Research Article

Post-Fire Seeding in Western United States Forests: Perspectives of Resource Managers

Donna L. Peppin[1*], Anne L. Mottek-Lucas[2], and Peter Z. Fulé[1]

[1] School of Forestry, Northern Arizona University,
200 East Pine Knoll Drive, Room 116, Flagstaff, Arizona 86011-5018, USA

[2] Mottek Consulting, PO Box 22511, Flagstaff, Arizona 86002, USA

[*]Corresponding author: Tel.: 001-248-535-6188; e-mail: donna_peppin@nps.gov

ABSTRACT

Recent reviews have brought into question the effectiveness of post-fire seeding in mitigating soil erosion and non-native plant invasions, yet millions of dollars continue to be spent annually on post-fire seeding as a primary post-fire rehabilitation response. Overall policy development and implementation direction regarding post-fire rehabilitation treatments rests heavily on national- and regional-level natural resource managers. We conducted personal interviews and telephone surveys with the population of national- and regional-level natural resource managers (N = 6 and N = 17, respectively) involved directly in post-fire seeding activities on federally managed lands. We found that 71% of the respondents felt that information on the long-term effects of seeding was not sufficient. Respondents' perception about the effectiveness of seeding in curtailing spread of non-native species was mixed: 64% felt seeding was very or somewhat effective and 36% felt it was not effective at all. Additional monitoring and research is needed that utilizes cost-benefit analyses for areas where values at risk are high. These analyses include whether or not to seed,

RESUMEN

Revisiones recientes han puesto en duda la efectividad de la siembra post-incendio para mitigar la erosión del suelo y la invasión de plantas no nativas, aunque todavía se gastan millones de dólares anualmente en la siembra post-incendio como respuesta de rehabilitación primaria después de un incendio. El desarrollo general de políticas y la dirección de su implementación respecto a la aplicación de tratamientos de rehabilitación post-incendio depende en gran medida de las y los manejadores de recursos naturales a nivel nacional y regional. Entrevistamos personalmente y encuestamos telefónicamente a manejadores de recursos naturales de niveles nacional y regional (N = 6 y N = 17, respectivamente) involucrados directamente en actividades de siembra post-incendios en tierras a cargo del gobierno federal. Encontramos que el 71% de la muestra consideró que la información sobre los efectos a largo plazo de la siembra post-incendio no es suficiente. La percepción sobre la efectividad de la siembra para disminuir la propagación de especies exóticas fue mixta: 64% de las y los encuestados consideraron que sembrar era mucho o algo efectivo y el 36% consideró que no era efectivo en absoluto. Es necesario desarrollar procesos de monitoreo e investigación adicionales que partan de análisis costo-beneficio en áreas en las que los valores de riesgo son altos. Estos análisis deben contemplar si se

seeding implementation methods, seed mix composition, and effectiveness of seeding in curtailing non-native species spread and reducing soil erosion. The majority of information available on seeding comes from short-term studies (≤2 years). Testimonies and recent reviews demonstrate the need for review and refinement of current policy that includes stronger mandates and adequate funding for dedicated staff to conduct long-term monitoring spanning 5 years to 10 years. Land managers and scientists agree that there is a need for data on the long-term effectiveness of seeding treatments as well as further inquiry regarding effectiveness of seeding in mitigating non-native species invasions. Stronger communication and collaboration between these two groups would allow researchers to develop well-replicated monitoring designs for areas that land managers consider to be high priority for intensive quantitative long-term research of post-fire treatments.

siembra o no, los métodos de implementación de la siembra, las mezclas de especies, así como la efectividad de la siembra en limitar la propagación de especies no nativas y en reducir la erosión del suelo. La mayoría de la información disponible sobre siembra proviene de estudios de corto plazo (≤2 años). Testimonios y revisiones recientes demuestran la necesidad de revisar y perfeccionar las políticas actuales, incluyendo instrucciones de mayor peso y financiamiento adecuado para contar con personal dedicado a realizar monitoreo de largo plazo, en periodos de 5 a 10 años. Las personas a cargo del manejo de tierras y la comunidad científica coinciden en que existe una necesidad de contar con datos sobre la efectividad a largo plazo de los tratamientos de siembra en la mitigación de las invasiones de especies no-nativas. Una mejor comunicación y colaboración entre estos grupos permitirá el desarrollo de programas de monitoreo bien replicados para áreas que los manejadores de tierras consideren que son de alta prioridad para la investigación cuantitativa de largo plazo de tratamientos post-incendio.

Keywords: BAER, effectiveness monitoring, emergency stabilization, native seed

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INTRODUCTION

The fire seasons of 2011 and 2012 in the United States were among the largest in United States history since 1960 (NIFC 2014). Following these extreme fire events, land managers were tasked with making critical decisions about rehabilitation. Climate-driven increases in large wildfire activity and longer wildfire seasons in the western United States (Westerling *et al.* 2006, Littell *et al.* 2009) has brought values at risk and subsequent rehabilitation needs to the forefront of not only land managers, but also fire management policy-makers.

Land management agencies in the United States, such as US Department of Agriculture Forest Service (USFS) and US Department of the Interior Bureau of Land Management (BLM), commonly prescribe seeding as an emergency watershed-rehabilitation measure to minimize threats of increased erosion and non-native species invasion, which often result from severe wildfire (Richards *et al.* 1998, Robichaud *et al.* 2000). This rationale has led to post-fire seeding being one of the most widely used post-fire rehabilitation activities and one of the largest categories of Burned Area Emergency Response (BAER) expenditures (Robichaud *et al.* 2000, Peppin *et al.* 2011).

Since 2000, several reviews have brought into question the effectiveness and effects of post-fire seeding treatments (Robichaud *et al.* 2000, Beyers 2004, Peppin *et al.* 2010, Peppin *et al.* 2011). The reviews suggest that: 1) seeding has a low probability of success during the first and second critical erosion years after fire (Robichaud *et al.* 2000); 2) successful grass establishment displaces native plant regeneration (Robichaud *et al.* 2000, Beyers 2004, Peppin *et al.* 2010); 3) seeded plots rarely reduce erosion compared to unseeded plots (Peppin *et al.* 2010); and 4) seeding has limited effectiveness in curtailing non-native species invasions (Peppin *et al.* 2010). Thus, the disconnect between the continued use of seeding as a post-fire rehabilitation measure and scientific evidence regarding its effectiveness is of concern.

Overall policy development and implementation direction regarding post-fire rehabilitation treatments rests heavily on national- and regional-level natural resource managers. Decisions and implementation direction made at these levels critically affect post-fire rehabilitation measures prescribed at the local level. As post-fire seeding continues as a primary tool to mitigate erosion and non-native plant invasion, it is important to understand perceptions of higher-level natural resource managers regarding the use of post-fire seeding treatments. To better understand current decisions on post-fire seeding and effectiveness in mitigating post-fire erosion and non-native invasions, we administered in-person interviews and telephone surveys with national- and regional-level managers. Results from these interviews and surveys are compared and contrasted with findings from recent reviews on post-fire seeding to determine gaps and inconsistencies in knowledge, practices, monitoring, and policy. Identifying and understanding these inconsistencies will assist in pinpointing areas in post-fire management that require further research and monitoring and may help enhance the efficiency and success of future post-fire rehabilitation.

METHODS

We conducted in-person interviews with a small group of fire management specialists (hereafter "key informants") who were especially knowledgeable about post-fire seeding activities on federally managed lands at the national level. Results from these exploratory interviews assisted in the development of a more structured study of regional resource managers.

We administered a telephone survey to a larger group of regional resource managers and specialists with expertise in post-fire seeding activities in forested ecosystems within federally managed lands across the western United States (hereafter "regional specialists"). We defined forested ecosystems as those dominated by coniferous or deciduous trees occurring at elevations above grasslands, pinyon-juniper woodlands, or chaparral vegetation in the western United States (Peppin *et al.* 2010). Regional specialists responded based on their own experience and did not provide an official position of a particular agency.

Key Informant Interviews

Through preliminary discussions with experts in the field and online searches, we identified key informant interviewees who were national-level natural resource managers directly involved in post-fire emergency response activities. We used key informant interviews to better understand current post-fire seeding policies, objectives, and other post-fire seeding treatment issues.

We conducted six key informant interviews with US Department of the Interior (USDI) national-level managers involved with Emergency Stabilization and Burn Area Recovery (ES&BAR) activities working for the BLM, Bureau of Indian Affairs (BIA), Fish and Wildlife Service (FWS), and the National Park Service (NPS). Due to a position vacancy at the time of the interviews, we administered a survey to the current Acting USFS National

BAER Coordinator during subsequent telephone interviews.

Telephone Survey with Regional Specialists

Based on contact information gathered from key informants, we established an exhaustive list of regional specialists (N = 29). The population contained regional specialists involved specifically in post-fire rehabilitation activities working for the USFS, BIA, BLM, FWS, and NPS.

To increase response rates, we sent a pre-notification e-mail to all potential respondents one week before the survey period. We screened potential respondents first to verify that their organization was involved in post-fire seeding in forested ecosystems and omitted those participants who did not qualify (10). After screening, the final survey population consisted of 19 potential respondents. Of the 19 identified regional specialists who remained, we completed 17 telephone surveys (89 % response rate [percentage of qualified or eligible respondents completing the survey]). Five respondents worked for the USFS and the remaining participants worked at various USDI agencies (Table 1).

Based on information gained from key informants, we developed a more focused set of survey questions administered to the larger group of regional specialists (30 seeding treatment and 7 demographic questions). Survey questions consisted of a variety of formats including closed-ended, multiple response, and open-ended questions. We designed contingency questions (subsequent questions asked contingent on a particular response to the first question in a series) to further clarify answers given in a preceding closed-ended question. We designed all survey questions to allow for grouping and ranking results. To validate the survey instrument, we pre-tested the survey and revised the content and format accordingly. We grouped seeding treatment questions into six categories: 1) evaluation and determination of the need for post-fire seeding; 2) implementation of post-fire seeding treatments; 3) post-fire seeding success and effectiveness; 4) monitoring of post-fire seeding treatments; 5) post-fire seeding treatment information availability and exchange; and 6) post-fire seeding policy.

The average length of time to complete the survey ranged from 25 to 30 minutes. Each interview began with an introduction that 1) identified the interviewer; 2) explained the project and the purpose of the survey; 3) explained how the results would be used; and 4) guaranteed respondent confidentiality and anonymity.

We summarized telephone survey responses by calculating answer frequencies (the number following each percentage) and valid percentages ("Don't know" or "Refused" responses omitted). Answer frequencies represent the total number of responses to an individual response category for a question. We calculated valid percentages by dividing the number for each response category by the total number of responses for that question. Total number of responses to a question may be greater or less than that of the total number of respondents due to multiple response questions and programmed skips within the survey.

Table 1. Agency and number of participants involved in surveys with regional natural resource managers.

Agency	Participants (*n*)
Fish and Wildlife Service	3
National Park Service	2
Bureau of Indian Affairs	4
Bureau of Land Management	3
US Forest Service	5
Total	**17**

RESULTS

Need for Post-Fire Seeding

According to regional specialists, deciding to seed is most dependent on the values at risk, fire severity, and threat of non-native species. A majority (88%, 14) of regional specialists reported natural regeneration as very effective (38%, 6) or somewhat effective (50%, 8) in achieving plant cover and reducing erosion (16 total responses; Figure 1).

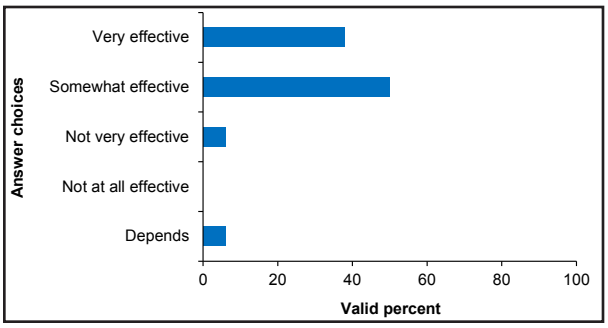

Figure 1. Answers to the single-response question, "In cases where you chose to allow the area to naturally regenerate, in general, how effective has this been?" (16 responses.)

Implementation of Post-Fire Seeding

Regional specialists stated that aerial seeding is the most commonly used method to seed (60%, 12) (20 total responses; Figure 2). When asked which method is most effective (three total responses), hand seeding and drilling were deemed superior (67%, 2 and 33%, 1, respectively).

Over half (52%, 11) of the regional specialists reported mulching as the treatment used most often in conjunction with post-fire seeding (21 total responses). Mulching was also selected as one of the most effective methods used with seeding out of seven total responses (43%, 3).

Out of 37 total responses, most regional specialists selected either natives (41%, 15) or annual cereal grains (non-native agricultural species cultivated for the edible components of their seeds, such as wheat, barley, oats, or cereal rye; 22%, 8) as the species typically seeded. At the same time, when asked what percentage of native and annual cereal grains is typically used in seed mixes, responses reflected a large range (10% to 100% and 5% to 80%, respectively). Although native species cultivars (a cultivated variety of a native species that has been deliberately selected for specific desirable characteristics), non-native species, and sterile annual cereal grains (non-reproductive annual grasses) were used less, the range used in the seed mixes was much smaller (5% to 25%).

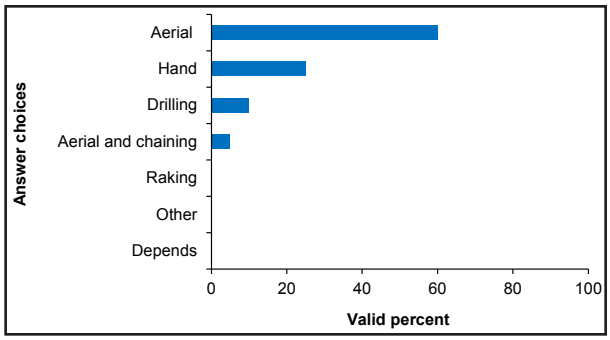

Figure 2. Answers to the multiple-response question, "What is the most commonly used application technique for post-fire seeding?" (20 responses.)

Post-Fire Seeding Success and Effectiveness

Over half (57%, 8) of the resource specialists reported post-fire seeding as somewhat effective in mitigating non-native species invasions, whereas more than one in three (36%, 5) stated it is not very effective (14 total responses; Figure 3). Regional specialists who answered "somewhat effective" explained their response further by stating that effectiveness of seeding to mitigate non-native species invasion depends on the proximity of non-native species populations to the rehabilitation site and the competitive abilities of the non-native species present. For those who answered that mitigating non-native species invasions was not very effective, elaboration of these re-

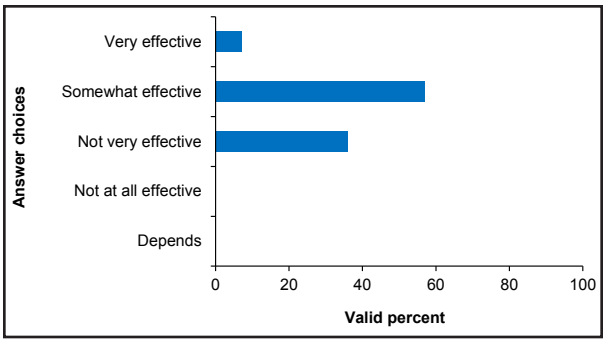

Figure 3. Answers to the single-response question, "How effective is post-fire seeding in mitigating non-native species invasions?" (14 responses.)

sponses included, "recent research results shows this," "strong competitive abilities of non-natives," and "the application method is unsuccessful."

Out of 17 total responses, regional specialists identified precipitation (47%, 8) and climate (24%, 4) as the main factors affecting seeding success. Out of 15 total responses, respondents reported that post-fire seeding treatments mitigate soil erosion in less than one year (33%, 5) or in one to two years (47%, 7).

Post-Fire Seeding Policy and Monitoring of Post-Fire Seeding Treatments

Out of 16 total responses, more than half (56%, 9) of the regional specialists reported that monitoring was either always (31%, 5) or often (25%, 4) completed, whereas almost the same number of respondents (44%, 7) said it was sometimes (31%, 5) or hardly ever (13%, 2) achieved. Those saying "hardly ever" explained that competing priorities, plus lack of time and dedicated staff, deters implementing a monitoring program. This issue also resonated among key informants who stated that lack of sufficient funding and personnel are major limitations in monitoring post-fire seeding treatments. Regional specialists further suggested that regular monitoring of the effectiveness of post-fire seeding treatments would improve if a funded monitoring plan supported dedicated staff.

Out of 16 total responses, the majority of regional specialists (81%, 13) agreed that information available to evaluate short-term benefits of post-fire seeding treatment is somewhat sufficient; however, more than two in three (71%, 12) said availability of information to evaluate long-term benefits is not very (59%, 10) or not at all (12%, 2) sufficient (17 total responses; Figure 4). Comments revealed that increased monitoring to address long-term effects of seeding on native plant communities and seeding effectiveness in preventing non-native species invasion is needed to assist land managers in making relevant post-fire seeding decisions. Out of 16 total responses, most regional specialists (63%, 10) identified either 5 years (38%, 6) or 5 to 10 years (25%, 4) as the ideal length of time to monitor a majority of post-fire seeding projects, while 19% (3) stated that 3 years of monitoring, the current length of time funding is available to monitor treatments after fire, was adequate.

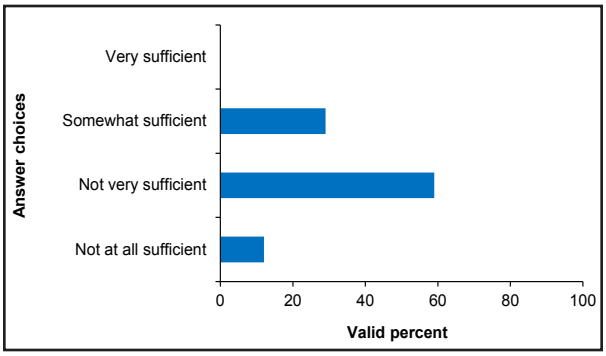

Figure 4. Answers to the single-response question, "Is the information available to evaluate the long-term benefits of post-fire seeding treatments?" (17 responses.)

DISCUSSION

Our comparison of interviews and survey findings with published scientific literature revealed consistencies as well as gaps and contradictions. This study identifies areas that require further monitoring and research as well as improvements for current decisions and policies regarding post-fire seeding effectiveness

in mitigating post-fire erosion and non-native invasions.

Regional specialists' decisions to seed based on values at risk, fire severity, and threat of non-native invasion is in line with current seeding policy (USDI and USDA 2006). Regional specialists commented that allowing the land to naturally regenerate may be just as effective as seeding for meeting rehabilitation objectives related to soil erosion. Similarly, Peppin *et al.* (2010) found that over three-quarters of the studies reviewed that evaluated seeded versus unseeded controls revealed that seeding was no more effective than the controls in reducing erosion. Given these findings, it is surprising that land management agencies continue to seed rather than allow these areas to naturally regenerate. These results imply that initial seeding assessments should be carefully considered and supported by evaluation of past practices, recent research findings, seeding success within the region, and land managers' primary rehabilitation goals.

Implementation techniques for seeding can have a significant impact on its effectiveness. Regional specialists and the literature agree that aerial seeding is one of the most commonly used methods to seed after fire (Robichaud *et al.* 2000, Peppin *et al.* 2010). Robichaud *et al.* (2000) found cost per unit area for aerial seeding considerably less than other rehabilitation treatments, which may be the cause for the high use of this practice. However, several studies note that aerial seeding effectiveness is highly variable (Barclay *et al.* 2004, Hunter *et al.* 2006, Wagenbrenner *et al.* 2006). In agreement with regional specialists, Monsen *et al.* (2004) also identified hand seeding and drilling as the most effective application techniques. Unfortunately, seeding by hand is both time and labor intensive and drill seeding is prohibited on steep slopes commonly found in forested ecosystems; for these reasons, neither are practical methods for treating large expanses of forested land. Several post-fire treatment decision tools have been made available to land managers in recent years. These tools make it possible to determine the most appropriate treatment methods including that of seeding, especially in areas where values at risk are high. Cost-benefit analysis for which spreadsheets currently exist is a valuable tool for calculating post-fire treatment and cost effectiveness to values at risk (Calkin *et al.* 2007, Robichaud and Ashmun 2013). Additional post-fire decision tools available include post-fire burn severity mapping and predictive modeling (Robichaud and Ashmun 2013). Erosion Risk Management Tool (ERMiT) has been developed specifically for post-fire assessments and is used to estimate the probability of hillslope treatment success for seeding, erosion barriers, and dry agricultural straw mulch (Robichaud *et al.* 2007). Regional specialists and the literature agree that mulching in conjunction with seeding is a more effective rehabilitation treatment. Studies reviewed by Peppin *et al* . (2010) noted that seeding for erosion control is more effective when implemented in concert with other treatments such as log erosion barriers, mulch, or biosolids (Meyer *et al.* 2001, Earles *et al.* 2005, DeWolfe *et al.* 2008). In recent years, the use of agricultural straw, hydromulch, and wood shred or wood strand mulches as post-fire treatments has increased (Robichaud *et al*. 2013*a*). Agricultural mulch has been established as an effective post-fire treatment while wood shred has been found to be similarly effective in reducing erosion (Robichaud *et al*. 2013*b*). However, the high cost of mulch limits its application to small, high-value areas (Robichaud *et al.* 2009). In addition, some mulch materials, such as agricultural straw, can be sources of undesirable weed seed (Kruse *et al.* 2004), exacerbating the invasion of non-native species. Thus, barriers to applying mulch, including high costs and potential introducing weeds, indicate the need for further long-term research on the effectiveness of mulching. Research would be further supported by utilizing cost-benefit analyses to ul-

timately assess the value of its application, especially when values at risk are high.

Cost for seeding materials appears to play a role in selecting species for seed mixes used to rehabilitate burned areas. Survey results corroborate outcomes reported in Peppin *et al.* (2011) that confirm an increasing trend of native species and non-native annual cereal grains use, with native species being seeded most. Although native and annual cereal grains are used more frequently, the large range used in seed mixes could reflect limited use due to high costs and inadequate supply (Beyers 2004, Peppin *et al.* 2011). Compounding these factors is a lack of research on these species' effectiveness and effects on plant communities over time (Beyers 2004, Peppin *et al.* 2011). Although determining a way to increase stock levels to reduce their cost may make for more consistent usage of these species, increased research on the effectiveness of native and annual cereal grains and their long-term effects on plant communities is imperative as their incorporation into seed mixes continues.

At present, it is unclear whether post-fire seeding treatments are successful in meeting rehabilitation objectives related to mitigation of non-native species invasions. Studies evaluating seeding treatment effectiveness in reducing non-native invasions revealed variable results, similar to perceptions of regional specialists, with almost an equal proportion of studies reporting seeding treatments are either effective (54%, 6) or ineffective (45%, 5) (Peppin *et al.* 2010). Studies that were successful in excluding non-natives resulted from seeding treatments that yielded high ground cover (Barclay *et al.* 2004, Keeley 2004). Ineffective treatments were often those that showed no difference in total ground cover on seeded versus unseeded sites (Sexton 1998, Hunter and Omi 2006, Stella *et al.* 2010). Based on survey results and recent review findings, seeding may be more successful at curtailing non-native invasions when seeded cover is high enough to crowd out non-natives. These diverging results, implicit in both the literature and from regional specialists, imply the need for further monitoring and research to fully understand post-fire seeding effects on non-native invasions.

Overall seeding success appears to be strongly driven by weather conditions within the treatment area. According to regional specialists and corroborated with recent research (Peppin *et al.* 2010), effective reduction of erosion within the first and second critical post-fire year is largely dependent on amount and timing of precipitation events. Peppin *et al.* (2010) further suggest that seeding treatments may be a more successful rehabilitation activity in Mediterranean and marine regimes (California and Pacific Northwest), which are less vulnerable to the high-intensity, short-duration rainfall events occurring shortly after severe wildfires as seen in temperate steppe regimes (Intermountain West and Rocky Mountains).

A main goal of post-fire stabilization treatments is to reduce soil erosion in the year immediately following a fire (Robichaud *et al*. 2000). Regional specialists' responses confirm that seeding treatments mitigate soil erosion within this timeframe. In contrast, recent review results indicate that seeding has a small probability of success in reducing erosion during the first two years after a fire event (Peppin *et al.* 2010, Robichaud *et al.* 2000). Peppin *et al.* (2010) found that evidence for seeding effectiveness drops substantially as study designs become more rigorous. For example, of the papers reviewed with the highest quality of evidence (articles containing data from replicated and randomized experiments and published in peer-reviewed journals), seeding appeared to be ineffective in reducing erosion. Agency publications and monitoring reports reviewed typically fell into the lower quality of evidence categories and often suggested seeding as an effective treatment measure to reduce erosion. Discrepancies among regional specialists' opinions and literature results regarding soil erosion may reflect differences in data collection methodologies among agencies and researchers. Considering these contradictions, it would be

beneficial for agencies to complete quantitative, controlled, replicated long-term monitoring to adequately assess seeding treatment effectiveness for soil erosion.

Among agencies, current monitoring policy and inadequate funding is a major factor limiting proper assessment of post-fire seeding effectiveness. Although the goals of post-fire watershed-rehabilitation for USDA and USDI agencies are similar, these agencies have slightly different policies regarding emergency stabilization and rehabilitation activities. US Department of Interior ES&BAR differs slightly from the USDA USFS BAER program in that ES&BAR policy places a stronger emphasis on longer-term rehabilitation and restoration objectives (up to 3 years) while providing funding to meet those objectives (USDI 2004, 2006).

Seeding treatment performance and effects are strongly related to length of time post-fire (P. Robichaud and W. Elliot, USDA Forest Service, Rocky Mountain Research Station, unpublished paper; Rough 2007). Currently, monitoring completed by land managers and researchers alike is rarely carried out for long enough to determine overall effects and effectiveness of seeding treatments; although, research has begun to expand to include long-term effects of treatments (Robichaud and Ashmun 2013). Studies rarely yield data beyond two years (Peppin *et al.* 2010). Peppin *et al.* (2010) stressed the need and importance of longer-term monitoring results, specifically those greater than five years, to assess effectiveness and impacts of seeded species. This strongly correlates with regional specialists' views that long-term monitoring, ranging from 5 to 10 years, will ultimately reveal results that will close the gap in the inconsistencies between managers' perceptions and research. In considering regional specialists' testimonies that short-term monitoring, which is currently required and funded, isn't always accomplished, fulfilling the need for longer-term monitoring may prove difficult. If longer-term monitoring is a priority of the post-fire management program, as research and resource specialists suggest it should be, stronger mandates are necessary for monitoring implementation that includes funding to support dedicated staff beyond three years.

In general, most indicators of seeding effectiveness in the literature reviews correlated with the regional specialists' findings. However, both the literature and regional specialists' responses suggest that results are variable for whether seed mixes used in post-fire seeding treatments are successful in meeting rehabilitation objectives related to mitigation of non-native species invasions. In addition, survey results varied from the literature in seeding effectiveness in mitigating soil erosion within the first year. These findings clearly indicate that additional monitoring and research, including cost-benefit analyses for areas where values at risk are high, are needed to adequately assess decisions to seed, seeding implementation methods and alternatives, seed composition, effects on non-native species invasions, and seeding effectiveness for soil erosion. These findings also suggest that current policy should be reviewed to incorporate stronger mandates for longer-term monitoring (beyond three years).

Understanding how current research compares to land managers' perspectives denotes the importance of continued interaction between researchers and land managers. There is agreement among land managers and recent scientific reviews that there is insufficient information on long-term seeding treatment effectiveness and uncertainty about the effectiveness of seeding mitigating non-native species invasions. Adequate funding for both research and on-the-ground monitoring is necessary to explore the longer-term effectiveness and effects of post-fire treatments. Stronger communication and collaboration between these two groups would allow researchers to develop well-replicated monitoring designs for areas that land managers consider to be high priority for intensive, quantitative, long-term research of post-fire treatments.

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