OVERCOMING BOTTLENECKS IN THE MIDWEST HAZELNUT INDUSTRY

An Impact Investment Plan

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Hazelnuts represent a timely economic and environmental opportunity. While the existing $7 billion global market is on track to double within the next decade, this perennial crop’s latent potential is likely much greater. The woody mass sequesters carbon, the perennial root system can help capture excess nutrients, and its permanent structure provides habitat for birds, beneficial insects, and other wildlife.

— p. 11

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ABOUT THE SAVANNA INSTITUTE

The Savanna Institute is a 501(c)(3) nonprofit research and education organization working to catalyze the development and adoption of resilient, scalable agroforestry in the Midwest U.S.. We work in collaboration with farmers and scientists to develop perennial food and fodder crops within ecological, climate change-mitigatingagricultural systems.

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ACKNOWLEDGEMENTS

This report was produced with generous support from the Jeremy and Hannelore Grantham Environmental Trust.

DEAR READERS,

At the Savanna Institute, we share a revolutionary vision: a multifunctional agriculture in the Midwest based on agroforestry systems of integrated trees, crops, and livestock and fostering ecological resilience, climate stability, economic prosperity, and vibrant rural communities. To achieve this important vision, we are working hard in collaboration with farmers, scientists, landowners, and many other stakeholders to catalyze the widespread adoption of tree crops and perennial agriculture.

Tree crop development is one of the three core pillars of the Institute's work. In the Midwest transition to widespread perennial agriculture and agroforestry, tree crops are the key tools at our disposal. To realize the full economic and ecological benefits of perennial agriculture, the transition will require (1) resilient tree crops for food & fodder, and (2) robust supply chains with scalable infrastructure.

Many local and regional tree crop industries are already appearing across the Midwest, launched by pioneer farmers, researchers, and educators. Each crop, of course, has its own set of hurdles and bottlenecks that limit growth. For some crops, these bottlenecks are primarily production issues on the farm. For others, consumer support is what is lacking.

Hazelnuts have been a target tree crop for the Midwest for over four decades. By some measures, progress has been slow, but steady nonetheless. A great many stakeholders have contributed to the industry's development over the years, and even more are joining today as the need for perennial agriculture becomes clearer than ever.

It is our hope that this document will serve as a catalyst for the Midwest hazelnut industry, providing a roadmap for connecting capital with the key practitioners, researchers, and educators on the ground. We have gathered critical information from across the community of Midwest hazelnut stakeholders, identified the industry's central development bottlenecks, considered the competing priorities and the contested merit of various approaches to overcome these hurdles, and conducted an objective assessment and ranking of priorities for impact investment.

I thank my fellow staff and all stakeholders who have contributed to this report. This community's vision for a new Midwest agriculture is noble and necessary. As you read this report, please consider where your role lies. Please join us in scaling the Midwest hazelnut industry and a broader perennial agriculture.

Sincerely,

KEVIN J WOLZ, PHD , *Co-Executive Director*

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EXECUTIVE SUMMARY

Row crop agriculture covers over 3.28 billion acres of land globally - an area equal to half of all land in North America. This practice has considerable negative environmental impacts, including substantial greenhouse gas emissions. Transformative solutions that transcend the fundamental issues of annual crops are needed in the face of climate change. Perennial staple crops are one such solution.

An established row of hazelnuts at Rush River Produce in northwest Wisconsin.

Hazelnuts, in particular, present a timely economic and environmental strategy in the Midwest U.S. While the existing $7bn global market is on track to double this decade, this perennial crop's latent potential is to supplant soybean as a staple source of protein and oil. If adopted broadly, hazelnuts could help reverse agriculture's role in climate change – over 1500 Mt carbon (~30% of annual U.S. CO_2 emissions) could be sequestered in woody biomass alone if hazelnuts replaced the existing 84 million acres of soybean across the Midwest. Additional benefits would accrue from the crop's deep roots, which capture excess nutrients and reduce eutrophication of surface waters, and from the habitat that plants provide for birds, beneficial insects, and other wildlife.

With declining production and instability in Turkey, the world's leading hazelnut producer, food companies are looking to diversify their supply chains with new hazelnut growing regions. The Midwest is well suited to growing hazelnuts – it is the center of the native range of the American hazelnut, and the low cropland prices, relative to current hazelnut production regions in Oregon, give producers a competitive advantage. Over the last several decades, researchers and farmers have developed an array of European-American hybrid hazelnut varieties adapted to the Midwest; advanced selections are poised for large-scale plantings.

Despite this promising position and substantial work to date, multiple bottlenecks limit the growth of the Midwest hazelnut industry. Effective micropropagation protocols are needed to provide inexpensive clonal planting material. "Chicken-and-egg" issues have prevented the deployment of either a large-scale pilot farm or the necessary processing infrastructure. A lack of robust variety trials and ongoing breeding work in the Midwest has hindered continued plant development. The lack of a mechanism to improve availability of low-risk farm startup capital costs is a major hurdle for growers wishing to plant hazelnuts at-scale.

This document presents ways to overcome these obstacles, and suggests entry points for public, philanthropic, and private capital to make positive social and environmental impacts. The concluding chapter – a ranking of strategies for development of the Midwest hazelnut industry – outlines a plan based on potential impact, investment needs, relative urgency, expected timeframe, and dependency on prerequisite activities. Support for enacting these strategies will hasten the expansion of the Midwest hazelnut industry and a truly ecological agriculture.

The American Hazelnut Company in Wisconsin uses Midwest hazelnuts in their value-added products.

INTRODUCTION

KEY POINTS

Incremental improvements in the efficiency of existing agricultural systems have limited potential for transforming how agroecosystems function.

Perennial tree crops represent a more transformative approach that have significant potential in terms of ecosystems services and carbon sequestration.

Hazelnuts are a healthy, oilseed crop that has the potential to out-yield and therefore replace soybeans in the Midwestern landscape.

Extensive disturbance and landscape simplification leaves little permanent habitat for diverse native wildlife.

The Problem of Agriculture

Row crop agriculture covers over 1.28 billion hectares of land globally[1] and over 75% of land in the Midwest[2]. Though extremely productive, these cropping systems rely heavily on external inputs of energy, nutrients, and pesticides, leading to many negative ecological impacts. The agricultural sector accounts for 10-12% of global anthropogenic greenhouse gas emissions[3] and a striking 55% of global nitrous oxide emissions[4].

Fertilizer applied to row crops has become the largest source of nutrient pollution and eutrophication in aquatic ecosystems[5]. Extensive disturbance and landscape simplification leaves little permanent ground cover or habitat for diverse native wildlife (above), leading to soil erosion and biodiversity loss[6] . Beyond its ecological challenges, row crop agriculture is highly sensitive to future climate change[7], and its profitability is volatile[8].

Incremental improvements to the prevailing system have been the primary focus of efforts to reduce these negative impacts in the U.S.[9] (right). Cover cropping, for example, extends soil cover beyond the primary cropping season to reduce erosion, capture excess nutrients, and improve soil quality[10] . Precision management uses high-resolution positioning and remote sensing technology to apply inputs more accurately only where needed[11]. No- or low-till practices reduce the level of annual tillage to improve soil stability, reduce erosion, and sequester carbon[12]. Organic production aims to minimize the use of synthetic inputs that have adverse ecological effects[13]. Despite the perceived benefits, adoption of these approaches remains low, with only 39% of U.S. cropland using reduced tillage, 1.7% utilizing cover crops, and 0.8% in organic production[14,15].

Incremental approaches, even if widely adopted, are thus unlikely to reverse greenhouse gas emissions and solve the ecological challenges of row crop agriculture[16-18]. For example, while no-till management and cover cropping exhibit lower net global warming potential than conventional crops, net emissions still remain positive[19]. Similarly, in simulations with ideal cover crop adoption across the Midwest, nitrate losses to the Mississippi River were reduced by approximately 20%[20] , falling short of the estimated 40-45% decrease necessary to meet hypoxia reduction goals in the Gulf of Mexico[21]. Instead, transformative solutions that address the fundamental issues associated with vast monocultures of annual crops are necessary, especially

Incremental improvements to the prevailing system have been the primary focus of efforts in the U.S.

in the face of climate change[22-27]. Successful transformative solutions must be ecologically sustainable, economically viable, and culturally acceptable. Ecological sustainability requires robust functioning of regulating and supporting ecosystem services alongside the provisioning services at the core of agriculture. Economic viability means profitability for farmers and prosperity for rural communities. Cultural acceptability entails meeting people's aesthetic, ethical, and practical needs while producing the carbohydrates, proteins, and oils that are the basic components of food systems and industrial supply chains[28-31].

The Tree Crop Solution

In his visionary work, J. Russell Smith[32] reviewed the potential of a wide range of tree crops for food and fodder production in a "permanent" agriculture. He described the "corn trees" of Castanea (chestnut) and Quercus (oak), as well as the "meat-and-butter" trees of Juglans (walnut) and Carya (pecan/hickory), the "stock-food trees" of Ceratonia (carob), Prosopis (mesquite), Gleditsia (honey locust), and Morus (mulberry), a "kingly fruit for man" in Diospyros (persimmon), and Corylus (hazelnut) that "fairly runs riot in many American fields". Smith's work has inspired perennial agriculture researchers and practitioners for 90 years, and his vision for widespread tree crops is more relevant than ever today[33].

Integrating trees throughout the agricultural landscape, today known as "agroforestry", is a transformative departure from the incremental improvements to row crops that focus on minor agronomic improvements or field margins[34,35]. Smith's focus on tree crops was primarily driven by concerns about widespread soil erosion. We now have a much more thorough understanding of the benefits that trees can have on agricultural soil retention, structure, and fertility[36,37]. We also now know that trees do a lot more than just stabilize soil. Integrating trees in agricultural landscapes can help mitigate climate change, adapt agriculture to disturbance, enhance crop yields, and improve ecological functioning.

Globally, agricultural tree biomass accounts for over 75% of biomass carbon storage on agricultural land[38]. Further integrating trees into agricultural landscapes has great potential for climate change mitigation and adaptation. Tree crop systems are among the few agricultural systems that exhibit true carbon sequestration potential, rather than just a reduction in greenhouse gas emissions, and are thus considered to be one of the most important approaches to carbon sequestration on farmland[19].

In addition to direct climate change mitigation, trees can help adapt agriculture to many aspects of climate change[39-44]. The more volatile and extreme weather patterns predicted with climate change are expected to have direct impacts on agricultural management and productivity[3,45]. Integrating trees can buffer the effect of weather extremes by protecting crops from wind stress[46], stabilizing air and soil temperatures[47], increasing soil water infiltration and storage[48], and reducing evaporation of

Transformative solutions to the issues posed by monocultures are being explored at New Forest Farm in southwest Wisconsin.

soil moisture[49]. Increases in biodiversity have been shown to improve the resilience of ecosystems to ecological disturbance[50]. Integrating trees in agriculture has also been demonstrated to increase biodiversity for many organisms, such as arthropods[51], mycorrhizal fungi[52], and birds[53].

Incorporating trees into the agricultural landscape also has the potential to address the widespread water quality and eutrophication issues of the Midwest. Tree roots can provide a "safety-net" by catching nitrogen that leaches beyond the crop rooting depth or growing season[54,55]. Even compared to perennial pasture, which has deeper roots and a longer growing season than annual crops, integrating trees can reduce peak soil nitrate concentrations by an additional 56%[56].

In addition to their ecological benefits, widespread integration of tree crops into the agricultural landscape also has potential for substantial economic benefits. In particular, food- and fodder-producing tree crops can simultaneously maintain high agricultural yields and ecosystem functions[27,57,58]. Tree crops can also diversify farm revenue, promote overyielding, and introduce nutritionally dense crops high in vitamins and antioxidants. The variety of harvest and management activities associated with the array of potential tree crops in the Midwest could also increase year-round employment opportunities in rural areas, which could help stabilize rural communities.

Compared to timber harvest rotations that span decades, the relatively short time to reproductive maturity and predictable annual yields in food- or fodder-producing tree crops can provide a more rapid economic return on investment[59]. Furthermore, shorter harvest intervals make tree crop returns less susceptible to natural disasters, climate variability, and changes in market preferences[60,61]. If monetized via future policy developments, the ecological benefits of tree crops can also become direct economic benefits. Incentivized ecological benefits could even constitute over two-thirds of the economic value provided by integrating trees into agriculture[62].

Widespread adoption of tree crops in the Midwest will require well-developed species that are highly productive and have robust markets. Many tree crops have longstanding global markets and have garnered increased investment by industry and academia over the past two decades. Though their potential growth beyond niche markets remains largely overlooked, many tree crops – especially nut trees – have great potential as staple food crops and animal fodder[32,33]. Dominant tree crops will vary by region based on environmental suitability of tree species[63], while also anticipating future climate conditions[64]. Furthermore, it will be critical to select tree crops that are already supported by a solid base of agronomic knowledge, foundational breeding work, and existing germplasm repositories.

J. Russell Smith reviewed the potential of a wide range of tree crops for food and fodder production in his his visionary work *Tree Crops: A Permanent Agriculture*.

Why Hazelnuts?

A climate-friendly oilseed crop

Hazelnuts represent a timely economic and environmental opportunity. While the existing $7 billion global market is on track to double within the next decade, this perennial crop's latent potential is likely much greater. In principle, well-adapted varieties could out-yield soybeans in terms of oil per acre (Table 1), and thus potentially supplant large acreage across the Midwest, dramatically changing the landscape[65,66.] Such a change could also yield significant ecological benefits: hazelnuts can sequester >1 t carbon/acre in woody biomass over their first five years[55], scaling to more than 18 t carbon/acre sequestered by maturity – over 1500 Mt carbon sequestered in total if hazelnuts replaced the 84 million acres of soybean across the Midwest, which does not include the potential accompanying sequestration in soil organic matter[67].*

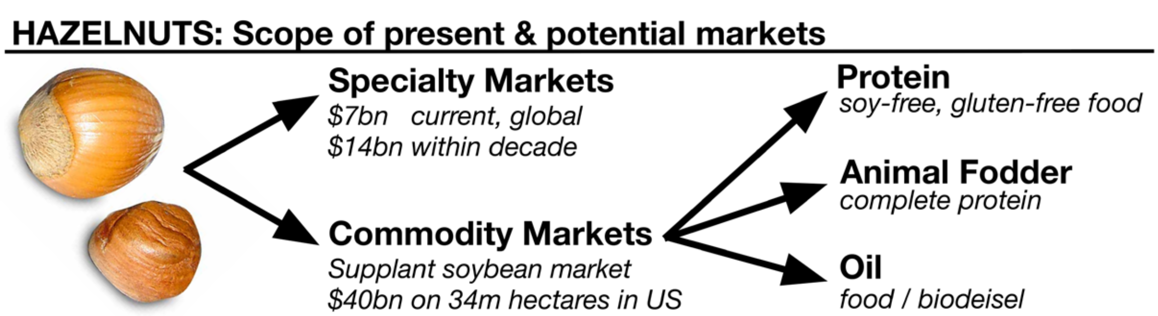
In addition, their perennial root system can help capture excess nutrients and reduce eutrophica-tion of surface waters, and the permanent structure would provide habitat for birds, beneficial insects, and other wildlife.

Healthy & nutritious

Hazelnuts contain very high (~60%) oil content, with high levels of monounsaturated fatty acids and low levels of saturated fatty acids[68]. Diets containing this ratio of fatty acids can help reduce total cholesterol, and thereby reduce both blood pressure and coronary heart disease risk[69,70]. Additionally, hazelnuts are a source of tocopherol and phytosterol, which have been shown to have a preventative effect on heart disease and tumour growth in some cancers[71,72,73]. Finally, the pressed meal of hazelnut kernels contains high levels of proteins, carbohydrates, fiber, and minerals[74].

Item	Soybean *modern*	Soybean *historical*	Hazelnut *best*
Caloric yield (Mcal/ha)	13	4	13
Oil yield (Mg/ha)	0.6	0.2	1.3

Table 1: Caloric and oil yield comparison of soybean and hazelnut. Hazelnut data are derived from countries with the highest yields– a potential goal for the Midwest[27].



*Updated carbon sequestration metrics for hazelnuts in development by the Savanna Institute. Agroforestry systems, such as windbreaks or silvopasture, can sequester between 1 and 5 tons of carbon dioxide per acre per year.

Source: Fargione JE, Bassett S, Boucher T, et al (2018) Natural climate solutions for the United States. Science Advances. https://doi.org/10.1126/sciadv.aat1869

BACKGROUND ON HAZELNUTS

KEY POINTS
The existing global hazelnut market (primarily confectionary products and snack foods) is experiencing rapid growth.

Currently, Oregon accounts for essentially all hazelnut production in the U.S., but despite recent expansion, it is estimated that this will not exhaust demand.

There is growing interest in alternative uses for hazelnuts, such as food products like cold-pressed oil, as well as processed commodity goods such as biodiesel and livestock feed.

Given these macro-economic trends, it is estimated that there is a market opportunity for approximately 175,000 acres of hazelnut production in the Midwest U.S.

Existing Uses

There are many possible end-uses for hazelnuts, each having different requirements for nut quality characteristics. Hazelnuts are typically sold unprocessed (cracked or whole) or processed into blanched, roasted, diced, or powdered form. Processed hazelnuts (58% of the market) appeal to the snack market and are primarily sold via retail channels. Unprocessed hazelnuts (42% of the market) are usually preferred to make food products and beverages like spreads, chocolate candies, nutrition bars, syrups, coffee creamer, biscuits, liquors, butter, and other related products[75].

Aside from the food & beverage sector, 18% of the global hazelnut market is dedicated to hazelnut oil production. The oil market primarily serves the cosmetic industry (e.g. skin and hair care) and is viewed as a primary driver of value and growth. Hazelnut oil also has applications in the pharmaceutical industry and the food preparation industry (as a gourmet oil adding complex flavors)[75]. When kernels are pressed into oil, the residual meal can be used as a high-protein, high-mineral livestock fodder[74].

Desired hazelnut traits vary depending on their end use. When used whole, kernel size and shape are important quality traits. Similarly, when used as a flavoring ingredient in confectionary products, nut flavor traits may be different or more important than when using the nut primarily as animal feed or feed concetrate.

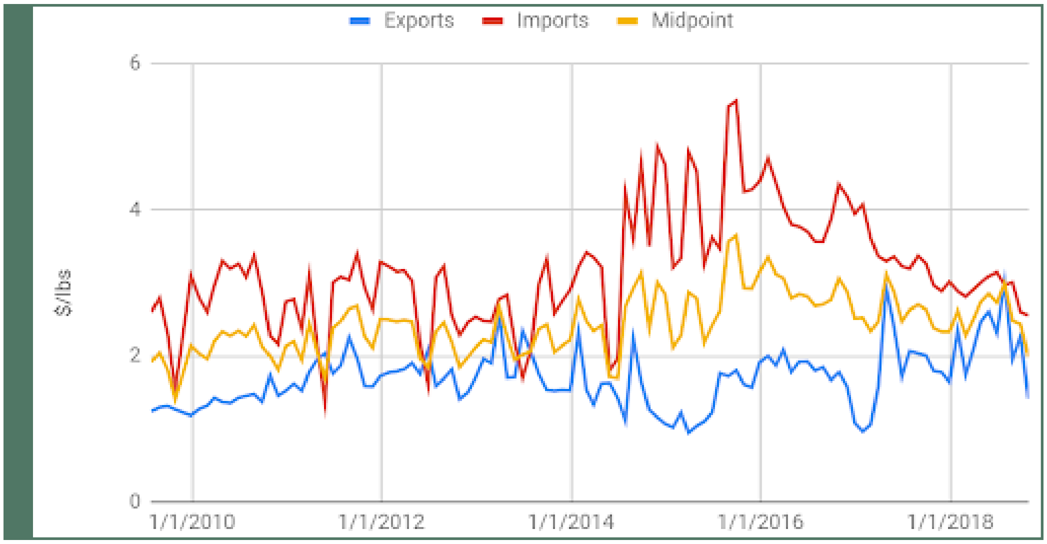


Figure 1: U.S. hazelnut prices over the last ten years ($/lb)[76].

Global Market

Size & Scope

The global hazelnut market is a $4.7 billion market (Table 2) exhibiting rapid growth (6.76% compound annual growth rate (CAGR), accelerating to 7.87% in 2021)[75,76] due to consumers' increased awareness of its health benefits and the nut's lower price compared to close substitutes (e.g. almonds, pistachios). Around 750,000 t of in-shell hazelnuts were produced worldwide in 2016, with Turkey growing over 50%, followed by Italy, then the US[31] (Table 2).

Due to world production concentration, in addition to production risk, Hazelnut prices exhibit large volatility[76] (Figure 1).

Major market participants

On the distribution side, major global market participants include[75]:

- Batsu Gida - natural, roasted, blanched, and diced hazelnut kernels and pastes
- Chelmer Foods - natural and roasted hazelnuts
- Kanegrade - caramelized hazelnuts, in addition to hazelnut paste and powder
- Olam International - natural, blanched, and roasted hazelnuts, pastes and meals
- Oregon Hazelnuts - natural, blanched, and roasted hazelnuts

On the demand side, industry manufacturers purchase ~58% of global hazelnut supply to make food products and beverages or cosmetic and pharmaceutical products via the extraction of oils[75]. Major global players in this segment include:

- Ferrero (with brands such as Nutella, Ferrero Rocher, and Kinder Bueno)
- Mondelez International (e.g. Cadbury & Milka for chocolates)
- Nestle (e.g. Coffeemate & Nescafe hazel latte, cappuccino, and coffee creamer)
- Hershey Company
- Mars
- Ritter Sport

Country	Production (t)	Estimated traded value ($ million)
World	**748,095**	**4,747**
Turkey	420,000	2,665
Italy	120,572	765
United States of America	39,916	253
Azerbaijan	33,941	215
Georgia	29,500	187
China, mainland	26,087	165
Iran (Islamic Republic of)	16,349	103
Chile	16,184	102
France	11,041	70
Spain	9,510	60

Table 2: Production and estimated traded value of the top 10 hazelnut producing countries in 2016 [31].

In addition, ~30% of global supply is purchased by the retail segment and dedicated to snack related products[75]. Although supermarkets represent the major outlets, convenience stores and online channels are also important. Finally, ~12% of global supply is sold to the food service sector such as restaurants, hotels, and bakers[75].

Macro trends

Demand for hazelnuts is highest in Europe and the Middle East, primarily driven by the easy availability and low cost of hazelnuts in the region[77] (Table 3). However, the market is growing faster in the Americas and Asia-Pacific, reflecting increased consumer interest as hazelnuts become more available[75] (Table 4).

In addition to growing consumer interest, other factors may benefit the growth of emerging production regions like the U.S. In 2014, for example, extreme frost followed by a drought caused Turkish production to drop to half its projected amount (Figure 2). This poor harvest meant major buyers dependent on the region were faced with a lack of supply[78]. Given that Turkey typically produces over 50% of the global hazelnut supply, Turkish hazelnut yield volatility can result in subsequent volatility in global hazelnut prices (Figures 1 and 2). This makes sourcing decisions especially difficult for major hazelnut buyers.

As a result of this volatility, major companies have been investing heavily in developing hazelnut production in new regions to diversify their supply chain and reduce concentration risk. For instance, Ferrero, which until recently had been relying primarily on Turkish hazelnuts, has invested in developing a new industry in Ontario, Canada[79].

Country	Consumption (t)
Italy	78,000
Turkey	60,000
Germany	55,572
France	25,290
United States	15,284

Table 3: Hazelnut consumption of the top five hazelnut consuming countries[77]

Region	2017	2018	2019	2020	2021
World	6.0%	6.2%	6.4%	7.5%	7.9%
EMEA	5.8%	6.0%	6.2%	7.2%	7.6%
Americas	6.6%	6.9%	7.2%	8.4%	8.8%
APAC	6.1%	6.4%	6.6%	8.2%	9.1%

Table 4: Hazelnut market growth (CAGR) projections by region[76]

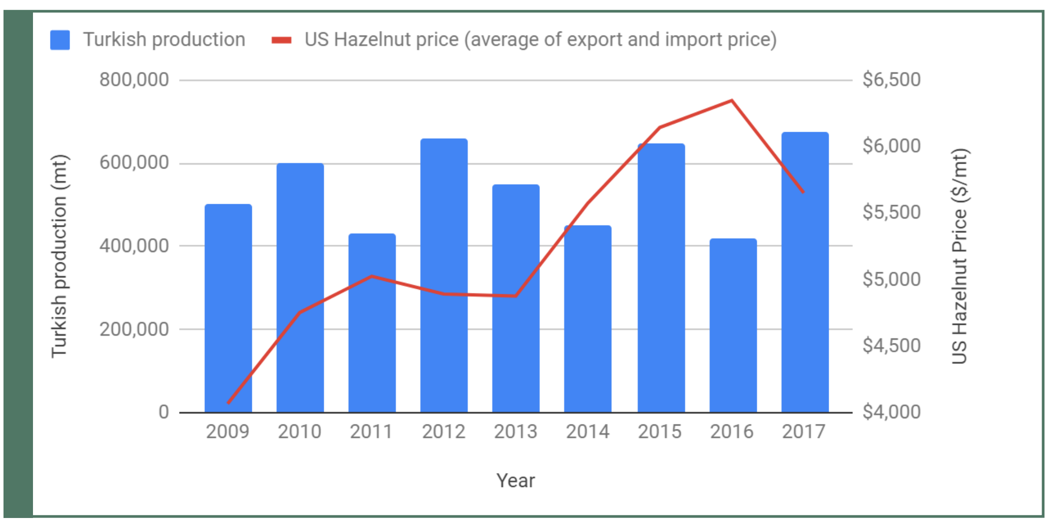


Figure 2: Impact of Turkish production on global market prices in the scope of present and potential hazelnut markets[31,76].

US Market

Existing production & market

Over 99% of hazelnut production in the Americas comes from Oregon's Willamette Valley and represents around $100 million in average annual revenue to growers[80]. The industry's rapid growth reflects an increased demand for hazelnuts by major confectionery companies, like The Hershey Company, which are looking to satisfy the increasing popularity of hazelnut spreads and nutrition bars in the US[75]. This trend is also partly driven by the low familiarity of U.S. customers with hazelnuts[80]. While hazelnut familiarity among U.S. customers is low, it is possible that, once Americans try hazelnuts or hazelnut-based products, adoption rates will go up. When this is coupled with staggering global demand growth and motivated offtakers looking to diversify away from concentrated suppliers, it presents a real and compelling opportunity for American hazelnut growers.

To respond to the rapidly growing demand for hazelnuts, the Oregon industry is adding acreage at a pace never seen before and is poised to double by 2025[81]. The industry is expected to produce 81,600 t of hazelnuts in 2025, eclipsing its 2018 estimated production of 42,60 0t. To reach these ambitious targets, 8,000 acres are currently being added annually to a base of 72,000 acres.

Historically, 60% of Oregon-grown hazelnuts have been sold to China as in-shell nuts for processing into snacks. Recently, however, a $20 million, state-of-the-art processing facility near Portland, Oregon has created significant capacity for U.S.-grown hazelnuts to be processed domestically. By doing so, U.S. growers can work with domestic processors to satisfy growing local and international demand[80].

This increased domestic processing capacity bodes well for producers facing the unfolding trade war with China. Since the start of the trade war, China has raised tariffs on U.S. hazelnuts by 65%[80]. Domestic processing capabilities give U.S. producers another option when it comes to marketing their harvest. A headwind that domestic producers may face in the near term is that a rapidly plummeting Turkish lira will make Turkish hazelnuts cheaper than hazelnuts produced in other countries.

The opportunity for the Midwest

This U.S. hazelnut opportunity is so large that it appears Oregon will not be able to satisfy it alone. While Oregon's expected increase in production capacity roughly matches expected demand resulting from U.S. market growth (to ~103,000 t by 2028), international demand for Hazelnuts is expected to grow by ~863,000 t[31,75] (Table 5).

This suggests that expanding hazelnut production outside of Oregon could be a way to have domestic production satisfy both the growing domestic and global demand for hazelnuts. If domestic producers were able to capture just 5% of the estimated growth in international hazelnut demand over the next 10 years, this would require another 43,000 t of hazelnuts. This level of demand, combined with several positive global trends, presents a clear opportunity to establish a Midwestern hazelnut industry.

In addition, as global brands continue to look for new ways to source hazelnuts from outside Turkey and Europe, a real opportunity exists for American growers to capture global market share.

Region	2018	2028	Growth (t)
World	841,431	1,762,823	921,392
USA	45,482	103,490	58,008

Table 5: Global and U.S. hazelnut demand estimates (t) 2018-2028[31,75].

Potential Novel Markets

While the projected growth in hazelnut demand is staggering, it only considers "traditional" hazelnut end markets related to human consumption. Hazelnuts also have myriad potential uses in other agricultural and industrial sectors. Targeting these alternative markets with hazelnuts is novel and not well developed, despite promising preliminary research from around the world[55].

In the conventional Midwestern agricultural system, soybeans are grown as a commodity source for protein and oil for use in livestock feed, biodiesel, and soy-based food products. Hazelnut, also comprised of primarily protein and oil, is a functional analog for soybean. Staple nut crops have served as the foundation of a number of civilizations[82], and modern research continues to develop the potential of nut-sourced carbohydrates[83], proteins[74], and oils[84] as staple food constituents.

While these alternative, commodity-scale markets will certainly command a lower price point than existing markets for human consumption, their massive potential size warrants further investigation - the Midwestern soybean market is ~$40 billion from over 84 million acres (Figure 3).

Biodiesel

Biodiesel is an important potential fuel that can reduce reliance on fossil fuels. Hazelnuts are composed of ~61% oil[85], making the crop a prime feedstock for biodiesel production. In contrast, soybeans are composed of only ~20% oil. As a result, the potential of hazelnut in biodiesel production has been actively researched and documented, including by the the U.S. Department of Defense[86].

In 2017, the U.S. consumed ~2 billion gallons of biodiesel[87] (Figure 4), a majority of which was derived from soybean oil feedstock[88]. Although the U.S. is a major producer of soybeans, this demand for biodiesel exceeds local production, hence requiring the U.S. to import ~300 million gallons of biodiesel annually[87]. Imported biodiesel is also primarily derived from soybean oil[89].

The potential for hazelnuts to play a role in meeting a portion of this demand for biofuels was observed as far back as the early 1990s[90]. Replacing biodiesel imports with domestic biodiesel derived from hazelnut oil would require ~2.25 billion pounds of hazelnut oil, or 1.68 million t of hazelnuts. Capturing just 10% of imports, therefore, would mean almost quadrupling current U.S. hazelnut production.

Livestock feed

The domestic production of the now-imported 300 million gallons of biodiesel would also generate around 672,000 t of high-protein hazelnut meal. This quantity of meal represents a small fraction of the amount of feed consumed by livestock in the U.S. - 236.3 million t[91] - suggesting that it could be easily absorbed by the market.

For hazelnut producers to tap these gigantic markets, it will be necessary to lower the cost of production and/or extract premium prices by addressing niche needs. While hazelnuts were recently trading at ~$5,600/t[76], turning the nut into oil for biodiesel and associated meal leftover would only yield around $532/t if subject to similar pricing as soybean oil and soybean meal. While this low pricing could make sense for a portion of a farm's output that would typically be wasted (e.g. if not suited to high value markets), this highlights the need for further investigation into production efficiencies. Most notably, addressing the following questions could help determine whether using hazelnuts for biofuels and animal feed is economical for farmers:

- Can hazelnut oil create a segment of "premium" biodiesel that certain customers looking for properties specific to hazelnut based biodiesel would be willing to pay more for? For instance, hazelnut-derived biodiesel gels at a lower tem-

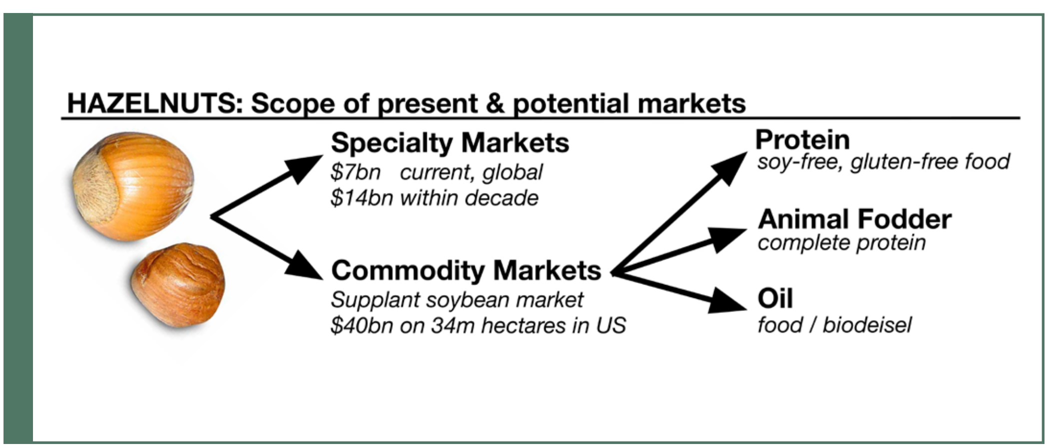


Figure 3: Diagram of the scope of present and potential hazelnut markets.

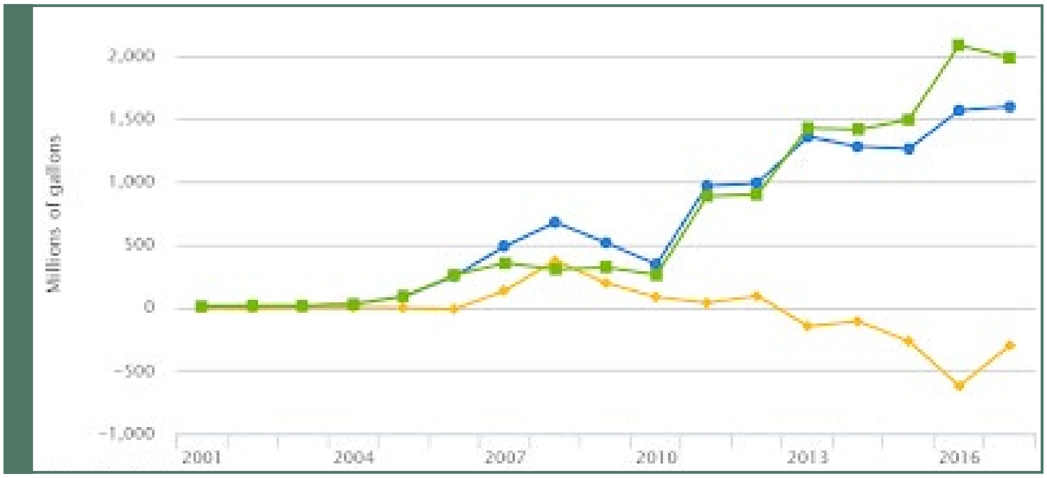


Figure 4: U.S. Biodiesel production, exports and consumption, 2001-2017[87].

perature than soybean-derived biodiesel[92]. The American military, in particular, has been interested in these properties.

- What economies of scale can be reached when deploying hazelnuts as a commodity crop? For example, could a low price for plant material be obtained from nurseries in exchange for large guaranteed orders? A partnership with micropropagation companies and nurseries could enable large growers or a cooperative pool of smaller growers to purchase plants at a lower price.
- Can a premium product with premium pricing be manufactured using hazelnut meal? For example, eggs from hens fed soy-free diets could command premiums. Does hazelnut meal give animals a particular, desirable taste? For example, hazelnut-finished pork could compete with other nut-finished pork products that are rapidly gaining popularity.

Coordinated industry research is necessary to address these questions and develop novel feed markets for hazelnuts.

Sizing the Midwest Opportunity

Both existing global market growth estimates and the potential for novel markets to play a role in future hazelnut demand help inform the size of the Midwestern hazelnut opportunity.

To calculate the addressable market for Midwestern hazelnuts, we conservatively assume a 5% international demand growth capture over the next ten years, or ~43,000 t produced per year – roughly the size of the Oregon market today. Our 10–20-year growth estimates are based on a 10% capture of the biodiesel market imports, adding up to 168,000 t. Together, these assumptions point towards a need to deploy ~158 million hazelnut trees in the Midwest (Table 6).

Metric	Existing markets	Potential markets	Total
Target volume (t)	43,000	168,000	211,000
Target volume (lbs)	94,772,000	370,272,000	465,044,000
Yield (lbs per acre)	2679	2679	-
Area (acres)	35,376	138,213	173,589
# of trees (908 trees/acre)	32,121,305	125,497,191	157,618,496

Table 6: Projected potential market opportunity for Midwestern hazelnuts (Yield and trees per acre assumptions[93]).

HAZELNUTS IN THE MIDWEST

Two Species & Their Hybrids

European hazelnut
The existing hazelnut industry in Oregon and the Mediterranean is built on the European hazelnut (Corylus avellana). This species produces large, thin-shelled nuts that can be sold to the dominant confectionary industry. European hazelnuts are grown as single-stemmed trees (Figure 5) and are primarily harvested with machines by shaking nuts from the trees and then picking them up off the ground.

American hazelnut
The American hazelnut (Corylus americana) is more bush-like, and produces relatively small nuts (Figure 5). This species is more tolerant of the Midwest climate and biotic stresses, but its nuts are not of sufficient size/quality to be directly usable in most hazelnut markets.

American x European hybrid hazelnuts
With neither the European nor American hazelnut species ideally suited for an industry in the Midwest, inter-specific hybrids resulting from crossing these two species together have also been explored as a way to combine the best traits of both species[65,66] (Table 7). Because of the ease with which this interspecific cross can be made, breeding can be performed upon both species independently, as well as within the diverse hybrid germplasm that currently exists.

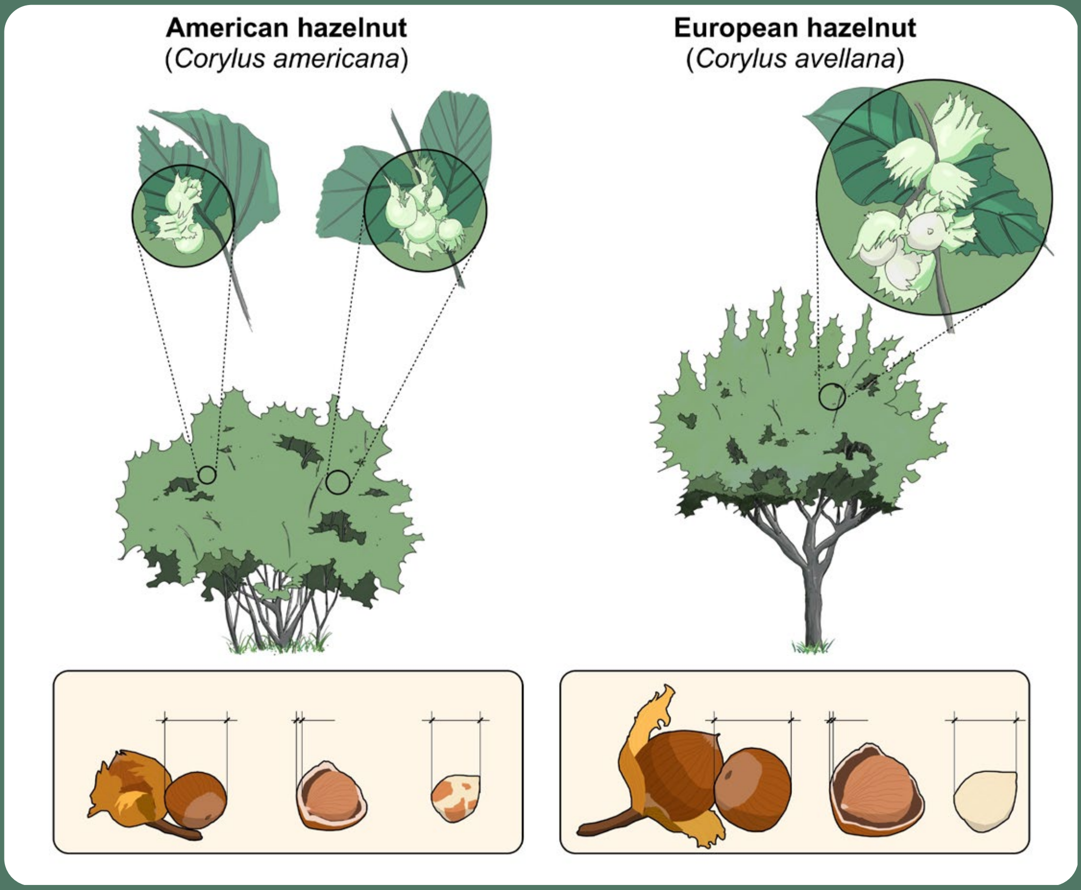


Figure 5: Comparison of the characteristics of American hazelnut (Corylus americana) and European hazelnut (Corylus avellana)[94]. While there are other Corylus species around the world (e.g. Corylus heterophylla and Corylus sieboldiana in Korea, or Corylus cornuta in Canada), they are not considered very important to industry development in the Midwest.

European vs. Hybrid Hazelnuts

KEY POINTS

Hybrid hazelnuts have competitive yields, high cold tolerance, and critical disease resistance, but the kernels, while promising, are currently untested in existing markets.

Hedgerow-grown hybrid hazelnuts feature over-the-row harvesting while crop is still attached to the plant, providing benefits to food safety, soil health, water quality, and biodiversity relative to Oregon model of sweeping fallen nuts off bare soil.

Given the success and growth projections of the European hazelnut-based Oregon industry, at face value it appears the Midwest industry should imitate the Oregon approach. Duplicating the Oregon approach as-is, however, is limited by several key environmental differences between Oregon and the Midwest. Consequently, two alternative approaches are being pursued for the Midwest:

1. Develop European hazelnuts with the stress tolerance traits necessary to thrive in the Midwest, and adapt management practices to work in the Midwest.
2. Develop the American x European hybrid hazelnuts that already thrive in the Midwest to have higher yield and improved nut quality.

Although the two approaches differ in several important aspects, they should not be viewed as mutually exclusive. This section compares the two approaches via the most important categories.

Nut quality & yield

The large, high-quality nuts of European hazelnuts are the gold standard in the confectionery industry. Though the nuts from hybrid hazelnuts are generally larger than pure American nuts, they are not as large as nuts from European cultivars. However, this may not be a liability in the processing market. According to Ferrero, the optimal kernel diameter is 10.5-12 mm, and some top hybrid selections produce nuts with diameters of 9-13mm.

The per-plant yield of hybrid hazelnuts is lower than that of European hazelnuts. However, since the bush-like hybrid hazelnuts are grown in dense hedgerows, per-acre kernel yields of the top selections approach those of the European hazelnut cultivars grown in Oregon. The hedgerow system is modelled after a growing trend in fruit and nut production to grow larger numbers of smaller trees per acre to maximize fruiting wood. Large trees are relatively inefficient in utilizing available growing space.

Characteristic	American	Hybrids	European
Yield	Medium	←	High
Nut size	Small	←	Large
Resistance to EFB	Resistant	→	Susceptible
Cold tolerance	High	→	Low
Harvestability	Mechanical "shake & catch"	→	Mechanical "shake & vacuum"

Table 7: Comparison of key characteristics from each hazelnut species desired when making hybrid crosses.

Eastern filbert blight

Eastern filbert blight (EFB; Anisogramma anomala) is a fungus that is lethal to many hazelnut species (below, left). It is native to a large region of North American east of the Rocky Mountains, where it is nearly exclusively found in association with the tolerant host American hazelnut[85,96,97]. In the case of the European hazelnuts that dominate commercial production, EFB is typically lethal within several years, and the prevalence of this pathogen in the Eastern U.S. has prevented the successful establishment of orchards[98].

Following the discovery of EFB in commercial orchards in Oregon's Willamette Valley in the 1960s, various forms of cultural and chemical control have been developed. While successful to varying degrees, these methods are often time- and cost-prohibitive. The breeding of genetically resistant cultivars has, therefore, been pursued, and cultivars have been released which rely on a single resistance gene (the "Gasaway" gene).

The Gasaway gene confers complete, race-specific resistance to EFB. However, given the greater diversity of the EFB which exists in the Midwest, combined with the inherent limitations of single-gene resistance, reliance on this source of genetic control is not ideal for a Midwestern industry[99,100]. The more durable multi-gene resistance observed in hybrid hazelnuts likely constitutes a much more appropriate mechanism upon which to base large-scale plantings within the natural range of EFB.

Cold hardiness

Within European hazelnuts, the most productive cultivars producing the highest quality nuts are typically the least cold hardy, both in terms of the bushes themselves, but most markedly in the male and female floral organs (below, right). This means that cold winters or spring frosts can result in high crop losses in the following season. Researchers at Oregon State University have concluded that if winter temperatures reach -20°C (a common occurrence in the Midwest), 50% death in male flowers will occur across European hazelnuts[101]. Conversely, American x European hybrids were found to have among the most hardy floral buds of any varieties tested.

Eastern filbert blight (left) is a fungus that is lethal to many hazelnut species; Within European hazelnuts, the cultivars producing the highest quality nuts are typically the least cold hardy, most markedly in the male and female floral organs (right).

Midwest Agroforestry Solutions in Illinois is intercropping hazelnuts with currants, rhubarb, and asparagus.

Orchard style & harvest methods

European hazelnuts are grown as single-stemmed trees and are primarily harvested with machines by shaking nuts from the trees and picking them up off the ground. In contrast, the bush-like growth habit of hybrid hazelnuts, and the fact that they hold ripe nuts on the plant, instead lend them to a hedgerow production system with over-the-top harvesting.

Because it continues to rain throughout the late summer and fall in the Midwest, it is critical that plants hold their ripe nuts within the husks of their clusters, and not drop them to the orchard floor, as the plants in Oregon do. The current hybrids being grown and evaluated in the Midwest do retain ripe nuts on the bushes; this has played a significant role in aiding the harvest of these bushes to date. This approach further benefits food safety (nuts never touch the ground) and soil/water quality (no need to maintain a bare soil understory).

There remain unanswered management questions about the hedgerow system such as optimal initial planting density, plant size management, and harvest, but trials have been established to begin answering those questions.

Limitations of monoculture

Modern monoculture tree crop systems are often no more diverse than conventional row crop systems. Hazelnut production in Oregon is no different – orchard floors are chemically kept bare of all vegetation. This approach runs counter to the desires of many Midwestern hazelnut growers, in part because it makes orchards very vulnerable to pests and disease. Replacing an annual monoculture system with a perennial monoculture system would certainly improve many of the ecological issues currently endemic to Midwestern agriculture, but it would still miss a substantial portion of the potential ecosystem services offered by agroforestry and more diverse perennial systems.

In this regard, the hedgerow system utilized for hybrid hazelnuts is predisposed to a more diverse agroecosystem with a better environmental footprint. The between-row space could be utilized for intercropping and/or grazing livestock, especially during the pre-production years. The Main Street Project in Minnesota is currently pursuing this approach by integrating poultry into their hazelnut production systems, New Forest Farm in Wisconsin has demonstrated the viability of pasturing pigs in conjunction with hybrid hazelnuts, and Midwest Agroforestry Solutions in Illinois is intercropping hazelnuts with currants, rhubarb, and asparagus (above).

History of Work on Hazelnuts in the Midwest

KEY POINT
Various efforts to develop improved plant material, markets, and farmers are ongoing but nascent and represent significant needs in the Midwest.

European germplasm development

Very little effort has been devoted to date on developing European hazelnut varieties that can tolerate the stresses of the Midwestern climate. One possible inspiration comes from Prof. Tom Molnar's work at Rutgers University. He has amassed a large germplasm collection of European hazelnuts, including plants from very northern European latitudes, and has successfully used this material to breed European hazelnuts that can grow in the mid-Atlantic region. The mid-Atlantic region does also have substantial EFB pressure, suggesting that there may be the possibility of mining the existing variation in the European hazelnut gene pool to develop cultivars that are not only single-stemmed and produce high-quality nuts, but can also withstand the disease pressures and cold of the Midwestern environment.

The European hazelnut selections from Rutgers have yet to be tested in the Midwest, but should be included in any new variety trials developed in the region. In addition, the "Yamhill" cultivar from Oregon State is currently being grown at the University of Illinois, and a handful of additional private growers, to evaluate if it can survive multiple years of harsh winters (Ron Revord). While not immediately ready for use in the Midwestern industry, European hazelnuts should be considered as another possible approach in the long-term as breeding continues.

Hybrid germplasm development

In lieu of attempting to breed purely within the European hazelnut gene pool, private and public breeders have been making crosses between European and American hazelnuts for more than 100 years, but initial efforts were sporadic, underfunded, and lacked the longevity necessary for woody crop breeding. Carl Weschcke pioneered early work in this area from the 1920s to 1950s[102,103]. In the 1980s, Philip Rutter (Badgersett Research Corporation in Canton, Minnesota) began further advancing this material, for the first time with the concept of growing hazelnuts as a staple crop[104].

These hybrids have been advanced several generations and have been selected for high yielding individuals that retain the favorable abiotic and biotic resistances of the American parent. Starting primarily with material from Badgersett, this work has additionally been pursued by Mark Shepard (Forest Agriculture Enterprises, Viola, Wisconsin),

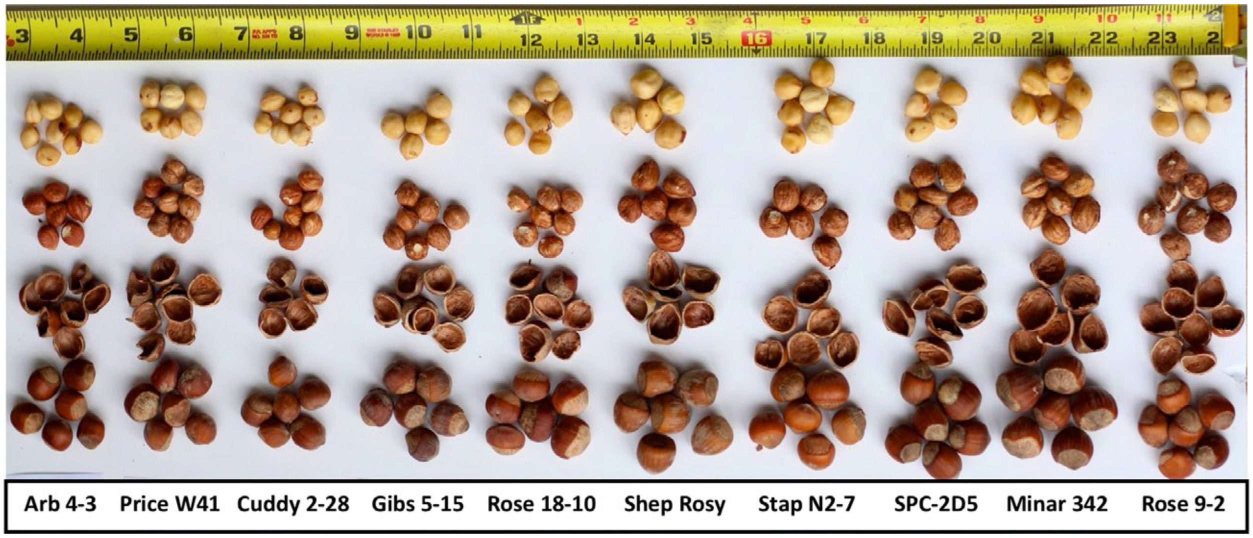


Figure 6: Visual comparison of nut characteristics of the top 10 hybrid hazelnut selections of the Upper Midwest Hazelnut Development Initiative (UMHDI).

the Arbor Day Foundation in Nebraska, and Martin Hodgson in Ontario, Canada.

It was from this material on small farms across the region that Jason Fischbach of the University of Wisconsin Extension and Lois Braun of the University of Minnesota requested "top performers" to be entered into the first coordinated and replicated variety trials of Midwestern hazelnuts. These trials, run by the Upper Midwest Hazelnut Development Initiative (UMHDI, formed in 2007), have since identified several top-performing hybrid selections. More than 150 accessions have been evaluated at five different sites, and from these trials the top 10 genotypes have been selected for propagation and distribution to growers (Figure 6).

These high performing plants, therefore, currently represent the most promising genetic basis for a hazelnut industry that has been comprehensively quantified to date. Many of these selections are in the early stages of tissue culture-based micropropagation to facilitate large-scale plantings.

The UMHDI has also initiated breeding efforts using these top selections in 2012. They have made crosses between the top hybrid selections and European hazelnut parents selected in cooperation with Prof. Tom Molnar at Rutgers University and Prof. Shawn Mehlenbacher at Oregon State University. With more than 7,500 progeny from these crosses now in the ground, along with 2,000 progeny from novel American x European crosses, the UMHDI is well-positioned to develop second generation material, as long as there are sufficient resources to sustain the program.

The selection of an array of potential cultivars by the UMHDI, the hedgerow production system, and deployment of hazelnuts in conservation plantings are all strategies that originated in communication with existing growers. Larger buyers have largely been absent from this development not for lack of interest but because there is not yet a large supply of nuts for evaluation.

The initial generations of breeding performed by Badgersett, New Forest Farm, and the UMHDI have been primarily aimed at obtaining hybrid bushes that survive in the Midwest while yielding a sufficient crop. There is no doubt that there is tremendous genetic gain that has yet to be realized, even with the breeding populations that currently exist at Badgersett Farm, New Forest Farm, and elsewhere. Limited funding has prevented rigorous, multi-year evaluation of any crosses made to date, but when clonal material becomes available, nut quality evaluation in collaboration with large buyers will become more feasible.

Furthermore, genetic sequence data from European, American, and the resulting hybrids now makes possible the identification of the genetic underpinnings of desirable traits. This should accelerate the screening of progeny created through hybrid crosses and selection of further improved hybrid material for testing in variety trials.

Plant material development

To date, hazelnut plantings in the Midwest have consisted entirely of seedling material generated through semi-controlled crosses at a handful of nurseries. Seedling plants have dominated primarily because the major nurseries (Badgersett and Forest Agriculture Enterprises) have been simultaneously involved in breeding and, therefore, have an interest in maximizing diversity on their farms. These operations have focused on controlled crosses with desirable plants to generate full-sibling and half-sibling breeding populations, from which nuts are harvested for sale to farmers.

This seedling approach has generated enormous phenotypic variability in the hazelnut plants on Midwestern farms. However, basing the entire Midwestern hazelnut industry on seedlings alone is undesirable for several reasons. First, variation in seedling growth habit and maturity date poses significant challenges for efficient management and harvesting. In addition, seedlings have variable nut quality traits (e.g. kernel-to-shell ratio, kernel quality, and nut size) that make post-harvest processing more complicated. Finally, there is concern that essential traits, such as EFB resistance, may not appear uniformly across the seedling material, which could prove disastrous for a grower.

The alternative to the seedling model is to adopt the model of hazelnut growers in Oregon and New Jersey (as well as the majority of large-scale growers of other nut and fruit crops in the U.S.): the cultivation of clones of high-performing selections. By micro-propagating selected plants through tissue culture, inexpensive and high-throughput production of genetically identical plants can be achieved. This provides growers with the best possible material at the lowest cost.

However, the clonal approach also has the potential drawback of limiting on-farm genetic diversity, which can leave farmers vulnerable to pest or disease outbreaks. Consequently, the ideal approach to hazelnut plant material in the Midwest will likely include some combination of clonal and seedling material. For example, growers can focus the majority of their production on clonal plants with high yields and top nut quality, while reserving a portion of their farm for seedling plants that improve the size and duration of the pollen cloud, while also increasing genetic diversity.

Market development

The scope of efforts to develop markets for Midwest hazelnuts have been limited to date, but have illuminated a number of potential sources of significant demand and strategies for supplying it. The energy that has been invested in stimulating market demand has not come from the public sector, nor from any existing hazelnut producers or processors. Rather, individual farmers have driven progress, and, partially because of this outsider status, market development has largely focused on developing novel end uses for the crop.

The most concerted efforts in this regard have gone into the creation of the American Hazelnut Company (AHC), which produces a variety of value-added products. Their main products are cold-pressed oil extracted from raw kernels and flour milled from the meal residue following pressing. Currently headed by Brad Niemcek and Mike Lilja, the AHC began operations in 2014. Officially incorporated as an LLC, it is owned primarily by small farmers and other local stakeholders who have purchased equity in the company. Due to its small scale, it operates more closely in accordance with the principles of a grower-owned cooperative. Because of the very limited existing supply of Midwestern nuts, the AHC currently imports nuts from Oregon, which are blended with the hybrid hazelnuts that are aggregated from across the Midwest.

The American Hazelnut Company produces a variety of value-added products using a blend of nuts from the Midwest and Oregon.

A company like the AHC seems critical to the success of the Midwestern hazelnut industry. As a centralized buyer and processor of nuts, they can offer critical price guarantees to growers and make processing/marketing far more efficient than growers attempting to do so alone. At the same time, the

AHC has the opportunity to dramatically scale up their operations immediately by simply importing more nuts from Oregon, at least until local production expands. Given the growing demand for hazelnuts, it is likely the Oregon-based companies will begin selling their nuts in snack foods or other forms in the Midwest regardless, and if the AHC can begin to occupy that market space, it could greatly benefit Midwestern hazelnut growers in the long run.

However, the AHC has yet to expand beyond niche, local markets. This is partly due to the costs of processing locally-grown hazelnuts, which is currently subsidized by University of Wisconsin Extension efforts, but is still cost-prohibitive at any economically significant scale. Another contributing factor is limited success in product marketing and a lack of volume to service larger players in the food product industries that might be interested in adding hazelnuts to their products. Novel products like culinary hazelnut oil can currently be produced and distributed, but enhanced customer awareness through targeted marketing is required to sell the oil in sufficient volume.

Farmer development

The most significant work to date in educating Midwestern farmers about the potential of hazelnuts has come from the UMHDI's outreach activities. Through their website (midwesthazelnuts.org), research bulletins, grower conferences, and field days, they have made significant strides toward training new growers in effective hazelnut establishment and management. They have also published an enterprise budget, which aids farmers' decision making when considering a new planting of hazelnuts.

The main limitations on farmer development have been (1) the unavailability of improved clonal planting stock, (2) a lack of consensus on the agronomic best practices of hazelnut production (e.g. establishment densities, fertilization requirements), (3) limited knowledge regarding the long-term performance of any specific cultivar, and (4) no consistent, stable coordinator of such activities.

BOTTLENECKS LIMITING MIDWEST HAZELNUTS

& STRATEGIES TO OVERCOME THEM

Overall, the recommendation of this plan is that the industry expand production with hybrid hazelnut selections in the near term, but that crop development with both European and hybrid selections continue.

The following sections identify the key bottlenecks limiting the Midwest hazelnut industry in this way:

A. Industry Leadership & Coordination
B. Variety Development
C. Plant Propagation
D. Farm Establishment, Maintenance, Harvest
E. Farmer Capacity
F. Aggregation & Processing

A. Industry Leadership & Coordination

A1. Core Leadership

KEY NEED
Dedicated leadership position for coordination of industry development.

Continued development of the Midwest hazelnut industry depends on strong leadership and coordinated efforts among stakeholders. Since 2013, Jason Fischbach has been the industry's core leader and coordinator[105]. As a University of Wisconsin extension agent, Fischbach has been able to dedicate his time to hazelnuts to spearhead grant writing, grower networking, communication with stakeholders, and cooperation with non-profit and for-profit partners (including assisting in establishing the AHC). In addition, Fischbach has run grower trainings, led efforts to identify potential farmer-adoption regions, and developed and tested harvesting and post-harvest mechanical solutions.

While other key individuals, such as Lois Braun and Constance Carlson of the University of Minnesota, have been involved in all of these tasks, Fischbach has been the central figure helping to coordinate and motivate nearly all of the progress over the last decade.

Unfortunately, following a reorganization of the University of Wisconsin Extension in 2018, funding for Fischbach's work to develop the hazelnut industry has become unstable and unsure. The potential loss of Fischbach's position would be a major loss for the fledgling industry, but with the ongoing decline in funding for universities across the country, administrators are forced to cut funding for everything but their core industries. For funding, the UMHDI is generally limited to whatever grant funding they can secure.

Having a permanent, stable, full-time industry leader who can manage and expand many of the activities currently spearheaded by the UMHDI will be critical as the industry begins to grow and the need for research and extension services increases.

B. Variety Development

B1. Assessment of Genetic Resources

KEY NEED
Systematic inventory and evaluation of existing Midwest hazelnut genetics to support further crop development.

The epicenter for the Midwest hazelnut industry's development to date has been the "driftless" region of southwest Wisconsin and southeast Minnesota, with a few specific farms playing outsized roles:

1. Badgersett Farm, 40 years with hazelnuts, Philip Rutter (badgersett.com)
2. New Forest Farm, 25 years with hazelnuts, Mark Shepard (newforestfarm.us)

Both Badgersett Farm and New Forest Farm have been key players from the early years, with each farm involved in hazelnut breeding, propagation, research, and education. By 2010, Badgersett Farm and New Forest Farm had supplied 48% and 38% of all hazelnut plants growing on Midwest farms, respectively[106]. Both farms are extremely important to the Midwest hazelnut industry, as well as the broader momentum for climate-friendly agriculture in the region. They both contain repositories of hazelnut and chestnut genetics, which are invaluable assets to the continued breeding work needed to catalyze Midwestern industries.

However, very little systematic data has been collected on either farm. Badgersett has maintained a database of phenotypic traits across its several generations of selection (Philip Rutter), but this data has not been compared to the top selections identified by the UMHDI. A more thorough assessment and comparison of existing genetic material is key to ensuring the most effective and efficient progression of hazelnut germplasm in the Midwest. Such an outside assessment was performed at Badgersett more than 20 years ago[104] and is in serious need of being updated.

B2. Variety Performance Trials

KEY NEED
Continuing and expanding variety trials of Midwest hazelnuts.

Average yields of the existing hybrid hazelnut seedlings planted in the Midwest are relatively low, but individual plants have shown significant potential. In 2006, the UMHDI began screening existing plantings to identify top performers, and in 2009 began evaluating 126 genotypes of the best material in replicated variety performance trials in Wisconsin and Minnesota. Plant characteristics evaluated in the trial included winter hardiness, EFB resistance/tolerance, big bud mite resistance, kernel yield, yield stability, percentage kernel, kernel quality (flavor, low pellicle, etc.), harvestability, shellability, and bush architecture.

In 2018, the UMHDI established a second round of variety performance trials ("Joint Performance Trials") at six locations in the Midwest (two each in Iowa, Minnesota, and Wisconsin). This round of trials includes the top 9 hybrid hazelnut genotypes identified in the first round, 12 of which are currently being prepared for licensing by the University of Minnesota. The intent is for these trials is to help guide variety choice decisions by growers as selections become more widely available and focus micropropagation resources on the most promising genotypes.

Ongoing variety trials are critical to hazelnut industry development. Moving forward, there are four key needs to maximizing trial efficacy:

1. To be scientifically sound and valuable to the industry, trials require rigorous maintenance and comprehensive data collection. Stable, long-term funding must be secured for staff to conduct trial maintenance and data collection at each site.
2. At least 10 additional trial replicates should be established at sites across the Midwest. Additional sites will help develop genotype recommendations for specific local climates and soils.
3. Existing UMHDI trials have not yet included all top selections from Badgersett nor East Coast breeders (e.g., only two selections from the Hybrid Hazelnut Consortium in Nebraska, five selections from Grimo Nut Nursery, and none of the soon-to-be-released material from Rutgers University). Inclusion of this material, as well as additional European hazelnut cultivars that have potential in the Midwest (only five have been tested so far), must be included to maximize the potential of identifying top selections for the Midwest.
4. The availability of clonal plant material has severely hindered the replication of variety trials at multiple sites. Overcoming the plant propagation bottleneck (see section C. Plant Propagation below) is critical to increasing trial replication.

B3. Breeding

KEY NEED
Ongoing breeding to incorporate novel pest and disease resistance traits and continually improve yield and crop quality traits.

The need for continued breeding is true for all agricultural crops, but is especially important for tree crops, which require years or even decades to develop new varieties[33,107]. The six- and four-fold increases in U.S. maize and soybean yields, respectively, over the last century[2] have been accomplished through massive investments in breeding and agronomic research. Analogous investments in tree crops can also be expected to substantially improve their performance[27].

In the near-term, to build an industry base, existing top selections from the UMHDI should be propagated and planted on a medium scale. In addition, a targeted cross-pollination and breeding program should now be established to continue development of hazelnut genetics for the Midwest. Ongoing breeding is especially critical for long-lived nut crops, in order to incorporate novel pest and disease resistance traits and continually improve yield and nut quality traits.

Hazelnut breeding at Oregon State University and Rutgers University has so far prioritized disease resistance and nut quality over yield gains[100,107]. Moving forward, breeders may also have room to focus on productivity[100]. New biotechnology techniques, such as the use of plant growth regulators and transgenes to stimulate flowering on juvenile tissue or high-throughput genomic screening of offspring, could greatly accelerate the development of superior tree crops[108].

Regardless of which hazelnut species/approach is utilized, the most robust and rapid gain from breeding will be obtained by ensuring that any given cultivar has multiple European and/or American ancestors, reducing the effects of undesirable traits. This could be most effectively accomplished by crossing existing hybrids that trace back to different European individuals.

It is not known, currently, if the dominant confectionary markets for hazelnuts will be out of reach for many existing hybrid selections that can grow in the region, but it is certainly possible. Back-crosses of the existing hybrid selections with specific European hazelnut parents could potentially improve both kernel size and quality. Research into the genetic control of these phenotypes, as well as stress tolerance traits would also greatly aid in the application of modern molecular methods. Encouraging evidence for this potential from Professor Tom Molnar at Rutgers University suggests that it should be possible to combine sufficient EFB resistance and cold hardiness into high-performing European hazelnuts to make it possible to grow confectionary-quality nuts even in the Midwest.

Beyond the existing European and hybrid hazelnut selections, wild populations of American hazelnut are enormous and incredibly genetically diverse[109]. These populations have never been explored for novel traits for flavor, insect pest resistance, or overall yield. Exploring these wild populations and incorporating their beneficial traits will help maintain important genetic diversity in the Midwest breeding program.

Midwest hazelnut breeding will begin under the auspices of a recent Specialty Crop Multi-State Program grant awarded to researchers at the University of Wisconsin and University of Minnesota. This research will use next-generation sequencing technologies to evaluate the genetic diversity, genetic architecture, and heritability of traits in American hazelnut, and in intra- and inter-specific crosses. Additionally, heritability of agronomically important traits in existing full-sibling breeding pools will be evaluated, along with the development of genomic selection strategies for selecting at the seedling stage. In addition, a more broad, but currently-unfunded USDA Specialty Crop Research Initiative grant written by this same team of researchers could provide an additional three years of funding to continue working on such objectives.

This short-term funded work is an important step in the right direction. However, continued breeding work must be further supported through stable, long-term funding if robust improvements in Midwest hazelnuts are to be achieved.

C. Plant Propagation

C1. Micro-Propagation Methods

KEY NEED
Large volume of clonal plantlets for supplying nurseries.

Conservative market capture assumptions suggest a need for 157 million hazelnut trees in the Midwest over the next 20 years. It is crucial, therefore, to understand how these plants will be best propagated and what entities will have the capacity to grow that many plants.

Historically, the only sources of hazelnut plants adapted to the Midwest have come from a small set of nurseries (e.g. Badgersett Research Corporation, Forest Agriculture Nursery) that have sold seedlings derived from semi-controlled crosses between top-performing material in their orchards. These seedlings have extremely diverse characteristics, since the production of inbred, true-breeding lines is currently infeasible in an outcrossing species such as hazelnut with multi-year generation times.

Therefore, the only method available to propagate uniform material for large-scale production is clonal propagation. Clonal propagation by tissue culture forms the basis of the Oregon hazelnut industry. Tissue cuttings from high-performing plants are rooted in a greenhouse and transferred to artificial media in sterile growth chambers. These rootless plants can then be multiplied indefinitely by dividing the material and initiating these new cuttings on growth media. Once a critical number of these clonal plantlets are growing under laboratory conditions, large numbers of genetically identical, field-ready plants can then be generated by rooting explants, transferring them to soil, and eventually re-acclimating them by moving them into greenhouses, and eventually field nurseries (Figure 7).

While this micropropagation approach has been extremely successful for European hazelnut plants in Oregon, researchers have only had limited success in applying this method to hybrid hazelnuts. Therefore, a major bottleneck limiting the immediate planting of even small- or medium-scale acreage of hybrid hazelnuts, is the lack of widely available clonal germplasm.

Although mound layering and similar approaches based on propagating suckering growth of coppiced bushes does allow for clonal propagation, these methods are inefficient in generating large plant quantities. To date, only small-scale experiments

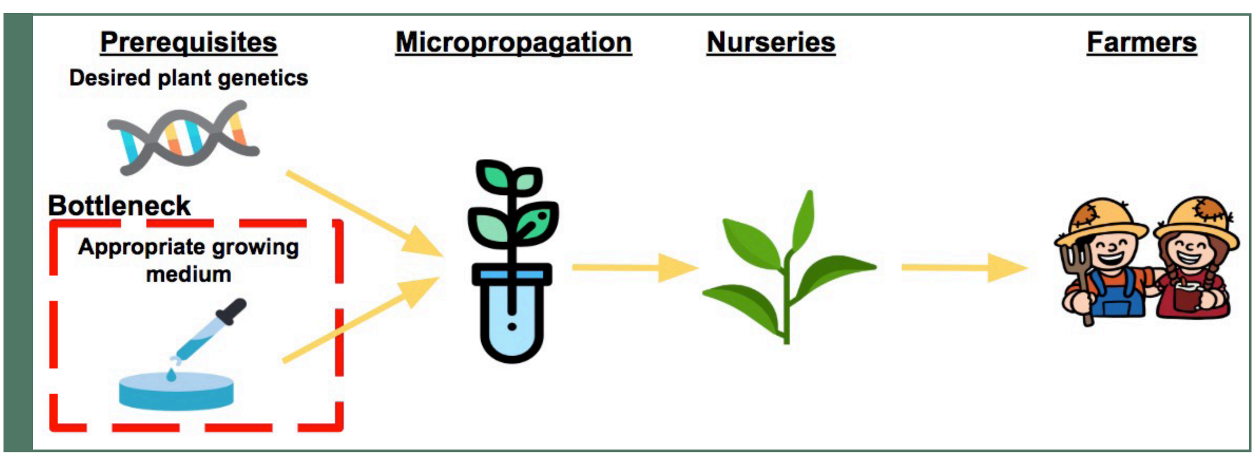


Figure 7: Plant material propagation pipeline via micropropagation.

	National Clonal Germplasm Repository (NCGR/OSU) + Public Sector Universities	West Coast Micropropagation Companies (Self-funded)	West Coast Micropropagation Companies (Externally-funded)	Midwest Companies (Knight Hollow Nursery)
Pros	• Specialized team with prior success • Results shared to whole industry	• Free • Diversification (higher likelihood of speedy success)	• Diversification (higher likelihood of speedy success)	• Locally-based, nationally-recognized leader in the field • Ongoing work
Cons	• Capital intensive • One team, hence less diversification in research	• Stringent IP • Limited capacity • Research could be delayed by lack of focus/prioritization	• Capital intensive • Less experience than NCGR/OSU • Likely to take longer or cost more	• Sub-optimal lab scale may lead to less thorough findings • Stringent IP • Limited capacity

Table 8: Comparison of potential avenues to solving the bottleneck of developing the micropropagation protocol for hybrid hazelnuts.

have focused on hybrid hazelnut micropropagation. The findings by Knight Hollow Nursery suggest that, while technically feasible, the protocols developed for European hazelnuts must be modified to be effective with hybrids. In particular, development of hybrid-specific growing media for tissue culture, as well as protocols for transitioning plant material out of tissue culture have been limiting steps (Figure 7).

Developing the micropropagation protocol for hybrid hazelnuts could be pursued via several potential avenues (Table 8):

1. Fund the National Clonal Germplasm Repository (NCGR) and Oregon State University (OSU), which developed protocols for Oregon's European varieties.

2. Fund Midwest researchers (e.g. Jerry Cohen, University of Minnesota or Praveen Saxena, University of Guelph), advised by members of the NCGR/OSU team. Critical research objectives would focus on understanding genotypic variation in the induction of rooting of tissue-cultured explants, as well as variable resilience and mortality following transition from tissue culture into the greenhouse.

3. Work with existing micropropagation companies in Oregon to develop their own protocol. Although larger entities typically prefer to take on the entire R&D cost in exchange for keeping their methods as protected trade secrets, there may be an opportunity to pay these companies to develop the protocol in exchange for making it publically available.

4. Invest in the existing activities in the Midwest led by Knight Hollow Nursery.

Because the NCGR's tissue culture lab is likely to close due to budget cuts, keeping it open for the purpose of running this R&D work would have the following costs:

1. $100,000 per year to keep the lab operating

2. $60,000 per year for staffing needs

3. Five years of minimum guaranteed funding

Given that Knight Hollow Nursery has already developed initiation protocols for several genetics, a partnership between the two organizations could reduce the timeline to three years, resulting in a total budget of ~ $480,000.

One method for lowering the cost of this option would be to instead fund a similar venture in the Midwest, leveraging existing lab facilities at either the University of Guelph or the University of Minnesota. This would reduce laboratory costs and execution risk that could arise from transporting living plant material from Oregon to the Midwest.

Finally, it should be possible to include additional, experienced West Coast micropropagation companies in the optimization of these protocols. Given that meeting the growing global demand for hazelnuts could require tens of millions of new hazelnut trees to be planted, the sheer size of the opportunity would easily make it economically worthwhile for existing tissue culture companies to become involved in the optimization of the micropropagation protocols. Although capital costs (~$5 million for a 5 million plant production capacity) are high, expected profit per plant and large volumes significantly offset these costs and lead to a 40+% internal rate of return (IRR) opportunity for existing tissue culture firms. With operating costs of $1.00-1.50 per plant and margin requirements around 50%, a $3 per plant sale price should be possible. It also appears that there could be room to negotiate that margin lower if the company could access long-term purchasing agreements, highlighting the possibility of getting plants offered at a cheaper rate to farmers—which will be crucial to expanding into commodity markets such as biodiesel and animal feed.

Conversations with existing West Coast companies (e.g. Carlton Plants, Rancho Tissue Culture, and North American Plants) suggests that they are typically better at refining micropropagation protocols than they are at creating them. In the case of the Oregon hazelnut market, the publicly funded research done by NCGR/OSU was then adapted and optimized by multiple companies to serve specific client needs. Therefore, these companies have suggested that they should not be the initial partner on the R&D phase of hybrid hazelnut micropropagation, but rather serve to diversify the number of entities involved in actually producing clonal material, once effective methods are optimized. Therefore, it seems that a combination of financing of basic research at the University of Minnesota and University of Guelph, coupled with order guarantees required to get West Coast micro-propagators engaged with hybrid hazelnut material would be an effective strategy for making the most rapid progress on this issue.

C2. Field Nursery Methods/Transition

KEY NEED
Large volume of field ready, uniform quality plants at competitive prices.

Once plantlets are produced by micropropagation, they need to be grown in nurseries for one year to create field ready plants for sale to farmers. Few nurseries in the Midwest are large enough to grow the required number of trees annually (~3 million per year over the next 10 years and 12.5 million per year over the following decade). Furthermore, most commercial nurseries are already at maximum capacity and not interested in taking on a new crop.

North American Plants, Phytelligence, and similar West Coast firms could combine these micropropagation and nursery stages. Their in-house process is potentially scalable and provides efficiency by keeping micropropagation and nursery production in the same location. Nevertheless, leveraging the existing supply chain of hazelnut seedling nurseries in the Midwest is likely a more efficient option.

Together, Mark Shepard (Forest Agriculture Nursery) and Tom Stecklein (Morrison Brothers Tree Farm) currently grow the vast majority of hazelnut seedlings grown in the Midwest. They are interested in building a new nursery to satisfy future demand for hazelnut plants. Given their extensive experience with hazelnuts, Shepard and Stecklein are well-suited to develop a nursery that can grow micropropagated plantlets to field-ready plants. This company could also act as a pilot program for new varieties and educate new farmers on growing best practices.

While clonal material is critical to future expansion of the Midwestern hazelnut industry, maintaining some percentage of plants on each farm as seedlings is important for pollination of clones, resilience to pests and disease, and maintaining genetic diversity. Consequently, even with the development of clonal hazelnut cultivars for the Midwest, existing nurseries that produce seedlings should continue to do so.

This combined clone-seedling approach is another important argument for working with the Midwestern nurseries (e.g. Forest Agriculture Nursery) that already provide seedlings to the industry once clonal material is ready. It is important to ensure that a wholesale industry switch to clone-dominated plantings does not leave these nurseries high-and-dry with their large existing investments seedling material.

D. Farm Establishment, Maintenance, Harvest

D1. Large-Scale Pilot Farm

KEY NEED
A pilot farm producing sufficient volume of high quality crop to catalyze supply chain development and encourage other growers.

There is a classic "chicken-and-egg" problem central to the development of all emerging crops. On the one hand, growers are hesitant to scale up crop acreage unless they know that the management technology, aggregation logistics, processing infrastructure, and markets are all ready to go. On the other hand, aggregators and processors are hesitant to invest in necessary infrastructure unless they know that the supply will be there. The end result is an industry on hold until someone bites the bullet.

Even the researchers and educators have their hands tied in this scenario. Without even one large-scale farm or a substantial supply of nuts, processing lines are difficult to design, scale-relevant management and harvest research cannot occur, and new farmers cannot set their sights on an example farm to emulate.

The chicken-and-egg scenario is even more pronounced for tree crops due to the large up front investment needed to establish plants. This certainly holds true for hazelnut and has continually hindered the industry's development.

Which side of the equation has to budge first? For hazelnuts, the multi-year lag to commercial yields suggests that the farm/production side of the equation must move forward first. Once a sizeable quantity of plants are in the ground, the rest of the supply chain has several years to catch up. Getting a large-scale pilot farm like this established is a critical need for investment by someone willing to shoulder the added risk and inefficiencies of being the first big industry player.

No matter how much research has been done in the industry to date, there will undoubtedly be new lessons learned when scaling to a large-scale hazelnut farm. Management, harvesting, aggregation, and processing all take on new complexity and new technology that can be difficult to sort out ahead of time. These lessons will provide critical insights for the industry as a whole, but they also mean that the pilot farm itself will certainly encounter unavoidable inefficiencies. Nevertheless, to break the chicken-and-egg bottleneck, this must happen even if the available plant genetics and management systems are not yet perfect.

The ideal size of this pilot farm would likely be in the range of 80-120 acres, with required upfront capital at $6,500-8,400 per acre, depending on the ultimate costs of clonal plant material.

The ideal pilot farm location would be near the University of Wisconsin - Madison, where the University already owns several machine harvesters and much

of the required post-harvest hazelnut processing line. If funded via public/philanthropic support, the pilot farm could even exist as part of a University research station, providing a long-term stable land base with equipment and staff (Jason Fischbach).

Alternatively, private investment could be used to support a large-scale Midwest hazelnut farm via either of two approaches:

1. Investment in both land and plants – The investor would purchase the land and invest in the upfront cost of hazelnuts plants and establishment.

2. Investment in just plants – The investor would still invest in the upfront costs of hazelnut plants and establishment, but would instead hold a long-term (20-99 years) lease with a private landowner.

The long-term lease approach has become an increasingly common mechanism for investors to maximize potential returns by focusing investment on the tree crops. The Savanna Institute has done substantial work on long-term lease agreements and secure land tenure with our collaborators at Farm Commons (farmcommons.org). Several resources are also available on the Savanna Institute's website (savannainstitute.org/resources).

Other strong potential collaborators in the development of a large-scale hazelnut pilot farm are the Main Street Project (mainstreetproject.org) and Regeneration Farms (regenerationfarms.com). These organizations will soon be deploying 1 million hazelnuts in Minnesota as part of a system that uses hazelnuts as feed and habitat for a pastured poultry enterprise (Reginaldo Haslett-Marroquin). While their focus so far has not been on growing hazelnuts as a commercial crop, they have substantial experience with the species and with scaling production.

D2. Management Trials

KEY NEED
Research-based best practices for Midwest hazelnut growers.

The long-term agronomic performance European x American hybrids is largely unknown. It is, therefore, critical to establish replicated field trials that can maintain orchards of the most common cultivars to observe and study the challenges growers will face before growers encounter them in their own orchards. Some of the most pressing questions related to crop management that need further investigation include:

- Fertility management (particularly nitrogen) both during orchard establishment and at maturity.
- Appropriate timing, intensity, and mechanization of pruning (e.g. regenerative pruning vs. full coppicing).
- Weed control requirements and approaches during orchard establishment under both conventional and organic management.
- Evaluation of ideal plant spacing in hedgerow systems during establishment and at maturity, both in terms of plant health and yield maximization.
- Investigation of intercropping approaches (e.g. asparagus, rhubarb, vegetables) and livestock integration in silvopasture.
- Evaluation of strategies for pest and disease management, as well as scouting for the emergence of novel pests and diseases as the size and number of hazelnut orchards in the region increases.

D3. Straddle Harvester Technology

KEY NEED
Improved harvesting efficiency for hedgerow hazelnuts.

The top hybrid hazelnut selections identified to date have the bush-type growth habit typical of American hazelnuts. These plants are most effectively grown as a multi-stemmed hedgerow with 900-1000 plants per acre (Mark Shepard, Jason Fischbach), with either regular regenerative pruning or periodic full-coppicing.

While there are many benefits to this approach, it also presents a unique challenge to mechanical harvesting. The harvesting equipment that is used in Oregon relies on single-stemmed, tree-form hazelnuts that form a closed canopy and drop nuts to the ground. Since hybrid hazelnut plants retain their clusters at ripening, mechanical harvesters must use a "shake-and-catch" approach. Harvesters using this approach are currently used in olive, blueberry, and other shrub fruit systems.

For hazelnuts, application of these harvesters must extract a high percentage of clusters in a single pass while limiting damage to the plant, especially male flowers already on the plant for next year. Ideally, this harvesting machinery would also have the capacity to de-husk the nuts in the field, reducing a post-harvest processing step.

With funding from the USDA Specialty Crop Program the UMHDI has initiated a program to develop an optimized straddle-type harvesting system for hedgerow hazelnuts. In 2018, a slapper-type unit (below) was trialed in multiple locations. They have since purchased a bow-head olive harvester and a rotary-shaker harvester to test as well. In addition, they hope to test a sway-type harvester in 2019.

Mechanical harvesting is necessary if a commercial Midwest hazelnut industry is going to compete with corn and soybeans or the Oregon hazelnut industry. UMHDI work on straddle harvester development has made substantial progress on improving the efficiency of harvesting hybrid hazelnuts. Nevertheless, several critical funding bottlenecks are holding back the final development of this technology, including (1) the purchase an additional used harvester for testing, (2) the purchase of a trailer to transport the harvesters to cooperating growers, and (3) funding to cover travel so the number of experimental sites can be expanded.

UMHDI has initiated a program to develop an optimized straddle-type harvesting system for hedgerow hazelnuts. In 2018, this slapper-type unit was trialed in multiple locations.

Savanna Institute Farm Manager Kaitie Adams leads a session on Practical Agroforestry for Working Farms at the MOSES Organic Farming Conference.

E. Farmer Capacity

E1. Farmer Training

KEY NEED
Skilled hazelnut growers to implement the best genetics and management techniques.

A deficit of skilled farmers trained in tree crop establishment and management is a core bottleneck holding back the widespread adoption of tree crops in general. This problem is further compounded for emerging crops like hazelnut, where the unfamiliarity and lack of market security increases farmer hesitation. Training a community of expert hazelnut growers that can effectively implement the best genetics and management techniques is critical to the expansion of the Midwest hazelnut industry.

While farmer training programs are common for annual vegetable production, they are nearly non-existent for tree crops and other perennials. The Savanna Institute piloted a farmer training and apprenticeship program in 2019 focused on agroforestry and tree crops – the first of its kind. In subsequent years, and as hazelnut best practices in the Midwest are developed, a hazelnut-focused version of the program should be established.

E2. Startup Credit Mechanism for Farmers

KEY NEED
Financing adapted to ROI time horizon for perennial crops.

Perennial, permanent crop systems typically present significantly higher income to farmers than row crop systems. Over the past 10 years, for instance, permanent crop income in the U.S. averaged an annualized return of 12.2%, compared to just 4.5% for annual crops[110]. However, permanent crops also present added risk associated with the multi-year lag between establishment and the breakeven point.

One acre of hybrid hazelnuts in the Midwest is estimated to cost ~$8,400 to establish and will ultimately generate an average annual net income of ~$1,900-$3,800[93]. While positive net income starts in year 6, farmers incur substantial costs during the first 5 years and will not break-even on their investment until at least year 9. Such an investment could provide an attractive 5-19% IRR over 20 years, depending on in-shell nut prices (13.4% IRR using the average nut price over the past 10 years - $1.68/lb)[76]. However, the initial capital outlay and revenue lag is prohibitive for most farmers and landowners.

Few existing mechanisms in the Midwest farm credit system can truly help farmers overcome this hurdle at scale. Although revolving loans exist, the current regulatory environment requires an annual principal repayment. "Evergreen" loans have been offered in the past, allowing for an interest-only feature up to 3 years, but not beyond this (Paul Dietmann).

Consequently, farmers looking to switch from row crops to perennial crops have opted to do it gradually over many years. A gradual transition, however, does not benefit from any economies of scale and can actually result in the farmer incurring much higher expenses compared to transitioning all at once.

New funding mechanisms are needed that allow farmers to take on more risk and convert a larger amount of their land to perennial crops at once. These funding mechanisms should:

- Provide enough funding to cover capital & operating expenses during years 1-5.
- Provide livelihood support to farmers during the same period if needed.
- Not require principal payments until cash flows can finally be generated.

Given that these new funding mechanisms would transfer some of the execution risk away from farmers, an equity funding mechanism would likely be more appropriate than a debt funding mechanism. Equity funding means each stakeholder that onboards additional risk would be compensated by owning a portion of the investment. In contrast, debt funding puts the majority of risk onto the borrower and not the lenders.

Farmstart LLP, a spin-off partnership between several farm credit agencies, is attempting something close to this, although at a relatively small scale (<$50,000). Capital is provided to beginning farmers up front, and is expected to be repaid in year 5—whether through cash flows or via rolling over into a regular loan. The mechanism is similar to an operating line of credit.

In the Oregon hazelnut industry, another fairly common approach is for investors to buy land and fund orchard establishment and maintenance until yield begins. Then, investors recoup the initial investment by selling the farm to hazelnut farmers. This allows farmers to enter the equation once the yield lag and high risk period has ended.

Revenue based loans could also help bridge the farmer's financing gaps. In this instance, investors would make a loan to the farmer with a repayment schedule tied to the borrower's revenue. The loan is fully repaid when cumulative payments reach an amount equal to the capital contributed, plus accrued interests. This instrument would include a maturity date that allows time to make the transition to perennials. Investors often get a security interest in the borrower's assets. However, unlike traditional loans, that security interest might consist primarily of intangible assets (e.g. accounts receivable), and there may be no requirement for a personal guaranty.[111]

In the case of Midwestern hazelnuts, if an entity were to finance 80% of capital needs via a revenue-based loan with a 10% interest rate, and assuming 75% of cash flow as a repayment rate, such a loan would take 14 years to be repaid. That said, it is possible that traditional lending mechanisms would become available as cash flows start to be generated by the enterprise in year 6. Traditional loans could then be provided with terms up to 7 years and interest rates at 6.0-6.5%. The biggest variable of such loans would then be in the loan to value ratio (LTV) that the regional bank would be willing to provide. For high certainty cash flows, farmers could be offered an LTV as high as 80% while for crops with lower market certainty, LTVs in the vicinity of 50% would be more likely (Paul Dietmann).

F. Aggregation & Processing

F1. Initial Processing Line

KEY NEED
Engineering and fabrication of more efficient post-harvest processing for current and future production.

A significant limitation to the expansion of a Midwestern hazelnut industry, as well as the current processing of Midwestern-grown nuts is a lack of an efficient post-harvest processing pipeline. The necessary de-husking, sanitizing, cracking, cleaning, and sizing the harvested hazelnuts requires properly designed machinery.

Achieving this engineering challenge also carries a chicken-and-egg dynamic. The capital needed to build processing lines is typically not available until sufficient production warrants their creation. On the other hand, stimulating sufficient production is difficult without proper processing lines in place.

Despite this challenge, significant progress has been made by Jason Fischbach towards creating an initial processing line that can handle the limited volumes expected in the near term. This initial processing line is also easily modifiable, allowing for the testing of various components and aiding the construction of a high-capacity processing line. This flexibility is also critical as the variety selection progresses – different processing practices and machines are optimized for the different size, shape, and shell characteristics of each potential cultivar.

This initial components of this processing line are housed by the University of Wisconsin. Several improvements to this line are critical for efficiently processing the existing and short-term Midwestern hazelnut crop. Developing this infrastructure, even in the context of processing Oregon-purchased nuts, would greatly aid Midwestern companies, such as the AHC, in increasing their market share.

Specifically, an improved drum sizer is required that has inflow and outflow mechanisms made of food-grade stainless steel and a variable speed drive to control drum speed and feeding rate. New drums should be designed with different style holes (slots, round holes, and half-moons) to allow efficient sorting of in-shell nuts, kernels, and shell fragments, respectively. Pendragon Fabrication has provided a quote of $17,000 to manufacture this unit (John Beshaw).

In addition, a combination sorting belt/inclined belt separator is required to increase the speed at which a final hand cleaning of the cracked kernels can be accomplished. When in its flat orientation this table can be used as an inspection table, and when tilted, a belt separator. Pendragon Fabrication has provided a quote of $18,900 to manufacture this unit.

Finally, a UV sterilization unit is required to surface sterilize the in-shell nuts prior to processing. Currently, a disinfectant dip and oven dryer are being used to perform sterilization, but this is both too slow and expensive. Quotes are currently being requested for such a unit.

F2. Food Processing Research for Novel Markets

KEY NEED
Research and development to match hazelnut crop characteristics with industry specifications for biodiesel and livestock feed markets.

Compared to existing hazelnut markets, there are massive potential novel market opportunities for hazelnut to supplant soybean as a biodiesel feedstock or livestock feed. Critical to accessing these markets, however, is meeting their biochemical and nutritional requirements.

While initial work has already occured on hazelnut protein and oil composition[74,84], substantial further work is necessary. In particular, further research is needed to quantify lipid, amino acid, and mineral composition of top Midwestern hazelnut selections. Furthermore, as continued breeding occurs, there is potential to match selection requirements with the biochemical and nutritional requirements of novel markets.

In addition to hazelnut chemical composition, research is needed to determine how a large-scale hazelnut industry could leverage the existing network of soybean storage, transportation, and processing infrastructure. Utilizing this existing infrastructure will make scaling the hazelnut industry much more effective and efficient, but will likely require some specific modifications to its design and use. Large soybean processing companies, such as Archer Daniels Midland and Cargill, could serve as key collaborators in this research.

PRIORITY STRATEGIES

TO OVERCOME BOTTLENECKS

The bottlenecks presented above each play a sizable role in holding back the Midwest hazelnut industry. This section provides an objective ranking to prioritize strategies to overcome the bottlenecks based on capital needs, relative urgency, expected timeframe, and dependency on prerequisite activities.

Overall, the suggested strategy is to concurrently pursue:

1. Bottlenecks limiting Midwest hazelnuts in general (i.e. bottlenecks that exist regardless of whether European hazelnuts or hybrid hazelnuts become ready first for widespread adoption).

2. The necessary research and development to overcome hybrid hazelnut-specific bottlenecks.

Each strategy is framed as a specific pitch leveraging either public/philanthropic support or private investment. Nevertheless, strategies could likely be enacted in a variety of ways, including various forms of blended capital.

It should be noted that private investment opportunities have been placed toward the end of the ranking because the research and development-oriented strategies are likely required to make those investments worthwhile.

The first two strategies concern urgent needs facing the industry and would have immediate, significant impact on the development of Midwest hazelnuts. Strategies 3-8 also represent crucial needs, but with impacts that would play out over a longer timeframe as the industry continues to develop. Finally, strategies 9-10 represent important but less urgent needs that generally require higher priority bottlenecks to be solved first.

1. Scaling Hybrid Hazelnut Micropropagation

Bottlenecks Targeted: C1, C2
Amount: $250,000
Mechanism: Public/Philanthropic Support
Lead Entities: North American Plants, Micro Plants, Rancho Tissue Culture, University of Minnesota, University of Guelph

An initial hurdle dramatically limiting the dissemination of existing germplasm is simply the lack of initiated genotypes at established micropropagation companies, who have proven track records of producing hazelnuts for commercial orchards in New Jersey and Oregon (e.g., North American Plants, Micro Plants, Phytelligence, Rancho Tissue Culture). The typical cost of initiating a specific hazelnut genotype is $5,000, although this could be marginally higher for the more difficult hybrid varieties.

This portion of the funding (estimated at $100,000 to get multiple companies involved in the top 10 hybrid selections) would also cover the labor costs of producing and sterilizing the juvenile tissue which is required for beginning tissue culture. This includes time and travel by University of Minnesota staff, who are licensing this germplasm, for coordination of a set of nurseries to aide in producing field-ready plants from tissue-cultured plantlets. Funding of a Pilot Farm (see Strategy 8) would also likely stimulate additional interest from companies seeking demonstrated demand for micropropagated plant material, because initial order guarantees are often required before scaling up the micropropagation of a new cultivar.

Further investment into the research and optimization of micropropagation protocols is also critical, and could be greatly aided through investment in the work being performed by University of Minnesota (Prof. Jerry Cohen) and the University of Guelph (Prof. Praveen Saxena). Conversations with all of these labs suggest that $150,000 would be sufficient to begin publishing optimized protocols that address remaining technical challenges.

2. Complete Initial Harvesting and Processing Line

Bottlenecks Targeted: D3, F1
Amount: $235,000
Mechanism: Public/Philanthropic Support
Lead Entities: University of Wisconsin Extension

A crucial current need is the capacity to efficiently harvest and process the nuts that are currently grown in the region, including small farmers selling to the AHC, as well as variety trials that are coordinated by the UMHDI.

The purchasing of a used sway bar harvester, modifications to adapt the unit, and transportation and experimentation at six field sites would cost roughly $140,000.

This processing facility should be set up to accommodate testing of various processing equipment to inform a larger "at scale" processing pipeline that would service a mature industry. That future processing line could be supported by private investment. Bids indicate $95,000 would facilitate the fabrication of the remaining pieces of equipment that are still lacking, as well as modification of recently donated materials from Oregon.

3. Assess Germplasm at Badgersett & New Forest Farm

Bottlenecks Targeted: B1
Amount: $150,000
Mechanism: Public/Philanthropic Support
Lead Entities: University of Minnesota, University of Wisconsin, Savanna Institute

Two years of funding for a graduate student to conduct assessment of genetic and phenotyping diversity at Badgersett Farm and New Forest Farm would provide a much needed understanding of the potential value of these germplasm collections for future breeding efforts. A deficit of record keeping over the past decade has left a significant gap in current understanding of the relative performance of existing populations.

The proposed funding would support (1) two years of a standard graduate student stipend with tuition remission at $50,000 per year, (2) $20,000 for research expenses, and $15,000 for farmer compensation for both Badgersett and New Forest Farm.

4. Permanent Industry Coordinator Position

Bottlenecks Targeted: A1
Amount: $1,500,000
Mechanism: Public/Philanthropic Support
Lead Entities: University of Wisconsin Extension, Savanna Institute

Critical to the long-term success of the Midwestern hazelnut industry is a guaranteed position that can perform critical industry leadership and coordination among stakeholders. As Jason Fischbach's position is currently housed in the University of Wisconsin Extension, this support could stabilize and secure Fischbach's position there. However, the potential of changing priorities of Universities adds uncertainty, as evidenced by the existing uncertainty around Fischbach's position. Alternatively, an industry coordinator could be housed within the Savanna Institute.

For either a university or another organization, a $1,500,000 endowment would provide ~$60,000 per year for a permanent industry leadership position that would continue to provide critical coordination between variety development, technical engineering tasks, farmer outreach, and general stakeholder engagement.

5. Centralized Variety Development

Bottlenecks Targeted: B2, B3
Amount: $100,000 - $6,000,000 (see tiers below)
Mechanism: Public/Philanthropic Support**Lead Entities:** University of Missouri Center for Agroforestry, University of Illinois at Champaign-Urbana, or University of Wisconsin - Madison, Savanna Institute

Oregon State University's support for the hazelnut industry has been critical to its success over the decades, and the investment of Rutgers University is the primary reason the hazelnut industry is set to expand in the mid-Atlantic region in the coming years. The ability to leverage university resources is critical to the continued development of improved variety development in the Midwest.

Based on conversations with senior faculty at several Midwestern universities, there are three general levels of investment that could support useful academic research into hazelnut breeding:

Tier 1

A fully endowed breeder would likely cost $2 million to hire at the Assistant Professor level, or ~$6 million to recruit an established mid-career Full Professor. This would provide both for salary dollars, some ongoing research costs, and partially offset start-up costs. Such a position could be tailored to be 100% research, and focus at least a large percentage of their time on hazelnuts in particular. Additionally, right-of-first refusal agreements could likely be obtained with the University's Technology Transfer Office to provide exclusive access by the funder to any germplasm developed through such a breeding program.

Tier 2

In lieu of fully endowing a new position, $500,000-$1,500,000 in funds could likely be leveraged to help shape the focus of new hires that a department would be pursuing in any event. For instance, $75,000 per year for 10 years could largely offset 50% of a new breeding hire, and therefore be used to shape the aim of this hire to be focussed on "tree crops" writ large.

In both of these cases, the substantial cost of funding a tenured professor would be offset by the significant resources such a professor could in turn leverage. Through grant-writing activities, access to university services such as greenhouses, labs, biotechnology centers, as well as the support of undergraduates, graduate students, and scientific staff, a professor-level position could form the stable basis necessary to drive the long-term improvement of hazelnut germplasm.

Tier 3

Absent such a substantial investment, significant benefits could still be obtained by accessing academic research capacities of universities. $100,000-$500,000 in funding to an already existing research lab could provide support for a discrete and relatively self-contained research project. Whether this is funding an established tissue culture lab (such as that of Praveen Saxena at the University of Guelph), or quantitative genetics program (such as that of Julie Dawson at the University of Wisconsin Madison), or a tree-nut breeding program (such as those that exist at the Center for Agroforestry at the University of Missouri or the Savanna Institute), specific research objectives could be addressed in this manner, again, by mobilizing the substantial resources of the university system.

6. Research and Development Funding Pool

Bottlenecks Targeted: D2, F2
Amount: $2,500,000
Mechanism: Public/Philanthropic Support
Lead Entities: Hazelnut Development Council

There are a substantial number of agronomic questions related to hazelnut production in the Midwest that still need to be addressed. As described above, these include fertility management, pest control, pruning strategies, orchard layout, and research into hazelnut processing for novel markets. Although there is a need to address all of these questions at some point, to some degree, they are certainly not all currently critical research questions, and indeed, it is not possible at this stage in the industry to identify what the most pressing questions will be after 10 years of industry expansion.

This need could be effectively addressed via a competitive grant funding apparatus administered by a newly formed independent Hazelnut Development Council consisting of industry stakeholders. This endowment will provide roughly $100,000 annually as awards to researchers or farmers to study questions of interest and importance on an annual basis. This could function in a manner very similar to the USDA's Sustainable Agriculture Research and Education Program, and create a very effective and adaptable resource to ensure that the industry is able to quickly address challenges as they arise.

7. Establish Large-Scale Pilot Farm

Bottlenecks Targeted: D1
Amount: $840,000
Mechanism: Private Investment
Lead Entities: Savanna Institute, Regeneration Farms, Propagate Ventures, Midwest Agroforestry Solutions

A large-scale pilot farm is needed to break the chicken-and-egg bottleneck in the Midwestern hazelnut supply chain. A farm producing sufficient volume of high quality crop could catalyze supply chain development and encourage other growers to get started. Similarly, a large supply of Midwestern nuts is critical to help perfect post-harvest processing methods and stimulate the market for Midwestern grown nuts.

While a large-scale pilot farm would work in close collaboration with industry researchers by providing an opportunity to perform agronomic research at scale, it is a potentially profitable investment and should be structured as a private investment. While, clonal plant material (see Strategy 1) will be required before this strategy can be pursued, a commitment to establish such a farm could act as a driver in providing micropropagation companies with a clear motive to develop clonal germplasm.

Locating the pilot farm near the University of Wisconsin - Madison would likely provide the most synergy with ongoing hazelnut efforts and maximize the farm's utility in supporting other strategies in this section. Based on the estimated start-up costs for hybrid hazelnuts in the Midwest of $8,400 per acre and a 100-acre ideal starting size, this strategy will require ~$840,000.

8. Farmer Training

Bottlenecks Targeted: E1
Amount: $2,500,000
Mechanism: Public/Philanthropic Support
Lead Entities: Savanna Institute, University of Missouri Center for Agroforestry

Another needed capacity-building investment is needed to support a large-scale, multi-year farmer training program to aid in disseminating the results of industry development activities to beginning farmers on the ground. This would occur at the large-scale pilot farm (Strategy 7) and other collaborating farms. This strategy is critical in a nascent industry, such as hazelnuts, where there is very little institutional knowledge either in an existing base of farmers or University extension programs, which focus exclusively on major crops currently grown.

Both the Savanna Institute and the University of Missouri Center for Agroforestry are well poised to lead farmer training around tree crops. In 2019, the Savanna Institute began an on-farm apprenticeship program and is ready to scale the program substantially in the coming years. The enumerated funding of a $2,500,000 endowment would provide ~$100,000 per year to fund two hazelnut focused educators ($40,000 per year) and educational activity costs of $20,000 per year.

9. Nut Aggregation, Processing & Marketing

Bottlenecks Targeted: F1, D3
Amount: $500,000 - $11,000,000
Mechanism: Private Investment
Lead Entities: New Entity, American Hazelnut Company

An at-scale harvesting, post-harvest processing, and distribution/marketing entity will be needed to support a mature hazelnut industry. As above, this entity will be needed, once clonal hazelnuts become widely available and yielding, at which point all of these services will both be in high demand and critical to the success of small farmers. This entity could provide a suite of services for the industry, as highlighted below.

Tier 1: Custom Harvesting ($500K - $1M)
Custom harvesting will be a critical need for the industry, due to the likely prohibitively high cost of efficient harvesting machinery.

Straddle harvesting machines that are currently being tested for hedgerow-grown hazelnuts retail for hundreds of thousands of dollars, and thus the most cost-effective solution for growers would likely be several harvesters stationed close to concentrations of small orchards to provide timely and efficient harvesting services.

Tier 2: Aggregation and Processing ($2M- $5M)
Centralized processing, and aggregated distribution of kernels will need to be accomplished by firms that can benefit from economies of scale and secure financing for the significant up-front costs of machinery. There are many possible models for such companies, as seen in the Oregon industry, but given the lack of any large companies currently filling this role in the Midwest, the opportunity for profitable investment is significant.

Tier 3: Market Development ($1M-$5M)
Any entity that was already engaged in harvesting, aggregation, and processing would be well positioned to also market these nuts to a variety of industry buyers, as well as produce their own hazelnut-based products and market directly to consumers. Critically, this latter function should begin now using Oregon-grown nuts, both as a way to demonstrate the economic viability of hazelnut production in the Midwest, but also to increase consumer awareness of the many possible hazelnut products.

10. Farm Establishment Credit Mechanism

Bottlenecks Targeted: E2
Amount: $290,000,000
Mechanism: Private Investment
Lead Entities: New Entity, Existing Bank

To grow 43,000 t of Midwest hazelnuts over the next 10 years, 35,500 acres of farmland will need to be planted. This will require a projected $290 million over the period to bridge the cash flow gap between planting and first harvest. Partnerships between conventional lenders and impact investors could leverage a large conventional capital base with innovative mechanisms. For instance, conventional lenders may be willing to offer long-term loans (with no principal payments until cash flows start) or revenue-based loans if backed by a credit enhancement from impact investors.

With much work remaining to address more urgent bottlenecks, pursuing this strategy is not as pressing. However, forming such a fund and developing its protocols will take time, so exploring details early will be important to its success.

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