuan Sandy Plains Semi-Desert Grassland	45	5
6322	Rocky Mountain & Sierran Alpine Bedrock & Scree	42	21
6189	Eastern Subalpine Shrub - Herb Vegetation	41	
6310	Eastern North American Temperate Cliff	38	1
6264	Chihuahuan Desert Succulent Scrub	37	10
6318	Great Plains Cliff Scree & Rock Vegetation	36	10
6037	North-Central Oak Savanna & Barrens	36	5
6296	North Pacific Alpine-Subalpine Turf & Herbaceous Meadow	33	7
6174	Appalachian Mafic Glade	33	2

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6009	Wet-Mesic Longleaf Pine Woodland	30	30
6139	California Coastal & Foothill Seral Scrub	30	7
6326	North-Central Appalachian Acidic Scrub & Grassland	29	
6209	Midwest Prairie Alkaline Fen	28	1
6267	Chihuahuan Gypsophilous Grassland	25	4
6050	Northern Dry Jack Pine-Red Pine-Hardwood Woodland	24	
6191	South Atlantic & Gulf Coastal Beach	22	
6202	North Pacific Maritime Coastal Scrub & Herb Beach & Dune	20	6
6196	Appalachian & Interior Riverscour Barrens & Prairie	19	13
6192	Great Lakes Shrub & Grass Dune	19	
6227	Central Shrub & Herb Depression Pond	18	
6002	Caribbean Hardwood Hammock & Coastal Strand Forest	12	
6206	Central & Southern Appalachian Seep	11	1
6218	Rocky Mountain Acidic Fen	10	1
6332	Texas Live Oak - Wax Mallow Motte & Coastal Forest	10	1
6166	South-Central Plains & Coastal Prairie	10	
6172	Southern Appalachian Shrub Bald	9	
6169	Central & Southern Appalachian Rocky Outcrop	9	
6277	Tamaulipan Dry Grassland	8	
6244	Temperate Pacific Freshwater Wet Mudflat	8	
6292	Eastern Alpine Dwarf-Shrub-Herb Vegetation	8	
6186	Southeastern Coastal Plain Patch Prairie	7	4
6097	Central & Appalachian Seepage Swamp	7	1
6231	Midwest Wet Prairie & Wet Meadow	7	1
6216	North Pacific Bog & Acidic Fen	7	
6121	Tamaulipan Wet-Mesic Scrub Forest	7	
6311	Midwest-Great Lakes Cliff & Shore	6	
6317	Great Plains Badlands Vegetation	5	16
6217	North Pacific Neutral-Alkaline Fen	5	1
6124	North Pacific Maritime Poor Fen & Bog Forest & Woodland	5	1
6236	Great Plains Riverine Scour	5	
6171	Southern Appalachian Grass Bald	5	
6197	Eastern North American Inland Lakeshore	5	
6199	Northern & Central Riverscour Wetland	5	
6307	Western North American Temperate Freshwater Aquatic Bed	4	1
6314	Colorado Plateau Hanging Garden Seep	4	
6208	North-Central & Northeastern Seep	4	
6041	Northern Plains Fescue Aspen Parkland	3	8
6170	Piedmont Dome & Flatrock Vegetation	2	

Group EVT_code	NVC Group Name	# of AK plots	# of expert plots
6187	Comanchian Barrens & Glade	2	
6329	Great Lakes Rocky Shore Vegetation	2	
6177	Great Lakes Alvar	1	
6188	Southeastern Coastal Plain Barrens & Glade	1	
6308	California Cliff, Scree & Rock Vegetation		21
6020	Southern Plateau Dry-Mesic Hardwood Forest		5
6323	North Pacific Alpine-Subalpine Bedrock & Scree		5
6093	Vancouverian Dry Coastal Beach Pine Forest & Woodland		1
6004	Caribbean Basin Mangrove		1
6214	Western North American Boreal Acidic Bog & Fen		1

F. Comparison of Plots Keyed to Ruderal versus to Ecological System or NVC Groups for the Northwest and Southwest Geo Areas

See report section **Comparison #1: Between Keys to Natural Types and Ruderal/Cultural** for a discussion related to the tables in this appendix.

Table 22. Comparison of plots that keyed to a ruderal or cultural type in the multi-region ruderal keys, but keyed to an ecological system in the AKR keys. The total number of plots in the top row is how many ruderal plots in the Geo Area keyed to an ecological system (see **Table 16** for an explanation of these numbers). Numbers in the columns are the count of those ruderal plots by which system.

# Ruderal Plots that keyed to the various Natural Systems	NW	SW
Total	1916	3795
California Central Valley and Southern Coastal Grassland		10
California Central Valley Mixed Oak Savanna		33
California Central Valley Riparian Woodland and Shrubland		17
California Coastal Live Oak Woodland and Savanna		33
California Coastal Redwood Forest	1	9
California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna		139
California Maritime Chaparral		1
California Mesic Chaparral		53
California Mesic Serpentine Grassland		1
California Montane Jeffrey Pine-(Ponderosa Pine) Woodland	17	9
California Montane Jeffrey Pine(-Ponderosa Pine) Woodland		13
California Montane Woodland and Chaparral		4
California Xeric Serpentine Chaparral		3
Central and Southern California Mixed Evergreen Woodland		24
Chihuahuan Creosotebush Desert Scrub		1
Chihuahuan Mixed Desert and Thorn Scrub		5
Chihuahuan Mixed Salt Desert Scrub		5
Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub		8
Colorado Plateau Blackbrush-Mormon-tea Shrubland		26
Colorado Plateau Mixed Low Sagebrush Shrubland		10
Colorado Plateau Pinyon-Juniper Woodland	2	66
Columbia Basin Foothill Riparian Woodland and Shrubland	4	
Columbia Plateau Low Sagebrush Steppe	8	
Columbia Plateau Scabland Shrubland	11	
Columbia Plateau Silver Sagebrush Seasonally Flooded Shrub-Steppe	4	3

# Ruderal Plots that keyed to the various Natural Systems	NW	SW
Total	1916	3795
Columbia Plateau Western Juniper Woodland and Savanna	6	
East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	8	
East Cascades Oak-Ponderosa Pine Forest and Woodland	1	
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	7	16
Great Basin Pinyon-Juniper Woodland		44
Great Basin Semi-Desert Chaparral		7
Great Basin Xeric Mixed Sagebrush Shrubland	5	60
Inter-Mountain Basins Active and Stabilized Dune		8
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	1	3
Inter-Mountain Basins Big Sagebrush Shrubland	399	550
Inter-Mountain Basins Big Sagebrush Steppe	78	77
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	1	
Inter-Mountain Basins Curl-leaf Mountain-mahogany Woodland and Shrubland	1	7
Inter-Mountain Basins Greasewood Flat	54	438
Inter-Mountain Basins Juniper Savanna		1
Inter-Mountain Basins Mat Saltbush Shrubland	16	12
Inter-Mountain Basins Mixed Salt Desert Scrub	64	502
Inter-Mountain Basins Montane Sagebrush Steppe	37	157
Inter-Mountain Basins Playa		21
Inter-Mountain Basins Semi-Desert Grassland		1
Inter-Mountain Basins Semi-Desert Shrub-Steppe	80	239
Inter-Mountain Basins Shale Badland		4
Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland		1
Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	3	2
Madrean Pinyon-Juniper Woodland		4
Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	12	15
Mediterranean California Foothill and Lower Montane Riparian Woodland		16
Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland	1	18
Mediterranean California Mesic Mixed Conifer Forest and Woodland	2	10
Mediterranean California Mesic Serpentine Woodland and Chaparral		2
Mediterranean California Mixed Evergreen Forest	22	20
Mediterranean California Mixed Oak Woodland		4

# Ruderal Plots that keyed to the various Natural Systems	NW	SW
Total	1916	3795
Mediterranean California Northern Coastal Dune	2	
Mediterranean California Red Fir Forest	2	4
Mediterranean California Serpentine Foothill and Lower Montane Riparian Woodland and Seep		3
Mediterranean California Subalpine Meadow		3
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	4	
Mogollon Chaparral		5
Mojave Mid-Elevation Mixed Desert Scrub		96
North American Arid West Emergent Marsh	4	5
North American Warm Desert Active and Stabilized Dune		1
North American Warm Desert Cienega		23
North American Warm Desert Interdunal Swale Wetland		2
North American Warm Desert Lower Montane Riparian Woodland and Shrubland		4
North American Warm Desert Playa		1
North American Warm Desert Riparian Mesquite Bosque		14
North American Warm Desert Riparian Woodland and Shrubland		12
North American Warm Desert Wash		3
North Pacific Avalanche Chute Shrubland	2	
North Pacific Broadleaf Landslide Forest and Shrubland	6	
North Pacific Dry Douglas-fir-(Madrone) Forest and Woodland	12	
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	14	
North Pacific Hardwood-Conifer Swamp	7	
North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	6	
North Pacific Lowland Mixed Hardwood-Conifer Forest	16	
North Pacific Lowland Riparian Forest and Shrubland	5	
North Pacific Maritime Coastal Sand Dune and Strand	1	
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	25	
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	428	
North Pacific Mesic Western Hemlock-Silver Fir Forest	24	
North Pacific Montane Riparian Woodland and Shrubland	2	
North Pacific Montane Shrubland	25	
North Pacific Mountain Hemlock Forest	2	
North Pacific Oak Woodland	4	2
North Pacific Seasonal Sitka Spruce Forest	19	
Northern and Central California Dry-Mesic Chaparral		88

# Ruderal Plots that keyed to the various Natural Systems	NW	SW
Total	1916	3795
Northern California Coastal Scrub	1	1
Northern California Mesic Subalpine Woodland		1
Northern Rocky Mountain Avalanche Chute Shrubland	4	
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	29	
Northern Rocky Mountain Foothill Conifer Wooded Steppe	6	
Northern Rocky Mountain Lower Montane Foothill and Valley Grassland	1	
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	12	
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	1	
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	5	
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	32	1
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	28	
Northern Rocky Mountain Subalpine Deciduous Shrubland	2	
Northern Rocky Mountain Subalpine-Upper Montane Grassland	2	
Northern Rocky Mountain Western Larch Savanna	2	
Northwestern Great Plains Highland White Spruce Woodland	2	
Northwestern Great Plains Riparian	2	
Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	246	
Rocky Mountain Alpine-Montane Wet Meadow	1	7
Rocky Mountain Aspen Forest and Woodland	15	36
Rocky Mountain Bigtooth Maple Ravine Woodland	1	1
Rocky Mountain Cliff, Canyon and Massive Bedrock	1	1
Rocky Mountain Foothill Limber Pine-Juniper Woodland	1	1
Rocky Mountain Gambel Oak-Mixed Montane Shrubland		89
Rocky Mountain Lodgepole Pine Forest	15	7
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	5	46
Rocky Mountain Lower Montane-Foothill Shrubland	4	35
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland		7
Rocky Mountain Subalpine-Montane Mesic Meadow	5	3
Rocky Mountain Subalpine-Montane Riparian Shrubland	22	28
Rocky Mountain Subalpine-Montane Riparian Woodland		2
Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	4	1
Sierran-Intermontane Desert Western White Pine-White Fir Woodland	4	
Sonora-Mojave Creosotebush-White Bursage Desert Scrub		39
Sonora-Mojave Mixed Salt Desert Scrub		10

# Ruderal Plots that keyed to the various Natural Systems	NW	SW
Total	1916	3795
Sonora-Mojave Semi-Desert Chaparral		32
Sonoran Mid-Elevation Desert Scrub		2
Sonoran Paloverde-Mixed Cacti Desert Scrub		16
Southern California Coastal Scrub		234
Southern California Dry-Mesic Chaparral		107
Southern California Oak Woodland and Savanna		4
Southern Colorado Plateau Sand Shrubland		6
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland		7
Southern Rocky Mountain Juniper Woodland and Savanna		1
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland		1
Southern Rocky Mountain Pinyon-Juniper Woodland		4
Southern Rocky Mountain Ponderosa Pine Savanna		9
Southern Rocky Mountain Ponderosa Pine Woodland	1	35
Temperate Pacific Freshwater Aquatic Bed	1	
Temperate Pacific Freshwater Emergent Marsh	1	
Temperate Pacific Subalpine-Montane Wet Meadow		27
Temperate Pacific Tidal Salt and Brackish Marsh		14
Western Great Plains Sand Prairie	1	
Western Great Plains Wooded Draw and Ravine	3	1
Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	1	1

Table 23. Comparison of plots that keyed to a ruderal or cultural type in the multi-region ruderal keys, but keyed to an NVC Group in the AKR keys. The total number of plots in the top row is how many ruderal plots in the Geo Area keyed to a Group (see **Table 16** for an explanation of these numbers). Numbers in the columns are the count of those ruderal plots by which Group.

# Ruderal Plots that keyed to the various natural NVC Groups	NW	SW
Total	1859	3744
Arid West Interior Freshwater Emergent Marsh	5	26
Baja Semi-Desert Coastal Succulent Scrub		1
California Broadleaf Forest & Woodland	1	215
California Coastal & Foothill Seral Scrub		8
California Coastal Beach & Dune Scrub	2	6
California Coastal Redwood Forest	1	6
California Conifer Forest & Woodland		9

# Ruderal Plots that keyed to the various natural NVC Groups	NW	SW
Total	1859	3744
California Maritime Chaparral		1
California Mesic & Pre-montane Chaparral		61
California Moist Coastal Mixed Evergreen Forest	16	28
California Montane Conifer Forest & Woodland	23	67
California Native Perennial Grassland		11
California North Coastal & Mesic Scrub	2	1
California Xeric Chaparral		206
Cascadian Oregon White Oak - Conifer Forest & Woodland	4	1
Central & Southern California Coastal Sage Scrub		226
Central Rocky Mountain Douglas-fir - Pine Forest	17	
Central Rocky Mountain High Montane Mesic Shrubland	12	
Central Rocky Mountain Interior Western Red-cedar - Western Hemlock Forest	5	
Central Rocky Mountain Lower Montane, Foothill & Valley Grassland	4	
Central Rocky Mountain Mesic Grand Fir - Douglas-fir Forest	9	
Central Rocky Mountain Montane Grassland	1	
Central Rocky Mountain Montane White Spruce Forest	2	
Central Rocky Mountain Montane-Foothill Deciduous Shrubland	27	1
Central Rocky Mountain Ponderosa Pine Woodland & Savanna	29	
Chihuahuan Creosotebush - Mixed Desert Scrub		6
Chihuahuan Desert Lowland Basin Scrub		4
Chihuahuan Desert Sand Scrub		19
Colorado Plateau - Great Basin Juniper Woodland & Savanna	1	43
Colorado Plateau Blackbrush - Mormon-tea Shrubland		38
Colorado Plateau Pinyon - Juniper Woodland	2	41
Columbia Plateau Scabland Shrubland	12	
Columbia Plateau Western Juniper Woodland & Savanna	5	
East Cascades Mesic Grand Fir - Douglas-fir Forest	6	
Great Basin Pinyon - Juniper Woodland		27
Great Plains Floodplain Forest	1	
Great Plains Sand Grassland	1	
Great Plains Shrub & Herb Riparian	1	
Intermountain Basins Cliff, Scree & Badland Sparse Vegetation	1	3
Intermountain Basins Curl-leaf Mountain-mahogany Scrub & Woodland	2	7
Intermountain Basins Subalpine Limber Pine - Bristlecone Pine Woodland		1

# Ruderal Plots that keyed to the various natural NVC Groups	NW	SW
Total	1859	3744
Intermountain Dry Tall Sagebrush Shrubland	355	485
Intermountain Dwarf Saltbush - Sagebrush Scrub	16	14
Intermountain Low & Black Sagebrush Shrubland & Steppe	13	79
Intermountain Mesic Tall Sagebrush Shrubland & Steppe	76	49
Intermountain Mountain Big Sagebrush Shrubland & Steppe	127	267
Intermountain Semi-Desert Grassland		1
Intermountain Semi-Desert Shrubland & Steppe	62	236
Intermountain Shadscale - Saltbush Scrub	47	394
Intermountain Sparsely Vegetated Dune Scrub & Grassland		9
Middle Rocky Mountain Montane Douglas-fir Forest & Woodland	4	
Mojave Mid-Elevation Mixed Desert Scrub		75
Mojave-Sonoran Bajada & Valley Desert Scrub		69
North American Desert & Semi-Desert Alkaline-Saline Shrub Wetland		140
North American Desert Alkaline-Saline Herbaceous Wetland & Playa		1
North American Desert Alkaline-Saline Shrub Wetland	49	353
North American Warm Desert Riparian Low Bosque & Shrubland	1	24
North American Warm Semi-Desert Dunes & Sand Flats		1
North Pacific Lowland Riparian Forest & Woodland	23	
North Pacific Maritime Coastal Scrub & Herb Beach & Dune	1	
North Pacific Maritime Douglas-fir - Western Hemlock Forest	441	
North Pacific Maritime Hardwood - Conifer Swamp	5	
North Pacific Maritime Silver Fir - Western Hemlock Forest	35	
North Pacific Mountain Hemlock - Silver Fir Forest & Tree Island	2	
North Pacific Red Alder - Bigleaf Maple - Douglas-fir Forest	6	
North Pacific Western Hemlock - Sitka Spruce - Western Red-cedar Seasonal Rainforest	24	
Northern & Central Great Plains Mesic Woodland	1	
Northern & Central Great Plains Oak Woodland	1	
Northwestern Great Plains-Black Hills Ponderosa Pine Forest & Woodland	245	
Rocky Mountain & Great Basin Lowland & Foothill Riparian Shrubland	7	15
Rocky Mountain & Great Basin Montane Riparian & Seep Shrubland		4
Rocky Mountain & Great Basin Montane Riparian Forest	6	15
Rocky Mountain & Sierran Alpine Turf & Fell-Field	1	
Rocky Mountain Cliff, Scree & Rock Vegetation	3	3
Rocky Mountain Lodgepole Pine Forest & Woodland	16	7

# Ruderal Plots that keyed to the various natural NVC Groups	NW	SW
Total	1859	3744
Rocky Mountain Subalpine Dry-Mesic Spruce - Fir Forest & Woodland	1	7
Rocky Mountain Subalpine-Montane Aspen Forest & Woodland	20	39
Rocky Mountain Subalpine-Montane Mesic Herbaceous Meadow	6	5
Sierra-Cascade Cold-Dry Subalpine Woodland	3	1
Sierra-Cascade Red Fir - Mountain Hemlock Forest	2	4
Sonoran Paloverde - Mixed Cacti Desert Scrub		12
Southern Great Plains Mesquite Shrub Prairie		1
Southern Rocky Mountain Gambel Oak - Mixed Montane Shrubland		94
Southern Rocky Mountain Juniper Woodland & Savanna		1
Southern Rocky Mountain Mountain-mahogany - Mixed Foothill Shrubland	8	37
Southern Rocky Mountain Pinyon - Juniper Woodland		3
Southern Rocky Mountain Ponderosa Pine Forest & Woodland	2	33
Southern Rocky Mountain Ponderosa Pine Savanna		9
Southern Rocky Mountain White Fir - Douglas-fir Dry Forest		7
Southern Vancouverian Dry Douglas-fir - Madrone Woodland	12	
Temperate Pacific Tidal Salt & Brackish Marsh		14
Vancouverian & Rocky Mountain Montane Wet Meadow		1
Vancouverian & Rocky Mountain Montane Wet Meadow & Marsh	2	27
Vancouverian & Rocky Mountain Subalpine & Alpine Snowbed, Wet Meadow & Dwarf-Shrubland	12	13
Warm Semi-Desert Shrub & Herb Dry Wash		7
Warm Semi-Desert Shrub & Herb Dry Wash & Colluvial Slope		1
Warm Southwest Riparian Forest & Woodland		71
Western Interior Chaparral		8
Western Madrean Chaparral		15
Western Montane-Subalpine Riparian & Seep Shrubland	19	15
Western North American Desert & Semi-Desert Alkaline-Saline Herbaceous Wetland & Playa		4
Western North American Montane Sclerophyll Scrub	13	11

G. Case Study Contingency Tables for Selected Auto-Key Regions.

See attached files:

Landfire CT_AKR14_Appalachia_both.xlsm

Landfire CT_AKR4_Rocky Mountain_both.xlsm

Landfire CT_AKR7_Western Great Plains_both.xlsm