Trust, Perceptions of Risks and Benefits, and Normative Acceptance of Approaches for Restoring American Chestnut Trees

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This article examined trust, perceived risks and benefits, and normative acceptance associated with using breeding and genetic engineering (GE) to restore American chestnut (AC) trees. Questionnaires were completed by a random representative sample of the public in the United States ($n = 278$) and a purposive sample of forest interest groups (FIG) such as scientists and managers ($n = 195$). These concepts were examined in relation to breeding (breed the AC with chestnut trees from Asia) and GE (add the oxalate oxidase [OxO] gene from bread wheat to the AC) approaches for mitigating chestnut blight and restoring AC trees. The public sample considered adding the gene from bread wheat (GE) to be more beneficial and slightly more acceptable, but also slightly riskier, compared to the breeding approach. The FIGs viewed the breeding approach to be more acceptable, less risky, and more beneficial than the GE approach. The FIGs viewed both approaches as less risky, more beneficial, and more acceptable than did the public sample. Path analysis showed that: (i) perceived environmental benefits were the strongest predictors of normative acceptance of both approaches for the public sample, (ii) perceived environmental risks were the strongest predictors of acceptance of both approaches for the FIGs, (iii) human benefits and risks were mostly unrelated to acceptance, and (iv) trust in government agencies charged with managing forests was only weakly associated with benefits, risks, and acceptance. Implications of these results for both research and management were discussed.

KEY WORDS: Benefits; forest breeding; genetic engineering; norms; risks; trust

1. INTRODUCTION

Forests are inextricably linked to the history, land ethic, and public identity in the United States (U.S.), and conserving these natural resources is thought to be a national priority (Nash, 2014). Threats to forests (e.g., diseases, pests, climate change), however, are common and have environmental, social, and economic ramifications. Given the value of forests (e.g., timber, recreation), it is important to consider all strategies and tools that are available for mitigating these threats. Approaches that can be useful in these efforts (e.g., to enhance pest or disease resistance) include: (i) traditional forestry practices such as silviculture and conventional breeding, and (ii) biotechnologies such as genetic engineering (GE). GE involves using laboratory techniques to modify existing genes within an organism or insert genes from other organisms (NASEM, 2019). Assessing the utility of these approaches requires understanding their potential benefits and risks, and whether various groups (e.g., public, other interest groups) accept these

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approaches and trust government agencies to safely use and regulate them in the future.

The American chestnut (AC; *Castanea dentata*) was a keystone tree species in eastern U.S. forests that provided habitat and food for wildlife, and timber and food (chestnuts) for humans. Around the year 1900, a fungus (*Cryphonectria parasitica*) that causes chestnut blight (CB) was accidentally introduced into the U.S. from Asia and has since largely decimated this once abundant tree species (up to 99% reduction in the AC native range). This fungus enters through bark wounds and emits oxalic acid that restricts nutrient flow and prevents trees from growing and reproducing (NASEM, 2019; Powell, 2016; Steiner et al., 2017).

Scientists have attempted many strategies for increasing the AC's resistance to CB and restoring this tree species to its historic range. Two approaches that have received substantial attention are breeding and GE. Common breeding techniques include hybrid and backcross methods to incorporate resistance from the Chinese chestnut (*Castanea mollissima*) into the AC. The Chinese chestnut has moderate to good resistance to the CB fungus, and the objective of these breeding efforts is to impart resistance from this chestnut species while also capturing the growth, adaptability, and other characteristics of the AC (NASEM, 2019). Decades of research, however, has produced somewhat mixed results and breeding studies are still ongoing that also include other chestnut species such as the Japanese chestnut (*Castanea crenata*; NASEM, 2019; Steiner et al., 2017). In the context of GE in AC trees, one of the most successful approaches involves inserting a gene from bread wheat that encodes the oxalate oxidase (OxO) enzyme that breaks down oxalic acid (NASEM, 2019; Powell, 2016; Steiner et al., 2017; Zhang et al., 2013). Given the success of field trials showing that this GE approach yields high resistance to CB in AC trees, researchers are currently seeking regulatory approval for releasing these GE trees at a wider scale. GE and breeding in trees can provide benefits such as reducing the need for herbicides and pesticides, improving forest health, and increasing tree growth, harvest rates, and profitability (Kempken & Jung, 2010). However, concerns include possible changes or reductions in the genetic diversity of native trees (e.g., through gene flow), long-term impacts on biodiversity that are currently unknown, and the role of humans in manipulating nature (NASEM, 2019).

The practical utility of approaches such as GE partially depends on societal acceptance (Frewer et al., 2013). Many studies have examined societal acceptance of breeding and GE, especially in the context of agriculture and food. Although chestnuts are occasionally consumed by some people, more popular examples of breeding and GE in agriculture and food include corn, soy, and potato. In the context of GE in agriculture and food, research has shown that although people can have extremely negative and positive views, public acceptance is, on average, generally negative (especially in Europe), many people are concerned about potential health hazards, and public knowledge tends to be quite low (NASEM, 2016; Scott, Inbar, Wirz, Brossard, & Rozin, 2018). The public also tends to be less accepting of GE than conventional breeding approaches (NASEM, 2016, 2019).

By comparison, only a few studies have examined societal responses to using breeding and GE in trees to address forest health threats such as CB (NASEM, 2019), with results mostly showing that the public can view the use of these approaches in trees differently (e.g., more positively; Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017a, 2017b; Petit, Needham, & Howe, 2021) than their use in more common food and agriculture (e.g., more negatively, perceive risks to humans; NASEM, 2016). Jepson and Arakelyan (2017a, 2017b), for example, found that some breeding and GE approaches were acceptable for addressing ash dieback in the United Kingdom (U.K.). Hajjar and Kozak (2015) found that more than 50% of residents in Western Canada accepted planting trees with traits introduced through breeding and GE to address forest threats from climate change. More recently, 90% of residents in this same region supported breeding local tree species, but only 25% supported reforestation with GE technologies to adapt to climate change (Peterson St-Laurent, Hagerman, & Kozak, 2018). Given the numerous benefits and values that forests provide, it is important to understand more about the acceptance of both breeding and GE as tools in forest conservation, as well as other factors related to this acceptance. This article, therefore, examined relationships among trust, perceived risks and benefits, and acceptance associated with two approaches that have received substantial attention for mitigating CB and restoring AC trees (breeding with chestnut trees from Asia, using GE to add a gene from bread wheat).

2. CONCEPTUAL FOUNDATION

2.1. Norms

Acceptance of these approaches is related to the concept of norms, which are standards that people use for evaluating conditions, activities, or management actions as unacceptable or acceptable; norms are what people believe should or should not be allowed in a given context (Vaske & Whittaker, 2004). Personal norms can be aggregated to assess broader social norms (Vaske & Whittaker, 2004). Assessing group differences in normative acceptance of natural resource issues has been a prominent line of research, especially between the public and other interest groups (e.g., scientists, agencies; Vaske & Whittaker, 2004). Studies have shown, for example, that nongovernmental organizations (NGOs), indigenous groups, and the general public can be less accepting of some issues, such as breeding or GE in forestry, compared to other groups such as scientists and industry representatives (Hajjar, McGuigan, Moshofsky, & Kozak, 2014; Jepson & Arakelyan, 2017b; Nilausen, Gélinas, & Bull, 2016).

Normative acceptance of using approaches such as breeding and GE in natural resource management has been investigated for issues including agriculture (Shew et al., 2016), nuclear energy (De Groot, Steg, & Poortinga, 2013; Visschers, Keller, & Siegrist, 2011), forest insect disturbances (McFarlane & Witson, 2008), and plantation forestry (Williams, 2014). Compared to research on acceptance of breeding and GE in agriculture and food (NASEM, 2016), acceptance of using these approaches in forestry has received much less attention (NASEM, 2019). A small number of studies have, however, focused on acceptance of using breeding and GE to improve the resilience of forests to climate change and disease, and to increase timber and biofuel production (Hajjar & Kozak, 2015; Hajjar et al., 2014; Jepson & Arakelyan, 2017a, 2017b; Kazana et al., 2016; Nonić, Radojević, Milovanović, Perović, & Šijačić-Nikolić, 2015; Peterson St-Laurent et al., 2018; Tsourgiannis, Kazana, & Iakovoglou, 2016). This research has shown more acceptance for using these approaches to address specific forest health threats (e.g., diseases, pests) than for more general issues that transcend forests (e.g., climate change; NASEM, 2019). In addition, studies have shown that breeding (especially with native or local species) can be more acceptable than using GE in forestry (Hajjar & Kozak, 2015; Hajjar et al., 2014; Jepson & Arakelyan, 2017a, 2017b; Peterson St-Laurent et al., 2018). Most of these studies, however, have been conducted in Canada and Europe. Little research has examined acceptance of using breeding and GE in tree species in the U.S. such as the AC, and this warrants attention given that both of these tools are being investigated for their potential to mitigate CB and other forest threats (e.g., diseases, pests, climate change).

2.2. Perceived Risks

Perceived risks can be negatively associated with normative acceptance (Siegrist, 2000; Vaske & Lyon, 2011). Compared to objective risk assessments (i.e., actual probabilities and consequences of hazards), perceived risks are subjective evaluations of hazards (Sigrist & Arvai, 2020; Slovic, 2010). Risk targets can include risks to oneself (personal risk), society (general risk), or other entities (e.g., forests, environment). These distinctions are important, as people often rate personal risks lower than risks to other people or objects, which involves a degree of risk denial (Sjöberg, 1998). Group differences in risk perceptions can also exist where members of the public rate risks more subjectively than do more specific interest groups (e.g., scientists, agencies) who often form assessments based on more objective probabilities and consequences of hazards (Slovic, 2010). As a result, these interest groups can perceive some issues as less risky (i.e., safer) compared to members of the general public (Savadori et al., 2004; Sjöberg, 1998).

Risk perceptions have been investigated in relation to natural resource issues such as wildlife diseases (Needham & Vaske, 2008; Needham, Vaske, & Petit, 2017), forest insect disturbances (McFarlane, Parkins, & Watson, 2012), and nuclear energy and waste (Visschers et al., 2011; Whitfield, Rosa, Dan, & Dietz, 2009). In the context of breeding and GE in forestry, researchers in the U.K. investigated solutions for addressing ash dieback and found that although the public was generally supportive of some approaches, they were concerned about risks from tampering with nature (Jepson & Arakelyan, 2017b). Tsourgiannis et al. (2016) found that concerns about human health and environmental impacts discouraged some people from supporting GE-based forest products in Greece. Kazana et al. (2015) examined perceived risks of GE in plantation forestry and found that biodiversity impacts from potential unintended gene flow into wild forests were concerns for respondents.

2.3. Perceived Benefits

Perceived benefits can be positively related to normative acceptance. These benefits are subjective evaluations that a particular behavior, entity, or technology will yield positive outcomes (De Groot et al., 2013). Similar to risk perceptions, perceived benefits can be assessed in relation to different targets (e.g., self, society, environment). These benefits have been examined in many contexts including nuclear energy (Visschers et al., 2011), medicine (James, Campbell, & Hudson, 2002), and conservation (Bottrill, Mills, Pressey, Game, & Groves, 2012). Most research on perceived benefits of breeding and GE has focused on agriculture and food where researchers have found positive relationships between benefits and normative acceptance (NASEM, 2016; Scott et al., 2018; Siegrist, 2000). In the context of forestry, acceptance of approaches such as breeding and GE has been associated with perceived benefits including improved consumer choice (Tsourgiannis et al., 2016), reduced pesticide and herbicide inputs (Kazana et al., 2015), increased tree growth (Kazana et al., 2016), and reduced harvest pressure on wild forests (Nilausen et al., 2016). Research examining public responses to using breeding and GE to address ash dieback in the U.K. found that people viewed these approaches more favorably when used for addressing tangible issues (e.g., tree diseases), suggesting that perceived benefits may correlate with acceptance of using these approaches in forestry (Jepson & Arakelyan, 2017a, 2017b). Perceptions of benefits, however, are highly contextual and can vary according to factors such as forest ownership type and scale (e.g., large plantation vs. small private forests), and the intention for employing the technologies (e.g., timber production vs. forest restoration; Strauss et al., 2017).

2.4. Trust

Social trust in institutions and managing agencies can be a related to benefits, risks, and normative acceptance (Connor & Siegrist, 2010). This trust is defined as the willingness to rely on individuals or organizations responsible for making decisions or taking actions affecting public health, safety, and wellbeing (Siegrist, Cvetkovich, & Roth, 2000; Stern & Coleman, 2015). The public may trust external sources (e.g., scientists, agencies) because of their expertise in assessing hazards (Siegrist, 2000). Trust has been examined in natural resource contexts, including nuclear power (Xiao, Liu, & Feldman, 2017), pesticides (Siegrist et al., 2000), wildlife diseases (Needham & Vaske, 2008), and forestry issues such as insect outbreaks (McFarlane et al., 2012) and using prescribed burning and mechanical thinning in response to risks from wildfire (Vaske, Absher, & Bright, 2007).

Trust in officials charged with managing hazards has generally been associated with lower perceived risks, greater benefits, and more acceptance (Connor & Siegrist, 2010; Perry, Needham, & Cramer, 2017; Siegrist, 2000; Stern & Coleman, 2015; Vaske et al., 2007; Xiao et al., 2017). These relationships have been examined in the context of forest conservation in general and the use of breeding and GE in forestry in particular. Research conducted mostly in Europe and Canada has demonstrated that trust is often negatively associated with perceived risks of using these approaches in forestry, and positively associated with both perceived benefits and acceptance of these approaches (Connor & Siegrist, 2010; Hajjar & Kozak, 2015; Jepson & Arakelyan, 2017a, 2017b; Neumann, Krogman, & Thomas, 2007). Additional research on these relationships is warranted in the context of this study given the potential utility of both breeding and GE for mitigating CB and restoring AC trees (NASEM, 2019; Powell, 2016; Steiner et al., 2017).

2.5. Hypotheses

This article built on this literature by examining relationships among trust, perceived risks and benefits, and normative acceptance associated with two approaches that have received substantial attention for addressing this topic (breed AC trees with chestnut trees from Asia, use GE to add a gene from bread wheat). Consistent with the theoretical model in Siegrist (2000) and the literature discussed above (e.g., Vaske et al., 2007; Visschers et al., 2011; Xiao et al., 2017), Fig. 1 shows the proposed relationships among these concepts. Five hypotheses were tested:

H_1: Perceived risks (to humans, to the environment) of using breeding and GE to mitigate CB and restore AC trees will be negatively related to normative acceptance of these approaches.

H_2: Perceived benefits (to humans, to the environment) of using breeding and GE to mitigate CB and restore AC trees will be positively related to normative acceptance of these approaches.

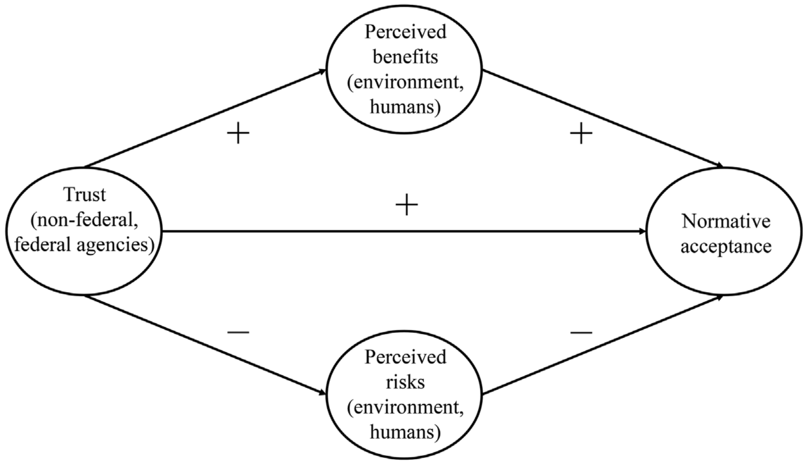

Fig 1. Conceptual model representing the hypothesized relationships among trust in governmental agencies, perceived risks, perceived benefits, and normative acceptance based on the theoretical model in Siegrist (2000).
+: a positive relationship between concepts, −: a negative or inverse relationship between concepts.

H_3: Trust in agencies (federal, nonfederal) will be negatively related to perceived risks (to humans, to the environment) of using breeding and GE to mitigate CB and restore AC trees.

H_4: Trust in agencies (federal, nonfederal) will be positively related to perceived benefits (to humans, to the environment) of using breeding and GE to mitigate CB and restore AC trees.

H_5: Trust in agencies (federal, nonfederal) will be positively related to normative acceptance of using breeding and GE to mitigate CB and restore AC trees.

This article also examined whether these relationships among concepts differed between samples of the general public and forest interest groups (FIGs [scientists, agencies, businesses, NGOs]).

3. METHODS

3.1. Data Collection

Data were from a mixed-mode survey of the U.S. general public and FIGs (university scientists, government agency representatives, businesses, and NGOs involved in forest issues) from January to June 2015. Sampling for the public was stratified by residents: (i) within the historic native range of the AC (i.e., chestnut counties), and (ii) in the rest of the contiguous U.S. (i.e., nonchestnut counties). Residents were sampled randomly and proportionally to county-level populations. The FIGs consisted of a purposive sample selected based on expertise and involvement in forest issues. Six contacts were used for increasing response rates and sample sizes, as follows: (i) postcard mailing with an option to complete the questionnaire online, (ii) full mailing (questionnaire, letter, postage-paid reply envelope), (iii) postcard reminder with an option to complete the questionnaire online, (iv) telephone call to encourage participation, (v) second full mailing, and (vi) final full mailing. This number of contacts is high for survey research (three or four contacts are more common; Vaske, 2019) and funding limitations and constraints imposed by the university human subjects/institutional review board prohibited any additional contacts.

In total, 473 completed questionnaires were received (15% response rate). Completions for each stratum included: (i) 142 from the public in chestnut counties (12% response rate), (ii) 136 from the public in nonchestnut counties (11% response rate), and (iii) 195 from FIGs (33% response rate). A telephone nonresponse bias check of nonrespondents from the public samples ($n = 107$) was conducted to determine if responses differed between respondents and nonrespondents, but no substantive differences were found. To address sample representativeness, demographic characteristics of respondents from the public samples were compared to U.S. census data to investigate any potential differences between the public samples and the larger population. There were slight differences in age (samples were slightly older) and education (samples were slightly more educated), so the data were weighted by these characteristics to improve public sample representativeness to the population. Few substantive differences were found between respondents from counties within the historic native range of the AC and those from the other counties, so responses from these two samples were aggregated into a single public sample.

Table I. Verbatim Wording for the Two Scenarios (Breeding, GE) Including Information About CB (CB Wording was Identical for Both Scenarios)

Scenario Number	Scenario Wording	Type of Approach
1–2	*Chestnut blight* has killed more than 99% of adult American chestnut trees within their native range. This disease is caused by a fungus that was accidentally introduced to North America around the year 1900.	n/a
1	*Breeding American chestnut trees with nonnative chestnut trees from Asia* is being used to help trees resist chestnut blight and restore American chestnut forests. This breeding involves selecting one American chestnut tree and one Asian chestnut tree, and then applying the male pollen from one tree to the female flower of the other tree. The resulting offspring contain thousands of genes from each chestnut species. Although many trees used in plantation forestry and for producing fruit and nut crops have been developed using breeding, there are concerns that Asian chestnut genes could unintentionally spread into nearby forests by seed, pollen, or other means.	Breeding
2	*Adding a gene from wheat (e.g., bread wheat) to American chestnut trees* is being used to help trees resist chestnut blight and restore American chestnut forests. This involves using modern laboratory approaches to add a new gene from wheat (e.g., bread wheat) to chestnut trees. This new gene breaks down a chemical produced by the chestnut blight fungus that damages the chestnut trees. The genetically modified trees (also known as genetically engineered trees) contain thousands of genes from the original tree, plus this one new gene from wheat. Although this can add a desirable trait to trees, there are concerns that the added gene could unintentionally spread into nearby forests by seed, pollen, or other means.	GE

Responses across the FIGs were also aggregated because they were not necessarily statistically representative of each of the four groups (scientists, agencies, businesses, NGOs) and the number of respondents in each group was small (n = 35–61 per group). In addition, only one (4%) of the 24 variables used in this article's analyses showed a statistically significant difference in responses among these four groups, with businesses having less trust than the other groups in the U.S. Forest Service (Kruskal–Wallis $H = 12.36$, $p = 0.006$; eta [η] effect size $= 0.39$). Responses to the other 23 variables (96%) were statistically equal and showed no significant differences among the four groups (H = 0.11–5.89, p = 0.117-0.990, η = 0.06–0.27, mean [M] $\eta = 0.16$).

3.2. Analysis Variables

Scenarios were embedded in the questionnaire to measure cognitions in response to the use of breeding (breed the AC with nonnative chestnut trees from Asia) and GE (add the oxalate oxidase [OxO] gene from bread wheat to the AC) to mitigate CB and restore AC trees (Table I). These scenarios were subjected to pretesting and expert feedback during focus groups. In both scenarios, respondents were first presented with a factual description: "CB has killed more than 99% of adult AC trees within their native range. This disease is caused by a fungus that was accidentally introduced to North America around the year 1900." The scenarios then described potential approaches for helping trees resist CB and restore AC forests. One scenario was "breeding AC trees with nonnative chestnut trees from Asia." Another scenario was "adding a gene from wheat (e.g., bread wheat) to AC trees."

Normative acceptance of each scenario was measured on two separate five-point semantic differential scales (1 "unacceptable" to 5 "acceptable," 1 "should not allow" to 5 "should allow"). These scales are consistent with previous research measuring norms (Ceurvorst & Needham, 2012; Vaske & Whittaker, 2004). Perceived risks were measured on nine-point scales of 0 "no risk" to 8 "high risk" in response to asking "to what extent do you think this scenario would pose a risk to each of the following": (i) "trees/forests," (ii) "the broader environment," (iii) "yourself," and (iv) "other humans or society in general." Perceived benefits were measured by asking "to what extent do you think this scenario would benefit each of the following" (same four targets listed above) on nine-point scales of 0 "no benefit" to 8 "highly benefit." Trust was not measured in direct response to the scenarios. Respondents were asked "how must trust do you have in each of the following to positively contribute to the management/stewardship of forests:" (i) "local governmental agencies (city, county, town);" (ii) "state governmental agencies;" (iii) "U.S. Forest Service" (USFS); and (iv) "U.S. Bureau of Land Management" (BLM) on nine-point scales of 0 "no trust" to 8 "high trust." [1]

4. RESULTS

Cronbach's alpha was used for measuring reliability of the multiple questionnaire items measuring each concept to justify computing mean composite indices (trust in federal agencies [USFS, BLM]; trust in nonfederal agencies [local, state]; risks to humans [yourself, other humans or society in general]; risks to the environment [trees/forests, the broader environment]; benefits to humans [yourself, other humans or society in general]; benefits to the environment [trees/forests, the broader environment]; normative acceptance of each approach [should not allow to should allow, unacceptable to acceptable]). All of the Cronbach alpha coefficients for each scenario (breeding, GE) for the public and FIG samples ranged from 0.89 to 0.99 for acceptance, risks, and benefits (Table II). The alpha coefficients also ranged from 0.79 to 0.87 for trust in federal and nonfederal agencies. These coefficients all exceeded the standard of ≥ 0.65 suggested by Vaske (2019) and all of the item-total correlations ranged from 0.65 to 0.99, indicating consistency among variables measuring each concept and justifying computing composite indices for each concept.

From a between-groups perspective, the public sample was, on average, significantly less accepting of both the breeding and GE approaches than were the FIGs (Table III). The point-biserial correlation (r_{pb}) effect size for the difference between groups regarding the breeding scenario was 0.49 and guidelines from Vaske (2019) for interpreting effect sizes suggest that the strength of this difference was "substantial." The difference between groups for the GE scenario was between "minimal" and "typical" ($r_{pb} = 0.17$). The public sample also viewed both approaches as significantly riskier to the environment and to humans than did the FIGs. The effect sizes were "substantial" ($r_{pb} = 0.35$ and 0.36) for the breeding approach and "minimal" to "typical" ($r_{pb} =$ 0.14 and 0.25) for the GE approach. The FIG sample viewed both approaches as more beneficial for the environment and for humans than did the public sample, but these differences between groups were only significant for the breeding scenario with "substantial" effect sizes ($r_{pb} = 0.35$ and 0.36). Differences between groups in perceived benefits from the GE scenario were not statistically significant. Both the public and FIG samples had moderate trust in the federal agencies and these groups did not differ statistically. The FIG sample had, however, significantly more trust in nonfederal agencies than did the public sample and the effect size was "typical" ($r_{pb} = 0.24$). Compared to the public sample, the FIG sample was more trusting of nonfederal agencies and viewed these scenarios (breeding or GE) as less risky, more beneficial, and more acceptable.

From a within-groups perspective, the public sample considered, on average, the GE scenario to be more beneficial and slightly more acceptable, but also slightly riskier, compared to the breeding approach (Table III). These differences between approaches were not statistically significant for acceptance and risks, but they were for benefits and the Cohen's d effect sizes of 0.37 for benefits were "minimum" to "typical" (Vaske, 2019). The public sample perceived slight benefits to humans from both the breeding and GE approaches, slight benefits to the environment from breeding and moderate benefits to the environment from GE, slight risks to humans from both scenarios, and moderate risks to the environment from each approach. The public sample was divided in acceptance of each approach, but GE (35% unacceptable/should not allow, 29% neutral, 36% acceptable/should allow) was slightly more acceptable than breeding (42% unacceptable/should not allow, 27% neutral, 31% acceptable/should allow).

Conversely, the FIGs viewed, on average, the breeding scenario as more acceptable, less risky, and more beneficial than the GE approach (Table III).

[1] Single exploratory factor analyses (EFA) of all variables measured in response to each scenario (breeding, GE) plus the trust variables, with the number of factors fixed to one and without rotation, showed that the single factors all explained less than 50% of the variance for each sample (public, FIGs). This approach, coupled with the high reliabilities for each concept, are consistent with Harman single factor tests (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) and suggest that common method variance or bias was generally absent.

Table II. Variables and Scale Reliabilities for the Public (First Value) and FIG (Second Value) Samples (Public $n = 278$, FIG $n = 195$)

	Mean (M)	Standard Deviation (SD)	Item Total Correlation	Cronbach Alpha
Scenario 1 – Breeding with nonnative chestnut trees from Asia				
Normative acceptance [a]				0.97, 0.98
Should not allow: Should allow	2.57, 4.14	1.19, 1.12	0.94, 0.96	
Unacceptable: Acceptable	2.63, 4.14	1.22, 1.08	0.94, 0.96	
Perceived risks to humans [b]				0.99, 0.99
Yourself	2.77, 1.18	2.29, 1.77	0.98, 0.99	
Other humans or society in general	2.91, 1.27	2.24, 1.79	0.98, 0.99	
Perceived risks to the environment [b]				0.99, 0.98
Trees/forests	4.07, 2.41	2.31, 2.25	0.98, 0.97	
The broader environment	4.04, 2.23	2.34, 2.25	0.98, 0.97	
Perceived benefits to humans [c]				0.95, 0.91
Yourself	1.92, 3.16	1.65, 2.43	0.91, 0.83	
Other humans or society in general	2.07, 3.78	1.71, 2.38	0.91, 0.83	
Perceived benefits to the environment [c]				0.96, 0.98
Trees/forests	2.91, 4.66	2.33, 2.38	0.92, 0.95	
The broader environment	2.69, 4.47	2.23, 2.34	0.92, 0.95	
Scenario 2 – Using GE to add a gene from bread wheat (OxO)				
Normative acceptance [a]				0.97, 0.98
Should not allow: Should allow	2.79, 3.41	1.39, 1.28	0.95, 0.95	
Unacceptable: Acceptable	2.78, 3.43	1.38, 1.29	0.95, 0.95	
Perceived risks to humans [b]				0.98, 0.94
Yourself	3.10, 1.79	2.36, 2.05	0.96, 0.89	
Other humans or society in general	3.16, 2.19	2.31, 2.19	0.96, 0.89	
Perceived risks to the environment [b]				0.99, 0.99
Trees/forests	4.16, 3.47	2.17, 2.20	0.97, 0.97	
The broader environment	4.11, 3.50	2.24, 2.30	0.97, 0.97	
Perceived benefits to humans [c]				0.96, 0.89
Yourself	2.39, 2.40	2.04, 2.30	0.92, 0.80	
Other humans or society in general	2.72, 3.05	2.16, 2.38	0.92, 0.80	
Perceived benefits to the environment [c]				0.97, 0.98
Trees/forests	3.54, 4.17	2.39, 2.41	0.93, 0.95	
The broader environment	3.41, 3.85	2.34, 2.33	0.93, 0.95	
Trust in federal government agencies [d]				0.85, 0.87
U.S. Forest Service	5.41, 5.44	1.91, 2.01	0.74, 0.76	
U.S. Bureau of Land Management	4.92, 4.56	2.00, 2.05	0.74, 0.76	
Trust in nonfederal government agencies [d]				0.84, 0.79
Local governmental agencies (city, county, town)	3.35, 3.61	1.96, 1.93	0.73, 0.65	
State governmental agencies	3.13, 4.79	2.15, 1.84	0.73, 0.65	

[a]Measured on five-point semantic differential scales (e.g., 1 “should not allow” to 5 “should allow”).
[b]Measured on nine-point scales from 0 “no risk” to 8 “high risk.”
[c]Measured on nine-point scales from 0 “no benefit” to 8 “highly benefit.”
[d]Measured on nine-point scales from 0 “no trust” to 8 “high trust.”

The differences between approaches were significant with “minimal” to “typical” effect sizes ($d = 0.32$–0.48; Vaske, 2019) for all but one concept, as only perceived environmental benefits did not statistically differ between scenarios. The FIG sample perceived moderate benefits to humans from the breeding approach, slight benefits to humans from the GE scenario, moderate benefits to the environment from both approaches, no risks to humans from the breeding scenario, slight risks to humans from the GE approach, slight risks to the environment from the breeding scenario, and moderate risks to the environment from the GE approach. The FIGs considered breeding to be much more acceptable (13% unacceptable/should not allow, 5% neutral, 82% acceptable/should allow) than the GE approach (25%

Table III. Sample (Public vs. FIGs [Between-Groups]) and Scenario (1 vs. 2 [Within-Groups]) Comparisons (Public $n = 278$, FIG $n = 195$)

	Between-Groups Analysis				
	Public*M* (*SD*)	FIGs*M* (*SD*)	Independent Samples*t* value	*p* Value	Effect Size (r_{pb})
Normative acceptance [a]					
Scenario 1 – Breeding with nonnative chestnut trees from Asia	2.76 (1.29)	4.14 (1.09)	8.05	< 0.001	0.49
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	2.93 (1.43)	3.42 (1.27)	2.45	0.015	0.17
Within-groups analysis: Paired samples *t* value	1.84	4.04			
p value	0.069	< 0.001			
Effect size (Cohen's *d*)	0.14	0.48			
Perceived risks to humans [b]					
Scenario 1 – Breeding with nonnative chestnut trees from Asia	2.81 (2.24)	1.22 (1.78)	5.55	< 0.001	0.36
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	3.13 (2.31)	1.99 (2.06)	3.49	0.001	0.25
Within-groups analysis: Paired samples *t* value	1.62	2.87			
p value	0.108	0.005			
Effect size (Cohen's *d*)	0.14	0.35			
Perceived risks to the environment [c]					
Scenario 1 – Breeding with nonnative chestnut trees from Asia	4.05 (2.31)	2.32 (2.23)	5.26	< 0.001	0.35
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	4.14 (2.19)	3.49 (2.23)	2.01	0.046	0.14
Within-groups analysis: Paired samples *t* value	0.33	3.86			
p value	0.741	< 0.001			
Effect size (Cohen's *d*)	0.04	0.46			
Perceived benefits to humans [d]					
Scenario 1 – Breeding with nonnative chestnut trees from Asia	2.00 (1.65)	3.47 (2.30)	4.94	< 0.001	0.35
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	2.56 (2.06)	2.72 (2.22)	0.53	0.598	0.04
Within-groups analysis: Paired samples *t* value	4.04	2.51			
p value	< 0.001	0.014			
Effect size (Cohen's *d*)	0.37	0.32			
Perceived benefits to the environment [e]					
Scenario 1 – Breeding with nonnative chestnut trees from Asia	2.80 (2.24)	4.56 (2.33)	5.35	< 0.001	0.36
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	3.47 (2.33)	4.01 (2.34)	1.56	0.121	0.11
Within-groups analysis: Paired samples *t* value	4.07	1.72			
p value	< 0.001	0.090			
Effect size (Cohen's *d*)	0.37	0.21			
Trust in federal government agencies [f]	5.18 (1.82)	5.00 (1.91)	0.72	0.471	0.05
Trust in nonfederal government agencies [g]	3.29 (1.93)	4.20 (1.71)	3.57	< 0.001	0.24

[a]Measured on two five-point semantic differential scales from 1 "should not allow" to 5 "should allow" and 1 "unacceptable" to 5 "acceptable."
[b]Measured on two nine-point scales (yourself, other humans or society in general) from 0 "no risk" to 8 "high risk."
[c]Measured on two nine-point scales (trees / forests, the broader environment) from 0 "no risk" to 8 "high risk."
[d]Measured on two nine-point scales (yourself, other humans or society in general) from 0 "no benefit" to 8 "highly benefit."
[e]Measured on two nine-point scales (trees / forests, the broader environment) from 0 "no benefit" to 8 "highly benefit."
[f]Measured on two nine-point scales (U.S. Forest Service, U.S. Bureau of Land Management) from 0 "no trust" to 8 "high trust."
[g]Measured on two nine-point scales (local governmental agencies, state governmental agencies) from 0 "no trust" to 8 "high trust."

unacceptable/should not allow, 18% neutral, 57% acceptable/should allow).

Bivariate correlations (*r*) for the public sample showed that benefits (to humans, the environment) and trust (federal, nonfederal agencies) were significantly and positively related to normative acceptance of each approach (breeding, GE), whereas risks (to humans, the environment) were negatively related to this acceptance (Table IV). The FIG sample showed the same relationships except for trust, which was not significantly correlated with acceptance of each approach. For the public sample, there were significant negative correlations between trust in nonfederal agencies and perceived risks to both humans and the environment for the breeding approach (Table V). Correlations for this sample also showed that trust in both federal and nonfederal agencies was significantly and positively correlated with

Table IV. Bivariate Pearson's Correlations for Predictors (Risks, Benefits, Trust) of Normative Acceptance for the Public (First Value) and FIG (Second Value) Samples (Public $n = 278$, FIG $n = 195$)

	Normative Acceptance[a]
Scenario 1 – Breeding with nonnative chestnut trees from Asia	
Perceived risks to humans	-0.38^{***}, -0.72^{***}
Perceived risks to the environment	-0.44^{***}, -0.83^{***}
Perceived benefits to humans	0.64^{***}, 0.60^{***}
Perceived benefits to the environment	0.84^{***}, 0.77^{***}
Trust in federal government agencies	0.40^{***}, 0.17
Trust in nonfederal government agencies	0.33^{***}, 0.16
Scenario 2 – Using GE to add a gene from bread wheat (OxO)	
Perceived risks to humans	-0.40^{***}, -0.53^{***}
Perceived risks to the environment	-0.45^{***}, -0.75^{***}
Perceived benefits to humans	0.68^{***}, 0.60^{***}
Perceived benefits to the environment	0.80^{***}, 0.76^{***}
Trust in federal government agencies	0.48^{***}, 0.05
Trust in nonfederal government agencies	0.43^{***}, 0.04

[a] $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Values (r) without an asterisk were not statistically significant ($p > 0.05$).

perceived benefits to humans and the environment for both approaches (breeding, GE). For the FIGs, however, only trust in federal agencies was significantly and positively correlated with these benefits for the breeding scenario.

Multivariate path analysis using linear regression showed that perceived risks to the environment were negatively related to normative acceptance of both the breeding (Fig. 2) and GE (Fig. 3) approaches after controlling for the other variables, but this was only statistically significant for the FIG sample and not the public sample. The FIGs who perceived that the use of these approaches was risky for the environment were less likely to accept these approaches. Perceived risks to humans, however, were not significantly associated with acceptance of either approach for each sample group. Perceived benefits to the environment were significantly and positively associated with acceptance of both approaches for the public and FIG samples. Those who perceived environmental benefits of the breeding and GE approaches were more likely to accept these approaches. Perceived human benefits were not significantly associated with acceptance of the breeding scenario for each sample group, but these benefits were significantly and positively related to acceptance of the GE scenario for only the public sample and not the FIG sample. Trust was not significantly associated with acceptance of the breeding approach for each group, but trust in both federal and nonfederal agencies was significantly and positively related to acceptance of the GE approach for only the public sample and not the FIG sample. Perceived benefits to the environment were the strongest predictors of acceptance of both the breeding and GE approaches for the public sample, whereas perceived risks to the environment were the strongest predictors of acceptance of both approaches for the FIG sample. The overall variance explained in normative acceptance of these approaches ranged from 74% to 79%.

There were significant positive correlations between trust in federal agencies and trust in nonfederal agencies for both the public and FIG samples. The public sample's trust in federal agencies was positively and significantly associated with perceived environmental and human benefits of both the breeding (Fig. 2) and GE (Fig. 3) approaches. For only the breeding scenario, there was also a significant negative relationship between the public sample's trust in nonfederal agencies and perceived risks to humans. There were no other statistically significant relationships between trust and both risks and benefits for the public sample. There were also no significant relationships at all between trust and both risks and benefits for the FIGs. Only 1–4% of the variance in risks and 1–16% of the variance in benefits were explained by trust.

5. DISCUSSION

These findings showed that compared to the public sample, the FIG sample viewed both the breeding and GE approaches for mitigating CB and restoring the AC as more acceptable, less risky, and more

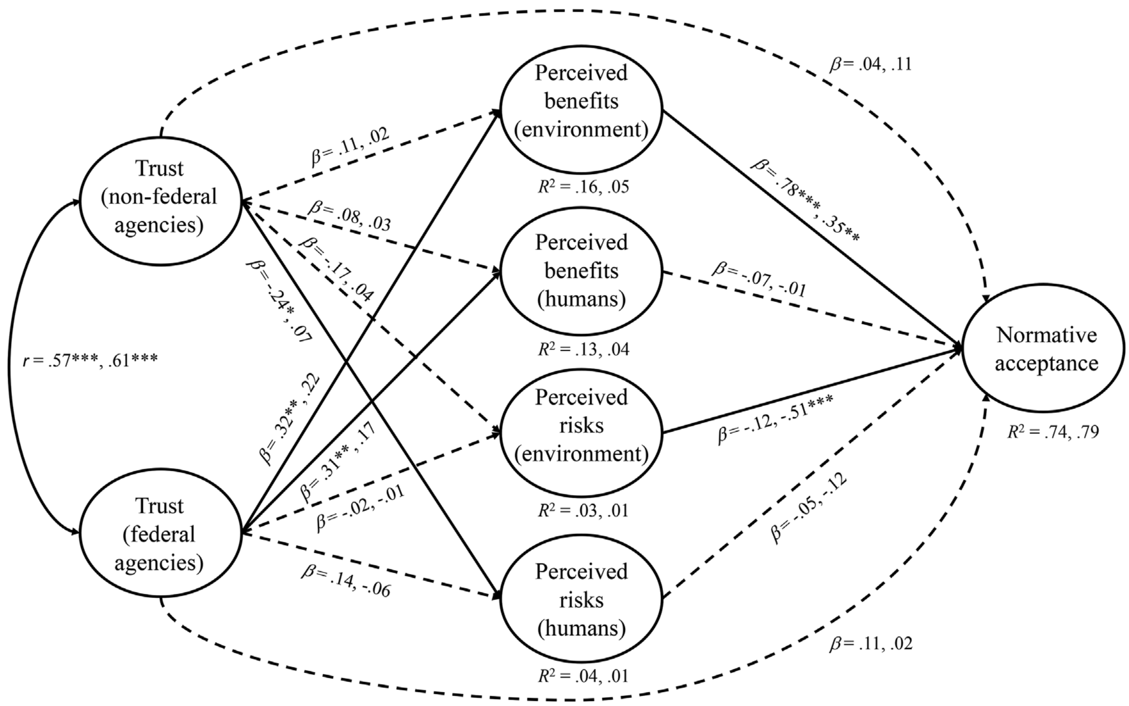

Fig 2. Multivariate path analysis predicting normative acceptance of using breeding with nonnative chestnut trees from Asia (scenario 1) for the public (first value) and FIG (second value) samples. Public $n = 278$, FIG $n = 195$. β = standardized betas, r = Pearson's correlations, R^2 = variances explained. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Values (β, r) without an asterisk were not statistically significant ($p > 0.05$). Dashed paths are those that were not statistically significant ($p > 0.05$) for both the public and FIG samples. Variance inflation factors (VIF) were only 1.49–3.34 (public sample) and 1.61–3.91 (FIG sample), suggesting minimal multicollinearity.

beneficial. For example, 82% of the FIG sample rated the breeding scenario as acceptable or should be allowed and 57% of these groups rated the GE approach this way. The public sample was less accepting and more divided over both the breeding (31% acceptable or should allow vs. 42% unacceptable or should not allow) and GE approaches (36% acceptable or should allow vs. 35% unacceptable or should not allow). This finding is consistent with research showing that special interest groups generally view these types of approaches more favorably compared to the public. Savadori et al. (2004), for example, found that experts (i.e., professors and Ph.D. students in biology) viewed food and medical technologies such as GE as less risky and more useful than did the public. Similar patterns have been found in the context of forestry (Hajjar et al., 2014; Jepson & Arakelyan, 2017b; Nilausen et al., 2016). Nilausen et al. (2016), for example, found that representatives of government agencies and the forest industry were more supportive of using technologies related to breeding and genetics in forestry than were citizen organizations (i.e., NGOs) and indigenous populations. These differences may occur because some interest groups (e.g., scientists, agencies, businesses) tend to judge risks more objectively and accurately (i.e., estimates closer to actual known probabilities), whereas the general public often perceive risks more subjectively (Sjöberg, 1998; Slovic, 2010).

On average, the FIGs viewed the breeding approach significantly more positively (i.e., higher acceptance, lower risks, higher benefits) than adding a gene from bread wheat (GE). This result is consistent with studies showing that people tend to be more concerned about genetic applications (especially those crossing species boundaries) than more common approaches such as breeding (Hajjar & Kozak, 2015; Peterson St-Laurent et al., 2018). For the public sample, however, there were fewer differences in responses between the breeding and GE scenarios, and this sample actually viewed adding a gene from bread wheat as significantly more beneficial and slightly more acceptable than breeding AC trees with nonnative Asian chestnut trees. Although seemingly counterintuitive, this finding is actually consistent with some other studies. Jepson and Arakelyan

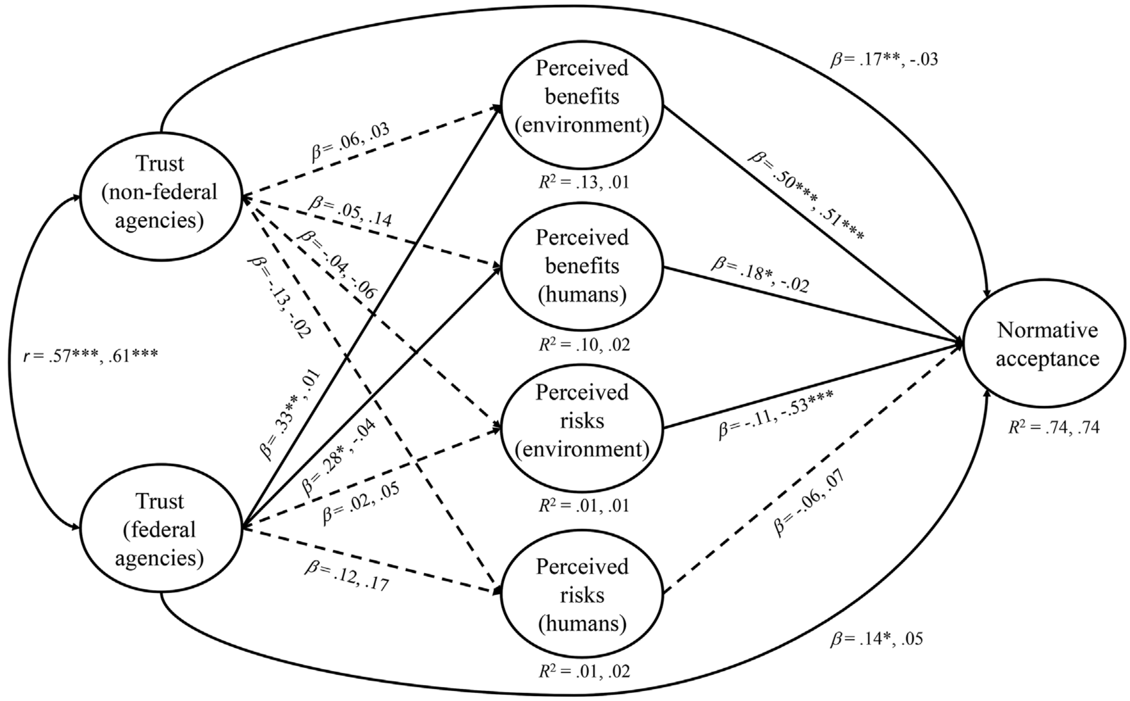

Fig 3. Multivariate path analysis predicting normative acceptance of using GE to add a gene from bread wheat (OxO; scenario 2) for the public (first value) and FIG (second value) samples. Public n = 278, FIG n = 195. β = standardized betas, r = Pearson's correlations, R^2 = variances explained. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Values (β, r) without an asterisk were not statistically significant ($p > 0.05$). Dashed paths are those that were not statistically significant ($p > 0.05$) for both the public and FIG samples. Variance inflation factors (VIF) were only 1.46–3.24 (public sample) and 1.66–3.13 (FIG sample), suggesting minimal multicollinearity.

(2017a), for example, found more support for some GE techniques than breeding ash trees with nonnative Asian ash species for addressing ash dieback in the U.K. Although forestry studies have found high support for breeding with native or local species (Hajjar & Kozak, 2015; Hajjar et al., 2014; Jepson & Arakelyan, 2017b; Peterson St-Laurent et al., 2018), breeding with nonnative species, such as chestnut or ash trees from Asia, seems to receive less support.

Although not measured here, these findings and also results of other research (Slovic, 2010; Tenbült, de Vries, Dreezens, & Martijn, 2005) suggest that perceptions of familiarity and naturalness may elicit different concerns in some cases. For example, Asian chestnut species are more closely related to the AC than wheat is, but are not as familiar to Americans as wheat (i.e., as a source of bread; Strauss et al., 2017). Perhaps the public sample viewed GE involving bread wheat slightly more positively because this is familiar, with both species (chestnuts, wheat) being consumed (Petit et al., 2021). Although speculative, the questionnaire used in this study was also administered at the same time as when frequent anti-Asia (e.g., China) messaging and rhetoric started being disseminated by the American presidential election campaigns (Skonieczny, 2018) and this familiarity and negative framing may have impacted some respondent answers to questions about breeding the AC with nonnative chestnut trees from Asia. It may also be that concerns about naturalness and purity of species are driving some perceptions, as the GE tree maintains a higher percentage of AC DNA than a tree bred with DNA from both the AC and Asian chestnut species (NASEM, 2019; Powell, 2016). In fact, research has shown that perceived transgressions of naturalness can drive concerns and levels of acceptance more than the intervention or approach (e.g., GE) itself (Hoogendoorn, Sütterlin, & Siegrist, 2021; Siegrist & Arvai, 2020; Peterson St-Laurent et al., 2018).

Research has shown that public attitudes toward using GE to mitigate CB and restore AC trees are slightly positive with a majority favoring this approach (Petit et al, in press; Petit et al, 2021). Results here, however, showed that the public sample was divided in their normative acceptance of using

Table V. Bivariate Pearson's Correlations for Predictors (Trust) of Risks and Benefits for the Public (First Value) and FIG (Second Value) Samples (Public $n = 278$, FIG $n = 195$)

	Perceived Risks to Humans[a]	Perceived Risks to the Environment[a]	Perceived Benefits to Humans[a]	Perceived Benefits to the Environment[a]
Scenario 1 – Breeding with nonnative chestnut trees from Asia				
Trust in federal government agencies	0.01, −0.02	−0.11, 0.01	0.36^{***}, 0.19^{*}	0.39^{***}, 0.23^{*}
Trust in nonfederal government agencies	-0.16^{*}, 0.03	-0.18^{*}, 0.03	0.26^{**}, 0.13	0.30^{***}, 0.15
Scenario 2 – Using GE to add a gene from bread wheat (OxO)				
Trust in federal government agencies	0.05, 0.15	−0.01, 0.01	0.31^{***}, 0.05	0.36^{***}, 0.03
Trust in nonfederal government agencies	−0.06, 0.08	−0.03, −0.03	0.20^{*}, 0.12	0.24^{**}, 0.04

[a] $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. Values (r) without an asterisk were not statistically significant ($p > 0.05$).

GE in this context (36% should allow, 29% neutral, and 35% should not allow). Attitudes, however, are not the same as norms. Attitudes are evaluations of an object or issue with some degree of favor or disfavor (e.g., bad, good), whereas norms are what people believe should or should not be allowed in a given context (Eagly & Chaiken, 1993; Vaske & Whittaker, 2004). Although members of the public have favorable attitudes toward the idea of using GE to mitigate CB and restore AC trees, they are more divided on whether this approach should actually be implemented or allowed to occur. This is not surprising, as the public sample not only perceived greater benefits (to humans or the environment) from this GE approach compared to breeding, but they also perceived greater potential risks of this GE approach, suggesting there is likely some public apprehension about allowing the use of this technology to restore the AC at a wider scale.

Results here also showed that similar to past research (Needham & Vaske, 2008; Siegrist, 2000; Siegrist & Arvai, 2020; Vaske et al., 2007), normative acceptance of the breeding and GE approaches was: (i) positively correlated with benefits to humans and the environment, and (ii) negatively correlated with risks to humans and the environment for both the public and FIG samples. After controlling for variables in the path analysis, however, perceived environmental benefits were positively related to normative acceptance of both approaches (breeding, GE) for the public and FIG samples. These environmental benefits were also the strongest predictor of the public sample's acceptance of both approaches. This finding is contrary to many studies that have shown perceived human or environmental risks to be primary determinants of acceptance of technologies such as GE (Frewer et al., 2013; Siegrist, 2000; Strauss et al., 2017). This finding here might relate to the most obvious beneficiaries of breeding and GE in this context. Forest conservation efforts, such as mitigating CB and restoring AC trees, might be seen as benefitting trees and forests (i.e., the environment) more so than eliciting perceptions of risks to humans or otherwise. In fact, some studies have shown that perceived benefits can be more strongly related to acceptance compared to perceived risks (Connor & Siegrist, 2010; Gaskell et al., 2004; Petit et al., 2021; Visschers et al., 2011). Gaskell et al. (2004), for example, examined perceptions of GE foods and concluded that the absence of perceived benefits was a stronger predictor of opposition to GE than was the presence of perceived risks. Visschers et al. (2011) found that perceived benefits of a secure energy supply were stronger predictors of accepting nuclear energy than were perceived risks. These findings suggest that the relative importance of risks and benefits in relation to normative acceptance can vary by context (e.g., forest conservation, food, energy).

In addition to these environmental benefits, perceived risks to the environment were most strongly related to acceptance of both scenarios (breeding, GE) for the FIG sample, with higher perceived risks associated with lower acceptance of each approach. This finding is consistent with research in other contexts showing that risks are often inversely related to acceptance of GE and other related approaches (Siegrist & Arvai, 2020; Slovic, 2010). Risks to the environment, however, were not significantly related to acceptance for the public sample, likely because acceptance for this sample was so strongly driven by environmental benefits. Although studies examining relationships between risks and normative acceptance of breeding and GE in the context of forest conservation are rare, Strauss et al. (2017) hypothesized that acceptance of using approaches such as these in forestry is likely to be negatively related to perceived risks and positively related to benefits. Findings here confirmed these relationships in a forestry context.

Results also showed differences in risk and benefit perceptions across targets (humans or the environment). Environmental benefits and risks most strongly predicted acceptance of breeding and GE to mitigate CB and restore AC trees. Benefits and risks to humans, however, were not strongly related to acceptance, as only one of eight relationships between acceptance and human risks and benefits was statistically significant in the path models. This finding is inconsistent with research focusing on risks and benefits to humans in relation to acceptance of GE and other approaches. Studies on using GE in food, in particular, have emphasized perceived human health concerns from consuming GE foods as a primary driver of acceptance (Frewer et al., 2013; NASEM, 2016; Scott et al., 2018). In this study here, however, both the public and FIG samples viewed the use of breeding and GE to mitigate CB and restore AC trees as having more environmental implications than consequences for humans. This finding is logical, as human health concerns could be less likely to supersede environmental issues in the context of forestry. Although chestnuts are occasionally consumed by some people, more common uses of breeding and GE in agriculture (e.g., corn, potato, or soy) can be perceived negatively due to possible health concerns from frequently consuming these foods (Scott et al., 2018). Concerns over potential impacts from employing approaches such as GE in forest conservation (e.g., gene escape, biodiversity loss) could likely be seen as primarily impacting trees and forests more than risks from consuming related products that involved breeding or GE. Studies in Canada and Europe found that reduced genetic diversity and unintended gene flow into wild or native forests were environmental concerns from using GE in trees (Nilausen et al., 2016; Nonić et al., 2015; Tsourgiannis et al., 2016). Research on perceptions of GE in plantation forestry also showed that biodiversity loss is a public concern (Kazana et al., 2015). These studies support results here showing that environmental benefits and risks were most strongly related to acceptance. Future research should examine various risk and benefit targets in other forest conservation contexts (e.g., other pests and diseases, climate change) to see if results found here generalize to these other contexts.

Findings showed that trust also played a role in predicting risks, benefits, and acceptance of breeding and GE in this context of forest conservation, but this was only a weak role. As hypothesized and consistent with past research, the public sample's trust in federal and nonfederal agencies positively predicted acceptance of the GE scenario, but these paths were not significant for the breeding approach. Public trust in federal agencies also positively predicted human and environmental benefits for both scenarios, and public trust in nonfederal agencies negatively predicted human risks for the breeding approach. This suggests that increasing public trust in agencies responsible for managing forests may slightly reduce some risks, increase acceptance, and increase perceived benefits associated with the use of breeding and GE in forest restoration.

For the public sample, however, there were no other significant predictive paths between trust and risks, benefits, and acceptance. Trust also did not predict risks, benefits, or acceptance for the FIGs. In addition, trust only explained small amounts of variance in these concepts. These findings are incongruent with the hypotheses and most of the existing literature that has shown relationships between trust and risks, benefits, and acceptance. Needham and Vaske (2008), for example, found that hunters who trusted agencies to manage chronic wasting disease in deer and elk reported lower risk perceptions associated with the disease compared to those with less trust. Likewise, Xiao et al. (2017) found that trust led to lower risk perceptions and greater acceptance of nuclear power plants. One possible explanation for the generally weak predictive power of trust found here is that the public and FIG samples, on average, slightly to moderately trusted the agencies, but still perceived slight to moderate risks associated with these breeding and GE approaches, perhaps because many potential risks remain largely unknown or outside of government agency control (NASEM, 2019). Research has shown, for example, that technologies such as GE can be viewed with concern due to unforeseen or unintended consequences, which can be difficult to anticipate and manage irrespective of the competence or trustworthiness of those responsible for managing the technologies (Sjöberg, 2004). This issue warrants additional research in forestry.

Given the results showed that environmental benefits and risks were most strongly related to acceptance of the breeding and GE approaches, communication efforts aimed at increasing acceptance of using these approaches in forest conservation should focus primarily on environmental factors, with an emphasis on potential environmental benefits that might result from using these approaches. In addition to communicating these benefits, discussion about any potential environmental risks of these approaches is also warranted, as they were also related to acceptance for the FIGs. Including known risks in communication efforts would help to maintain transparency and provide a sense of accountability and balance in messaging. In addition, social psychology research has shown that communication campaigns are often more effective when messaging uses a type of "inoculation effect" by including some potential concerns (e.g., risks) alongside favorable information (e.g., benefits; Banas & Rains, 2010; Eagly & Chaiken, 1993).

Findings also showed that although both the public and FIG samples had moderate trust in federal agencies, they only had slight trust in state and local agencies. These nonfederal agencies serve as day-to-day managers of many public lands and often cooperate with federal agencies to manage forests at broader scales. Many nonfederal agencies may also be charged with regulating and monitoring approaches such as breeding and GE, as well as informing the public about these efforts. Research suggests that trust-building efforts should: (i) focus on facilitating transparent dialogue between agency personnel and the public, (ii) involve the public in agency planning efforts, (iii) emphasize local benefits of management strategies, (iv) minimize turnover in agency personnel who often interact with the public, and (v) assess local contextual factors that shape or constrain these efforts (Shindler, Brunson, & Cheek, 2004; Stern & Coleman, 2015).

In conclusion, approaches that have received substantial attention for mitigating CB and restoring AC trees involve: (i) breeding these trees with non-native chestnut trees from Asia, and (ii) using GE to add a gene from bread wheat. Results here showed relationships among concepts related to acceptance of these approaches. These findings, however, are limited to samples of the public and FIGs, and their responses to addressing a single forest health threat (CB) in one tree species (AC). The public sample was selected randomly from addresses of American residents and these data were weighted by census information to improve representativeness to the population. The FIG sample was a broad cross-section of individuals and organizations with various interests and positions related to forestry (e.g., timber companies; genetics companies; scientists; local, state, and federal government agency employees; environmental advocacy or anti-GE groups; woodland and forest owner associations; foundations; forestry and growers councils). Despite these efforts to achieve representative and diverse samples using established survey research methods, the sample sizes and response rates were relatively low, even after six contacts (Vaske, 2019). The samples were also not necessarily representative of smaller, targeted, and more homogeneous subgroups with specific interests (e.g., environmental advocacy or anti-GE groups). Although response rates have declined in survey research on natural resource issues (Stedman, Connelly, Heberlein, Decker, & Allred, 2019; Vaske, 2019), studies with larger or different samples are needed to address these issues and could allow for more advanced analytical approaches such as structural equation modeling.

Path analysis showed that 74–79% of the variance in acceptance and only 1–16% of the variance in perceived benefits and risks were explained in this study. The unexplained variance (i.e., error) suggests that other factors not measured here are also related to these concepts. Research is needed to understand additional characteristics and concepts that could serve as predictors. The scenarios measuring risks, benefits, and acceptance were also presented in the questionnaires in the same order (breeding followed by GE) for all respondents and were not randomized in their order, so research should test for any starting point bias and order effects. In addition, although the reliabilities were high, only two variables were used for measuring each concept and more variables may increase reliability and validity. For example, some researchers have claimed that there are multiple types of trust (e.g., interpersonal, dispositional, procedural, social or shared values) and trust is contextual and consists of multiple dimensions (e.g., fairness, responsibility, integrity, competence, credibility, consistency, inclusiveness, transparency; Stern & Coleman, 2015). Finally, the applicability and generalizability of the results to other contexts, including additional forest health threats such as climate change and other diseases and pests (e.g., emerald ash borer, mountain pine beetle), remain topics for further empirical investigation.

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