



The Forestry Reclamation Approach: An Essential Tool for Controlling Invasive Exotic Plants on Active Mine Sites

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Mining companies use the Forestry Reclamation Approach (FRA) when reclaiming mined land with the aim of establishing functional forests as a post-mining land use. Invasive exotic plant species (IES) can interfere with successful reforestation. Thus, reclamation of active mine sites should aim to prevent colonization of IES plants if native forest restoration is the end goal. Once IES become established, they are difficult to eradicate and can potentially delay bond release. Therefore, it is best to manage for IES before they become established. Following the FRA is a good way to accomplish this.

In Advisory No. 16 (Adams et al. 2019), the problems of IES on legacy and abandoned mine sites were described, along with detailed descriptions of common IES plants and control measures. This Advisory (No. 17) explains the issues related to IES plants on active mine sites and presents guidance on controlling IES to ensure successful reforestation.

Why are IES plants a concern when reclaiming active mine sites?

Appalachian mine sites are especially prone to invasions by undesirable exotic plants. Mine sites are highly disturbed areas: the native vegetation has been removed, soils have been removed and replaced, and the formerly forested site has been opened up to full sunlight. Such disturbed lands tend to be more vulnerable to IES invasions than undisturbed natural ecosystems (Hobbs and Huenneke 1992; Lake and Leishman 2004; Jauni et al. 2015). Because many IES plants thrive in open sunlight (Blumenthal 2005), full sunlight near the ground surface early in the reclamation process can make mine sites more favorable to exotic invasions

than forest areas where tree canopies provide ground shading (Cole et al. 2005).

Furthermore, IES populations are often well-established on areas mined and reclaimed in the past (legacy and abandoned mine lands; Zipper et al. 2011; Oliphant et al. 2017; Adams et al. 2019). This is because some plant species currently considered as problematic IES were used commonly for reclamation in the past (before being prohibited by agency policies) because they established quickly and grew well on disturbed areas. For example, sericea lespedeza (*Lespedeza cuneata*), bicolor lespedeza (*Lespedeza bicolor*), and autumn olive (*Elaeagnus umbellata*) were used routinely for reclamation plantings in some states in past years. Hence, when new mining occurs in close proximity to older reclaimed mines, IES that have established on the older mine sites often invade the more recently reclaimed sites.

Many IES, if they establish and proliferate early in the reclamation process, can compromise reforestation success and ecosystem succession processes on active mine sites by inhibiting growth of planted trees and hindering recruitment of desirable native understory species.

For example, IES including autumn olive, Paulownia (*Paulownia tomentosa*), and sericea lespedeza grow more rapidly than planted native trees, and can inhibit growth of planted trees by establishing a dense canopy that prevents native seedlings from accessing sunlight (Evans et al. 2013). Some IES including autumn olive, tree of heaven, (*Ailanthus altissima*), sericea lespedeza, and tall fescue (*Schedonorus arundinaceus*), also produce biochemical compounds that inhibit establishment and growth of native plants – a mechanism known

as “allelopathy” (Heisey 1990; Orr et al. 2005; Rudgers et al. 2007; Rudgers and Orr 2009). Finally, IES tend to produce large amounts of seeds relatively early in their life history and the young IES plants emerging from these seeds can outcompete young native plants during early seedling stages.

In addition to inhibiting establishment of native plants, some IES plants can persist as the emerging forest develops. For example, autumn olive and multiflora rose (*Rosa multiflora*) establish easily and proliferate in open sun, but also have the capacity to persist in the understory of a regenerating forest (Moore et al. 2013). Other IES that establish easily in open sun, including tree of heaven and Paulownia, can grow into large trees, comparable in size to native oaks and hickories (Landenberger et al. 2007; Miller et al. 2015). They grow more rapidly than native planted trees and thus can become significant components of post-mining forests. Such forests, if composed partially of exotic trees, would not be consistent with the goals of the Appalachian Regional Reforestation Initiative (ARRI) of re-establishing native forests on mine sites.

Finally, should they become established on mine sites, IES can spread into adjacent areas. While open-sun areas such as livestock pastures are at greater risk for IES invasion, forests, especially those with canopy gaps that enable sunlight to reach the forest floor, are also at risk. Some IES, including autumn olive and multiflora rose, are able to invade forest areas (Carter and Ungar 2002; Kohri et al. 2002; Nauman et al. 2010).

Guidance for Managing Invasive Species When Reforesting Mine Sites

Although IES present significant challenges to successful forest establishment on reclaimed mine sites, there are low-cost actions available to mining operators that can aid effective IES control. Some of these actions are described below.

1. Apply all five steps of the FRA.

Rapid establishment of native vegetation and an intact forest canopy create conditions less favorable to invasion than the open-sun, disturbed-soil conditions that occur during reclamation. Application of the FRA, including all five steps as described by Burger et al. (2005; Advisory No.2) and other ARRI Advisories, can establish shading forest canopies rapidly, resulting in conditions less favorable to exotic invasions (Sena et al. 2015). Selecting and placing the topsoil or best available growth medium is especially important. If soil conditions are not optimal for tree growth, such as where unweathered or compacted spoils have been used, IES may have a competitive advantage over planted native trees. Research demonstrates that tree growth is often slowed on spoil materials that are alkaline and/or saline, such as often occurs on unweathered spoils (Photos 1 and 2; Wilson-Kokes et al. 2013; Zipper et al. 2013; Sena et al 2015). Seeding a site with fast-growing groundcover that is not tree-compatible (such as tall fescue (*Festuca arundinaceae*) or sericia lespedeza) can have similar effects. Slow growth by planted trees due to poor soil conditions or aggressive ground covers can provide prolonged opportunity for sun-loving exotics to establish, grow, and proliferate.

2. Ensure that no invasive exotic species are seeded or planted during reclamation.

Performance standards, as defined by the Surface Mining Control and Reclamation Act (SMCRA), require that mining firms

*“establish ... a diverse, effective, and permanent vegetative cover of the same seasonal variety **native to the area** ... except, that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan” (515(b)(19).*



Photo 1. This active-mine reclamation area was reclaimed using an alkaline siltstone spoil with FRA-compatible grading and planted with native trees 6.5 years prior to the photo. Although some of the planted trees established successfully (visible in the foreground), their growth was inhibited, likely by the chemical properties of the spoil. The largest plants on the site are autumn olive, an IES that was not planted but invaded from nearby areas that were reclaimed decades prior to the photo.

The term “introduced species,” as used in the SMCRA regulation, refers to IES. Numerous mine sites have been reforested successfully without the use of IES, demonstrating that such species are not necessary to achieve a forestry post-mining land use. Further, the presence of such species is not “desirable” on mine sites – or almost anywhere.

State conservation agencies have developed lists of IES that are considered problematic in each state (Table 1). Some of these plant species have been used in reclamation in all Appalachian states. For example, autumn olive was a common reclamation species in past years and is marketed still by some nurseries and garden centers as a plant that produces food for wildlife. Autumn olive, however, is considered a problematic invasive species in all Appalachian states and a noxious weed in West Virginia. Referring to these lists can help managers and reclamation specialists avoid planting IES on mine sites. Also, Forest Reclamation Advisory No. 6 provides lists of tree-compatible reclamation seed mixes of native plant species (Burger et al. 2009.)



Photo 2. This active-mine reclamation area was reclaimed using a weathered brown sandstone, as recommended FR Advisory No. 8 (Skousen et al. 2011), with FRA-compatible grading and seeding, and planted with native trees approximately 6 years prior to the photo. Excellent growth by planted trees was enabled by FRA reclamation practices, which also created conditions far less favorable to exotic plant invasions than on the mine site in Photo 1.

3. Become familiar with invasive plant species that occur in the local area.

Hundreds of IES occur in the Appalachian coalfields. It would be difficult for any land manager to become aware of strategies for controlling them all. In any given location, however, the number of problematic species is far fewer. Awareness of IES that are threats locally, including their characteristics and habits, can aid the early identification that is essential to cost-effective management and control. State agencies provide lists of IES that are problematic within a State (Table 1). Also, Forest Reclamation Advisory 16 (Adams et al. 2019) provides a description of common IES and their characteristics and control methods. This information may be helpful once an IES of concern has been identified.

4. During reforestation planning, determine what level of control is possible and necessary to ensure successful reforestation.

Being aware of the IES that are problematic in the local area can aid strategic and cost-effective control. Such decisions should consider the

particular exotic species present in the local area, the cost and difficulty required for their effective control, and the consequences of their establishment if not controlled. Three examples are described below.

Sericea lespedeza is common in many coalfield areas (especially in central Appalachia) and often begins invading mine sites during the first year of reclamation. While this situation is not desirable, the costs of preventing such invasions would likely be prohibitive. However, experience has shown that if the FRA has been implemented properly, planted trees are able to establish and grow despite this invasive plant's presence, and that *sericea*'s competitive vigor will decline as a developing tree canopy reduces its access to sunlight (Sena et al. 2015). In contrast, if the FRA has not been implemented properly and the planted trees are growing slowly, *sericea lespedeza* may be more competitive, and will have more time to establish dense and competitive stands that will hinder young trees' survival and growth and retard the re-establishment of the forest canopy. Once *sericea* invades and begins producing seed (which can happen during a *sericea* plant's first year), the chances of eliminating this species from the understory of an emerging forest are slim to none; but the presence of rapidly growing trees can aid control and enable successful reforestation.

Paulownia invasions of reclaimed lands are often highly visible because of the tree's rapid growth, unique stature, very large leaves, and showy purple flowers and seedpods. Hence, invading Paulownia can be spotted even at a distance during the first few years following reclamation. The consequences of Paulownia invasions can be dramatic, given its potential to grow more rapidly than planted native trees, proliferate on the mine site, and persist in the forest stand. Paulownia invasions, however, can also be controlled at relatively low cost if identified and addressed quickly—within the first few years after initial establishment and before the trees begin producing seed. Killing Paulownia early in the reforestation process—such as with the hack-and-squirt method (Adams et al. 2019; Advisory No. 16)—will allow the planted native tree seedlings

additional time for growth in the absence of Paulownia competition. Once those native trees begin producing a shading canopy, opportunities for additional Paulownia invasions will be reduced.

A final example is autumn olive, which is easily visible in young emerging forests during the early spring season because it produces leaves a few weeks earlier than most native hardwoods. As the spring progresses, individuals that are old enough to produce seed remain easily visible due to its distinct coloration during blossoming—although a better outcome would result from identifying and killing invading autumn olives before they bloom and begin producing seed. The consequences of allowing autumn olive to proliferate early in the reforestation process are great, given its rapid growth and rapid spread once it starts producing seed (Photo 3). Therefore, early control of invading autumn olive, so as to prevent seed production, is likely to be more effective and efficient.



Photo 3. Autumn olive that was not controlled early in the reclamation process can become an impenetrable grove that inhibits regeneration and growth of planted seedlings.

5. For IES species targeted for control: Identify and eliminate infestations soon after they occur.

Application of this strategy will aid in both limiting the cost and increasing the effectiveness of control efforts. As time passes following an infestation, the number of plants requiring control is likely to increase as the species proliferates and spreads.

The cost of control methods is likely to increase with larger populations of IES (Photo 3).

It is especially important to control infestations before the problematic species begins producing seed, if possible. Seed production for many invasive exotic species enables their further spread. Seeds of some species will also become resident in the soil, meaning that subsequent removal of the above-ground plant would not be adequate to remove the species as additional plants would be able to grow from the seeds already present in the soil seed-bank.

6. As control measures are applied, be sure to kill the targeted invasive exotic plants.

Match the control methods with the IES to ensure that plants are killed. This usually requires herbicide. Although it is possible to kill plants of some species by manual methods, this usually requires removal of the entire plant, including its roots (Adams et al. 2019). Effective root removal becomes more difficult as a plant grows larger. Correct application of an appropriate herbicide will kill both the above-ground plant and its roots with far less effort than is required for effective manual removal.

For some species, manual cutting and removal of the above-ground plant without removing or killing the roots can make the infestation worse. Both autumn olive and tree of heaven, for example, respond to cutting of the above-ground stem by producing numerous new sprouts from the roots. In such cases, a combination of chemical and manual methods may be required to control the invasive species effectively. For a review of IES control methods, see Forest Reclamation Advisory 16 (Adams et al. 2019).

Summary

Applying the Forestry Reclamation Approach is essential to successful reforestation of active mine sites in the face of IES plant invasions. Rapid establishment of a native-tree canopy sufficient to provide ground shading is a cost-effective means of

IES management. Knowing which plants to avoid or not plant is also critical. Once plants of native species become established and begin growth, IES are less of a threat to reforestation success.

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Photo 1: Carl Zipper

Photo 2: Scott Eggerud

Figure 3: Scott Eggerud

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Table 1. Sources of information on problematic invasive exotic plant species in the Appalachian states.

State	Designating Agency	Problematic invasive exotic plant species listings
KY	Department of Fish and Wildlife Conservation, and Division of Forestry	As posted by Kentucky Exotic Pest Plant Council, https://www.seeppc.org/ky/list.htm
MD	Department of Natural Resources	"Invasive Species of Concern in Maryland", http://www.mdinvasivesp.org/species-of-concern/
PA	Department of Conservation and Natural Resources	"Invasive Plants in Pennsylvania", http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20033694.pdf
OH	Department of Natural Resources	"Ohio's Invasive Plant Species", https://www.iopc.info/invasive-plants-of-ohio.html
TN	Department of Agriculture	As posted by Tennessee Invasive Plant Council, http://www.tnipc.org/revised-list-of-invasive-plants/
VA	Department of Conservation and Recreation, Division of Natural Heritage	"Virginia Invasive Plant Species List", http://www.dcr.virginia.gov/natural-heritage/document/nh-invasive-plant-list-2014.pdf
WV	Department of Natural Resources, Natural Heritage Program	"Invasive Plant Species of West Virginia," can be accessed from http://www.wvdnr.gov/Wildlife/InvasiveWV.shtm