CHAPTER 11

Invasive Plants

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The national Forest Health Monitoring (FHM) Program of the Forest Service, U.S. Department of Agriculture, funded six Evaluation Monitoring (EM) projects on invasive plants. The projects belong to one of two broad groups: the effects of management actions on the distribution of invasive plants, and investigating the use of remote sensing or existing data from the Forest Inventory and Analysis (FIA) Program of the Forest Service or from local inventory as a means of gathering distribution or inventory information on invasive plant species.

Critical to the successful management of invasive plants is determining a baseline of existing infestation levels, understanding how management activities can influence the spread of invasives, and early detection and rapid response. The first three of the six FHM projects on invasive plants deal with management effects, specifically management associated with fire use or fire suppression, and look at the utility of existing inventory systems to assist in invasive plant inventory and population change. A fourth project investigates a method of aerial remote sensing techniques to determine the location and extent of annual invasive grasses in Hawaii, with the goal of providing land managers with a risk map of especially fire prone areas. A fifth project uses FIA data to predict vulnerability to successful invasion by exotic plant species on the Allegheny National Forest. The last project, based in Virginia and North Carolina, uses survey data to determine why some invasive plant species are more likely than others to move off roadsides into the interior forest lands adjacent to the roads.

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Project INT-F-04-01: Understanding the Effects of Fire Management Practices on Forest Health: Implications for Weeds and Vegetation Structure

There were two primary objectives of this study. The first objective was to determine whether certain fire management tactics (e.g., fireline construction, spike camps, and helispots) increased short-term post-fire weed establishment as compared to burned areas in same fire.

The second primary objective was to determine whether the intensity of fire suppression tactics (from wildland fire use through containment to suppression) would cause long-term differences in post-fire patterns in vegetation structure. This was to be accomplished through the comparison of actively suppressed fires, contained fires, and wildland fire use fires. The authors intended to test two hypotheses: (1) that suppressed fires have a simpler shape than natural fires; and (2) that there is less internal heterogeneity in suppressed fires than in natural fires. Simpler landscape shapes could provide a more conducive environment for future forest health issues through large-scale heterogeneity. Less internal heterogeneity within fire areas could result in more invasive plants as a result of increased areas of suitable seedbed and less vegetative competition over a larger area.

Another objective was to assess the opportunity to use FIA data and more-intensive, locally collected data to assist in monitoring these effects. Invasive plant data collected from existing FIA survey methods was compared to a more intensive survey method incorporating linear transects using the same plot center. The intent was to determine whether the FIA method or the more intensive method would be more accurate in locating invasive plant species. It was determined that neither method was more accurate overall and that neither method detected all species of invasive plants known to be present. When topographic variation was higher, the linear transects showed an improved ability to detect invasive plant species. Current landscape sampling methods, such as those by FIA, that use widely spaced plot designs are useful for landscape vegetation sampling but are not of fine enough scale to resolve the heterogeneous distribution of many invasive plant occurrences.

The study showed that different fire management tactics increase short-term post-fire weed establishment. Fire suppression activities that disturb the ground increase the risk of invasive plant spread. Firelines have more invasive species than surrounding burned areas. Handlines had more occurrences of invasive plants at the beginning of the handline. This increase was most notable near the "anchor-point" (where the handline is anchored to another feature that prevents fire movement), most likely because of the proximity of this location to previously disturbed areas. Over time, the handline may serve as a corridor for the dispersal and establishment of nonnative invasive plants as they move along the length of the handline. Firefighter spike camps had more invasive plant species and more occurrences than the surrounding areas. Fewer nonnative plants were detected on bulldozer lines as compared to handlines, but there were more than in control areas.

The portion of the study that was to determine whether actively suppressed fires would cause landscape-level effects different than wildland use fires or containment fires was hampered by the lack of consistent datasets involving fire perimeter shape and location. Fire perimeter data were inconsistently developed, missing, were not digitized, or did not reflect final fire shape and size. The authors settled on the use of Burned Area Rehabilitation Classification maps developed by the Remote Sensing and Applications Center because they are developed using a consistent methodology. Due to missing data, only fires from 2003 and 2005 were sampled. There were no significant differences found between suppressed and wildland fire use fires, i.e., perimeters were not more simplified in suppressed fires. There was a correlation between the size of the fire and the complexity of the fire shape; the larger the fire, the more complex the shape, regardless of management method. As to the question of whether suppressed fires resulted in less internal heterogeneity, the study could not answer this conclusively. It appeared that wildland fire use fires had more internal heterogeneity, but this difference was lost as fire size increased or if individual fire years were considered.

Project Number: WC-F-05-02: Ecological Impacts of Invasive Species After Fire

This study was intended to inventory and record new noxious weed populations associated with disturbance caused by wildland fires and associated activities, focusing on high disturbance areas such as heliports, staging areas, firelines, and travel routes. The study focused on the bluebunch wheatgrass and Idaho fescue plant communities on the Wallowa-Whitman National Forest. The study was to determine the extent and severity of noxious weed sites in relation to extent and severity of fire. Finally, the study was to compare new data to existing data of known sites and survey plots—a local current vegetation survey (CVS).

Monitoring began on the Tryon Fire Complex immediately after it burned in 2005 and continued twice a year for 2 more years (2006 and 2007). The study could not use the grid-established CVS plot data for monitoring invasive plants as these particular species were not included in the data collection and the grid-based design was not conducive to sampling invasive plants. One of the results of this study was a modification of local CVS plot procedures to include invasive plant species. The initial CVS plots were revisited and invasive plant information was recorded and additional weed monitoring plots were established using a combination of transects and 100 percent sampling circular plots within the Tryon Complex, centered on known invasive plant populations. There was an increase in both the number of invasive plant species and the percent cover of these species in the Tryon Fire Complex as a result of the fire.

Project Number: WC-F-06-06: Ecological Impacts of Invasive Species After Fire

This project is a follow-up to WC-F-05-02. Using plots established in the previous project within the 2005 Tryon Complex, the intent was to (1) determine the extent and the direction of spread of known noxious weed sites located within the Tryon Complex fire perimeters; (2) survey for new noxious weed sites within 2005 fire perimeters; (3) evaluate the relationship between weed response and fire intensity/severity; (4) monitor CVS plots within the Tryon Complex fire perimeters for noxious weeds; and, (5) monitor for survival of biological agents released within the area but prior to 2005 fires.

The invasive plant monitoring plots and the CVS plots demonstrated that there was an overall increase in weed densities within the plots during the initial green-up stage following a fire. Fires of low to medium severity, such as the fires monitored in this study, result in the removal of approximately 95 percent of the aboveground vegetation, but do not harm underground root or seed banks of existing vegetation. Invasive plants are the first to take advantage of the exposed surface, enhanced nutrients, and increased light that result from fire and thus increase seed germination. The study concluded that treatment of weeds during the initial green-up stage after a fire is essential, as it provides excellent visibility of invasive species and increased treatment efficiency. Invasive plants were found to have an accelerated rate of spread post-fire. This is likely due to the removal of competing vegetation. The original objectives of determining responses of invasive plants to fire were not discussed in the conclusions, probably because the invasive plants found during these post-fire surveys were treated with herbicides about a year after the fire, in September 2006. The herbicide treatments resulted in a decrease in invasive plants 2 years post fire and subsequent successful restoration of native bunchgrasses. Monitoring of biological agents concluded that stem weevils on Dalmatian toadflax and seed feeders on yellow starthistle can survive late summer, low severity burns that move quickly through grasslands, but numbers may be significantly reduced. Therefore, biological treatment effectiveness is initially reduced as a result of fire.

Project WC-F-01-06: Evaluating Fire Fuel Loads for Nonnative Grasses in Hawaii from Hyperspectral Reflectance Data

The natural fire regime in Hawaii has been altered markedly by the rapid spread of alien grasses. The disturbance of alien grasslands and adjacent forests by fire often encourages invasions of additional introduced plants. The intent of this project was to develop a remote sensing methodology capable of quantifying the fire fuel load of nonnative fine fuels (grasses) that threaten forest health in Hawaii. This would be accomplished through a combination of vegetation analysis, imaging spectroscopy, and radiative inverse transfer modeling techniques. If successful, the same techniques could be applied to airborne imaging spectrometer data collected over the entire Hawaiian archipelago to map both the spatial extent of dry vegetation cover and the biomass density of these fuels.

The study documents an automated method of analyzing high-altitude aerial spectral imagery to determine the percent cover of photosynthetic (PV) and non-photosynthetic (NPV) vegetation and bare ground in a cross-section of habitat types on the island of Hawaii. Field analysis determined that NPV is primarily made up of senescent nonnative grasses; therefore, for this study's objective, the determination of NPV is critical, as these areas would be considered fire prone and are often adjacent to native woodlands.

An important initial step in the project involved the analysis of reflectance spectra data to determine the unique wavelength indicators for PV, NPV, and bare ground. Once the digital signature of these three classes was determined, imagery representing a cross section of rainfall, elevation, and vegetation types was analyzed to determine the relative amounts of PV, NPV, and bare ground. This remotely sensed data was then field verified through vegetation transects. The resulting correlations between field measurements and remote measurements were very high (all three classifications had correlation coefficients ≥ 0.89).

The percentage of NPV peaked in the subtropical dry and thorn forest and lower montane thorn steppe life zones. The subtropical systems had particularly high percentages of NPV and also low levels of bare ground, suggesting these areas may be fire prone, as the data suggest a high cover of dry grass with little to stop a fire. In contrast, the upper montane moist and wet forests had high NPV values (30 to 42 percent) but also high bare ground cover, indicating an open, depauperate structure with a lower fire risk. When combined with precipitation data, NPV cover was consistently high when the mean annual precipitation was less than 59 inches (1 500 mm). In the range of mean annual precipitation between 29.5 to 39.4 inches per year (750 to 1 000 mm/year), the combination of low levels of bare ground (15 to 26 percent) combined with high levels of NPV (49 to 55 percent) would indicate the most fire prone areas, and the areas that should be the focus for land managers.

The authors conclude that this method of remote sensing allowed for high precision estimates of live and senescent vegetation and bare ground, and was as accurate as more expensive field surveys. Unique combinations of PV, NPV, and bare ground quantify fundamental differences in ecosystem structure.

Project NE-EM-05-01: Evaluating Environmental and Disturbance Conditions Associated with Invasive Plants Using the Allegheny National Forest Intensive Plot Data

This project was designed to evaluate the applicability of using FIA data to predict vulnerability of the Allegheny National Forest to successful invasion by exotic plants, then to develop a forest health indicator of potential invasion and test the indicator using other FHM data from Pennsylvania.

The project selected three types of variables: biotic, abiotic, and disturbance or landscape features related to disturbance. Seven biotic, ten abiotic, and nine disturbance variables were considered. Native species richness was the only important biotic variable for predicting the presence of invasive species; the presence of invasive species was more likely with high native species richness. Soil pH was the only abiotic factor showing any relationship to the presence of invasive exotic species, but the positive relationship between alkaline sites and the presence of invasive exotics was only marginally important and did not hold for all species evaluated. Stand age (younger stands were more likely to be invaded), the presence of nonforest land, and distance to the nearest exotic species planting were the only disturbance variables significantly associated with the presence of invasive exotic plant species.

Combining all variable types with $p \leq 0.1$ and presence of invasive species as the response variable, native species richness, presence of nonforest land, and stand age were significantly associated with the presence of invasive species. This model was the strongest of all the combined models with an adjusted R^2 of 0.43.

Project SO-F-05-04: Locate, Map, and Establish Long-term Monitoring of Exotic Invasive Plant Species in the Southern Appalachian Mountains

This project started with previously collected survey data of nonnative invasive plants from alongside roads, railways, powerlines, and other right-of-ways (ROW) in three areas of the Southern Appalachian Mountains in Virginia and North Carolina. The study investigated (1) development of a consistent and reliable method to survey forest interiors once invasive plants were found along an adjacent ROW; (2) capability of the surveys to detect the movement of invasive plants off the ROWs; and (3) the biotic or abiotic factors most associated with successful invasions of these invasive plants into the interior forest.

The project utilized three types of surveys, called L1, L2, and L3 in this study. L1 surveys were uncontrolled ROW surveys that were linear in design and conducted by “citizen-scientists” and where the presence or absence of nonnative invasive species (NNIS) was recorded. L2 surveys were plots based on the occurrence of NNIS from the L1 surveys, and, combined with information about the individual NNIS, were located in forest interiors in areas where conditions would allow for the NNIS to exist. L3 surveys were based on FIA protocols (FIA version 4.0 field guide) and were to be used to determine rates of spread of NNIS; however, the study authors determined that the timeframe for measuring rate of spread using this method would be much longer than the study parameters, and, therefore, the authors did not complete this part of the study.

One of the more important findings of the study was that the number of NNIS found along ROWs was not indicative of NNIS in interior forests; relatively few of the species found in L1 surveys were detected in L2 surveys. Although the study determined that there were some broad similarities in the biotic/abiotic factors associated with NNIS presence, there was also high variability in these numbers. Overall, NNIS presence in interior forests was more commonly associated with mesic conditions and disturbed areas (e.g., old roads, alluvial fans, etc.).

Summary of Key Findings

- The number of species found during roadside surveys or surveys along other types of ROWs do not necessarily indicate that all of these species would be found within forested lands adjacent to the ROW.

- Grid-based circular sampling plots tend to detect more invasive plant occurrences when the terrain is more uniform, while a more intensive survey could better detect occurrences in more variable terrain. Often nonnative invasive plants, based on their sporadic distribution, cannot be detected well by either method. One of the challenges of inventory and early detection of invasive plants is the difficulty in finding the individual plants, especially when recently introduced, within the background of existing vegetation. Fixed plot designs or a more intensive project-level fixed plot method such as considered in INT-F-04-01 are not well designed to sample for non-continuous species distributions as are common with invasive plants. Intuitive surveys, such as the surveys conducted under SO-F-05-04, are better suited for early detection purposes.

- Aerial or satellite remote sensing may provide the invasive plant manager with a method of detection that is both quick and relatively inexpensive. However, remote sensing studies must resolve the unique characteristics of the invasive species against the existing vegetation; this can be a formidable challenge. The challenge is to find those characteristics of a plant species unique to that particular species and the environment it is in. New techniques must be developed for each environment and invasive plant species.

- In the Interior West, invasive plants show a quick positive response to fire, while native bunchgrasses do not respond as quickly. It appears that the rate of spread of invasive plants increases within the fire area when compared to unburned areas.

- Low- to medium-severity fires remove 95 percent of the aboveground vegetation but do not harm underground roots or seed banks of existing vegetation. Both invasive plants and native bunchgrasses reestablish after fire.

- Immediate survey and treatment of invasive plants after a fire, during the initial green-up stage, is critical to effective control and to the reestablishment of native bunchgrasses. These early surveys and treatments can eliminate the need for re-seeding of native bunchgrasses, assuming the native bunchgrasses made up a significant proportion of pre-fire vegetation (> 30 percent cover).

- Although invasive plant biological control agents may survive a fire, their numbers may be greatly reduced. Biological control effectiveness is therefore initially reduced after a fire.

Utilization of Project Results

- The study on hyperspectral imaging data being used to determine nonnative grass invasions in Hawaii (WC-F-01-06) has led to additional studies by the lead author and others in which the methods from the study were combined with newer Light Detection and Ranging (LiDAR) technology to further improve the remote sensing of invasive plants (Asner and others 2005, Elmore and others 2005, Varga and Asner 2008).

- The National Environmental Modeling and Analysis Center (NEMAC) at the University of North Carolina at Asheville is collaborating with the Eastern Forest Environmental Threat Assessment Center (EFETAC) of the Forest Service to develop Web-enabled tools in risk assessment and decision making processes. The results from project SO-F-05-04, which developed location information and abiotic/biotic factors affecting movement of invasive plants from ROW edges into interior forests, were used by these organizations to develop a risk model for interior forest invasion by Japanese stiltgrass in the Hot Springs area of the Pisgah National Forest in North Carolina.

Suggested Further Evaluation

- Further research to develop a statistically valid sampling design that incorporates a linear sampling component ("walking and observing") that is both quick and inexpensive is needed if we want to be able to monitor the effectiveness of treatments or rates of spread.

- Continued research into remote sensing methodology that would allow for more efficient use of limited funding would be fruitful, although some priority of invasive species may be desirable. Other agencies and organizations are also doing work in this area; a review of existing studies should be done so that we do not duplicate efforts made elsewhere.

- Evaluate the applicability of remote sensing and GIS analysis methods such as kriging to supplant the tedious and expensive collection of field data for spatially heterogeneous variables such as the presence of invasive plant species in a variable landscape.

- There is an assumption that over time, as native vegetation is established in a fire area, the disturbed areas that provided an initial post-fire environment for invasion would become less hospitable to those invasive plants. Monitoring burned-over areas with similar fire intensity regimes over time would answer this question, and would be useful in determining whether these disturbed sites remain an invasive plant seed-source.

- The observation that handlines often had more invasives at the point where their construction began led to the conclusion that this was due to the anchoring points of these handlines being along roads, trails, or other disturbed areas, which provided a seed source. More intensive monitoring of these anchor sites and monitoring these handlines over a longer period may shed light on this hypothesis and determine whether existing plant occurrences or new sources (e.g., fire equipment) could be the cause.

- More studies that compare significant biotic, abiotic, and disturbance variables associated with native plants, exotic plants, and invasive exotic plants may help to determine if certain variables can be of general use in predicting risk of invasion or spread of invasive plant species.

Literature Cited

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