Navigating the "Noxious" and "Invasive" Regulatory Landscape: Suggestions for Improved Regulation

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In the United States, only species listed on state or federal noxious weed lists are regulated. According to our analysis, these regulatory lists poorly represent invasive plants in unmanaged (i.e., nonagricultural) systems. To improve the representation of invasive plants on state regulatory lists, we recommend allocating listing authority to invasive species councils and provide guidance for the science-based reform of noxious weed lists. We also recommend commercial best practices to test for invasiveness prior to intentional introduction of new plant products. Finally, we introduce a negligence liability scheme to discourage the introduction of potential invaders. If adopted, our recommendations could benefit nonagricultural ecosystems and could have positive consequences for bioenergy producers and others in plant industry, who are under scrutiny for promoting potentially invasive species as energy crops. As the bioenergy industry gains momentum, a revised regulatory regime may alleviate the concerns regarding one potential negative consequence of novel plant introduction.

Keywords: bioenergy, invasive, liability, negligence, noxious weed list

Increased demand for bioenergy feedstocks to meet renewable energy mandates will require the development and deployment of newer, bigger, and better plant resources (Ragauskas et al. 2006). Ideal bioenergy traits—fast growth and the ability to outcompete local vegetation, tolerance of and adaptability to a variety of soil and climatic conditions, resistance to pests and diseases, and a lack of herbivores in the recipient ecosystems—also typify much of our invasive flora (Raghu et al. 2006, Barney and DiTomaso 2008, DiTomaso et al. 2010, UNEP 2010). This raises particular concerns when the species at issue is nonnative within the production region or has improved traits for bioenergy production (e.g., as a result of genetic engineering), because the novel or enhanced genes could spread. Therefore, next-generation feedstocks may be productive and profitable but may also pose a risk of becoming invasive, thereby potentially damaging the broader ecosystem, the livelihoods of farmers, and the economy (IUCN 2009). Accordingly, the agronomist's search for yield-maximizing bioenergy crops for deployment into novel agricultural systems and less-productive environments, combined with a policy priority of encouraging bioenergy production (Energy Independence and Security Act [2007] Public Law no. 110-140, 121 stat. 1492), prompts a careful examination of the regulatory landscape for noxious and invasive plants to assess the potential for improvements to the current policy landscape. For example, the Biomass Crop Assistance Program (BCAP) officially prohibits government payments for the establishment of any plant that is or has the potential to become noxious or invasive—an important step by the federal government to limit the potential for unintended consequences of widespread bioenergy production (Food Conservation and Energy Act [2008] Public Law no. 110-246, 112 stat. 1651).

Because scientists, federal programs (e.g., the US Department of Agriculture's [USDA] BCAP, the National Invasive Species Council), and international conservation groups (e.g., the Global Invasive Species Programme [GISP] and the International Union for Conservation of Nature [IUCN]) increasingly recognize the potential for invasiveness in bioenergy crops, the nascent bioenergy industry will be entering a more difficult regulatory landscape. Here, we examine the strengths and weaknesses of current invasive species regulations at the state and federal levels and discuss how these could affect bioenergy species. We then propose several legal reforms to improve accountability for

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unintended escape and to ensure the protection of environmental resources into the future.

Current invasive plant regulations, or the lack thereof

Nonagricultural invasive plants cost the US economy more than $7.7 billion annually in income losses (e.g., through the degradation of grazing land) and control expenditures (Pimentel et al. 2005). In addition to their economic impact, invasions by nonnative organisms are thought to be the second leading cause of biodiversity losses in the United States (Wilcove et al. 1998) and, in many cases, have irreversible negative consequences on ecosystem function (Simberloff 2005). Although these environmental and economic consequences are substantial, invasive species affecting nonagricultural landscapes are largely unregulated by states or federal agencies.

The federal government, through the USDA's Animal and Plant Health Inspection Service (APHIS), restricts the movement and cultivation of 111 aquatic, parasitic, and terrestrial plant taxa through placement on the Federal Noxious Weed List (*http://plants.usda.gov/java/noxious*). Similar state-level noxious weed lists formally restrict, to varying degrees, an additional 620 unique plant taxa across their respective states. The term *noxious weed*, defined in the federal Plant Protection Act ([2000] Public Law no. 106-224, 114 stat. 440) as "any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment," benefits from a sweeping definition, yet in most states, noxious weed laws are administered by states' departments of agriculture, which introduces a potential bias toward agricultural systems. Therein lies the current regulatory system's greatest strength: an agricultural focus that protects this important segment of the economy and its attendant lobby (Harl 2000, Min et al. 2008). Accordingly, the political influence on noxious weed lists is unsurprisingly large in some cases. One example is the Florida Farm Bureau's opposition in 2001 to a federal weed control proposal that would have authorized the US Department of the Interior—rather than the more agriculture-focused USDA—to control some plant pests.

In contrast, other, nonregulatory lists of invasive species are often created and maintained by nongovernmental state and regional invasive plant councils (IPCs) or exotic pest plant councils (EPPCs), which generally draw researchers, land managers, and weed workers as members. These organizations (hereafter, collectively referred to as IPCs) independently record, monitor, and synthesize information on invasive plants and often compile lists by surveying land managers and property owners across the state or region to identify and rank problem species. Note that the term *noxious* refers to any taxon that is regulated by a government entity, whereas invasive plants are not necessarily regulated. Furthermore, *invasive plants* can be operationally defined as those that affect non- or less-managed "natural" systems (as opposed to agricultural weeds). The ranking procedures used by IPCs include transparent and objective procedures (e.g., the California IPC), nominations and votes (e.g., the Florida EPPC), voted rankings (e.g., the Georgia EPPC), and more-opaque procedures (e.g., the Ohio IPC). Unfortunately, the presence of invasive species on these lists generally carries no legal requirement for control or restriction of the plant's entry to the state, and individuals may distribute and cultivate plants on these lists with impunity. In addition to IPCs, some state governments have created invasive species councils (ISCs), which maintain advisory roles for departments overseeing noxious weed lists. Like IPCs, however, governments rarely give ISCs direct authority to list or delist regulated species (supplemental table S1, available online at *http://dx.doi.org/10.1525/bio.2013.63.2.8*, outlines the available criteria for identifying species for inclusion or evaluation by IPCs and ISCs).

Considering the historical agricultural bias in noxious weed laws and the fact that nongovernmental IPC lists have no regulatory authority, we hypothesized that most states primarily regulate agricultural species and largely ignore invasive plants. To examine this empirically, we created a database of the noxious weed lists in every state and cross-referenced each state's noxious weed list with the corresponding state or regional IPC or ISC list (please see the methods and details in the supplemental material). The number of species in common to the two types of lists indicated the degree to which a state was representing invasive species on its regulatory lists (table 1). Therefore, a relatively high number was considered better than a low number. In a subtly different analysis, we looked at the number of species regulated by a state that were not also listed by an IPC or ISC. A large value here suggested that states were overregulating agricultural species or species that were otherwise not deemed important by expert members of IPCs or ISCs. Furthermore, we sorted each state's regulatory system into several general categories: the branch of government responsible for official noxious weed lists (i.e., legislative or administrative), the level of government with authority to initiate the legislative or administrative process (i.e., a state official in a top-down regime, a local official in a bottom-up system, or a hybrid system), and the state agency with enforcement authority (i.e., the state's agriculture or environmental regulation agency or the local government) (supplemental figure S1).

We found that, on average, states list 34 species as noxious (after we removed species redundant with the federal list), whereas the state IPCs and ISCs listed more than twice that number (72) as invasive, on average. State noxious weed lists only included an average of 19.6% of the species considered invasive by the state IPCs and ISCs, and just five states (Connecticut, Massachusetts, New Hampshire, Oregon, and Washington) included more than 50% of the known invaders. When regulatory categories were tested

Table 1. The number of regulated (noxious) and invasive species in each state and the number in common to both types of lists.

State	Noxious species	Invasive species	Number in common	State	Noxious species	Invasive species	Number in common
Alaska	14	167	8	Montana	36	0	—
Alabama	27	68	16	North Carolina	21	79	11
Arkansas	22	11	0	North Dakota	15	0	—
Arizona	47	4	2	Nebraska	18	73	0
California	176	204	57	New Hampshire	57	29	28
Colorado	93	0	—	New Jersey	5	29	1
Connecticut	78	96	73	New Mexico	34	0	—
Delaware	4	29	0	Nevada	45	0	—
Florida	26	152	16	New York	9	59	1
Georgia	8	144	0	Ohio	18	27	2
Hawaii	70	31	7	Oklahoma	40	53	8
Iowa	26	0	—	Oregon	123	43	31
Idaho	59	0	—	Pennsylvania	11	38	6
Illinois	18	102	11	Rhode Island	4	26	0
Indiana	10	68	4	South Carolina	31	95	3
Kansas	18	0	—	South Dakota	17	0	—
Kentucky	6	99	2	Tennessee	10	135	9
Louisiana	7	11	0	Texas	18	147	13
Massachusetts	77	66	63	Utah	30	48	1
Maryland	5	44	3	Virginia	0	3	0
Maine	10	27	5	Vermont	25	35	0
Michigan	40	42	14	Washington	140	38	25
Minnesota	23	57	13	Wisconsin	5	66	5
Missouri	12	255	11	West Virginia	13	10	3
Mississippi	2	165	0	Wyoming	54	3	1

Note: Since the federal noxious weed list applies in every state, species that were redundant with the federal list were subtracted from the number in the "Noxious species" column. Georgia, Kentucky, Louisiana, New Jersey, and New York maintain only noxious weed seed laws; the species listed as prohibited under those laws were included. Virginia shows 0 noxious species because the 2003 law that listed two *Lythrum* species was repealed in 2008.

for their influence on this metric, none were found to have a significant effect (see supplemental table S2 for the mean scores for each regulatory system). Conversely, on average, 64% of the species listed as noxious weeds in a state were not considered invasive by the corresponding IPC or ISC in those states (that is, states were overregulating noninvasive species, primarily agricultural weeds). Again, none of the regulatory categories were found to have a significant effect on this metric. Only two states (Connecticut and Massachusetts) had a desirable combination of redundancies between noxious and invasive weed lists in the state (i.e., over 50% of the regulated species were on the IPC or ISC lists, and less than 50% of the regulated species were missing from the IPC or ISC lists; supplemental figure S2). Although the two states have administrative input, they differ in other typologies. Massachusetts is a top-down state whose Department of Agricultural Resources enforces the noxious weed rule, whereas Connecticut operates on a hybrid system, with Department of Energy and Environmental Protection enforcement. Unfortunately, we found no consistent system that appeared to work best across all states, and we cannot, therefore, rely on existing regulatory typologies to design protections against the potential invasion by bioenergy crops. However, we noted that ISCs in both states (the Massachusetts Invasive Plant Advisory Group and the Connecticut IPC) have been given formal advisory roles in state government.

Impacts of existing regulatory shortfalls

The incongruence between regulated noxious weed lists and unofficial invasive species lists (e.g., IPC lists) can have important environmental consequences. A delay in listing (the best-case scenario) or a failure to ever reconcile regulated and unofficial lists (the usual case) has long-term

ecological implications, because funding priorities for invasive species control tend to be directed at formally listed noxious weed species (Rice 2008). This is a serious misplacement of effort to manage invasive species, because the cost of effective control grows exponentially as an invader establishes itself over time (McNeely et al. 2003, Rice 2008). In addition, control costs are lowest in the early stages of invasion, which, unfortunately, is before the political process can assess whether to include the plant at issue as an official noxious weed. In contrast, ISCs and IPCs often benefit from input by boots-on-the-ground resource managers keen to spot nascent invasions, which could help them speed the listing process and direct control efforts accordingly. Admittedly, IPC and related lists are not free from bias and sometimes lack transparency in their listing process.

In the future, it will be increasingly important to support objective and science-based policies for the regulation of introduced plant species, especially but not limited to bioenergy crops (IUCN 2009, DiTomaso et al. 2010). This includes implementing restrictions on known invaders while providing adequate flexibility to investigate and commercialize noninvasive bioenergy feedstocks. Official federal policy reflects this balance of precaution and flexibility regarding plant innovation. For example, Presidential Executive Order 13112 prohibits federal agencies from engaging in actions (including the funding of third parties) that are likely to promote the introduction or spread of invasive species unless the purported benefits clearly outweigh the potential harm (Clinton 1999). Interestingly, there are restrictions in place for several bioenergy crops considered for production. A small number of species with bioenergy potential are currently outlawed at the federal level (e.g., *Prosopis pallida*, *Saccharum spontaneum*), and states already regulate several others—many of which are also listed as invasive by nonregulatory bodies: *Arundo donax* is regulated as noxious by 4 states and considered invasive by 14, *Phalaris arundinacea* is listed as noxious by 2 states and as invasive by 16, and *Sorghum halepense* is listed as noxious by 20 states and as invasive by 16. In addition, closely related taxa of many bioenergy candidates and species that may be improved or hybridized through genetic modification or traditional breeding programs are also regulated at the state and federal level (e.g., *Miscanthus sacchariflorus*, one of the parents of the highly productive hybrid *Miscanthus* × *giganteus*, is regulated as a noxious weed in Massachusetts). Florida and Mississippi have already enacted laws relating to the prevention of invasion by bioenergy crops, and more states will likely follow in the near future. Therefore, the regulation of bioenergy crops and their relatives may prove to be a complicating factor for the bioenergy industry because of varying rules among jurisdictions and regulatory uncertainty with respect to candidate bioenergy feedstocks.

Concurrently, state regulatory regimes will face increased pressure to control the spiraling costs of invasive species management. Accordingly, states should implement science-based regulatory programs to minimize the establishment of invasive species without overly restricting novel crops with strong potential as bioenergy feedstocks or ornamental crops. We focus primarily on the state level rather than on the federal, because states represent more localized political jurisdiction but also because species or populations that are invasive in one area may not survive or invade in others. In other words, states can respond to those species specifically threatening areas within their boundaries and can regulate as necessary.

Recommended improvements to invasive plant regulation

Given the current absence of invasive plant regulations in most states, we suggest several regulatory reforms designed to protect natural landscapes against the potential threats of introduced plants.

Reforming noxious weed lists. Several prominent national and international organizations (e.g., GISP, the IUCN, the Roundtable on Sustainable Biofuels, the Invasive Species Advisory Committee) have called attention to the potential for bioenergy feedstocks to become invasive and have published white papers that outline feedstock selection and management strategies, as well as regulatory and policy changes, designed to prevent widespread invasion. These organizations point out the need to consult official noxious weed lists for production regions prior to the introduction of new feedstocks (GISP 2007, IUCN 2009), recommend a strengthening of government authorities with jurisdiction relating to environmental protection (ISAC 2009, IUCN 2009), and suggest making policy changes based on sound ecological principles (IUCN 2009). Our recommendations are in line with these general principles, but we provide more specific guidance for regulatory reform.

Because all people are legally required to avoid planting listed species within a jurisdiction, noxious weed lists represent a first line of defense in preventing and containing invasions. However, our analysis shows that most existing noxious weed laws fall woefully short of representing the existing and potential threats to natural areas. Therefore, we strongly recommend the reform of these lists, in a manner that prevents the introduction and establishment of new invaders without undue regulation of species that pose a low risk in the respective state (Rice 2008).

In 90% of US states, noxious weed lists are currently administered and enforced by that state's department of agriculture, which may account for the large proportion of agricultural weeds on most noxious weed lists. To ensure that regulatory lists better represent invasive plants of natural areas, while maintaining the protection of agricultural resources, we recommend a stronger and more integrated role for ISCs. Recall that these differ from IPCs in that they exist within state governments, are mandated with compiling information and creating management plans for all invasive taxa (not just plants), and often have official advisory roles in the listing process—although how often

and how effectively this advisory function is employed is not yet known. In rare cases (i.e., in eight states: Arkansas, Iowa, Louisiana, Oregon, Rhode Island, South Dakota, Wisconsin, and West Virginia), governmental ISCs actually have the authority to list and delist noxious species. Current ISCs vary with respect to their structure and operation and the priority given to plant invaders, but some follow the model of the National Invasive Species Council and are represented by the secretaries of relevant state agencies (e.g., agriculture, natural resources, environment) and advised by invasive species advisory committees composed of scientists, industry representatives, and laypeople. This structure is ideal, because it balances the agendas of a variety of stakeholders but also allows input from practicing invasive plant experts and others.

In addition to establishing ISCs in states where they do not yet exist and restructuring council memberships in existing states to enhance stakeholder representation, we recommend that these councils be given direct authority to revise noxious weed lists on the primary basis of a standardized weed risk assessment protocol that would assess invasiveness potential of incoming and existing species in each state. Although weed risk assessments do not represent a perfect assessment of risk (Hulme 2012), it has been pointed out that the benefits of weed risk assessments far outweigh the environmental risks of invasion (Roberts et al. 2011). A new weed risk assessment framework has been recently released by the Plant Protection and Quarantine (PPQ) division of APHIS (Koop et al. 2012), which performs more accurately than the widely used Australian weed risk assessment system (Pheloung et al. 1999) and also includes a measure of analyst uncertainty, which reflects the often incomplete nature of data used to parameterize weed risks.

We propose that the more accurate PPQ weed risk assessment (PPQ–WRA) system (Koop et al. 2012) be adopted by state ISCs to revise existing regulatory lists with greater attention to invasive plants of natural areas and to create quarantine-like lists for questionable species (figure 1). In addition to reviewing existing noxious weed lists, ISCs should consider lists maintained by nongovernmental IPCs, as well as lists of invaders in neighboring states. Members of the public or the plant industry should also have a framework to petition ISCs for a review of additional species.

Under this system, a tiered list would emerge, with publicly available scores and recommendations for all species considered by ISCs. Following the PPQ–WRA evaluation, each species would undergo a secondary evaluation by ISCs and their advisory committees to further consider their potential impact, establishment, and spread and the feasibility of any remediation strategies. This secondary screening would account for common-sense factors that may be missed by standard weed risk assessment questions (e.g., plant traits that prevent the establishment in certain climates). Those plants with a high composite weed risk assessment and secondary screening outcome would be placed on the regulated noxious weed list, whereas others (e.g., those with a high weed risk assessment score but a lower secondary-screening score) would be placed in a newly created watch list category. As they are under current rules, species on the noxious weed list would be banned from importation and sale within the state. Noxious species could carry further regulatory requirements, such as the control of existing populations, according to each state's statutes and budgetary constraints. Plants on the watch list would not be regulated, but this list of species would be distributed to local or county offices of agriculture and the environment, as well as to importing and transportation industries (e.g., nursery, agriculture, shipping, transportation, border patrol). If these species are encountered, the authorities should be notified, which would prompt a reevaluation by weed risk assessment or immediate containment and eradication where that is possible. Plants that receive an *evaluate further* score from the PPQ–WRA would be placed on a caution list, which would carry a recommendation against planting these species until further information were available. However, these plants would not be officially regulated. Finally, plants that receive a *low risk* score from the PPQ–WRA would be categorized as such (i.e., as low risk), with the implications that it is permissible to plant them at the present time but that they still carry some level of risk. Similar to the University of Florida's Invasive Plant Working Group assessment system (IFAS 2011), species evaluated through the PPQ–WRA should be reevaluated if new data become available or in 10 years. This system would result in more robust protection for natural areas, and the use of an improved risk assessment would ensure transparency, rigor, and equity among states.

Industrial reforms. For nonnative species and novel genotypes that are intentionally introduced as commercial products (e.g., bioenergy crops and ornamentals) or for other purposes (e.g., erosion control and biological control), we endorse additional steps that industry should take to prevent invasion. Along with others (Anderson et al. 2006, ISAC 2009, IUCN 2009, Davis et al. 2010, Quinn et al. 2010), we call for developers of new commercial crops (e.g., bioenergy feedstocks and ornamental plants) to take the following precautions prior to production: Developers should consult and abide by official noxious weed lists or the recommendations for the state in which these crops will be produced. If their crops have not been previously evaluated, developers should compile all relevant data to be entered into the PPQ–WRA and send them to the state ISC for review and an initial recommendation. Developers should breed novel genotypes for low invasiveness or use native genotypes but should recognize that even taxa commercially bred and marketed for low fertility can still represent an invasive threat (Knight et al. 2011). They should conduct field trials and provide data to ISCs for final recommendation and should assess transport routes to quantify the potential escape vectors and the overall likelihood of escape. And they should

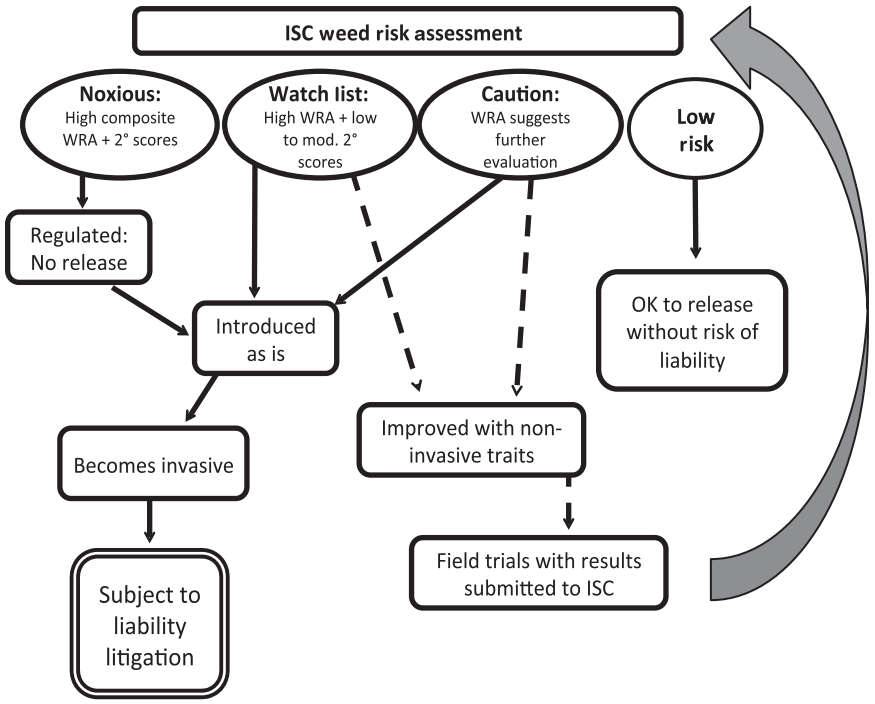

Figure 1. Conceptual diagram of current regulatory and commercialization process and proposed changes to this system. Abbreviations: 2°, secondary (see the text for details on the secondary scoring system); ISC, invasive species council; WRA, weed risk assessment; mod., moderate.

thoroughly test the methods of eradication under a variety of environmental conditions and should use this information to develop a plan for control.

Early consultation with state ISCs to receive initial recommendations from the PPQ–WRA would allow developers the opportunity to receive feedback at an early stage in development. If the initial recommendation is anything above *low risk*, the developers may choose to terminate development prior to greater investment in the product or to adjust their breeding program to introduce more noninvasive traits before petitioning for a final recommendation.

Although others have discussed the need for *in situ* invasiveness trials (Davis et al. 2010), few specific guidelines have been offered regarding protocols and oversight. We make several suggestions here as a starting point but recognize that specific protocols must be tailored for the biology of each crop and production system (e.g., annual versus perennial grasses, herbaceous versus woody species). Because of the long lag times commonly observed in invasion histories, conclusive evidence of invasiveness is unlikely within a reasonable timeframe prior to commercial release. However, factors correlating with invasiveness should be recorded over multiple growing seasons in environments relevant to production sites. Data from these field trials should be provided to ISCs as new data, which would prompt a reevaluation and a final recommendation. Key factors include fecundity, germination rates, dispersal behavior (dehiscence versus retention on inflorescence), dispersal distance (as documented in searches for volunteers beyond field edges and through standard seed-trapping protocols), seed dormancy, vegetative reproduction rates, evidence of vegetative fragmentation and movement by farm equipment or nearby water sources, and the incidence of spontaneous regrowth or germination following the harvest or cleanup of field trials. Depending on the species, it may be appropriate to monitor additional factors. Evidence of high reproductive output, long-distance dispersal of seeds or vegetative fragments, the ability to germinate or sprout vegetatively under a wide variety of conditions, and longevity in the propagule bank could predict the potential for invasion (Radosevich et al. 2007) and would probably influence weed risk assessment scores toward higher risk categories.

The requirement of field trials is not new to agricultural developers. Agricultural biotech companies routinely perform field trials in which the risk of transgene escape is evaluated through pollen and seed dispersal. These tests and others are required for each new transgenic modification by the Plant Protection Act (7 CFR § 340), the statutory authority for both noxious weed regulation and plant pest regulation in the genetic-engineering context. In the case of genetically engineered crops, the results of field trials are transmitted to federal authorities, who make a regulatory determination regarding commercialization. Our system would operate in a similar fashion, but commercial products would be subject to regulation only if state ISCs determined that the product should be placed on the noxious weed list. If the final review did not prompt regulation, the developers could proceed with commercialization but would still be responsible for any negative impacts of their products (see below).

Incentives and consequences for industry. Because even the most thorough weed risk assessments and trait-based breeding programs fail to prevent all invaders, there will always be a need for implementation of *ex post facto* actions that safeguard the environment when preventive approaches fail. *Ex post* policies should include plans for the cleanup and eradication of escapes (see the suggestions in GISP [2007], ISAC [2009], and IUCN [2009]), but we argue that additional actions would motivate developers to act responsibly before commercialization. What we propose is a gap-filling supplement to the current regulatory system through the use of private liability. Enforcement mechanisms that connect responsibility for invasive plant introductions with *ex post* liability assessments for the resulting economic and

ecological harm would align private incentives with the objectives of the regulatory regime and relieve the government (and thereby the society) of some of the immense financial expenditures involved in invasive species eradication (Simberloff 2005). Historically, the legal system has addressed asymmetric alignments of costs and benefits through the imposition of taxes (e.g., a polluter-pays tax; Pigou 1920), through the assignment of property rights (Coase 1960), or through attendant liability mechanisms (Shea 1978). The polluter-pays principle has been suggested in the bioenergy context by the IUCN to provide for government regulations that would allow developers or producers to be pursued for compensation if their product should become invasive (IUCN 2009). However, this amounts to a strict liability regime, the consequences of which could be seen as prohibitive to development of the nascent bioenergy industry.

Instead, we recommend a more flexible negligence liability regime in which allegations of negligence would trigger an inquiry into the underlying reasonableness of the action causing harm. If the commercial developer performs its due diligence to ensure a low risk of invasion, there is no fault and, therefore, no liability. In our proposed system, reasonable action would require taking the necessary measures (e.g., incorporating noninvasive traits into breeding programs and monitoring test plots for invasive correlates over multiple seasons) to ensure a final *low risk* recommendation by state ISCs prior to the release of a novel plant species, cultivar, or genotype. If companies commercialize invasive products despite designation on the caution or watch list, there would be fault—negligence—and, therefore, liability may attach (figure 1). If the final assessments indicated a low risk of invasiveness but were later proved incorrect (i.e., a false negative), there would be no unreasonable conduct and, therefore, no liability (figure 1). Dealing with incomplete knowledge or uncertainty is not insurmountable in the invasive plant context; the legal system has demonstrated competence in weighing these issues in a multitude of environmental contexts (e.g., nuisance, air or noise pollution). There is no reason to believe that the legal system would struggle in the invasive plant context (i.e., determining what is a reasonable or unacceptable risk) any more than in other endeavors. In summary, negligence is based on the reasonableness of a plant developer's decision at the time of action, which therefore prevents retroactive liability and allows for some degree of scientific uncertainty coupled with precaution.

Implications for bioenergy and the plant industry

Our proposal could represent major improvements for environmental protection and could alleviate societal costs brought forth by invasive species while not overburdening the plant industry. This has particular relevance for cases in which plants are intentionally introduced, such as in traditional agriculture and horticulture, that later prove ecologically detrimental (e.g., Johnsongrass, *S. halepense*). If greater scientific rigor informs regulatory lists in the future, a greater number of plants may be prohibited prior to widespread introduction. If the species of interest is not listed as noxious, individuals or companies could proceed along the path toward commercialization by conducting trait analyses to identify and develop noninvasive varieties and by running thorough weed risk assessments and invasiveness field trials (figure 1).

In the absence of formalized weed risk assessment requirements, some states have imposed other restrictive measures on bioenergy plantings. Mississippi has recently passed legislation (Mississippi Code of 1972 § 69-25-10 [1 July 2012]) that prevents the planting of any nonnative fuel plant at a scale greater than 1 acre without a permit, subject to review by the Department of Agriculture and Commerce and by invasive species experts at Mississippi State University. A permit application can be denied if the plant is suspected of being invasive. Successful permits must be accompanied by surety bonds that provide for the removal and destruction of all plants. This law, with its vague terminology (e.g., *invasive* is not defined in the law), and the lack of defined protocols used during permit review has the potential to interrupt development of the bioenergy industry in Mississippi. Similarly, Florida has recently implemented a permitting requirement for the cultivation of nonnative plants intended for energy production (Florida Administrative Code [2008] Biomass Plantings § 5B-57.011). Although a permit and bonding process could, in theory, prevent invasions, the existing state regulatory processes are largely nontransparent or fail to incorporate scientific evaluation. As an illustration, permitting requirements in Florida that are applicable to plantings larger than 2 contiguous acres do not require a weed risk assessment and, therefore, do not review or restrict the cultivation of potentially invasive plants, including *A. donax*, *Jatropha curcas*, or *Pennisetum purpureum*. However, the permit requirements apply equally to plants with low invasive potential, which thereby increases the costs and potentially unnecessarily restricts the development of the bioenergy industry. Although the Florida and Mississippi permit systems provide some protection, the *ex ante* regulatory reform and *ex post* liability regime that we propose better tailors legal measures to the prevention of invasive species through the increased scientific involvement in the development of regulatory lists to prevent the cultivation of invasive bioenergy crops along with a liability requirement contingent on actual harm. Some in the bioenergy industry are already performing field-based invasiveness evaluations, which suggests that our proposed framework would formalize existing practices while also making them obligatory and uniform across states.

Finally, as plant breeders increasingly turn to genetic-engineering technologies to enhance crops' agronomic traits or the ability to convert cellulose into biofuel (e.g., Chuck et al. 2011), it is important to consider how our proposal would affect what constitutes a reasonable weed risk assessment.

Although it has not yet been implemented, APHIS proposed in 2008 a revision to its genetic-engineering plant regulatory regime that would require a separate weed risk assessment of the transformed trait (USDA 2008). Current APHIS rules evaluate the genetically engineered plant under its plant pest rules, and our proposal does not suggest any changes to that system.

Challenges

Change at the state level is always difficult and incremental—whether those changes are relatively straightforward rules, such as a minimum drinking age (*South Dakota v. Dole*, 483 US 203 [1987]), or complex rules for welfare entitlements (*Goldberg v. Kelly*, 397 US 254 [1970]). We are under no illusion that our recommendations will be easy, fast, or even uniform in their implementation. Of course, assistance from stakeholders and the National Invasive Species Council would provide further impetus for legislative action—even in an age of political gridlock. But the existence of gridlock does not preclude an attempt at reform. With respect to our weed risk assessment and negligence regime, we note that some states have informally adopted this approach on private lands (*Collins v. Baker*, 668 N.W.2d 548 [S.D. 2003]). Again, our suggested reforms will not be easy but, rather, an incremental, state-by-state approach. However, we argue that our suggestions would better protect natural landscapes and would also allow the nascent bioenergy industry to operate and grow safely and profitably.

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