

Reply to Proença et al.: Sown biodiverse pastures are not a universal solution to invasion risk

Proença et al. (1) highlight that sown biodiverse pastures (SBP) can provide local solutions that increase production while limiting the risk of new pasture taxa invading natural areas. We agree that in Portugal SBP is an innovative approach for reducing the weed risk. However, SBP does not offer a universal solution to the problems we identify in our assessment of the risks of new pasture taxa (2). We see three issues that limit the potential of SBP as a global solution to invasion risk from pastures.

First, the advantages of SBP may not be replicated in other regions. To begin with, the Mediterranean Basin has a rich flora of leguminous species and productive, rhizomatous grasses that can be co-opted into pasture systems. This is not the case in other parts of the world, notably Australia and New Zealand, where reliance on alien plants might lead SBP to increase the variety of introduced species in pastures. Also, although SBP may prove beneficial in marginal soils, it may not be the solution in productive soils. Finally, Old World Mediterranean ecosystems appear to be relatively resilient to plant invasions (3), and thus the risk of introducing alien species in SBP in Portugal is unlikely to be representative of other regions.

Second, even where the plant species sown in SBP may not themselves become invasive (a risk that should be assessed before widespread introduction), the emphasis on ensuring that species are inoculated with rhizobia raises the risk that rhizobia may themselves facilitate plant invasions. The absence or scarcity of rhizobia can limit the performance of alien species and further introductions of rhizobia could enable some species to invade, when previously they were noninvasive (4, 5). Mutualistic microorganisms (bacteria, fungi) in general can pose a risk if they create novel associations with other alien or native species in the community.

Third, landscapes are usually heterogeneous, with low and high nutrient areas interspersed, such as uplands compared with drainage lines, stream-sides and river-banks. Adding exotic pasture species in a SBP program increases invasion risk to interspersed nutrient-rich areas.

SBP may be a good local solution to minimizing invasive species risk, provided the taxa introduced do not invade low nutrient soils, new rhizobia do not increase invasiveness of other plants, and there are no accessible high nutrient areas. Unfortunately, we do not think this model can be applied in most of the situations described by Driscoll et al. (2), where alien pasture varieties are at a high risk of becoming invasive species. Developing a polluter-pays system would encourage agronomists, companies, and governments to think carefully about environmental risks before new pasture species or endosymbionts are introduced. We think this is an important and urgent policy development for governments around the world if they are to avoid escalating economic and environmental costs associated with invasive pasture plants.

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- 1 Proença V, Aguiar C, Domingos T (2015) Highly productive sown biodiverse pastures with low invasion risk. *Proc Natl Acad Sci USA* 112:E1695.
- 2 Driscoll DA, et al. (2014) New pasture plants intensify invasive species risk. *Proc Natl Acad Sci USA* 111(46):16622–16627.
- 3 Vila M, et al. (2008) Widespread resistance of Mediterranean island ecosystems to the establishment of three alien species. *Divers Distrib* 14(5):839–851.
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- 5 Wandrag EM, Sheppard A, Duncan RP, Hulme PE (2013) Reduced availability of rhizobia limits the performance but not invasiveness of introduced *Acacia*. *J Ecol* 101(5):1103–1113.

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