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BRIEF REPORT

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Strategic science planning for responsible stewardship and plant protection at the U.S. Department of Agriculture

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Societal Impact Statement

Agriculture is comprised of managed ecosystems, which can include forests, rangelands and crops; these managed ecosystems are vital resources, providing a host of economic and societal benefits. However, these systems face a multitude of challenges: from climate change and limited natural resources; to exotic pests and pathogens; to growing global populations and food demands. Responding to these global challenges requires interdisciplinary innovation and strategic planning to maintain production and sustainability while responsibly feeding the future. The U.S. Department of Agriculture and its Research, Education, and Economics, and Forest Service agencies plan to meet these challenges via research programs and initiatives.

KEYWORDS

forest health, plant breeding, resilience, stewardship, strategic planning, USDA

1 | INTRODUCTION

This article provides an overview of how research at the U.S. Department of Agriculture (USDA) is oriented to meet the current ecological and environmental challenges facing agricultural systems through strategic planning, as coordinated by the Office of the Chief Scientist (OCS). Strategic planning is a rigorous process across the USDA's agencies and offices, often requiring input from multiple stakeholders and multiple sectors. A subset of those agencies engages in, and supports, research.

The OCS supports the USDA's Chief Scientist by coordinating high-level strategic science planning across the Department on both annual and five-year cycles (REE, 2012). OCS strategic science plans are reviewed and updated annually, and completely reformulated every 5 years. To develop these plans, senior advisors to the Chief Scientist work in tandem with partner agencies, such as the Forest Service (https://www.fs.fed.us/), and experts from across the Department. These strategic plans play a major role in setting the tone and prioritization for research by first, making ongoing research visible and accessible to Department leadership for informed decision-making; and second, by making research and priorities accessible to stakeholders, which also ensures visibility.

These strategic planning cycles incorporate in-house programmatic and academic review, as well as active stakeholder engagement, including surveys, public listening sessions and USDA-sponsored meetings to identify research and development needs and opportunities. Research initiatives are developed with an aim to both maintain and enhance productivity, while ensuring responsible stewardship of resilient natural resources. The high-level strategic plan developed by the OCS sets the tone for science across the Department and is aligned to USDA-wide strategic goals. Individual agencies and offices additionally engage in more detailed strategic planning to implement research efforts. We do not describe those individual processes here, instead, we highlight examples of research at two USDA agencies: Research, Education, and Economics (REE, https://www.ree.usda.gov/), and the Forest Service to illustrate how the Department orients scientific efforts to meet future challenges. We consider this specifically in relation to two of the seven major strategic goals of the Department: fostering productive and sustainable use of the U.S.'s national forest system lands; and employing technology and research to nurture private lands, in the realm of plant health, production, and protection (USDA, 2017).

2 | BREEDING AND RESILIENCE

Breeding productive crops that meet the food, fiber, and fuel needs of growing populations while using fewer resources is a major focus of research efforts at the USDA, supporting one of the Department's strategic goals. Today, plant breeding research relies on a combination of techniques, some well-established and some nascent. A number of these well-established techniques have their roots in methodologies established thousands of years ago during the advent of plant domestication—such as phenotypic selections for desirable traits (Kean, 2010; Larson et al., 2014). Modern researchers also often employ controlled trials, quantitative genetics, and careful experimental design. In more recent times, USDA plant breeders have begun to incorporate nascent techniques into programs, including molecular marker assisted selection, high-throughput phenotyping, and genome editing to more precisely target traits of interest (Kean, 2010; Larson et al., 2014). These new methods expand a plant breeder's toolbox and can introduce desirable new traits more quickly and precisely, potentially saving years, or even decades, when creating new varieties (Kean, 2010; Larson et al., 2014). Partly because of these potential benefits for plant breeding precision and efficiency, the USDA does not plan to regulate the plants that have been developed through genome editing, which are indistinguishable from those developed through traditional breeding methods, and which are “not plant pests or developed using plant pests” (USDA, 2018).

Incorporating diversity into breeding efforts, both on molecular and species levels, is key both to long-term forest health, and to creating national energy and food security. One strategy for promoting diversity and resilience in domesticated species is to leverage gene banks to identify genetic traits and variation in wild relatives that could be integrated into existing crops (Khoury et al., 2013). The USDA National Plant Germplasm System (NPGS, https://www.ars-grin.gov/npgs/) is the world's largest repository of living plant material with over 600,000 accessions at 27 locations. By leveraging collections such as these, we might gain new insights into how we could tap into and exploit the genetic diversity available in wild crop progenitors and their relatives in breeding efforts.

With the advanced breeding techniques now available, breeders can produce crops that tackle both the environmental and food security priorities inherent to the Department's strategic goals. The tepary bean (*Phaseolus acutifolius*), for example, is a highly heat- and drought-stress tolerant crop, native to the Southwestern United States and Mexico (Suskiw, 2016). Considerations of such environmental tolerances are becoming increasingly important and sought after in crops. However, there has been limited research on tepary bean genetics, nutritional value, and cooking characteristics, which are key aspects when considering its potential for broader global adoption as a drought-resistant food crop. To address this gap, USDA researchers developed the Tepary Diversity Panel (TDP), composed of 320 tepary bean samples representing all of the publicly available tepary germplasm, from collections such as the NPGS, in the Americas (Suskiw, 2016). Subsets of the TDP were evaluated for response and resistance to bean common mosaic virus, biological nitrogen fixation, root rot resistance, and heat tolerance. USDA researchers also found that tepary beans have half the fat and double the sucrose concentration when compared to common beans. Additionally, several tepary bean lines showed consistently shorter cooking times and higher water uptake than common beans (Suskiw, 2016). The diversity, seed composition, and cooking characteristics of the tepary beans will be used by USDA researchers and their partners to genetically improve a highly nutritious and drought-resistant crop, with the aim of meeting a strategic goal to ensure the food security of a growing population in the face of environmental challenges. This strategy of using a systems approach to address challenges—e.g. surveying the attributes of genetic variation within a crop broadly—combined with advanced breeding technologies can be incorporated into a wide variety of managed systems, from row crops to forest trees.

An alternative research avenue for meeting the environmental and production challenges of tomorrow is to develop varieties that can be grown in controlled settings indoors. Controlled-environment agriculture for specialty crops has many potential environmental benefits, including using substantially less water than field agriculture some industries report using 1% of the water of conventional farms (Wang, 2017), fewer pesticides, and high production volumes on small footprints (Despommier, 2010). Currently, much of the indoor growing industry in the U.S. focuses on high yield, fast turnaround, and high-market value crops such as herbs and microgreens. USDA researchers are working to expand this portfolio to include orchard crops, such as plums. By transforming European plum (*Prunus domestica*) with the Flowering Locus T1 (*FT1*) gene from *Populus trichocarpa* that encodes a mobile signal that induces flower transition, USDA breeders produced plants through a “FasTrack” process that lacked juvenility/dormancy requirements and which flowered to produce fruits within 1 to 10 months after transfer to soil (Srinivasan, Dardick, Callahan, & Scorza, 2012). Beyond having the potential to transform the indoor growing industry, these sorts of crops and innovations have wide-ranging applications: USDA is currently collaborating with National Aeronautics and Space Administration (NASA, https://www.nasa.gov/) to explore the possibility of growing plum trees and other crops for consumption during space exploration (Graham et al., 2015). This FasTrack approach may also have applications in reducing the breeding timeframes for some forest trees.

3 | RESPONSIBLE LANDSCAPE STEWARDSHIP OF FOREST SYSTEM LANDS

A major component of supporting strategic planning for the sustainable use of national forest system lands is promoting resistance in

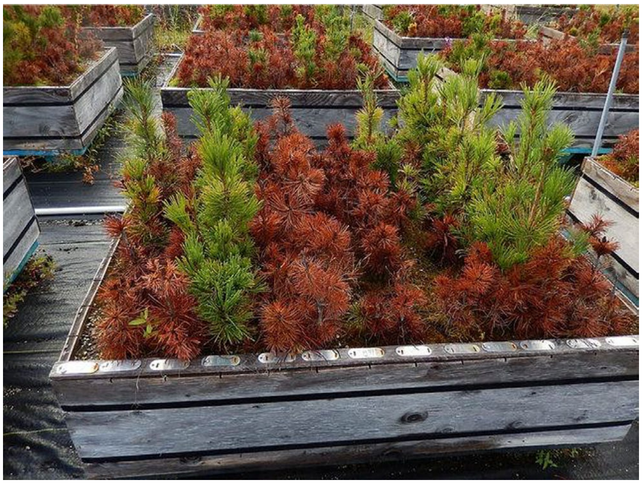

FIGURE 1 Whitebark pine trees with variable resistance to white pine blister rust. Photograph: Richard Sniezko

trees to pests and pathogens, which put relentless pressure on forests. The repercussions of these pests are not limited to the trees they impact: they threaten local economies, threaten clean water supplies, dramatically alter ecosystems, and limit carbon storage—impacts which reverberate across both rural and urban landscapes. Diseases and insects such as Chestnut blight, Dutch elm disease, white pine blister rust, and emerald ash borer, for example, have caused high mortality rates in U.S. forest ecosystems, urban forests, and forest plantations, resulting in ecological and economic impacts (Sniezko & Koch, 2017). To achieve pest and pathogen resistance in forest trees, it is important that the plans developed by the USDA to promote forest research and stewardship take into account the long generation times of the organisms themselves.

Forest tree breeding programs and technologies play a large role in ensuring the responsible stewardship and long-term management of healthy and productive forests. Forest tree breeding initiatives at the USDA Forest Service target the development of trees that are resistant to current threats and explore whether, with sufficient genetic variation, they might be resilient to environmental perturbations, such as novel pests and pathogens or climate change (Sniezko & Koch, 2017). Many of the breeding approaches and technologies applied in the cropping systems outlined earlier are applicable to forest tree breeding programs. The FasTrack approach used on early flowering plum, for example, could be adapted to help forest tree breeders assess the fecundity of genetic lines, or reduce generation times (i.e., time until fruit) in trees with lengthy cycles that might otherwise prove logistically difficult to incorporate into breeding programs. Similarly, the approach used with the tepary bean to identify genetic diversity and environmental tolerances is translatable to forest breeding programs seeking to develop, plant and manage (for whatever use-value) populations resilient and responsive to environmental change.

USDA tree breeders and scientists work with state, academic and private partners to breed populations of trees resistant to current pests, with enough genetic variation to grow, reproduce and endure for many years to come, and which are able to meet the challenges posed by unforeseen outbreaks in the future. This requirement for broad-spectrum and long-term resilience means that solutions relying solely on gene editing for resistance at a single locus may not be effective over forest tree-relevant timescales. This is due to the potentially rapid rate of pest and pathogen evolution, and the genetic diversity needed to maintain healthy forests may be difficult to obtain using current gene editing techniques alone (Sniezko & Koch, 2017). Rather, these powerful tools can be leveraged as components of a broader forest health strategy that also takes in to account the need to breed trees with broad-spectrum resistance. Such a hybrid strategy is currently being employed to great effect with the American chestnut (*Castanea dentata*) (Sniezko & Koch, 2017).

The breeding programs at the USDA for broad-scale multiple resistance are applied programs that aim to include a conservation and restoration aspect: trees bred for resistance are incorporated into planting initiatives to ensure long-term forest health and productivity. These initiatives include developing blister rust resistant white pine trees (*Pinus* spp.) over the last 50 years (Figure 1). This breeding program resulted in the implementation of a successful restoration program for whitebark pine (*Pinus albicaulis*) in the Northwestern forests of the U.S. (Sniezko, Smith, Liu, & Hamelin, 2014). An ongoing breeding program that could lead to restoration initiatives involves the development of a plan to save the native Hawaiian koa tree (*Acacia koa*) from wilt disease (Dudley et al., 2015). More recently, USDA scientists have begun working with the few surviving North American ash trees (*Fraxinus* spp.), with the aim to identify those unique plants with the ability to repel or kill emerald ash borer larvae (Koch, Carey, Mason, Poland, & Knight, 2015). Much of this research shows slow but incremental progress providing an excellent return on the investment to ensure forest survival.

4 | CONCLUSIONS

In the USDA OCS, coordinating and supporting science planning for the REE agencies and their partners revolves around an applied mission to "do right and feed everyone" by meeting strategic goals of productivity, technological advancement, and responsible stewardship. Healthy, resilient, and productive croplands, forests, and rangelands represent essential natural resources, and USDA research initiatives for both forests and crops recognize that profitable production leveraging these resources must increase to meet the needs of a growing population. At the same time, we must promote practices to improve the resiliency of these essential natural resources to ensure future production capacities. These desired outcomes require interdisciplinary and innovative research designed around a systems approach that incorporates multiple scales, methodologies, and a wide-range of stakeholder inputs.

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AUTHOR CONTRIBUTIONS

S.F. and P.Z wrote the manuscript while employed by the USDA Office of the Chief Scientist. Both authors reviewed the manuscript before submission.

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REFERENCES

Despommier, D. (2010). *The vertical farm: Feeding ourselves and the world in the 21st century*. New York, NY: Thomas Dunne Books.

Dudley, N. S., Jones, T. C., James, R. L., Sniezko, R. A., Cannon, P., & Borthakur, D. (2015). Applied disease screening and selection program for resistance to vascular wilt in Hawaiian *Acacia koa*. *Southern Forestry*, *77*(1), 65–73.

Graham, T., Scorza, R., Wheeler, R., Smith, B., Dardick, C., Dixit, A., … Stutte, G. (2015). Over-expression of *FT1* in plum (*Prunus domestica*) results in phenotypes compatible with spaceflight: A potential new candidate crop for bioregenerative life support systems. *Gravitational and Space Research*, *3*(1), 39–50.

Kean, S. (2010). Besting Johnny Appleseed. *Science*, *328*(5976), 301–303. https://doi.org/10.1126/science.328.5976.301

Khoury, C. K., Greene, S., Wiersema, J., Maxted, N., Jarvis, A., & Struik, P. C. (2013). An inventory of crop wild relatives of the United States. *Crop Science*, *53*(4), 1496–1508. https://doi.org/10.2135/cropsci2012.10.0585

Koch, J. L., Carey, D. W., Mason, M. E., Poland, T. M., & Knight, K. S. (2015). Intraspecific variation in *Fraxinus pennsylvanica* responses to emerald ash borer (*Agrilus planipennis*). *New Forestry*, *46*, 995–1011. https://doi.org/10.1007/s11056-015-9494-4

Larson, G., Piperno, D. R., Allaby, R. G., Purugganan, M. D., Andersson, L., Arroyo-Kalin, M., … Fuller, D. Q. (2014). Current perspectives and the future of domestication studies. *Proceedings of the National Academies of Sciences of the United States of America*, *111*(17), 6139–6146. https://doi.org/10.1073/pnas.1323964111

REE. (2012). Action Plans and Reports. Retrieved from https://www.ree.usda.gov/resources/action_reports

Sniezko, R. A., & Koch, J. (2017). Breeding trees resistant to insects and diseases: Putting theory into application. *Biological Invasions*, *12*, 3377–3400. https://doi.org/10.1007/s10530-017-1482-5

Sniezko, R. A., Smith, J., Liu, J.-J., & Hamelin, R. C. (2014). Genetic resistance to fusiform rust in southern pines and white pine blister rust in white pines: A contrasting tale of two rust pathosystems—Current status and future prospects. *Forests*, *5*(9), 2050–2083. https://doi.org/10.3390/f5092050

Srinivasan, C., Dardick, C., Callahan, A., & Scorza, R. (2012). Plum (*Prunus domestica*) trees transformed with poplar *FT1* result in altered architecture dormancy requirement, and continuous flowering. *PLoS ONE*, *7*(7), e40715. https://doi.org/10.1371/journal.pone.0040715

Suskiw, J. (2016). Feeding the future with pulse crops. *Agricultural Research*, *64*(2), 1–4.

USDA. (2017). USDA Strategic Goals: 2018–2022. Retrieved from https://www.usda.gov/our-agency/about-usda/strategic-goals

USDA. (2018). Secretary Perdue Issues USDA Statement on Plant Breeding Innovation. Retrieved from https://www.fas.usda.gov/newsroom/secretary-perdue-issues-usda-statement-plant-breeding-innovation-0

Wang, S. (2017). This high-tech vertical farm promises whole foods quality at Walmart prices. Bloomberg Businessweek.Retrieved from https://www.bloomberg.com/news/features/2017-09-06/this-high-tech-vertical-farm-promises-whole-foods-quality-at-walmart-prices

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