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Restoration ecology in conflict along the Colorado front range

G. Robert Brakenridge[1,2], Tim R. Seastedt[1]

Abstract

Introduction: Cheatgrass (*Bromus tectorum)* is a challenge to restoration in western North America. It attracts the attention of academic and government research scientists, weed managers, and chemical companies. Attempts to control it cause conflicts among these groups.
Objectives: All agree that protecting biological diversity and ecosystem services on public lands is a central goal. We demonstrate how this goal has been confounded by a rush to endorse chemical methods that motivated the environmental movement of the 1960s. We also examine whether some indaziflam studies are compromised by non-disclosure and conflict of interest.
Methods: We review the literature focused on the Colorado Front Range at the nexus between cheatgrass ecology and the chemical control agent indaziflam.
Results: Indaziflam is observed to have negative impacts on soil biota, fish, and aquatic invertebrates; to be accompanied by PFAS chemicals; and to induce pesticide resistance. The chemical persists in soils for ∼4 years; one of its degradation products (FDAT) is a short-chain PFAS that can leach into ground and surface waters. Indaziflam has now been observed to be genotoxic. Some studies indicate that it can help certain plants reestablish; others demonstrate harm to non-target species. Unlike studies in the Great Basin, we located no research implicating cheatgrass as contributing to extreme wildfires in the Colorado Front Range.
Conclusion: Along the Front Range, field data indicate that cheatgrass does not invade plant communities unless there has been disturbance. Absent control measures, recovery from disturbance includes declining cheatgrass cover. The ecological and human health issues motivate against continued indaziflam applications for cheatgrass control in this region.
Implications For Practice: In most natural lands along the Colorado Front Range there is no need for cheatgrass control via pesticide applications. There may be locations where local cheatgrass control is useful to create fuel breaks. However, non-chemical methods can be used. The long-lasting ecological damage caused by indaziflam spraying is documented; ecological restoration must avoid such control measures. Also, PFAS chemicals contaminate samples of indaziflam commercial products. They and the FDAT degradation chemical may bioaccumulate in the environment and this raises additional concerns.

Key words: biodiversity, cheatgrass, indaziflam, pesticides, PFAS, succession, wildfire

Introduction

Can public land managers along the Colorado Front Range accomplish ecological restoration using pesticides on non-native weeds? In the case of one target species (cheatgrass, *Bromus tectorum*), indaziflam spraying programs are underway to control this plant on public land even while stakeholders' web pages condemn the spraying. Opponents believe this synthetic poison kills many other species, increases bare ground, and thereby sets the stage for new weed growth and future spraying. Many citizens are also concerned about the collateral damage to non-target species and the implications for human and ecological health. They share Rachel Carson's point of view: "As crude a weapon as the cave man's club, the chemical barrage has been hurled against the fabric of life" (Carson 1962).

Proponents in Colorado argue instead that the pesticide spraying is addressing the restoration goals of wildfire risk reduction (c.f. Beck 2012; Clark et al. 2019) and increased biodiversity (Sebastian et al. 2025), and that indaziflam is acceptable for large-area use in natural areas if label descriptions are followed (BLM 2024). The manufacturer-supported research on indaziflam for cheatgrass control is, however, questioned by opponents who consider it to be biased, weighting benefits more heavily than risks or documented harm. The need for independent review is clear. Does scientific evidence clearly justify both the need for and the safety of wide-spread releases of this new pesticide into the environment. If so, what are the ecological and environmental health consequences?

The perceived need in Colorado for cheatgrass control derives from prior disturbance. Cattle grazing, mining, extreme

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[1]Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado, USA
[2]Address correspondence to G. Robert Brakenridge. email robert.brakenridge@colorado.edu

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wildfires, floods, and invasive species have repeatedly altered the region's grasslands, shrublands, and forests. In recent decades, as ranch land and farms were converted to housing and commercial development, local governments and conservation organizations acquired hundreds of thousands of acres for open space preservation. These organizations look back to presettlement time as a guide to natural landcover and restoration goals. They also depend on the ecological science community to provide objective guidance, including about the potential risks posed by any management tool.

The presence of, and in some cases, expansion of cheatgrass in the region is widely viewed by public land management agencies as a problem to be solved. It supposedly threatens the ecological integrity of these natural lands; it is believed to reduce biodiversity and wildlife habitat and to increase fire hazard (Clark et al. 2019; Sebastian et al. 2025). However, cheatgrass is a late 19th century immigrant to this landscape: it is as common as the common dandelion (*Taraxacum officinale*). In recognition of this situation, cheatgrass is a "C-listed" species on Colorado's noxious weed registry. It is widespread and well-established; state law does not require control. Is it indeed in need of widespread treatment on these lands?

A variety of synthetic herbicides have been used over decades in attempts to control cheatgrass. These include glyphosate, 2,4-D, dicamba, triclopyr, chlorsulfuron, imazapyr, imazapic, and indaziflam. The case of indaziflam is timely, because it is relatively newly approved for management of natural lands and grazed rangelands, and its use is rapidly increasing (Kraehmer et al. 2014). Our review demonstrates the manufacturer's support for multiple studies designed to demonstrate the efficacy and safety of its proprietary product. However, this support unavoidably raises questions of bias (Chopra 2003; Lexchin 2012; Nestle 2016). Independent evaluations of ecological effects of this pesticide on native flora are relatively few, but they appear to demonstrate harm. Also, the lack of important information is evident. For example, negative health effects of indaziflam on aquatic invertebrates have been documented elsewhere (Tissot et al. 2022). Yet studies on aquatic invertebrates in Front Range soils (nematodes, rotifers, tardigrades, and single-celled organisms) have not been accomplished. A balanced approach to this topic must include these areas of uncertainty.

Objectives

Our focus is the nexus between cheatgrass control as part of regional ecological restoration and the use of a relatively new synthetic pesticide being used for such control: Rejuvra™ and its active ingredient, indaziflam. The rationale for such use can be convincing: biodiversity is less in the areas covered by dense growth of cheatgrass, the senescent grass is flammable and contributes to fire hazard when dry, it is an alien species, and its displacement of native plants may affect native consumers (including pollinator) populations (Sebastian et al. 2025). Thus, we must evaluate both the reasons for use in natural lands restoration and any concerns about human and ecological safety that motivate against such use.

In this regard, the "first, do no harm" (*Primum non nocere*) ethical principle in medicine, from the writings of Hippocrates, offers useful guidance for those confronted with difficult decision-making. Land management decisions must often proceed without complete information. However, in medicine, "Doctors should neither overestimate their capacity to heal, nor underestimate their capacity to cause harm" (Shmerling 2020). A portion of the ecological restoration community has adopted the same guidance with respect to management of invasive species (Davis et al. 2011; Sax et al. 2022). In the present case: will the pesticide applications cause harm? In Europe, the regulatory use of the "precautionary principal" provides similar advice (Tosun 2013). In essence, both counsel prudence: erring on the side of caution in the face of inadequate information if public and ecological safety is involved.

Here we: (a) review the safety issues around the indaziflam pesticide, (b) consider the ecology of cheatgrass along the Front Range, (c) examine field studies and their conclusions regarding ecological impacts of indaziflam applications, and (e) provide a concluding summary of our findings. Supplement S1 provides examples of non-disclosure of conflict of interest in the cheatgrass control literature. The conclusion stresses the need for restoration ecologists to exert caution, to avoid underestimating harm, and to thereby avoid repeating mistakes made in the past.

Ecological and Human Health Effects of Indaziflam-Based Pesticides

Indaziflam herbicides are increasingly popular in the public sector for cheatgrass control. The proprietary Rejuvra™ product was recently added to the U.S. Bureau of Land Management's list of approved herbicides for its 245 million acres of public land (BLM 2024). Extensive applications of this chemical may be planned in the future. If there are downsides to its very widespread use, now is the time for these to be evaluated.

Previously, the post-emergent herbicide glyphosate and other chemicals have been used, but cheatgrass seeds survive such treatment and, without persistence, cheatgrass quickly reinvades the bare ground created. This contrasts with lipophilic herbicides such as indaziflam, which have a lower water solubility and much longer persistence in the soils (Brabham et al. 2014; Ahrens 2015). Indaziflam persists also in the tissue of some aquatic organisms and at higher concentrations than other widely used pesticides such as atrazine (Scully-Engelmeyer et al. 2021; Tissot et al. 2022).

Indaziflam is not only a herbicide but is also a pesticide. It is known to be harmful to fish (Futch et al. 2010; NCBI 2026). It is lethal to the most common soil fungus (*Trichoderma*) (Ribeiro et al. 2025) and to aquatic invertebrates, including amoeba: organisms with potentially large effects on soil food webs (Mungroo et al. 2021a). It is now known to be a powerful antiamoebic/antibiotic (Mungroo et al. 2021b; Siddiqui et al. 2022) and has recently been determined to be genotoxic to human cells (Könen Adıgüzel 2023). It is a neurotoxicant (PPDB 2026) and may be an endocrine system disruptor (Ewence et al. 2015; Apú et al. 2025; Liu et al. 2025). Many

of these findings were not available during US EPA permitting of the chemical in 2010 and 2016.

Unlike indaziflam, most other current-use herbicides do not accumulate in animal tissues. An observed tendency to bioaccumulate was a major reason for the U.S. banning of DDT fifty years ago (Bernard 1966). The jury is out in this regard on indaziflam. On the one hand, and according to (Tissot et al. 2022): "Widespread detection of indaziflam in bivalve tissue is especially notable as the compound…is classified as both "very toxic to aquatic life" and "very toxic to aquatic life with long lasting effects." On the other, there is a lack of observational studies investigating indaziflam further up the food chain.

Indaziflam is a very effective poison. It is considered to be the most potent inhibitor of the cell wall biosynthesis ever discovered (Mendoza-Huizar et al. 2019). I. Kosan first patented fluoroalkyl triazine chemicals in 1991. Bayer scientists developed indaziflam from this class, patented its use for weed control, and first registered it in the U.S. in 2010 (Kraehmer et al. 2014).

Indaziflam is a "PFAS-like" chemical. One of its primary degradation products (FDAT, or 1-fluoroethyl diaminotriazine) is classified as a PFAS (per- and polyfluoroalkyl substance) chemical (OECD 2021; NCBI 2026). FDAT can be classified as PFAS because it includes at least one strong C-F bond that resists environmental degradation. However, FDAT contains only one fully fluorinated carbon, and may not be classified as PFAS under a recent EPA determination. In any case, these chemicals are generally highly persistent, resist breakdown in the environment, and can cause widespread contamination and accumulate in water and tissues. Other indaziflam metabolites include indaziflam-carboxylic acid, indaziflam-triazine-indanone, indaziflam-hydroxyethyl, and indaziflam-olefin. The triazine-indanone is also mobile, relatively persistent, and of regulatory concern: it is analyzed alongside other residues in agricultural products.

Rejuvra™, like other pesticides, includes unspecified "inert ingredients" and there is rising concern regarding which of these may also be PFAS substances. According to one study, of the 11 US EPA-registered organofluorine inert ingredients, 8 met the OECD definition of PFAS. However, information on which pesticide products contain these ingredients is considered confidential business information (Donley et al. 2024). This is unfortunate, because "there can be serious consequences if the uncertainty involved in a pesticide approval decision ultimately leads to an underestimation of risk coming from pesticide degradates. The generation of fluorinated degradates that have half-lives in the decades or centuries means that any release into the environment will likely be irreversible" (Donley et al. 2024).

In this regard, 18 recent lab analyses commissioned by Public Employees for Environmental Responsibility of the commercial Rejuvra™ product detected 1–3 ppb for the PFAS chemicals perfluorohexanoic acid (PFHxA) and perfluorohexanesulfonic acid (PFHxS), and 2–3 ppb for perfluorobutanesulfonic acid (PFBS) and perfluorooctanesulfonic acid (PFOS) (PEER 2026). Thus, even prior to any degradation to FDAT, application of this pesticide includes broadcasting PFAS and PFOS chemicals onto the soil and into the environment. The detected amounts are 3 orders of magnitude above federal water supply limits. Several of these measured highly persistent chemicals are known to be highly toxic to, and to bioaccumulate in, animals and humans (Panieri et al. 2022; Brown et al. 2023).

Solely on the basis of sorption, indaziflam would be assigned a low to moderate mobility, but due to its environmental persistence and its degradates, it is a potential emergent water contaminant (Mendoza-Huizar et al. 2019). Especially when sprayed from the air, drift to non-target areas including local wetlands is possible. As well, indaziflam may attach to dust particles in air and then be transported large distances. In the case of one of its close chemical relatives, atrazine, dispersal long distances from the spraying location is well-documented: atrazine has been found in rainwater more than 300 km from the nearest application area. Thus, the broader ecological and environmental risks of aerial spraying of indaziflam may be underestimated (Ribeiro et al. 2025).

Because of its residual activity in the soil over some years, indaziflam affects multiple generations of seed viability, and resistance in annual grasses is expected to develop. This has now occurred (Miranda et al. 2026). Resistance to indaziflam appears to be associated with more than one herbicide site of activity (both cell wall biosynthesis and hormone regulation may be involved). That hormones are also affected is new to indaziflam science. Herbicides with long soil persistence and wide application windows, such as indaziflam, are generally at greater risk for fostering resistant species due to the strong and prolonged selection pressure.

Indaziflam may have unexpected direct medical uses. As a repurposed compound, it appears to be a powerful amoebicide (Mungroo et al. 2021a; Siddiqui et al. 2022). Anti-amoebic assays indicate that indaziflam is effective against the lethal species *Naegleria fowleri* and *Balamuthia mandrillaris*. The chemical strongly inhibits excystation of *N. fowleri*. Work on its effects and mode of action on other amoebae or bacteria is lacking. The existing EPA label does not reflect this aspect of toxicity.

EPA regulates antimicrobial pesticides as a different category of products. However, amoebae are numerous and are important predators in soil; they control bacterial populations, cycle nutrients, and affect plant-microbe interactions. In addition to being a significant part of soil microbiota, they may also act as reservoirs for antibiotic resistance genes and shape bacterial community structure through their grazing, making them key ecosystem engineers (Hu et al. 2025). Thus, coupled to the possible medical utility of indaziflam, there are expected but poorly constrained negative impacts predicted for Front Range soils and their biota.

The Ecology of Cheatgrass on the Colorado Front Range

Given these concerns, how compelling is the need to use indaziflam to control cheatgrass? Namely, is large area proactive management of cheatgrass necessary?

Front Range public sector weed managers have justified their chemical applications primarily on cheatgrass's potential to enhance catastrophic wildfire intensities and frequencies, and also on its impact on native biological diversity. These are

seemingly self-evident motivations: the intermittent carpets of cheatgrass interspersed with other vegetation cover in the foothills landscape appear at first to be lacking in biodiversity and native flora, and the grass is clearly highly flammable after its senescence in early to mid-summer. There is also an extensive and diverse literature describing its negative effects in the more arid regions to the west (Schmelzer et al. 2014; Kleinhesselink et al. 2023; Molvar et al. 2024; Gamba et al. 2025; Kreitler et al. 2025; Mumford et al. 2025).

However, does cheatgrass in this region actually increase wildfire threat? Cheatgrass senesces in early to middle June in the Front Range (Prevéy et al. 2024), resulting in dry fuel ready to burn if a summer drought and an ignition occur. However, the area receives on average nearly 50% of its annual precipitation between April and July. This is a much higher amount and percentage of annual precipitation than in the Great Basin, where cheatgrass does contribute to wildfires (Bradley et al. 2018). Thus, in most years the senescent cheatgrass in the Front Range is surrounded by green herbaceous vegetation (Fig. 1). Cheatgrass dominated sites can burn intensively, but at the landscape level the larger wildfires in the Front Range do most of their damage during the non-growing season. Also, within a mixed grassland, cheatgrass in the spring may increase live fuel proportion and reduce fire spread then (McGranahan et al. 2013). As cheatgrass is not more productive than most other grasses, the net effect of cheatgrass on catastrophic wildfires in the Front Range may at most be neutral. The tendency for senescent cheatgrass vegetation to be compacted and lessened in height through time also decreases its fire contributions during the non-growing season.

The impact of cheatgrass on the native biological diversity of the Front Range differs substantially from its impacts on the west side of the Continental Divide, partly due to its inability to change fire return intervals in this region but also because of differences in plant competition interactions. The mechanism(s) for cheatgrass's success overall must be considered. Thus, cheatgrass invaded the western U.S. as a result of cattle grazing and overgrazing that removed native species and allowed cheatgrass to colonize bare ground. Early-on, cheatgrass was also utilized across the West for cattle and sheep forage (Mack 1981). Studies based mainly in the Great Basin deserts and rangelands indicate that cheatgrass was a disturbance specialist, capable of exploiting resource opportunities created by management and mismanagement (Klemmedson & Smith 1964; Molvar et al. 2024). By the time cheatgrass was widely established, the damage to biodiversity began to be recognized. The damage and the ecosystem



Figure 1. Cheatgrass (the senescing, reddish patches) surrounded by actively growing species in mid-June. The cheatgrass can carry a fire, but these fires are constrained by surrounding green vegetation. Long term monitoring shows that the areal extent of cheatgrass is retreating at this location without any herbicide treatment, from 60% of cover in 2011 to about 15% of relative cover by 2025 (Prevéy & Seastedt 2025).

services it nevertheless provides were eloquently described in an essay by Aldo Leopold initially written in the 1930s and subsequently republished in "A Sand County Almanac" (Leopold 1970): e.g., "Cheat reduces the erosion that would otherwise follow the overgrazing that admitted cheat."

Overgrazing and improper seasonal grazing by cattle in Colorado, beginning in the mid 1800s and continuing until recent decades, and as in the Great Basin, is probably the main cause of cheatgrass dominance (Molvar et al. 2024; Fig. 2). In contrast, we note that judicious, seasonal grazing can be used to reduce cheatgrass dominance; the key being the removal of cheatgrass biomass prior to seed production (Kray et al. 2025). Cheatgrass was not documented to dominate healthy grasslands in our region (unlike in some drier areas to the west (c.f. Urza et al. 2024). Instead, it spread and flourished in already-damaged grasslands. Regional vegetation assessments conducted along the Front Range in the last century identified cheatgrass as a dominant species in foothills herbaceous communities (Peet 1978). However, studies to understand the factors contributing to cheatgrass success and persistence following disturbance in this region were initiated mainly in recent decades (c.f. Blumenthal et al. 2008).

A contributing factor to cheatgrass's bad reputation and the perceived need for control is its persistence in these formerly disturbed sites. In this regard, the continued presence and abundance of an invasive plant species in general is encapsulated by its fitness-niche assessment (MacDougall et al. 2009), and the most recent meta-analysis by Blumenthal et al. (2025) supports that model. That study concluded that non-native plants have a subset of adaptive traits that affect their abundance and impacts. As an annual species, the plant is expected to be very nutrient and water sensitive, with a large allocation to seed production. Rapid growth and seed maturation in the spring and senescence by early summer is cheatgrass's specialty (e.g., Concilio et al. 2017).

Although plant traits contribute to the invasiveness tendencies of cheatgrass, it is the plant-community interaction that determines the impacts of the invader. These impacts can be site specific. In an analysis of over 1,500 individual cases that addressed the impact of an introduced plant species, impacts are shown to be strongly dependent on context (Pyšek et al. 2012). A species can have a positive effect under one set of conditions and management and a negative effect under a different set (Hobart et al. 2026). Thus, effective management must be place-based and decided by place-specific science measurements (Cordell et al. 2021).

In this regard, Prevéy and Seastedt (2014, 2025) demonstrate that non-growing season precipitation in the Front Range

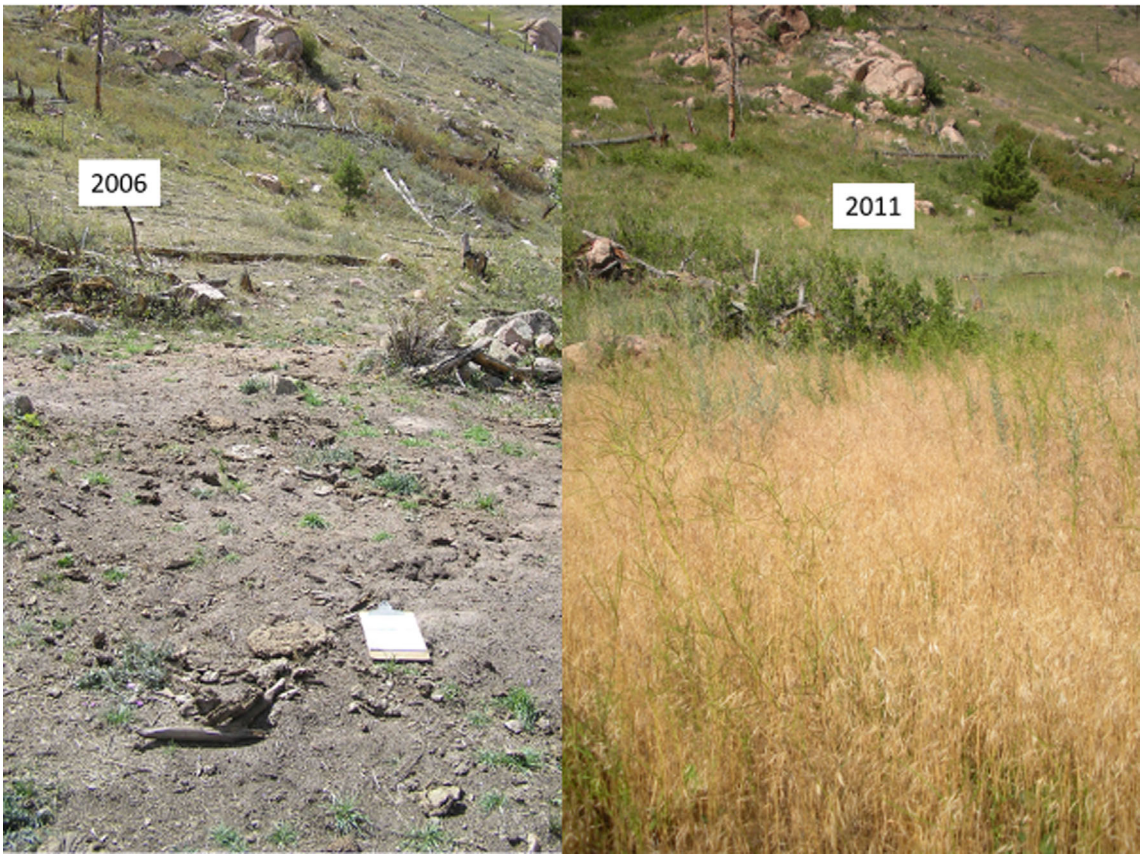


Figure 2. Overgrazing by cattle produces dense cheatgrass patches in the Colorado Front Range. Cattle were removed from this site after 2006 (Photos by T. Seastedt).

benefits cheatgrass. Also, Concilio et al. (2016) and Concilio et al. (2017) report that cheatgrass in this region responds strongly to extreme precipitation events with large increases, whereas native grasses and forbs show relatively less change in productivity or composition under varying climatic or edaphic conditions. This finding again reinforces the 'opportunist species' descriptor for this annual grass.

Concilio et al. (2017) present results showing that cheatgrass is not an aggressive competitor. Instead, the species benefits from its unique phenological niche and its timing and length of life cycle: fitting the criteria suggested by MacDougall et al. (2009) that allow for its persistence. Finally, monitoring studies can empirically verify invasiveness. The few studies that exist in the Front Range instead demonstrate decline in cheatgrass dominance through time and increases in plant species diversity (Prevéy & Seastedt 2025; Sebastian et al. 2025). Such findings put into question the need for major control efforts.

We have, however, observed cheatgrass to invade and increase on land targeted by restoration efforts in the Front Range (Behringer et al. 2019). In this study, a former gravel pit was resurfaced with a relatively infertile topsoil and drill-seeded with native grasses. These grasses established (Cherwin et al. 2009), and the dominant native species persisted through time. However, in the years that followed the planting, cheatgrass and its close relative, field brome (*Bromus arvensis*), increased in abundance in the bare spaces left between the drill-seeded native species. As seen elsewhere, these annual grasses invaded the bare soil left by the planting method. This restoration effort created a grassland dominated by native species, but it did not rapidly remove all of the resource opportunities available to the disturbance specialist, cheatgrass. However, without pesticide applications and as shown in the other Front Range studies, an eventual cheatgrass decline at this site is predicted if the site is left undisturbed.

Dominant plants suppress local species richness, and cheatgrass patches suppress richness (Prevéy & Seastedt 2014). However, in the Sebastian et al. 2025 study that monitored plots for 8 years, native species richness in untreated plots increased. The presence of cheatgrass appears to suppress rather than eliminate the competition. That is not a characteristic of an aggressive invader that displaces the native plants. Although the cheatgrass was apparently decimated by the initial spraying of the two pesticides on the treated test plots (no pretreatment observations are provided), the study measured a significant average decline in cheatgrass cover over time, from 78.3% to 51.3%, in the untreated plots. In contrast, the treated plots that had cheatgrass initially removed showed an increase, from 0.7% to 2% (Fig. 3). This again begs the question of whether the pesticide applications are necessary or even helpful over longer intervals.

In summary, cheatgrass's fall-spring growth strategy provides it a largely unique phenological niche that will allow the species to become naturalized in many landscapes where it is found. While recognizing the uncertainties generated by changing climate and other environmental variables, we consider that cheatgrass in this region exhibits the characteristics of an early seral to mid-successional species and is an expected and useful ecological component in post-disturbance succession in this region. Wise and cost-effective restoration might best work with rather than against this dynamic.

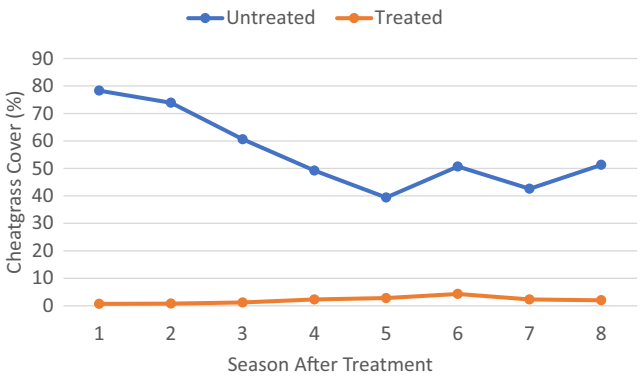


Figure 3. Optical percent cover cheatgrass averaged over 12 study plots by yearly season after treatment for glyphosate- and indaziflam-treated plots, as compared to the untreated plots. Data are from tab. 3 (Sebastian et al. 2025); see that reference for methodological details.

Ecological Impacts of Boulder County Indaziflam Applications

In contrast to the above findings, many publications (e.g., Clark et al. 2019) describe the menace of cheatgrass in Colorado and the need for chemical control. We sought to understand why and were confronted with evident cases of non-disclosure and conflicts of interest by the authors. The non-disclosures are important given the large financial and ecological stakes. In particular, Rejuvra™ (indaziflam) is being marketed by its proprietary manufacturer throughout the western half of North America to land managers as an ecologically safe and effective method for cheatgrass control. We provide a list of four examples of non-disclosure as Supplement S1.

A recent study examines indaziflam and other pesticide impacts on Boulder County, Colorado open space cheatgrass and non-target species (Sebastian et al. 2025). This work provides an example of results that are being communicated to restoration ecologists and land managers to promote use of this product for large-area cheatgrass control. Remarkably, however, there is little if any relevant information concerning the effects of indaziflam alone. The title is "Indaziflam for Cheatgrass (*Bromus tectorum*) control increased native species richness for up to 8 years in Colorado Front Range (United States)." However, the sprayed plots in this case were treated initially with both indaziflam and glyphosate, so the results apply to that combined treatment, not just to indaziflam. Glyphosate alone can have prolonged effects on soil invertebrate and microbial biota (de Mesquita et al. 2023; McQueen et al. 2024), but is now banned on Boulder County public lands. To apply two pesticides and then provide a title that states that the biological effects are due to just the single chemical is inaccurate.

These authors compare non-sprayed to sprayed parcels and followed native (only) plant populations over as much as 8 years

of time. They state in the abstract: "When restoring less degraded native plant communities, one indaziflam application was effective for long-term Cheatgrass control, which likely increased resources available for the germination and establishment by the in situ native seed bank and existing plants. This case study demonstrates how controlling Cheatgrass increased native species richness on the Colorado Front Range shrub-steppe." To the contrary and as noted in their paper, what was applied was a glyphosate/indaziflam mix. There are multiple other recent studies that confirm the strong negative effect on cheatgrass and other annuals but also report non-target effects on native plants and plant richness in indaziflam-treated plots (Meyer-Morey et al. 2021; Alba et al. 2024; Dombro et al. 2025; Muslic 2026; Teichroew et al. 2026). These negative effects often took time to emerge. Dombro et al. (2025) used a seeding-greenhouse study and found reductions in diversity in their fourth year of study, perhaps a result of perennial plants reaching the end of their life cycle, coupled with less regeneration of these species from seed during the interim due to the pesticide applications. The seedbank results indicate the reduction in diversity may have been caused by the inhibition of forb establishment rather than the establishment of perennial grasses (Dombro et al. 2025). Thus, although indaziflam clearly poisons cheatgrass, the evidence for benefits to native species is problematic.

Sebastian et al. (2025) acknowledge the need for further study. However, its abstract reads: "*Indaziflam is an effective restoration tool that led to more diverse and resistant plant communities*." Any time the abundance of a dominant species is reduced, diversity indices, as measured by most ecologists, will increase. This study further states that the increased species richness observed in their chemically-treated plots was the result of those species already being present but not recorded in the plots at the initiation of the experiment. Thus, the cheatgrass had not removed those species when it invaded the meadows. Also, the study plots indicate that native species richness increased in the untreated plots through time. To generate this effect, there must be an existing diverse community, even though the abundance of species is suppressed by cheatgrass. If the presence of cheatgrass in addition to the disturbance event harms species, then remaining species should decline through time in the untreated cheatgrass dominated areas. The Sebastian et al. (2025) results instead support our contention that cheatgrass is not an aggressive invasive species in the Front Range.

Finally, another recent study emphasizes the need for more knowledge about the effects of the Rejuvra™ product on plant species (Roeslein et al. 2025). In greenhouse studies, 1 month after herbicide application, both monocot and dicot emergence was significantly reduced, and there was decreased survivability after emergence. The pesticide did not target monocots, as expected, but reduced total plant emergence and survivability. Clearly, this will deplete the seed banks of annual species, both non-desired weeds and desired native species (Roeslein et al. 2025). Again, the implication is once again that spraying this persistent, broad-spectrum pesticide has the potential to cause damage to a very wide array of desirable resident plant species.

Conclusions

We reviewed the science literature about cheatgrass control along the Colorado Front Range and the ecological and human safety aspects of a cheatgrass control pesticide, indaziflam (Rejuvra™). We also considered whether non-disclosure is occurring (Supplement S1) and examined closely some of the study findings on which land agencies in the region are basing their management actions.

In some cases, needed information is lacking. Important human and ecological health risks have been left unaddressed and await further study: "The current scarcity of research in major agricultural regions likely underestimates the broader ecological risks of indaziflam" (Ribeiro et al. 2025). This is in the context of a molecule which "poses a significant risk due to its high persistence in soil, with a long residual activity, as well as high toxicity" (Ribeiro et al. 2025).

We provided four examples of non-disclosure by study authors of pesticide manufacturer's support or even authorship of the papers (Supplement S1). This adds indaziflam to the unfortunate list of products that have been promoted by commercial interests in the scientific literature without adequate disclosure. Tobacco, DDT, and OxyContin are other examples. In the case of ecosystem damage from indaziflam chemical applications versus from an invasive species, we showed why cheatgrass is not an aggressive invasive species at the regional level in the sense that this term is most widely used. It does not invade healthy grasslands and it does not dominate at the multi-decadal level in grasslands recovering from disturbance.

Some specific findings:

(1) After application, indaziflam is a persistent pesticide bound to the topsoil for ~4 years. During that time, it begins to degrade and liberate FDAT (a short-chain PFAS chemical) and other degradates: these are more mobile and move down into the soil profile or run off into drainages with the potential to contaminate water supplies and local wetlands. During application, some aerial dispersal (over many km) to non-target areas is expected. After application, dispersal may occur via windblown soil particles.
(2) FDAT persists in the environment. FDAT may bioaccumulate; there is a lack of needed knowledge of FDAT in particular, but its class of chemicals shares this behavior. Recently, fully fluorinated PFAS contaminants have also been detected at significant concentrations in the commercial Rejuvra™ product.
(3) One recent study shows indaziflam to be genotoxic to human cells, which is a screening test for carcinogenicity. It is also observed to be a potent amoebacide and fungicide, which raises important unexplored ecological questions about persistent impacts on the soil micro- and macro-biota.
(4) Indaziflam applications have been found in several studies to degrade non-target components of the local flora. The species affected, native or non-native, are important and valued parts of natural lands ecosystems. We conclude that real ecological harm has already been demonstrated on natural lands involved in indaziflam spraying-based restoration projects. Such must be considered when evaluating the need for

and harm caused by large scale indaziflam spraying for cheatgrass control.

(5) For fire risk reduction along the Front Range, any wide-scale application of indaziflam is not task-focused; we found no research indicating that its reduction will actually reduce fire hazard in our region. Cheatgrass control to address fire hazard reduction must be highly targeted and directed to very specific locations, just as for other potential fire fuels.

(6) Long-term monitoring in the Colorado Front range indicates that cheatgrass is an early seral species that declines in abundance at decadal scales. At least in some cases, application of pesticides may actually delay ecological restoration of later seral vegetational cover. In pure cheatgrass monocultures, use of the chemical leaves bare soil in place for multiple years.

(7) Annual grass resistance to indaziflam has emerged, and this follows a familiar path common to pesticides used for weed control. If extensive indaziflam applications on cheatgrass continue, cheatgrass too can be expected to acquire resistance

In conclusion, the use of pesticides for weed management on natural lands poses different challenges and constraints than their use on agricultural lands or rangelands. The differences have profound management implications. Given the different goals and in the context of increasing knowledge, public lands managers must abide by the highest standards to protect the ecology of their properties and the public. There is consensus that pesticides are partly responsible for major declines in insect and bird populations (van Der Sluijs 2020; Buddhadev et al. 2023; Edwards et al. 2025; Johnston et al. 2025; Leuenberger et al. 2025). There is also much evidence that they play a role in various human diseases (Yan et al. 2016). The lands set aside for nature can become refuges from such harm. Ecological restoration efforts may best proceed without chemical applications that are incompatible with such a goal.

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Supporting Information

The following information may be found in the online version of this article:

Supplement S1: Examples of non-disclosure in cheatgrass control literature.

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