OVERCOMING BOTTLENECKS IN THE EASTERN US CHESTNUT INDUSTRY

An Impact Investment Plan

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> At present prices of these nuts there is no more inviting field in all horticulture than the growing of chestnuts. At this time, when the prices of many farm products are verging on the cost of production, and some going far below it, chestnuts alone not only yield a large profit to the grower, but sometimes make returns that seem fabulous.
>
> —CHARLES PARRY
> *Nuts for Profit, 1897*

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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-mitigating agricultural systems.

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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.

Chestnuts have been a target tree crop for the Eastern U.S. for over a century. 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 Eastern U.S. chestnut 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 Eastern U.S. chestnut 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 agriculture is noble and necessary. As you read this report, please consider where your role lies. Please join us in scaling the Eastern U.S. chestnut 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 like chestnuts are one such solution.

Worldwide demand for chestnuts exceeds all other nuts except for coconuts and peanuts. Chestnuts are a unique temperate nut crop with a starchy rather than oily texture and they can serve as a staple food and as a replacement for corn in processed food and industrial applications. These properties combined with the genetic diversity within the chestnut genome and breeding work that has been done over thousands of years make chestnuts a resilient perennial crop capable of being scaled up quickly. Modern chestnut cultivars produce nuts relatively early and on an annual basis and the nutritional profile closely matches that of corn and rice. The protein in chestnuts is high quality and contains an amino acid balance similar to milk or eggs. The global market for chestnuts is $5.4 billion and is projected to increase by 2.2% annually over the next five years. Growth is being driven by an expanding middle class around the world and increased interest in healthy eating and gluten free alternatives to grain.

Chestnuts are currently being grown in 27 countries around the world. Chinese farmers in particular have worked over the centuries to transform the chestnuts that originally grew as a native forest tree into an orchard crop. In addition to Chinese chestnuts, species of chestnut from Korea, Japan, the U.S., and Europe have all been domesticated and crossed with each other. This has created diverse chestnut germplasm with great potential to be further developed as a commercial crop.

Despite this promising position and substantial work to date, multiple bottlenecks limit the growth of the Eastern U.S. chestnut industry. Effective clonal propagation protocols are needed to provide inexpensive clonal planting material. Infrastructure and best management practices need to be enhanced and a lack of robust cultivar trials and ongoing breeding work in the U.S. has hindered continued plant development. The lack of a mechanism to improve the availability of low-risk farm startup capital costs is also a major hurdle for growers wishing to plant chestnuts 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 Eastern U.S. chestnut 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 Eastern U.S. chestnut industry and a truly ecological agriculture.

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.

Chestnuts are a healthy nut crop that has the potential to replace corn in the Eastern U.S.

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 Chestnuts?

A climate-friendly carbohydrate crop

Chestnuts (Castanea sp.) – once the foundation of many civilizations – are large trees that produce a uniquely carbohydrate-rich nut. Chestnuts are a resilient staple crop capable of supplying a high quality source of food, fodder, and industrial feedstocks. Well adapted varieties are capable of producing 2,000-3,000 pounds of chestnuts per acre while simultaneously allowing for (1) alley crop production on over 75% of the same acre while trees are young and (2) pasture livestock production when trees are mature. Among nut crops, chestnuts mature rapidly and yield consistently from year to year, boding well for expansion.

Broad adoption of chestnuts could also help “flip the script” on agriculture’s role in climate change: carbon sequestration in soil and woody biomass is inherent in chestnut production. Chestnuts can sequester >0.75 t carbon/acre in woody biomass over their first five years[55], scaling to more than 8 t carbon/acre sequestered by maturity. This does not include the potential accompanying sequestration in soil organic matter or understory crops[65]. In addition, their perennial root system can help capture excess nutrients and reduce eutrophication of surface waters, and the permanent structure would provide habitat for birds, beneficial insects, and other wildlife.

Healthy & nutritious

The nutritional profile of chestnuts is unique among nuts. Chestnuts contain 40-45% carbohydrate, 2.5-4% protein, 1-1.5% fat, and the balance is water. Chestnuts are low in fat, have no cholesterol, and contain as much vitamin C as an equivalent weight of lemons. They are high in fiber and have been found to promote gut health. Nutritionally, chestnuts are similar to brown rice, but with twice the protein and 1% of the sodium. The protein is high quality, with an amino acid balance similar to milk or eggs.

The Food and Drug Administration recognizes nuts as a “heart healthy” food. Chestnuts contribute macronutrients, micronutrients, and bioactive phytochemicals to human diets. Chestnuts and their byproducts provide natural antioxidants that serve as functional food ingredients and nutraceuticals. Consumption of chestnuts has been associated with potential health benefits, including antitumour, antimicrobial, antioxidant, and antimalarial effects[66].

BACKGROUND ON CHESTNUTS

KEY POINTS

The existing global chestnut market is dominated by China with 84% of worldwide production. Every country that produces chestnuts faces challenges from climate stress, insects, disease, and cultural and political changes.

The U.S. is the only country in the world that can produce chestnuts that does not have a significant commercial chestnut industry.

Consumer interests in alternatives to grain, gluten free foods, and a strong preference for local foods combined with the perishable nature of chestnuts create a market opportunity for approximately 120,000 acres of chestnut orchards in the U.S.

Existing Uses

Chestnuts are a carbohydrate rich staple crop with many potential end uses. Since demand for fresh chestnuts typically exceeds the supply, the potential of this crop to be processed has not been fully developed. As a result, 90% of chestnuts are sold as fresh whole nuts and 10% are processed[8]. The most common form of processed chestnuts sold in the U.S. is flour, followed by dried kernels, and peeled frozen chestnuts (Figure 1).

Peeled and Frozen

Peeled and frozen chestnuts are the preferred form for restaurants and most consumers. This product category could open up sales to food service and restaurants along with the majority of consumers in the U.S. Infrastructure, processing equipment and marketing need to be refined and coupled with improved agronomic performance and larger scale chestnut production to make this a viable market niche. Australia has a chestnut industry that is about the same age and scale as the U.S. chestnut industry and a few pioneering chestnut farmers in Australia have developed a market for peeled and frozen chestnuts. They are working on mechanized processing, but at present they have chestnuts hand peeled in China or Vietnam and they are marketed in Japan and Australia.

Dried Chestnuts

Dried chestnuts can be sold into retail markets and when sliced into chips they can be sold to brewers.

Chestnut Puree

Chestnut puree has a long history of use in Europe as an ingredient in baked goods. Recent research has explored the possibility of fermenting chestnut puree to create gluten free products for the beverage and yogurt markets[69]. Strains of bacteria were found that created fermented puree with potential to be used in gluten free foods. Another potential new market for puree is for use in baby food.

Chestnut Flour

Chestnut flour contains high quality proteins with essential amino acids (4–7%), a relatively high amount of sugar (20–32%), starch (50–60%), dietary fiber (4–10%), and a low amount of fat (2–4%). It also contains vitamin E, vitamin B group, potassium, phosphorus, and magnesium[70]. Chestnut flour can be used to make sourdough bread, quick bread, cookies, extruded snacks, gel, and cake. Further refinement and additional uses can be developed by chemically, enzymatically, and physically modifying chestnut starch to obtain desired properties[71]. The high sugar content and corresponding sweetness of chestnut flour can be used to create sweet foods without having to add sugar. This would allow for a clean label.

In addition to the primary uses described above, chestnut trees have cosmetic uses, including bark infusions for sensitive skin and after-shave lotions. Chestnut leaves have also been used to dye fabric[71].

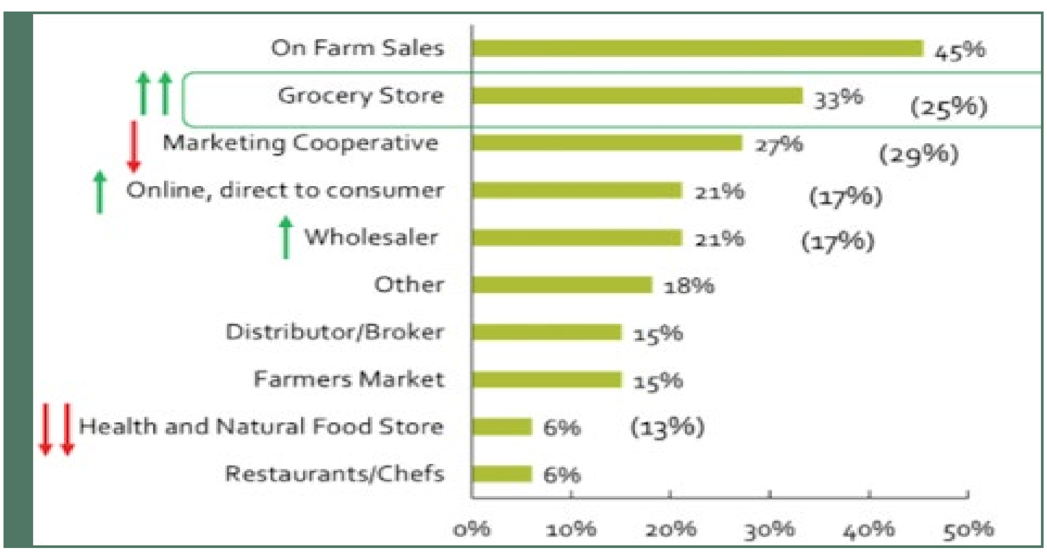

Figure 1: Results of a 2019 survey of U.S. chestnut farmers indicating marketing channels for chestnuts[67]. Only about 10% of chestnuts are processed, with the remainder sold as fresh whole nuts.

Country/Period	2012	2013	2014	2015	2016	2017	2018	CAGR, 2012-2018
	Thousand Tons							
China	1711.8	1721.7	1686.2	1668.9	1903.9	1939.7	2024.2	2.8%
Turkey	57.9	60.0	63.8	63.8	64.8	62.9	63.7	1.6%
Italy	58.7	53.8	51.1	51.6	52.2	52.4	52.6	-1.8%
South Korea	62.3	64.2	59.5	55.6	53.6	52.8	50.8	-3.4%
Greece	17.7	18.8	28.1	30.0	28.3	36.0	39.3	14.2%

Table 1: Chestnut production by country.[72]

Global Market

Major market participants

On the distribution side, these companies represent the largest aggregators and distributors for chestnuts in the worldwide market:

- Berjaya Corp. Berhad
- Chengde Shenli Food Co. Ltd.
- Chestnut Growers Inc.
- E. and A. Potamianou Inc.
- Planet Green Holdings Corp.
- Qinhuangdao Yanshan Chestnut Co. Ltd.
- SAMRIOLU Group of Companies
- Shandong Maria Food Co. Ltd.
- Shandong Zhifeng Foodstuffs Co. Ltd.
- V. Besana Spa.

Size & scope

Chestnuts are grown in 27 countries and worldwide production in 2018 was 2.4 million tons with a value of $5.4 billion. China produces 84% of global production, followed by Turkey, Italy, South Korea, and Greece which produce 10%[72]. Bolivia does not produce chestnuts, their inclusion is due to a mistranslation of the word for Brazil nuts (Table 1). The U.S. currently produces chestnuts on 1,587 farms that cover 4,228 acres[73]. This is less than 1% of total worldwide production and the U.S. is the only country in the world capable of growing chestnuts that does not have a chestnut industry. The total volume of global production increased by an average of 2.7% between 2012-2018 and the total area harvested was 1,533,870 acres[72]. The global average yield was 3,239 pounds per acre. The lowest yields recorded were from Bolivia with 1,336 pounds per acre and the highest yields recorded were from China with 3,475 pounds per acre[72].

Import prices over the past six years have fluctuated between $2.3 and $3 U.S. dollars per kilogram[72].

Macro trends

Demand for chestnuts is expected to increase worldwide by 2.2% compound annual growth rate (CAGR) between 2018-2025[72]. At present, U.S. consumers eat 0.1 lb of chestnut per capita on an annual basis, while Europeans average 1.0 lb per capita. Koreans are the world's largest chestnut consumers at 4.0 lbs per capita[72].

Most regions of the world that produce chestnuts are facing increased challenges from extreme weather events, political and social upheavals, and insect and disease pressure from the Asian gall wasp, blossom end rot, phytophthora, chestnut blight, increased labor costs, and shifting consumer tastes and preferences for convenience foods. Importers, distributors, and businesses that sell chestnuts are also responding to these challenges by producing chestnuts in a pre-cooked, shelf stable, ready-to-eat form. This includes steamed, frozen, and pureed chestnuts along with chestnut flour.

The challenges of producing commercial scale quantities of consistent high quality chestnuts are also an opportunity to create a profitable niche and transition what is currently a specialty crop into a commodity crop. Clear models exist to do this and they have been developed for other crops. The primary challenges for scaling chestnuts include: variable small scale production, lack of market standards, lack of branding, poor competitiveness relative to other more developed crops like apples, lack of infrastructure, lack of supply chain components, and lack of improvements to genetics and management. Many of these challenges have been overcome in different regions of the world.

The decline of the chestnut industry in Europe provides an example of how a region can recover. Chestnut blight and phytophthora root rot have had a dramatic effect on chestnut production in Europe. From the turn of the century, when chestnut blight was introduced, most of the traditional chestnut-producing areas of Europe have shown a progressive decline in chestnut production. Both France and Italy suffered an 85% decline between the turn of this century and 1965. This has been partly due to urbanization and population drift toward the cities; partly to increasing labour costs and the difficulties of mechanization in many production areas (trees are most often on steep slopes); but mostly due to the spread of disease.[74] Expensive and prolonged research efforts into breeding new, disease resistant cultivars, improved disease controls and the development of better rootstocks and cultivation methods have helped stabilize this decline in recent years. High prices for processed, peeled and frozen chestnut products, especially in the United States where they sell for more than $6.00/kg, have prompted moves to expand the chestnut industry in many countries.

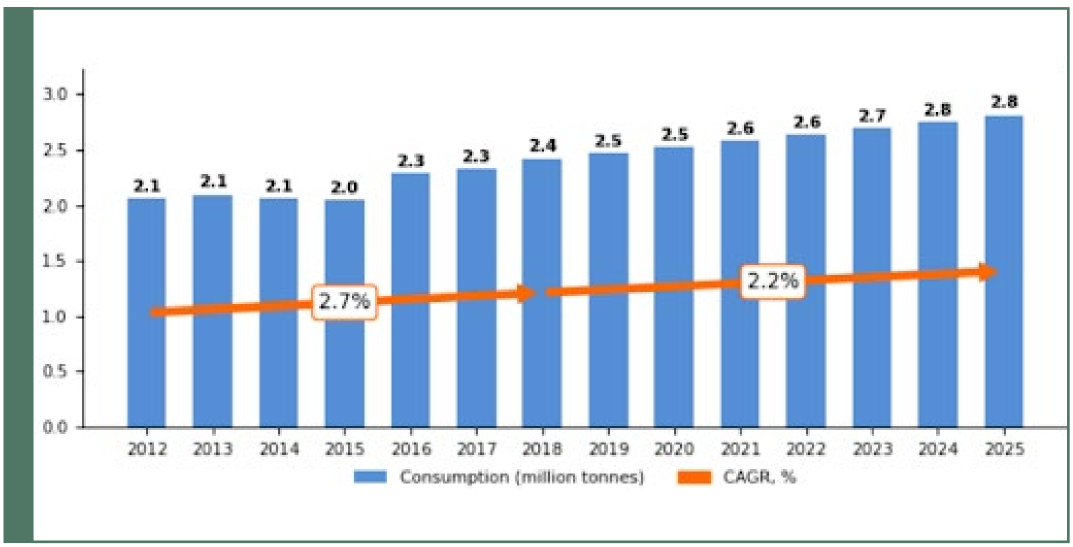

Figure 2: Worldwide Chestnut Market Forecast to 2025.[72]

US Market

Existing production & market

The U.S. currently produces chestnuts on 1,587 farms that cover 4,228 acres[73]. This is less than 1% of total worldwide production. States with the most acreage in chestnut orchards include Michigan (675), California (370), Iowa (333), Ohio (332), Florida (323), and Virginia (299)[73].

The current 0.1 pounds per capita consumption in the U.S. would support 20,000 acres of chestnuts[72]. If the U.S. reached the European level of 1 pound per capita that would support 200,000 acres of chestnuts and a $1.2 billion chestnut industry in the U.S. Historically, per capita consumption of chestnuts by families that depended on them for food reached 330 pounds[74]. If U.S. consumers replaced a portion of the starch they consume in the form of grains and vegetables with chestnuts they could reach this level of consumption and it would support 40 million acres of chestnuts. A consumer pull through strategy that increases demand for local chestnuts is an

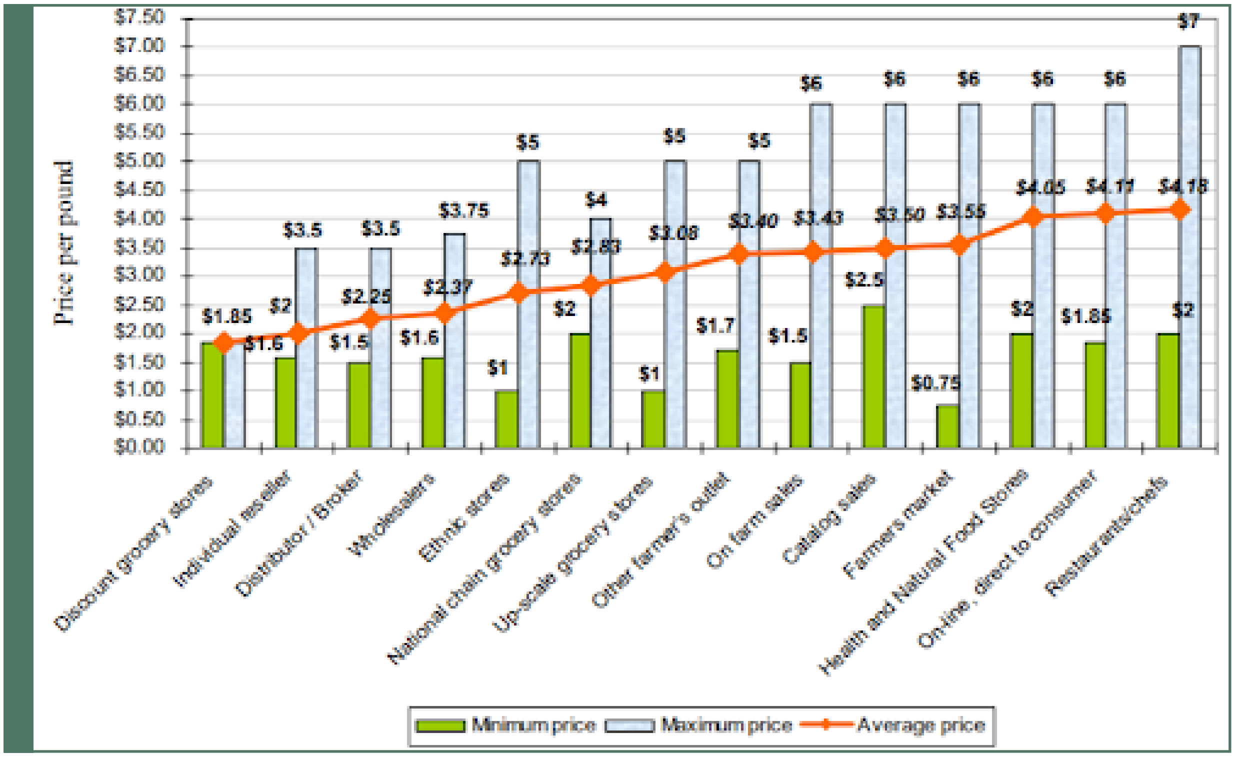

Figure 3: Retail outlets for U.S. grown chestnuts sold in the US[76].

effective mechanism to reach 1 pound per capita consumption in the U.S.[76] Chestnuts are a specialty crop primarily sold locally as fresh whole nuts for the holiday season. There are markets for all sizes of chestnuts. The primary retail outlets include grocery stores, restaurants, farmers, markets, and online sales (figure 3).

Tier 1: Direct sales to existing customers

Direct sales of U.S. chestnuts to existing customers could support 20,000 acres of chestnut orchards in the U.S.[72] The bulk of these sales currently consist of imported chestnuts. Chestnut markets in the U.S. are seasonal, and sales of fresh whole chestnuts occur primarily around the holidays in November and December. Chefs and the food service sector also use peeled frozen nuts, puree, and chestnut flour. In 2018, members of Chestnut Growers of America reported that value-added chestnut products comprise 10% of total sales, 48% of chestnut growers sell fresh chestnuts direct to consumers, and 11% sell fresh chestnuts to distributors [77].

Three chestnut distributors with varying levels of management complexity are operating in the Midwest. These include Route 9 Cooperative, Chestnuts Growers, Inc., and Prairie Grove Chestnut Growers. They currently work with 104 farmers. These distributors sold 342,590 pounds of fresh chestnuts in 2018, 188,454 pounds in 2017, and 322,473 pounds in 2016. Most chestnuts were sold to Georgia, Illinois, Iowa, Michigan, Minnesota, Massachusetts, New York, and Virginia. A very small percentage of chestnuts (0.33%) sold by distributors are organic. Chestnuts sold by distributors have a retail price between $3/lb and $7/lb, and a whole sale price between $2.5/lb and $4.2/lb. Outlets for those chestnuts include restaurants and chefs ($4/lb), distributors and brokers ($3.45/lb), groceries ($3.60/lb), and online consumers ($5.07/lb)[77].

Tier 2: Expanded production to meet growing demand of US consumers

Chestnuts are undergoing a resurgence around the world and they are seen as an important component of regenerative food systems and climate friendly crops. An increasing awareness of the benefits of chestnut growing cultures and the ecological communities they foster has led to a recognition of a holistic suite of benefits derived from associated products such as: mushroom cultivation, lumber, pasture, herbs, tourism, and an increased quality of life for farmers who tend the trees and as well as area residents. These attributes and a growing interest in healthy eating among consumers are driving increased interest in chestnuts. The most important attribute influencing consumer purchasing decisions is where chestnuts are grown and the least important attribute is price[66]. Consumers are ten times more likely to purchase chestnuts grown in their home state and five times more likely to purchase chestnuts grown in the U.S. compared to imports[76]. A targeted marketing campaign that focuses on local production of high quality organic chestnuts can drive consumer demand and lead to premium prices for farmers.

Tier 3: Processed Chestnuts

The worldwide chestnut industry is moving toward more processed chestnut products to align with the broader trend toward convenience foods. Developing the capacity to produce consistent, high quality peeled and frozen chestnuts is an important step toward increasing the scale of the U.S. chestnut industry to the level of 1 pound per capita consumption. Reaching this level of production will require investments in improved genetics and management and processing and supply chain infrastructure. The primary challenges to creating a viable market for peeled and frozen nuts are competition from existing producers in Europe, Australia, and China, and increasing the scale of the industry to provide enough chestnuts to justify investments in processing equipment and supply chain infrastructure.

Tier 4: Commodity Markets, Animal Feed, Starch, and Tannins

Ninety-six million acres of corn were planted in the U.S. in 2020 and one-third of that, or 32 million acres, is used for human food, beverages, and industrial uses. Chestnut starch has properties intermediate between cassava and cornstarch and it can serve as a replacement for cornstarch in applications where lower processing temperatures are used[78]. Chestnuts can replace corn anywhere it is grown on acidic well drained soils in plant hardiness zone 5 or higher. This includes most of the area highlighted in figure 5. Replacing one-third of the acreage of corn devoted to human food, beverages, and industrial uses would result in 10 million acres of chestnuts.

Sizing the Eastern US Opportunity

Existing Imports

The U.S. imported 3,500 tons of chestnuts in 2017[73]. Based on the worldwide average yield of 3,239 pounds per acre, it would take 2,161 acres to produce the quantity of chestnuts imported annually into the U.S. Imported chestnuts are typically sterilized at their point of origin and then fumigated with Methyl Bromide upon arrival to the U.S. based on APHIS protocols. This could reduce nut quality and may have implications for human health. Due to the perishable nature of chestnuts and the fact that cold storage is not always consistently maintained during transport, imported chestnuts can be dried out or moldy when they reach retail outlets in the U.S. In addition, Italian chestnut flour and dried chestnuts have been found to contain aflatoxins in 62% and 21% of samples tested in retail outlets in northern Italy. These same samples also contained high levels of Ochratoxin in 100% of the products tested[79]. There have been no reports of contaminants in chestnuts in China. Chestnut flour is also subject to adulteration due to the high price of the flour compared to grains and 12 different species of grain have been found in chestnut flour[79]. These and other health concerns related to the opaque nature of imports creates an opportunity for domestic production.

Increased Consumer Demand

Consumers across the United States, Australia, New Zealand, and Europe, have an increased interest in chestnuts as a crop and food.[81] This interest is part of a broader trend towards increased tree nut consumption. Between 1970 and 2016 tree nut consumption in the U.S. has increased from 1.38 pounds per person to 3.69 pounds per person[82]. These increases are likely driven by promotional programs that highlight nutritional qualities of nuts and increased interest in nut milk[82].

Consumers in the United States have demonstrated a strong preference for locally produced chestnuts and frequency of consumption is increasing, however, most consumers in the United States have low familiarity with chestnuts as food and preferred markets include restaurants and in processed products[76]. Chefs have also indicated that they

Metric	Tier 1 (0.1 lbs per capita)	Tier 2 (0.5 lbs per capita)	Tier 3 (1 lb per capita)	Tier 4 (Starch and industrial uses)	Total
Target volume (t)	20,000	82,000	200,000	10,000,000	10,302,000
Target volume (lbs)	40,000,000	164,000,000	400,000,000	20,000,000,000	20,604,000,000
Yield (lbs per acre)	2,000	2,000	2,000	2,000	2,000
Area (acres)	20,000	82,000	200,000	10,000,000	10,302,000
Number of trees (48 trees/acre)	960,000	3,936,000	9,600,000	480,000,000	494,496,000

Table 2: Projected potential market opportunity for eastern U.S. Chestnuts.

prefer frozen and peeled chestnuts to fresh whole chestnuts[83]. Product development, marketing, and raising consumer awareness have the potential to increase chestnut consumption and move U.S. per capita consumption toward the European level of 1 pound per capita. A large potential market exists with restaurants for peeled and frozen chestnuts Importers will consider buying domestic peeled and frozen chestnuts if the price and quality are competitive with imports.

Potential Novel Markets

Potential novel markets for chestnuts include: cosmetics, dyes, tannin, wood, burs, shells, and agri tourism. Developing markets for all the possible uses of chestnut products could lead to the development of an industry that supports a culture based on tree crops. This would add an important element of biodiversity to food systems and align with current interest from the United Nations and major global brands in protecting biodiversity to prevent destabilizing their supply chains and undermining the natural capital upon which their business depends[84].

The U.S. has the potential to create a modern chestnut culture that supplies diverse products to major food brands while supporting biodiversity, regenerative agriculture and resilient supply chains. A review of the history of chestnut culture in Corsica places the U.S. chestnut culture in a broader context and shows similar social and ecological dynamics at work[85].

"Corsicans consistently resisted those policies that were so incompatible with their livelihood system. Under Genoese domination, resistance went through a phase of rejecting the chestnut, and it took more than a century for Genoa to impose the chestnut tree; five ordinances were promulgated between 1548 and 1646. Under French occupation, defending the chestnut tree had become a means for asserting identity and self-determination, and Louis XV did not succeed in restricting its plantation.

Beyond the overturn of the chestnut's role in local political struggles, the association of the chestnut tree to independence, freedom, and resistance to the oppressor is constant throughout the island's history. Resistance consistently relates to the global confrontation between local agrarian values and administrative development ideologies. From the 16th to the 18th century, the early capitalistic dynamics of colonizers could not accommodate the island's communitarian "horto-pastoral" civilization in which money hardly existed, development of social relationships was more important than accumulation of commodities, and property was not a precondition to production but the result of human labor[85].

The current U.S. food system contains a similar dynamic, where farmers are coerced through a system of subsidies, insurance, manipulative contracts, debt, and social pressure to grow annual row crops and confined livestock that are not in their own best interest. Over 71% of farmers that raise broiler chickens under contract live below the poverty line. The stress of this arrangement also contributes to farming having the highest suicide rate of any profession in the US[86]. Taking a broader view of mid sized farms in general shows that as of 2017, more than 40 percent of midsize farms—defined as family farms with gross cash receipts between $350,000 and $1 million—had an operating profit margin of less than 10 percent, placing them at high risk of financial problems, according to the U.S. Department of Agriculture[87]. Chestnuts could be developed as an alternative crop that farmers come to see as having real benefits to them and their communities. This could lead to widespread adoption and loyalty to food companies that treat farmers fairly.

Commodity Markets

Flour and Sweetener

Chestnut flour is gluten free and can be used as a replacement for wheat and corn flour in a wide variety of recipes.[88] Testing of chestnut flour has demonstrated that optimum elasticity associated with starch gelatinization is impacted by drying time, temperature for drying, and the method of mixing[89]. The physical structure of chestnut starch can be modified by cooking and treating with enzymes[90] (figure 4) . Chestnut starch is considered to be slowly digestible compared to starch from annual grains and this creates a beneficial metabolic profile, resulting in lower levels of circulating triacylglycerols and lipoproteins. It has been shown that eating slowly digestible starch-containing foods at breakfast improved carbohydrate metabolism and reduced insulin requirements for insulin-treated Type 2 diabetic patients[91].

Animal Fodder

The primary use for chestnuts in livestock feed is for pigs. However, interest in tannins as a substitute for antibiotics has led to research with chestnut tannins that show improved performance in broiler chickens[92] as well as broader benefits to cattle and layer performance.

Cosmetics

Companies like Lush Cosmetics are investing in lesser known plants and regenerative agroecological systems to support the development of more diverse food systems. They employ an ethical buying team to ensure ingredients are as sustainable as possible. This enhances market differentiation in their products and provides an opportunity to stand out in the marketplace.

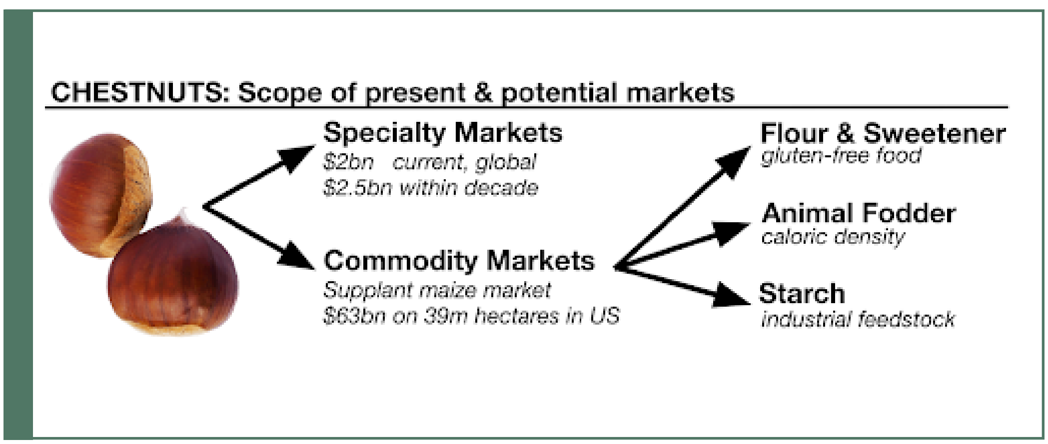

Figure 4: Diagram of the scope of present and potential chestnut markets.

CHESTNUTS IN THE EASTERN US

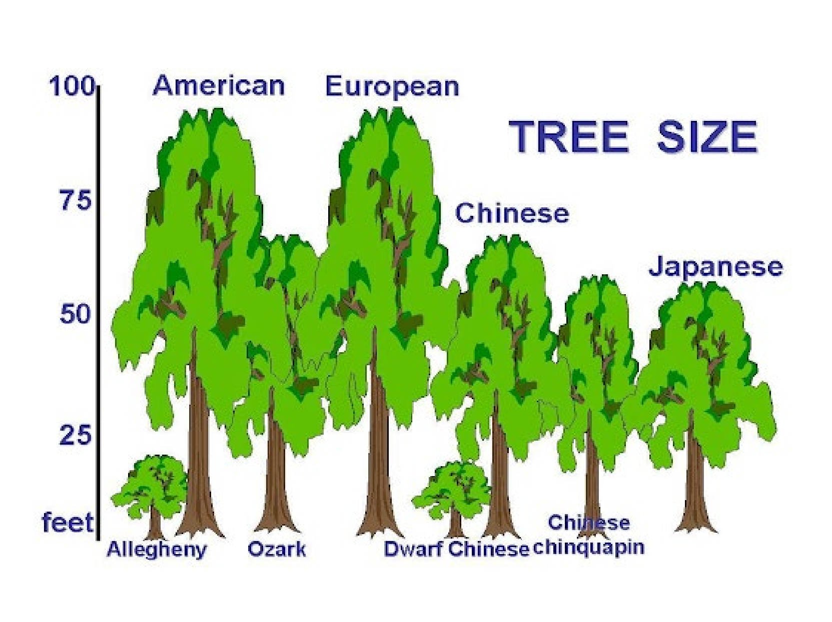

Figure 5: Relative size of trees in the genus Castanea.[93]

Eight Species & Their Hybrids

KEY POINT
Thousands of years of selection by farmers has created diverse cultivars suitable for commercial production. The key to developing their potential is to leverage strategic investments to combine the best traits from different species into improved cultivars.

Chinese Chestnut
Castanea mollissima
Most commercial chestnut production in the world is based on Chinese chestnuts. Many of the best performing cultivars in the U.S. are pure Chinese chestnuts or hybrids based on Chinese crossed with other species. In rare instances complex hybrids from multiple species have produced valuable trees that are commercially viable.[93] Chinese farmers have spent thousands of years selecting Chinese chestnuts to be an orchard tree and these trees now resemble large apple trees in size and shape[94]. Chinese chestnuts also tend to be blight resistant, precocious, cold tolerant, and consistently produce large, dense, sweet, round chestnuts that peel well.

Japanese Chestnut
Castanea crenata
Japanese chestnuts are native to Japan and Korea and are grown in commercial orchards in Japan. They are valued for their large nut size, precocity, disease resistance, open canopy structure, and high yields. Nuts tend to be bland and difficult to peel and some have off flavors.

American Chestnut
Castanea dentata
American chestnuts produce medium sized sweet nuts with a relatively high fat content. They are valued for their vigorous upright growth and open canopy structure. They were almost completely eradicated by chestnut blight by the early 1900's.

Chinese Chinquapin Chestnut
Castanea henryi
Chinese Chinquapin chestnuts are resistant to gall wasps and have been crossed with Chinese chestnuts in an attempt to add this trait to Chinese chestnuts. They are native to southern China and have limited cold hardiness.

Allegheny Chinquapin Chestnut
Castanea pumila
Allegheny Chinquapin chestnuts are a small tree to large shrub that is valued for its cold tolerance, drought tolerance, high yields, small stature, precocity, ability to be maintained as a small tree for lab work and nut quality attributes.

Ozark Chinquapin Chestnut
Castanea ozarkensis
Ozark Chinquapin chestnuts are valued for their genetic diversity and cold tolerance. They also possess resistance to asian gall wasp. Studies at Missouri Botanical Garden have shown that some individuals are more blight resistant than Chinese chestnuts. Ongoing research and breeding work is being carried out by the Ozark Chinquapin Foundation in Missouri.

European Chestnut
Castanea sativa
European chestnuts are native to southern Europe and Asia Minor and they are a large long lived tree that is cultivated for timber and nut production. They tend to have limited cold hardiness and are susceptible to chestnut blight and ink disease. They produce medium to large nuts with variable flavor from bitter to sweet.

Seguin's chestnut
Castanea sativa
Seguin's chestnuts are medium sized trees native to China and produce three small nuts per bur. Some individuals exhibit continuous flowering and extended nut drop.

Seedling and Grafted Chestnuts

Most commercial production of chestnuts in the U.S. is based on seedling Chinese chestnut trees, which are considered by most growers to be the best option currently available for establishing profitable orchards in the eastern U.S. Due to more than 2,000 years of selection by farmers, Chinese chestnuts purportedly produce 25% of offspring that are better than the parents, 50% that are about the same, and 25% that perform worse. Underperforming trees in the orchard can be grafted by topworking or removed from the planting.

There are profitable orchards of grafted chestnut trees in Michigan, Missouri, and other areas. The chestnut industry in Michigan is largely based on grafted Japanese/European hybrids that are well suited to their northern climate. The River Hills region of central Missouri is considered to be ideal for growing chestnuts and grafted cultivars grown on the well drained loess soils in that region have performed well in research plots and on farms.

Most commercial nut and fruit production for other species is based on clonally propagated selections of the best performing trees, and, over the long term, development of clonally propagated chestnuts could enhance the viability of the chestnut industry in the U.S. The potential challenges for clonal propagation of Chinese chestnuts are that some farmers experience delayed graft failure, low vigor and low yield. These tend to be more pronounced in cooler climates and under stressful conditions. Well managed grafted Chinese chestnuts grown in zone 6 or warmer tend to experience few if any of these problems. Grafted trees of other species of chestnuts, including European/Japanese hybrids tend to display more vigor than Chinese chestnuts, however, they can be susceptible to blight and biennial production. An important goal for sustainable production is to maintain enough genetic diversity within selections to have resilient plants capable of thriving under holistic management that can keep expenses low enough for farmers to generate a profit. Narrow genetics tends to make plants more susceptible to pests and disease pressure and as these threats are constantly evolving plants that do well initially may develop problems over time. This highlights one of the challenges with grafted trees. They are static, represent an evolutionary dead, end and may have a limited life span due to shifting weather patterns and associated pest and disease pressure.

The benefits of seedling Chinese chestnuts are more pronounced in plant hardiness zones 4, 5, and 6, and the performance of grafted trees is closer to that of seedlings in warmer climates. Table 3 outlines key traits for seedling and grafted trees.

Tree Type	Vigor	Diversity	Cost	Availability	Yield	Consistent Production	Nut Size
Seedling	High	High	Low	High	Moderate to High	Variable	Variable
Grafted	Moderate to High	Low	High	Moderate	Moderate to High	Variable	Variable

Table 3: Comparison of seedling versus grafted chestnut trees.

Figure 6: Chestnut range map for the Eastern U.S. (Chestnut Hill Nursery).

History of Chestnuts in the Eastern US

KEY POINT
Farmers and researchers have been creating hybrid chestnuts in the U.S. for the past 247 years. The result is diverse chestnut germplasm composed of well adapted cultivars that are primed and ready to be developed into the foundation for a large scale chestnut industry.

Three species of chestnuts are native to the United States: The American chestnut (Castanea dentata), the Ozark Chinquapin (Castanea ozarkensis), and the Allegheny Chinquapin (Castanea pumila). The American chestnut was a dominant tree in eastern forests from Maine to Mississippi and it played an important role in sustaining rural populations across its range[93]. The Ozark Chinquapin was an important component of forests in Oklahoma, Missouri, Arkansas, Louisiana, Mississippi, and Alabama until chestnut blight decimated the trees in the mid 1900's. Ozark Chinquapins produce small sweet nuts annually that were prized by wildlife, Native Americans, and early settlers. The Allegheny Chinkapin is a spreading shrub or small tree that reaches heights of 20 feet. It grows in forests in the southeastern U.S. that extend from Pennsylvania to Texas. All species of chestnuts have been dramatically reduced in population size due to chestnut blight and ink disease. These exotic disease organisms have infected plants across their range in the U.S.

Hybrid Germplasm Development

The value of the chestnut prompted breeding work as early as 1773 when Thomas Jefferson grafted European chestnut scions onto American chestnuts at his farm near Charlottesville, VA[95]. Enthusiasts started importing Japanese chestnuts in the late 1800's and seedlings from these trees were sold in nurseries on the east and west coasts[96]. Crosses between species soon followed and as the species native to the U.S. started to decline due to introduced diseases, breeders began searching for disease resistance in the Japanese and Chinese species. Walter Van Fleet was one of the early breeders and he began by crossing Japanese chestnuts with Allegheny Chinquapins as part of his work with the USDA in the early 1900's[97]. His work was continued by Arthur Graves, Richard Jaynes, and Sandra Anagnostakis who continued to breed chestnuts as part of their work for the USDA and the Connecticut Agricultural Experiment Station[93].

During this same time period hobbyists and farmers were breeding their own trees. The Northern Nut Growers Association (NNGA) was founded in 1910 and this non-profit has members across the U.S. and in 15 foreign countries. One of the largest commercial chestnut orchards in the U.S. is owned by NNGA member Greg Miller. Greg and his father Jay planted 500 Chinese chestnut seedlings in 1972 in Carroll County, Ohio and started Empire Chestnut Company. Their company is now part of Route 9 Cooperative, which supports five farms in eastern Ohio that have 100 acres planted to chestnut orchards. Chinese chestnut seedlings and grafted trees have since been planted on hundreds of farms across the Midwest and that network now has 7,000 trees of bearing age that are being trialed and evaluated as part of a distributed participatory breeding network. This population represents a diverse genetic base with potential for creating improved varieties with higher yields and improved nut quality. The Center for Agroforestry and Notre Dame University, received $1 million dollars in grant funding in 2020 from the USDA to begin evaluating these trees as a first step toward establishing a breeding network.

Tom Wahl and Kathy Dice with Red Fern Farm in Wapello, Iowa started planting Chinese chestnuts in 1992 and they run a perennial plant nursery which serves as an important source for improved chestnut genetics. Tom and Kathy have bred their own hybrid cold hardy trees that are adapted to their zone 5 location in central Iowa.

Michigan State University provides research and Extension support for an established chestnut industry in Michigan. Michigan has 675 acres of chestnut orchards, which is more than any other state in the U.S. Seventy percent of chestnut orchards in MI are planted with grafted European x Japanese hybrids. Colossal is the primary cultivar. However, Colossal is susceptible to chestnut blight and biennial production. These production issues hamper marketing and the profitability of the crop and have prompted interest in Bouche De Betizac, which is another European cultivar that is being considered as a replacement for Colossal. The remaining 30% of orchards in Michigan are planted with Chinese chestnuts.

The Ozark Chinquapin Foundation works to save Ozark Chinquapin chestnuts from extinction by finding and breeding blight resistant individuals that remain in their native range in Missouri, Arkansas, Texas, Louisiana, Alabama, and Oklahoma. They have located 45 seed producing trees. Ozark chinquapin was once a keystone Ozark forest species before chestnut blight decimated the population in the mid 1900's. Ozark Chinquapin trees that are naturally resistant to blight occur as 0.1-3% of the population. These individuals form the basis for their breeding program where they have been pursuing quantitative or durable multi-gene blight resistance for the past ten years. Research conducted in collaboration with the Missouri Botanical Garden in 2019 has shown that they have individual trees that are more blight resistant than Chinese chestnuts. Ozark Chinquapins also have more genetic diversity than American or Allegheny Chinquapins and they are thought to be the ancestral variety. They may contain valuable traits for use in a breeding program for Chinese chestnuts. The work of the OCF may rescue this species from extinction.

American Chestnut Foundation and Genetically Modified Chestnuts

In 1983 Charles Burnham and Phillip Rutter founded the American Chestnut Foundation (ACF) with the goal of breeding hybrid Asian/American chestnut trees that could be used to restore American chestnuts to their former range in the forests of the Eastern U.S. ACF is using three approaches to accomplish this goal:

1. They manage a traditional breeding program at their research farm in Meadowview, Virginia and at more than 500 orchards located throughout the American chestnut's native range. During the past 36 years, offspring from blight resistant hybrids have been bred with American chestnuts from across the species' range. Four generations later, this traditional breeding program has produced a genetically diverse population of American chestnut hybrids with improved blight tolerance from Chinese chestnuts (Castanea mollissima).
2. Moving forward, their breeding efforts are focused on further improving blight tolerance and incorporating resistance to Phytophthora cinnamomi, which causes a fatal root rot in chestnuts. They are using genomics to increase the speed and accuracy of selecting trees with the greatest tolerance to chestnut blight and root rot.
3. Scientists at the State University of New York, College of Environmental Science and Forestry (SUNY-ESF) discovered that a gene from wheat produces an enzyme, oxalate oxidase (OxO), which enhances blight tolerance significantly. ACF's breeding program uses this gene to stack multiple blight resistance genes and increase the proportion of American chestnut genes in the resulting progeny. ACF and its partners are also investigating the incorporation of CRISPR and other gene-editing technologies for restoration purposes.

Market Development

The primary market for chestnuts in the U.S. is selling fresh whole chestnuts directly to consumers or to local retail outlets. The U.S. market consists of seasonal sales between late September and Christmas and sales to immigrant communities in major metropolitan areas. Sales to immigrant communities are handled through existing distributors and through on farm and online sales.

Mike Gold with the Center for Agroforestry at the University of Missouri has conducted marketing research on Midwest chestnuts over the past 20 years. His data is published in peer reviewed journals and in the Chestnut Growers of America (CGA) newsletter. CGA was founded in 1996 and now has over 100 growers as members. This organization hosts field days and provides agronomic and marketing information and support for its members. The purpose of the organization is to promote chestnuts, to disseminate information to growers, to improve communication between growers, to support research and breeding work and generally to further the interests and knowledge of chestnut growers. The association advocates the delivery of only high quality chestnuts to the marketplace.

Several pioneering farmers have played key roles in market development for chestnuts. These include: Greg Miller with Route 9 Cooperative in Ohio. Greg manages a cooperative composed of five chestnut farms that produce 100,000 pounds of chestnuts annually. These chestnuts are primarily sold in 50-pound bags to immigrant communities across the U.S. Route 9 Cooperative also sells small quantities of chestnut flour. Bob Stehli with Wintergreen Tree Farm in northern Ohio is one of the members of Route 9 Cooperative. He manages u-pick operations for blueberries, chestnuts as well as christmas tree sales. Bob planted 4,425 seedlings from 25 of the best chestnut cultivars he could source through the Northern Nut Growers Association in 1997. He has since been managing this diverse population to produce his own chestnut seedlings. His genetics represent a diverse mixture of Chinese, Japanese, European, and American chestnuts.

Chestnut Growers Inc. in Michigan started in 2001 and is a grower cooperative that markets fresh chestnuts from member farmers. Treeborn is a sister company that sells value added chestnut products. These include dried chips for the brewing market and chestnut flour.

Red Fern Farm has played an important role in demonstrating the viability of u-pick chestnuts and establishing what is now Prairie Grove Chestnut Growers. This business buys and markets chestnuts from farmers in Iowa and neighboring states. Red Fern Farm has also functioned as an extension service for chestnuts and their dedication, success, and knowledge have inspired many other farmers to establish commercial chestnut orchards.

Chestnut Breeding

There is a lot of genetic variation in chestnuts being grown in the U.S. The overall approach for a breeding program is to focus on identifying, evaluating, and developing a more comprehensive understanding of the best Chinese chestnuts cultivars and their genetics so that they can be used as a well adapted base to explore crosses with other species to improve agronomic performance. In order to realize the full potential of advances in breeding, the improved germplasm must be optimized for and integrated into new sophisticated forms of professional management.

Prioritized list of breeding goals:

- Kernel rots and molds
  - Blossom end rot
  - Mold/fungal infection
  - Storage ability
- Consistent production
- Vigor and canopy structure
  - Timber form
  - Open canopy
  - Dwarf tree
  - Pruning and central leader shape
- Regional adaptability
  - Ability to resprout after frost damage from secondary buds and flowers.
  - Drought Tolerance
  - Ripening time (early versus late, condensed versus spread out)
- Insect and disease resistance
  - Gall wasp
  - Chestnut weevil
  - Japanese beetle
  - Potato leafhopper
  - Blight
  - Ink disease
- Nut quality traits
  - size (7/8 minimum) and shape (round)
  - flavor
  - peelability
  - storage
- Kernel traits for processing (dried, frozen, chips, flour, puree)
- Ease of harvest (round nut shape)
- Reduced pollen production (pollen sterile and mutations with reduced male catkin size)

Based on the currently available cultivars, knowledge, and management techniques used in the eastern U.S. the most common way to establish a profitable chestnut orchard is to plant seedling Chinese chestnuts. Open pollinated Chinese chestnuts will produce 25% of offspring that are better than the parents, 50% will be about the same, and 25% will perform worse than the parent. Underperforming trees can be grafted or removed from the planting. Grafting success is increased by topworking 5-10 year old trees compared to direct planting of grafted trees.

The benefits of seedling Chinese chestnuts are more pronounced in plant hardiness zones 4, 5, and 6 and the performance of grafted trees is closer to that of seedlings in warmer climates. The benefits of seedling Chinese chestnuts include: vigorous growth, genetic diversity, lower initial cost, wide availability, opportunities for adapting trees to a given farm and region, high yields of quality chestnuts, and opportunities for planting at high densities and thinning underperforming trees. The downside of using seedling trees is that there is variability in important agronomic traits that can limit profitability.

The benefits of grafted trees include: the ability to control genetics, the potential for more consistent nut size and quality traits, and the ability to produce superior seedling trees. The downside to grafted trees includes: delayed graft failure, reduced tree vigor, reduced genetic diversity and higher cost for trees.

An important goal for a chestnut breeding program is to maintain enough genetic diversity within selections to have resilient plants capable of thriving under holistic management that can keep expenses low enough for farmers to generate a profit. Narrow genetics tends to make plants more susceptible to pests and disease pressure and as these threats are constantly evolving, plants that do well initially may develop problems over time. At this point in the development of chestnuts as a crop in the eastern U.S. it is possible to avoid the pitfalls of large scale monocultures of a few clones that are managed for maximum yield with little to no regard for hidden costs that lead to degradation of the environment. Given the long term nature of chestnuts as a crop, a prudent approach would be to establish orchards based on high quality seedlings with diverse genetics that represent multiple species in the near term and to integrate clonally propagated chestnuts over time as they become available and have proven themselves through on farm trials.

Continuing to develop existing participatory breeding networks and professional management techniques that complement breeding work is another important facet of developing the chestnut industry. Both seedling and grafted trees will perform better under professional management that works to maximize ecosystem services by working with biological systems to create healthy and resilient chestnut trees. In order for this approach to work, farmers need to understand the ecology of chestnut orchards and pay attention to many small details as exemplified by the subtle differences highlighted in the image of chestnut gall wasp larva and its parasitoid larva in figure 7.

Figure 7: Image of the interior of a gall with Asian chestnut gall wasp larvae (Dryocosmus Kuriphilus) on left and its parasitoid larvae (Torymus sinensis) on right[98].

Chestnut Genome

Researchers in the U.S. are advancing our understanding of the chestnut genome. They are working on creating a reference genome that would provide the opportunity to identify valuable genes and associated traits of interest. This knowledge could inform future breeding work and accelerate progress in creating improved hybrids. Extensive genetic analysis has been done in China and there are opportunities for collaboration with them that would greatly accelerate our knowledge and progress.

Market Development

There is a large unmet demand for chestnuts in the U.S. This is reflected in the approximately 3,500 tons imported annually. As a result of the strong demand, most chestnut producers in the U.S. sell fresh whole chestnuts directly to local or regional consumers. Distributors and wholesale brokers have developed to facilitate larger scale marketing efforts and these have primarily focused on fresh whole chestnuts. The small size of the U.S. chestnut industry coupled with variation in chestnut qualities between producers and regions makes chestnuts more of a specialty crop at this point in time. However, there are isolated instances of value added processing and the most advanced infrastructure for this is owned by Michigan State

University. They purchased a commercial chestnut peeling line in 2002 and have peeled Colossal and Chinese chestnuts. Challenges to this approach include variation in nut size and shape and less than optimal nut characteristics that make peeling more difficult. In addition, peeled nuts lose one-third of their weight compared to fresh nuts and the costs incurred through processing make the break-even price higher than most consumers are willing to pay. Once nuts are peeled, other options open up for processing and Treeborn Inc. in Michigan has developed toasted chestnut chips for brewing. This involves taking peeled chestnuts, slicing them thinly, and toasting them. Brewers use these chips to add flavor to beer and other drinks.

Farmer Development

The Northern Nut Growers Association, Center for Agroforestry at the University of Missouri, Michigan State University, The American Chestnut Foundation, and regional nurseries have all made significant contributions to educating farmers. As a result, the chestnut industry in the U.S. has matured to the point where 18% of the annual marketing survey respondents for the Chestnut Growers of America report earning a gross income of $50,000 to over $100,000 from the sale of chestnuts. The survey respondents likely skews to larger commercial scale producers, but it does indicate that farmers are generating significant revenue from chestnuts.

Barriers to success in the chestnut business include:

- Systemic challenges based on the USDA allocating a majority of its resources to supporting large scale monocultures of annual crops and associated industrial livestock operations
- Lack of information for producers, retailers, and consumers
- 6 to 10 year time lag to get a return on investment
- Shortage of available chestnut nursery stock of commercial cultivars
- Pest and disease control
- Market uncertainties
- Lengthy quarantines for cultivars from other countries
- lack of chemicals registered for use with chestnuts are also considered barriers to success.

In order to address these challenges, chestnut grower associations, universities, and state and federal agencies must develop diverse long-term collaborative approaches to fund and support chestnut research and industry development over the long-term.

BOTTLENECKS LIMITING EASTERN US CHESTNUTS

& STRATEGIES TO OVERCOME THEM

Profitable commercial chestnut production is possible now with existing cultivars and management protocols. However, significant barriers exist to scaling up chestnut production across the region. This section outlines those barriers:

A. Scaling Up the Supply Chain
B. Variety Development
C. Research & Development

A. Scaling Up the Supply Chain

A1. Investment Capital for New Chestnut Farms

KEY NEED
Securing investments that are tailored to perennial cropping systems to facilitate transitioning the industry to professional management.

Family farms in the Midwest that contain soils suitable for chestnuts provide an opportunity to introduce agroforestry and diversified production to current landowners. Perennial, permanent crops typically present significantly higher income to farmers and investors than row crop systems. From 2003 to 2013, for instance, permanent crop income in the U.S. averaged an annualized return of 12.2%, compared to just 4.5% for annual crops[100]. However, permanent crops also present risks associated with the multi-year lag between establishment and the break-even point. These risks have limited investments and led to a fragmented and inefficient perennial crop food system that is poised for growth. An expanding middle class and strong demand for healthy foods is driving sales of tree crops and this presents an opportunity for transitioning an inefficient market to professional management across the value chain.

One acre of chestnuts is estimated to cost ~$2,500 to establish in year one. The total cost over the first five years is ~$5,000 per acre. An acre of chestnuts will ultimately generate an average annual net income of ~$2,000-$10,000. Small scale farms that have u-pick operations near urban centers and sell direct to consumer can realize higher returns, while larger scale commercial production tends to achieve lower net returns per acre. With this level of profitability, a ten acre chestnut orchard can support a family and provide a middle class income. Chestnut orchards can also diversify income streams as part of larger farm operations that have other established enterprises. While production starts around year 6, farmers will have incurred substantial costs by that time and will not break even on their investment until at least years 10-12. Such an investment could provide a 20% IRR over 30 years. 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 three 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.

For Midwest chestnuts, a dedicated private equity vehicle following a "buy-develop-sell" business model similar to the Oregon hazelnut industry could effectively expand planted chestnut acreage. In contrast to single-property development efforts by independent investors, a coordinated private equity strategy would enable greater economies of scale – both in farm operations and markets – and would help diversify execution and geographic risk. Farmers purchasing mature chestnut operations would benefit from reduced risk and immediate ongoing cash flows. Given the early stage of the U.S. chestnut industry, the most likely sources of capital for such a private equity vehicle would be impact investors and other forms of patient capital.

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 guarantee.[111]

In the case of eastern U.S. chestnuts, 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 six. Traditional loans could then be provided with terms up to seven 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 Dietman).

A2. Nursery Infrastructure

KEY NEED
Develop a network of regional nurseries, brokers, and cooperatives to foster growth and development of the chestnut industry.

The largest tree nurseries selling known cultivars of chestnuts that serve the Midwest include: Forrest Keeling Nursery, Stark Bros Nursery, Red Fern Farm, Empire Chestnuts, Oklahoma Chestnut, and Chestnut Hill Nursery. These nurseries supply the majority of chestnut trees planted in commercial orchards in the Midwest. The state of Michigan is unique in that they are under quarantine to prevent gall wasp importation and they focus on growing grafted Japanese/European hybrid chestnuts. Farmers in Michigan purchase trees from Forrest Keeling and nurseries on the west coast. These include Washington Chestnut Company and Burnt Ridge Nursery. There are also large wholesale nurseries and smaller scale regional nurseries supplying farms in the Midwest and on the East Coast.

Each of the primary nurseries serving the Midwest faces a variety of challenges meeting existing demand and planning for future growth. Challenges impacting all nurseries include a limited supply of high quality seed and underdeveloped infrastructure that leads to difficulties generating a profit from the sale of trees. In addition, many nursery owners are at or near retirement age, and some do not have a clear succession plan. Forrest Keeling is one of the largest nurseries selling chestnut trees, but they are primarily a native plant nursery, and 99% of their business is based on selling native plants. The state of Missouri recently categorized Chinese chestnuts as an invasive species, and this change could potentially impact their decision to continue to produce Chinese chestnut trees (Lupe Rios). Chestnut Hill Nursery is based in the south and they produce Dunstan chestnuts, which are not well adapted to northern states. In addition, many of their trees are planted by hunters that use them as food plots for deer.

Nursery owners have reported strong demand for their trees and Forrest Keeling Nursery sells out of trees before they start grafting and they have to turn down a lot of orders (Lupe Rios). The estimated total number of trees produced by the primary nurseries serving the Midwest is 40,000. This represents a combination of potted and bare root trees. It takes between 50 and 220 trees to plant an acre depending on the tree spacing and whether the trees are overplanted to allow for thinning or planted at their final spacing. Consequently, the 40,000 chestnut trees produced annually can plant between 180-800 acres.

If 20-foot by 20-foot spacing is used as an approximate midpoint and reasonable scenario, this leads to 40,000 chestnut trees being planted on 367 acres. An additional point to consider is that there are a variety of complex biological and social factors that contribute to tree mortality or trees being used for personal use. This means that it is highly likely that the number of acres of chestnuts that are planted annually that will end up as commercially viable orchards is less than 367 acres. When you account for all the stressors on trees and farmers and mistakes made in planting and managing trees, it is reasonable to conclude that the initial plantings shrink over time due to these factors.

This leads to an estimated 200 acres of chestnut trees that are planted annually in the Midwest that end up as commercially viable orchards. These 200 acres are being added annually to the existing 4,000 acres of chestnut orchards in the U.S.

Scaling up nursery capacity can be accomplished in several ways, including: (1) increasing production at existing nurseries by providing loans and investments, (2) developing new nurseries, and (3) developing partnerships and contracts with existing tree nurseries that currently do not sell commercial cultivars of chestnuts. Many large scale wholesale nurseries exist that own hundreds of acres of land and have the infrastructure and expertise to grow trees. These companies could grow under contract and produce chestnut trees for commercial production. One example of a candidate for this is Cold Stream Farm in Michigan. They are a wholesale tree nursery that currently produces Chinese chestnut trees.

A3. Seed Production Orchards

KEY NEED
Produce large quantities of high quality full sibling seeds from the best combinations of parent trees.

Seed production orchards composed of carefully selected grafted trees are needed to produce large quantities of high quality seeds. The current supply of high quality chestnut seeds is largely produced at the University of Missouri's Horticulture and Agriculture Research Center (HARC) outside of Columbia, Missouri. Their seeds are produced by grafted trees of known cultivars that have been trialed and evaluated for commercial viability. However, their seeds are the product of open pollination and the pollen parent is not known.

Depending on this single source for quality seed is a major bottleneck for scaling up the industry. Demand for these seeds exceeds the supply, and weather stress and limited staffing have reduced availability and quality in some years.

High quality seeds with known parentage will allow breeders and farmers to learn which crosses make the most valuable and productive offspring. This work will complement the genetic analyses that are ongoing and provide a better understanding of how each species and cultivar interacts with other species and cultivars. These orchards would be dedicated to seed production, and they would have a roughly twenty year lifespan. Ideally, they would be planted on well drained acidic soils in zone 6 or 7 and would be well-managed to ensure they meet the goals of producing high quality seeds. Many experts consider Missouri to be the best location for seed production orchards. Controlled crossing would be achieved through orchard design and layout and the resulting seeds would have a known parentage from parents with valuable traits. These seeds would then be used to establish orchards with improved seedling trees.

This bottleneck can be overcome by investing in people and infrastructure to establish well managed seed production orchards. Investments in the existing HARC orchard and the Center for Agroforestry is one option along with creating a new business that is focused on this important work.

A4. Post-Harvest Infrastructure

KEY NEED
Develop a network of chestnut aggregators and associated supply chain infrastructure to support growth in the industry.

Post-harvest infrastructure has proven to be a key asset that has helped stimulate growth in the chestnut industry. Most farmers are used to growing and selling commodities that they deliver to a central buyer. Providing this same service for chestnuts facilitates more farmers planting chestnut orchards.

There are existing chestnut aggregators in Ohio (Route 9 Cooperative), Michigan (Chestnuts Growers, Inc.), and Iowa (Prairie Grove Chestnut Growers). Collectively, they currently work with 104 farmers and sold 342,590 pounds of fresh chestnuts in 2018, 188,454 pounds in 2017, and 322,473 pounds in 2016. Assuming an average yield of 2,000 pounds per acre, the 342,000 pounds sold in 2016 could be produced on 171 acres.

Investing in chestnut supply chains and producing value added products that appeal to U.S. consumers could support the development of the potential markets outlined in Table 2 (page 18). This level of production would require a dramatic increase in the scale and sophistication of infrastructure to handle the increased capacity and diversity of products.

Developing robust regional food system infrastructure in areas well-suited to growing chestnuts would help drive growth in the industry. This infrastructure would ideally develop in tandem with increased production. Expanding existing infrastructure can work as a near-term approach to scaling up production. Loans and investments in existing businesses can increase their capacity, but investments in new businesses will be required to supply the quantities needed to meet existing U.S. demand for chestnuts. Once a certain level of production is reached the mid stream infrastructure can become more sophisticated and diversified and capture more value by targeting new markets and developing new products that align with modern consumer trends for healthy convenience foods.

A5. Farmer Training

KEY NEED
Highly skilled chestnut growers using professional management at scale to create profitable businesses.

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 chestnuts, where unfamiliarity increases farmer hesitation. Professional management applied at scale is a key need to realize the higher returns perennial crops are capable of delivering.

Michigan, the leading producer of chestnuts in the U.S., was able to increase production quickly due to the existing population of highly skilled farmers that have been managing orchards across the state for generations. These farmers were already working closely with Michigan State University and the Extension Service and when MSU started providing training and support for chestnut growers. That support was key in catalyzing the industry.

However, even under these promising conditions, there are growing pains and challenges with chestnut production in Michigan. Lessons learned in Michigan can help inform a broader effort to train farmers across the Eastern U.S. in efficient and profitable chestnut production. Combining best practices from chestnut producing regions around the world with the diverse management approaches developed at the University of Missouri's Center for Agroforestry, Red Fern Farm in Iowa, and Route 9 Cooperative in Ohio would provide a solid template for farmer training and development.

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 during 2019 and 2020 focused on agroforestry and tree crops – the first of its kind. In subsequent years, a chestnut-focused version of the program should be established.

B. Variety Development

B1. Genomic Tools for Breeding

KEY NEED
Develop a more comprehensive and practical understanding of the chestnut genome.

Recent advances in high-throughput genotyping methodologies, as well as rapidly increasing computational resources, have dramatically expanded the potential use of genomic information in traditionally under-resourced crop species. It has become increasingly affordable to genotype thousands of plants within a breeding program with high precision, developing hundreds of thousands of genetic markers that characterize diversity across the genome. Computational resources have also improved for efficiently utilizing this wealth of genetic information—both in order to determine the variable degrees of relatedness within large populations of individuals, as well as the prediction of phenotypic performance on the basis of genotypic information alone. Taken as a whole, these novel technologies now allow genomic prediction to be used within nearly any breeding program.

The efficiency gains that these tools offer are particularly significant in the context of tree breeding. Because trees have longer generation times than annual crops and often do not reach maturity until several years after becoming reproductively active, the most significant bottleneck to genetic progress within tree breeding programs is the time it takes to complete a breeding cycle. Genomic selection offers the potential to dramatically accelerate this breeding cycle, by allowing for the evaluation of plants at the seedling stage instead of waiting often more than a decade to determine performance. In addition, selection intensity can also be markedly increased, since the cost of genotyping an individual seedling requires orders of magnitude fewer resources than growing that seedling to maturity.

Through a participatory breeding network organized by the University of Missouri and the University of Notre Dame, efforts are currently underway to evaluate thousands of half-sibling chestnut families planted on farms throughout the Midwest. This work will produce a robust database of the phenotypic diversity that exists currently in the region and leverage the decades of energy and resources invested by farmers in establishing mature chestnut orchards. Such a resource could provide an ideal initial multi-environment training population with which to build a set of genomic predictions for a suite of key breeding objectives in chestnut.

Additional investment will be critical to realizing this potential. Replicated trials of training populations in particular will be essential to developing accuracy predictive models. Further development of reference genomes and linkage maps, assembled specifically for key cultivars in the Midwest will improve the accuracy of marker development, and reduce the long-term costs of high-throughput genotyping. In addition, developing protocols for implementing long-read sequencing technologies in chestnut will allow for more precise haplotype estimation, and thus more precision in identifying favorable alleles. This in turn will aid in identifying and utilizing novel sources of genetic diversity identified through, for example, genome-wide association studies.

B2. Breeding

KEY NEED
Creating professional centralized variety development programs to create modern cultivars with improved yield, nut quality, and disease resistance.

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. corn 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].

There is no institutional or coordinated participatory chestnut breeding program in the U.S. However, there is a growing network of chestnut farms in the Eastern U.S. that have planted more than 7,000 chestnut trees in commercial orchards. These trees are typically half-sibling seedlings of Chinese chestnuts with an unknown amount of genes from other species in the mix. With half sibling trees, the mother tree is typically known, but the pollen parent or father is usually not known. This introduces variation and potentially reduces the agronomic performance of chestnut trees. Recent grant funding from the USDA is supporting a new project at the University of Missouri Center for Agroforestry to inventory, assess, and create genetic markers for these existing chestnut trees. This work will enable future efforts to make informed crosses to create improved cultivars with known traits, and it represents an important advance in institutional engagement in chestnut breeding that can lead to broader work within universities and the USDA.

This broader engagement is a key next step in improving chestnut germplasm. USDA tree breeders are struggling to adapt popular tree fruit and nuts to our changing climate, and crops like peaches, tart cherries, and almonds have experienced stress and reduced yields due to erratic weather conditions. Mild winters combined with late spring frosts has also made breeding work more difficult and breeders are now shifting their priorities to select for later flowering trees. This same approach could be applied to chestnuts with the goal of increasing regional adaptability.

Shifting existing USDA resources to chestnuts is one scenario for creating a centralized breeding program. Investing in a new, nimble, and focused private business is another option for beginning the process of centralized breeding. The focus for a centralized breeding program should be identifying, evaluating, and developing a more comprehensive understanding of the best Chinese chestnuts cultivars and their genetics so that they can be used as a well adapted base to explore crosses with other species to improve agronomic performance. To realize the full potential of advances in breeding, the improved germplasm must be optimized for and integrated into new sophisticated forms of professional management.

Existing chestnut growers also have tremendous potential to create improved cultivars. Farmers have the ability to select trees that are ideally suited to their locations. This regional adaptation can create resilient trees that thrive under lower input management systems that lead to increased profitability. Bob Stehli in northern Ohio and Steve Lucas in eastern Oklahoma are two farmers that are taking this approach to on farm breeding. They produce seedlings and grow dense plantings of chestnuts that get thinned over time based on their assessment of the top performing trees. Seed from the best trees is then used to create the next generation of seedlings and the process is repeated to allow the trees to adapt to the specific climate, soils, and pest pressures present at a given location.

The ideal scenario for chestnut breeding would likely be to combine the best attributes of institutional breeding with the strengths of on-farm breeding to get consistent performance of the best genetics adapting to on farm conditions.

B3. Germplasm Repository

KEY NEED
Save existing germplasm and create multiple repositories to ensure cultivars are not lost.

The USDA maintains the National Plant Germplasm System as a collaborative effort to safeguard the genetic diversity of agriculturally important plants. This network of 18 genetic repositories spans the United States and is part of the larger international GRIN-Global Project. All commercially viable species and a selection of their wild relatives are included in this network.

There are federal funds allocated to supporting a USDA-housed chestnut germplasm repository, and that program is currently housed in the pecan breeding program in the Southern Plains Agricultural Research Center in College Station, Texas. However, this location focuses on pecans and they have not worked with chestnuts. These funds could be reallocated to support a dedicated chestnut repository in the center of the growing region for chestnuts in the U.S. The Center for Agroforestry at the University of Missouri is interested in housing this program. Their location in plant hardiness zone 6 and past experience with chestnuts makes them an ideal candidate to establish a germplasm repository.

In addition to establishing a federally supported chestnut germplasm repository, it is also important to preserve existing chestnut orchards and university breeding programs. Both of these sources of chestnut genetics have a tenuous existence and they are susceptible to changes in funding, pests and disease pressure, and urban development. These factors result in orchards being damaged or lost to development and other land uses. In some cases, this results in the loss of potentially valuable cultivars. Given the current restrictions on importing new germplasm into the U.S., it is important to save existing cultivars so we retain a broad base of genetics to work with in breeding programs.

Another approach to preserving chestnut genetic diversity is to work with existing chestnut growers to identify and assess existing genetics that are being grown on farms and to ensure multiple trees of each valuable cultivar are being grown on farms across the eastern U.S. Recent grant funding is supporting this work and efforts are underway to characterize existing germplasm on farms and to better understand the chestnut genome. This work will document the existing distributed network of chestnut trees that can serve as an additional source of valuable genetics and serve as a safety net for an official germplasm repository.

C. Research & Development

C1. Agronomic Research

KEY NEED
Research-based best practices for Eastern U.S. chestnut growers

An extensive network of institutions, researchers, and farmers around the world have generated a large knowledge base for best practices and management guidelines for chestnut orchards. China, in particular, is relevant for the Eastern U.S. As the world's largest chestnut producer and the center of origin for Chinese chestnuts they have the most comprehensive understanding of the Chinese chestnut best management practices. Consequently, translation of Chinese research and cooperation between the U.S. and China can fast track the development of the Eastern U.S. chestnut industry.

Nevertheless, new and ongoing research on chestnut agronomy specific to the Eastern U.S. will be critical, especially in the following areas:

- Fertility management both during orchard establishment and at maturity
- Appropriate timing, intensity, and mechanization of pruning
- Weed control requirements and approaches during orchard establishment under both conventional and organic management
- Evaluation of ideal plant spacing 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
- Resilience to biotic and abiotic pressures introduced by climate change

Strategic investments that leverage and coordinate existing research and institutions can position chestnuts as a viable staple crop worthy of broader engagement from mainstream institutions like the USDA and the U.S. Forest Service. When these institutions engage in significant chestnut research and development, chestnuts will make even more rapid gains in agronomic performance.

Key U.S. institutions currently conducting research on chestnuts include: Michigan State University, University of Missouri Center for Agroforestry, State University of New York (SUNY), University of Illinois at Urbana-Champaign, Route 9 Cooperative, Wintergreen Farm, The American Chestnut Foundation, The Chinquapin Chestnut Foundation, Chestnut Growers of America, Northern Nut Growers Association, the Savanna Institute, and various grower-led research projects associated with individual farms.

There is also tremendous potential to cooperate with researchers in China, Europe and other chestnut producing regions to learn from their work. A researcher exchange program would advance our understanding of chestnuts and successful management practices. These programs are already in place at major universities and funding chestnut research could tie into these existing avenues for cooperation.

C2. Clonal Propagation

KEY NEED
Develop efficient protocols to produce affordable grafted and tissue cultured trees.

While grafted European chestnuts are widely planted in commercial orchards in Europe and other parts of the world, Chinese chestnuts have proven more difficult to graft. The few grafted Chinese chestnut trees that are available in the U.S. are only commercially viable in select locations with ideal climate, soils, and management conditions. More research and development is needed to better understand the factors limiting the viability of grafted Chinese chestnut trees.

However, tissue culture, another method of clonal propagation, could sidestep the graft issue altogether if successfully applied to chestnuts. Faculty at the SUNY College of Environmental Science and Forestry in Syracuse, New York have developed some of the first promising protocols for tissue culture of chestnuts, though the process has proven to be very time consuming and complex. Each species and variety of chestnut requires its own protocol with varying levels of hormones, time, temperature, and other variables dialed in through detailed experimentation and testing.

The work at SUNY focuses on American chestnuts, but they have also developed the ability to produce tissue cultured trees for Colossal, a European x Japanese chestnut variety, and they have the potential to produce Chinese chestnuts given adequate time and funding. Z's Nutty Ridge Nursery in New York is currently offering tissue cultured Colossal chestnuts for sale, and they have plans to offer more cultivars in the future. Investing in tissue culture-based clonal propagation could build upon the work that has been done to date and greatly accelerate progress towards scaling up production and expanding the availability of more diverse germplasm.

C3. Autonomous Robotic Harvesters

KEY NEED
Autonomous robotic harvesters that facilitate (1) efficient commercial harvesting for strong economies of scale as well as (2) capture high-resolution yield data to support variety development.

The primary harvesters in use on small to medium sized chestnut orchards are homemade vacuum based harvesters that are typically pulled behind a tractor. These harvesters pick up chestnuts, burs, and debris that get sorted out post harvest with a variety of other cleaning and sorting equipment. Some larger scale chestnut orchards use European chestnut harvesters. These machines function like a small combine and they harvest and separate nuts from debris while harvesting. Typically, some level of debris remains after harvest and additional cleaning and sorting is required. These machines are expensive and are cost prohibitive on orchards under ten acres in size.

Orchard management needs to be optimized for a given type of harvester to realize the full benefits of mechanical harvest. Optimum orchard management varies with soil types, climate, cultivars, and intensity of management. In some cases multiple machines may be used to prepare an orchard for harvest. For example, DeKleine Orchards in Michigan uses a modified black walnut harvester as a first pass to pick up debris and unpollinated burs from the orchard floor prior to actual harvest. This increases the efficiency of their operation by reducing the volume of burs that they need to handle during harvest. While these increases in efficiency are important, further advances are needed to increase the scale of the chestnut industry.

Professionally managed commercial chestnut production requires mechanical harvesters that are optimized for the scale and type of farm. Dan Guyer at Michigan State University has done testing,

Figure 8: Image of the interior of a gall with Asian chestnut gall wasp larvae (Dryocosmus Kuriphilus) on left and its parasitoid larvae (Torymus sinensis) on right[98].

evaluation, and research into developing a new type of chestnut harvester for U.S. growers. He has determined that there is a niche for a U.S. made harvester for farms with 2 to 9 acres of chestnuts. Below two acres hand harvesting is economical and above 9 acres European made harvesters like FACMA can be justified (Figure 8). Many questions remain regarding the best harvester option for different orchard sizes and types of management.

Autonomous robotic harvesters represent the next frontier for chestnut harvesting technology and this approach has the potential for large gains in efficiency as well as improved data collection that can inform management decisions. A “swarm” of robotic harvesters can collect data as they harvest and communicate with each other to focus effort on the most productive areas of the orchard while minimizing time in areas with little to no chestnuts on the ground. The data collected by these harvesters will identify the most productive trees, determine nut sizes, and the harvest window each season (Figure 9).

One potential partner in this work is the University of Illinois and the technology company EarthSense (earthsense.co). EarthSense is developing robots for various applications in row crops, and much of the technology can be applied to chestnuts. EarthSense estimates that they can leverage their existing technology to create a prototype robotic chestnut harvester in two years (Girish Chowdhary).

C4. Food Processing for Novel Markets

KEY NEED
Research and development to match chestnut kernel characteristics with industry specifications for starch and livestock feed markets.

Compared to existing chestnut markets, there are massive potential novel market opportunities for chestnuts to replace corn as an industrial starch or livestock feed. Critical to accessing these markets, however, is meeting their biochemical and nutritional requirements. Researchers in Europe and China have evaluated chestnut starch for its suitability for use in industrial and processed food applications. Their research has demonstrated that chestnut flour can be used in gluten free processed foods and as a component of baked goods, including sourdough bread.

For industrial applications, chestnut starch can be processed and modified through heat and enzymatic treatment as well as through fermentation. This produces a starch that is intermediate between cassava and corn starch, and, once treated, chestnut starch can replace corn starch in a variety of uses where lower processing temperatures are used.[78]

While initial work has already occured on chestnut starch, substantial further work is necessary. In particular, further research is needed to quantify starch properties for top Midwestern chestnut 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 chestnut chemical composition, research is needed to determine how a large-scale chestnut industry could leverage the existing network of corn storage, transportation, and processing infrastructure. Utilizing this existing infrastructure will make scaling the chestnut industry much more effective and efficient, but will require specific modifications to account for the perishable nature of chestnuts. Large corn processing companies, such as Archer Daniels Midland and Cargill, could serve as key collaborators in this research.

Figure 9: Existing EarthSense crop management robots that could be adapted into autonomous robotic chestnut harvesters.

PRIORITY STRATEGIES

TO OVERCOME BOTTLENECKS

The bottlenecks presented above each play a sizable role in holding back the Eastern U.S. chestnut 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:

1. Scale up the Eastern U.S. chestnut supply chain using existing genetics and management practices that already work.

2. Pursue research and development to ensure long-term success via improved cultivars, efficiency-driving technology, and novel market channels.

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.

The first two strategies concern urgent needs facing the industry and would have immediate, significant impact on the development of chestnuts in the eastern U.S. 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 9-11 represent important but less urgent needs that generally require higher priority bottlenecks to be solved first.

1. Private Equity Vehicle for Investment in Chestnut Farms

Bottlenecks Targeted: A1
Amount: $12,500,000
Mechanism: Private Investment
Lead Entities: Perennial Crop Investors Advised by Savanna Institute

The small scale of existing chestnut operations – typically less than 10 acres – limits the perceived viability of chestnuts as a commercial crop. A private equity vehicle would be able to establish commercial chestnut operations at a larger scale. The establishment of 50-acre chestnut farms in key geographies across the Midwest would send important market signals to farmers, lenders, and food product companies, while generating a fair return for investors. By deploying this capital in partnership with diversified family farms, through a structure such as "equity in trees" or other creative financing opportunities, such an investment vehicle would be able to leverage farmer networks to augment its impact while setting up a future exit opportunity on a shorter time scale than the productive life of the trees.

Establishing 50 such operations across the Midwest on this model would plant 2,500 acres of chestnuts, and would require $12,500,000 in capital – a mix of equity and debt – over seven years. An investment term of 10-15 years would be sufficient to bring the trees to maturity, begin to generate returns from the crop, and execute on a structured exit to the diversified family farm partner. Further partnerships between impact investors and agricultural lenders could leverage a large conventional capital base with innovative mechanisms. For example, conventional lenders may be willing to offer long-term or revenue-based loans to a well-capitalized investment vehicle, allowing these lenders to get comfortable with these crops and time scales at reduced risk, enabling a broader base of farmers to access these financial products in the future.

2. Scale Up Nursery Production

Bottlenecks Targeted: A2
Amount: $1,000,000
Mechanism: Private Investment/Debt
Lead Entities: Empire Chestnut, Red Fern Farm, Forrest Keeling Nursery, Warren County Nursery, Cold Stream Nursery

Scaling up nursery production is dependent upon increasing the scale of chestnut seed production. Scaling up nursery production from the existing ~40,000 trees produced annually to the needed 9.6 million trees needed to satisfy potential domestic markets will require a multi-pronged approach to both (1) scale up existing chestnut nurseries (e.g. Empire Chestnut, Forrest Keeling Nursery) and (2) encourage new wholesale nurseries (e.g. Warren County Nursery) to start producing chestnut seedlings.

The nature of the business requires that nurseries take enormous risk by allocating/expanding infrastructure and planting out seeds 1-2 years in advance of sales, without certain knowledge of actual demand. Private investment and/or debt to expand nursery infrastructure and cushion nurseries during sporadic transition years will be key to enabling the industry to scale up plant availability. Transition debt could be relatively short-term, with expanded nursery profits over 3-7 years enabling repayment.

3. Establish Seed Production Orchards

Bottlenecks Targeted: A3
Amount: $3,750,000
Mechanism: Recoverable Grant
Lead Entities: Savanna Institute, University of Missouri Center for Agroforestry

There are not enough seeds from top parent trees to supply nurseries as they scale to produce the needed 9.6 million trees over the next decade. These seeds should be produced by vetted high-quality grafted parent trees. New grafted-tree orchards need to be established to produce this high-quality seed.

Because the produced seed will also be of high genetic value in developing the next generation of top cultivars, routing this investment through the Savanna Institute as a recoverable grant will allow the genetic IP to remain protected in public trust and, ultimately, potentially fund long-term breeding in the public sector.

The investment should be distributed across several orchards to hedge risk associated with climate and disease. Furthermore, due to the sensitive nature of the genetic IP, the orchards should be established on owned land. Due to the temperamental nature of grafted Chinese chestnut trees in northern climates, these seed production orchards should be established no further north than St. Louis, Missouri. The $3,750,000 shown here is based on three 40-acre orchards on owned land.

4. Nut Aggregation, Processing and Marketing

Bottlenecks Targeted: A4
Amount: $2,500,000
Mechanism: Private Investment
Lead Entities: Route 9 Coop, Chestnut Growers Inc., Prairie Grove Chestnut Growers, Janies Mill, Savanna Institute, North American Staple Crop Network, Emerging Businesses.

Modern, efficient, and high functioning infrastructure is needed to support the development of a viable commercial industry for chestnuts. Ideally, this infrastructure would be based on cooperative business models capable of supporting small scale farms. Efficient post harvest infrastructure is needed to produce peeled and frozen chestnuts, dried chestnuts, and chestnut flour. These products are necessary to reach mainstream American consumers whose diet is largely composed of processed foods. Investment can be made into existing entities (e.g. Route 9 Coop, Chestnut Growers Inc., Prairie Grove Chestnut Growers) or via a new entity. Recent conversations with the largest natural cracker and baking mix company in Chicago have prompted the Savanna Institute to outline different scenarios for supplying them with chestnut flour and peeled and frozen chestnuts. This company plans to release products made with imported chestnut flour in 2021 and they intend to source local chestnut flour in the future.

A chestnut processing and marketing company could operate initially by purchasing imported chestnuts and processing them for buyers. The presence of this company would confer legitimacy on the chestnut industry and stimulate production. This would lead to a larger domestic supply. Approximately 25% of annual harvests in the Midwest are composed of small chestnuts. These have limited value in the current marketplace and sell for approximately $1.30 per pound. These small chestnuts could be used as an initial source for local chestnuts for processing.

5. Take Over for Retiring Farmers of Mature Chestnut Farms

Bottlenecks Targeted: A1, A5
Amount: $3,500,000
Mechanism: Private Investment
Lead Entities: Sustainable Iowa Land Trust (SILT), Iroquois Valley Farmland REIT

Like most farms, existing chestnut orchards are owned by an aging population. Many chestnut orchard owners are at or near retirement age. This presents an opportunity to build upon their work and to facilitate a transition to the next generation of chestnut growers. A typical mature chestnut orchard is 10 - 30 acres with a combined value of the land and trees of $10,000 - $15,000 per acre. Thus, each chestnut operation could be acquired for $100,000 - $450,000 if the chestnut orchard was purchased separately from the broader farming operation of which it is a part. Additional acreage could be used for further chestnut expansion or incorporated into a diversified farming operation. This transition can be accomplished by working with an existing real estate vehicle like SILT or Iroquois Valley Farmland to buy the orchards. There are an estimated 10 -20 mature chestnut farms whose owners will retire in the coming years, providing an investment opportunity of roughly $3,500,000.

6. Permanent Industry Leadership

Bottlenecks Targeted: B1, B2, B3, C1, C2, C3, C4
Amount: $6,000,000
Mechanism: Philanthropic
Lead Entities: University of Missouri Center for Agroforestry, Michigan State University, University of Illinois, Savanna Institute

Critical to the long-term success of the U.S. chestnut industry is a high functioning team of rotating researchers, scholars, and technical service providers that can guide the development of the industry. Significant chestnut expertise exists within Europe and China in particular and creating this team would provide an avenue for integrating this knowledge into the U.S. A chestnut team housed at the Center for Agroforestry, University of Illinois and/or the Savanna Institute could provide comprehensive support to the industry based on the model exemplified by the Chestnut Research and Development Center in Piemonte, Italy. This chestnut leadership team could recruit employees from China and Europe as a way to leverage their expertise and help build relationships with researchers and experts around the world.

7. Centralized Variety Development

Bottlenecks Targeted: B1, B2
Amount: $6,000,000
Mechanism: Philanthropic Support/ Recoverable Grant
Lead Entities: University of Missouri Center for Agroforestry, Michigan State University, Savanna Institute, University of Tennessee, Purdue University, Notre Dame University, State University of New York (SUNY)

A broad coalition of universities has increased our understanding of chestnuts in the Eastern U.S. over the last few decades. However, variety development, in particular, remains slow, as none of these institutions have yet dedicated the necessary long-term resources or personnel to the work. Centralized variety development spearheaded by a public institution to leverage university resources is critical to the development of improved chestnut cultivars in the eastern U.S.

Based on conversations with senior faculty at several universities, there are three general tiers of investment that could support chestnut 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 chestnuts in particular. Right-of-first refusal agreements could likely be obtained from the university 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 could be leveraged to help shape the focus of a new hire that a university is already pursuing. For instance, $75,000 per year for 10 years could offset ~50% of a new breeding hire, and therefore be used to shape the focus of this hire on chestnuts.

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 chestnut germplasm.

Tier 3

Absent such a substantial investment, significant benefits could still be obtained by accessing academic research capacities of universities. Discrete grants on the order of $100,000-$500,000 to existing research labs would provide support for specific research projects that still mobilize the substantial resources of the university system.

8. Genomic Tools for Breeding

Bottlenecks Targeted: B1
Amount: $1,000,000
Mechanism: Philanthropic
Lead Entities: University of Missouri Center for Agroforestry, Notre Dame University, State University of New York (SUNY)

Researchers at the University of Missouri and Notre Dame University are poised to develop an ancestry informative marker set (AIMS) from mapped simple sequence repeats within expressed sequence tags (EST-SSR's) in Castanea. This will be used to determine the genetic makeup of existing cultivars. It can also be used as a "fingerprinting" tool to characterize and validate chestnut clones (cultivars). This will help accelerate progress toward creating improved cultivars.

9. Robotic Harvester Development

Bottlenecks Targeted: C3
Amount: $5,000,000
Mechanism: Private Investment/ Recoverable Grant
Lead Entities: EarthSense, University of Illinois

Earthsense has deployed 100 robots for rowcrop applications since 2018. They have 13 full time employees that focus on AI engineering and robotics. They want to leverage their technology to develop robots for agroforestry. This includes robotic chestnut harvesters that would use machine vision and learning to collect data in the field and turn it into valuable information that can be used to inform management and breeding. We are in discussion with Earthsense to lay out a long term plan for developing robotic chestnut harvesters.

10. Farmer Training

Bottlenecks Targeted: A5
Amount: $2,000,000
Mechanism: Public/Philanthropic Support
Lead Entities: Michigan State University, University of Wisconsin Food Finance Institute, University of Missouri Center for Agroforestry, Savanna Institute, SILT, Private Consultants

A key bottleneck limiting chestnut production is the lack of high functioning teams of people capable of professionally managing large chestnut orchards. Professional management applied at scale is key to moving the industry forward and transitioning chestnuts from a specialty crop to a staple crop. In order to effectively train these teams, investments are needed to create and disseminate information through field days and existing venues like conferences, and winter seminars for groups like Certified Crop Advisors. In addition, new partnerships should be developed between the business community and farms to ensure that farms operate as viable businesses. Training and recruitment should put a priority on new farmers and provide them with comprehensive support to overcome social, financial, and agronomic challenges.

11. Research and Development Funding Pool

Bottlenecks Targeted: B1, C1, C2, C3, C4
Amount: $20,000,000
Mechanism: Public/Philanthropic Support
Lead Entities: Michigan State University, University of Missouri Center for Agroforestry, University of Illinois, University of Wisconsin, University of Minnesota, Savanna Institute, Chestnut Development Council

The agronomic and commercial viability of any crop is built up over time via continuous research and development. Chestnuts in the U.S. are at an early stage of development, equivalent to corn in the 1930's. Chestnuts are poised to make rapid gains in productivity with basic research and development applied to them. Achieving a doubling of yield is feasible with chestnuts.

A dedicated, industry-led research and development funding pool would allow continuous funding of the most pressing issues as the industry grows, maximizing the likelihood of industry success and profitability of investments across the supply chain. These issues include many of those in the core bottlenecks identified in this report:

- B1 – Genomic Tools for Breeding
- C1 – Agronomic Research
- C2 – Clonal Propagation
- C3 – Autonomous Robotic Harvesters
- C4 – Food Processing for Novel Markets

A $20,000,000 endowed funding pool would generate over $1,000,000 in interest each year that could be used to fund a competitive grant apparatus. This program could be administered by a newly formed Chestnut Development Council consisting of industry stakeholders. The program would function similarly 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.

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APPENDIX

Descriptions of Chestnut Cultivars

The combined efforts of many people have led to the development of a diverse selection of cultivars that are currently being grown in the eastern U.S. This description of cultivars is largely based on James Nave's research[101] and it includes cultivars used in commercial production and cultivars with valuable traits that are being used in breeding projects.

Qing (20 nuts per lb)

Qing (Ching) is the standard against which all other Chinese chestnuts are compared. Nuts have good flavor and are exceptionally sweet. Nuts are sweeter than most small Chinese nuts growing in the United States. Nuts fall early to mid-season and are shiny and dark brown. A small percentage of burs have more than three nuts, otherwise average nut size would be even larger. Nuts store very well, even for a Chinese nut. Tree is a heavy producer. This tree was planted in the late 1950's or early 1960's and is much smaller than an adjacent Chinese tree planted at the same time, probably because this tree puts more of its resources into nut production than into vegetative growth.

Mossbarger (30-34 nuts per lb)

A 1983 selection from Kentucky. Reputed to be pure Castanea mollisima, but may be some kind of hybrid. Although the tree looks predominantly Chinese, the tree and its seedlings have unusually thick stems, branches and trunk. Nuts have very good flavor raw or cooked but some do develop splits, a quality that seems to be much more common in hybrids.

Sleeping Giant (34-38 nuts per lb)

Hybrid-Chinese x (Japanese x American) originating in 1938 at the CT Agricultural Experiment Station Sleeping Giant Plantation in Hamden, Connecticut where the original tree still stands. Excellent flavor. Upright timber form.

AU Homestead (39 nuts per lb)

One of the three Chinese chestnuts released by Auburn University in 1980. Homestead has the longest ripening period of the three and would thus be more suitable for the home than for commercial plantings. This nut is considered by Hongwen Huang, chestnut researcher from the People's Republic of China, to be exceptionally fine flavored. In Chinese terminology, the nut apparently has a glutinous quality which is preferred in China. Technically, the glutinous quality relates to the temperature at which the nut's starches gelatinize. Nuts which gelatinize at less than 60 degrees centigrade are considered to have a glutinous quality. In lay terms the glutinous quality is probably best described in terms of "mouthfeel". In that sense the glutinous quality represents a rich and complex texture. Although I have never seen testing done on this point, I would suspect that the better quality European and American chestnuts have a lower gelatinization temperature than most Chinese nuts, which plays a role in their excellent flavor. Many of the Chinese chestnuts which are considered better flavored by the Chinese seem to have a texture more similar to European and American nuts. And 'Homestead', like most European and even many American nuts, tastes much better roasted than raw.

Orrin

Originated from an orchard belonging to Orrin Good of Lock Haven, Pennsylvania. Named by J.W. McKay in 1963. Nuts have good flavor. Tree has a very erect growth pattern. Probably originated with Peter Liu's 1935 importations.

Colossal

Although often listed as a complex E x C x J hybrid, 'Colossal' is almost certainly a first or second generation E x J hybrid of trees introduced by Felix Gillet in Nevada City, California. The original tree was planted around 1888 while Chinese nuts were not widely imported until after 1907. Gillet is known to have imported the best French and Japanese cultivars. No mention has been made of his importation of Chinese nuts, nor is it likely he would have used an unidentified seedling tree in his breeding program. Therefore, historically, it is highly unlikely that Chinese germplasm was used in the hybridization of 'Colossal'. Nor is there any phenetic reason to assume Chinese breeding. Nothing in the morphology of the 'Colossal' tree, nor in the hundreds of 'Colossal' seedlings I have evaluated, lends credence to any Chinese heritage. Although nut size is sometimes reported as large as eleven nuts per pound, I have been unable to substantiate an average nut size larger than 14 nuts per pound from any one tree. Nut size varies considerably on most 'Colossal' trees and some growers clearly have a tendency to forget the smaller nuts when calculating average weights. Nut flavor is good when well cured because of a nice level of sweetness. Peeling is sometimes very good and sometimes not good at all.

Bouche De Betizac

A seedling of the vigorous and well known French cultivar 'Bouche Rouge', open pollinated by Castanea crenata. Very vigorous tree and an erect grower. Pollen sterile. Good flavor, peels well. Handles the heat of the California central valley very well. Nuts fall two to three weeks after 'Colossal'.

Szego

Szego is a very complex hybrid, a seedling of the California hybrid Linden, which is predominantly Crenata/Pumila. The pollen parent of Szego may be the Dunstan hybrid chestnut, Revival. Szego is a very vigorous and erect tree. It grafts well on Chinese trees, Chinese hybrids, Japanese hybrids and European hybrids. It is a heavy pollen producer. Nuts are uniformly large (12-16 per lb), but easy peeling and fairly dense, much like a Chinese nut. Nuts are sweet and flavorful, generally with more flavor than pure Chinese nuts. The nuts drop mid season (2-3 weeks after Colossal) and store very well. The tree is resistant to phytophthora root rot. It does have some blight resistance but the extent is not yet known. It has been growing for more than nine years in many blighted areas without noticeable signs of blight.

Luvall's Monster

This tree is a first generation seedling of two probable Japanese/American hybrids growing on the Mississippi River in Dallas City, IL. The trees are probably at least fifty years old. The Monster nut is at least twice as large as the nut on either parent tree. The nut has very good flavor raw or roasted and the pellicle often pops off the kernel in one piece. I don't know how well the nuts store but they do have a tendency to develop the "hollow heart" that is common in both Japanese and American nuts, so long term storage might not be good. The tree was grown by NNGA member Verne Luvall of Galesburg, IL. Mr. Luvall has in the past made scionwood available to other NNGA members. Grafts of the tree are being tested in Byron, GA to determine gall wasp resistance and to see whether nut size may be even larger in a longer growing season. According to Bryan Caldwell, the tree does bear well in upper New York state with good sized nuts for that area. The tree is pollen sterile. It may have some degree of blight resistance although there has been no formal testing. Tree should definitely be planted further in short season areas. The source of the Dallas City parent trees is unknown but they are most likely products of the breeding programs of E.A. Riehl of Godfrey, IL or George W. Endicott of Villa Ridge, IL. Endicott passed away in 1914 and Riehl in 1925. Both worked with American and Japanese trees. Riehl used the cultivars Dan Patch (JxA), Boone (an 1896 Endicott JxA hybrid) and McFarland (a Luther Burbank hybrid-probably AxExJxC) and originated many high quality American hybrids such as Rochester, Gibbens, Fuller, Champion, Progress and others. Dr. A.S. Colby once described some of these hybrids as combining "the size of the Japanese with the quality of the American parent." That is certainly a fair description of 'Luvall's Monster'. Other possible sources for the Dallas City trees are Benjamin Buckman of Farmingdale, IL and Dr. A.S.Colby himself, who taught at the University of Illinois at Urbana. Buckman died in the early 1920s and Dr. Colby in 1925. Both did significant work with chestnuts. Colby's best tree was later named 'Colby' by Dr. Clarence Reed of the USDA. It should be noted that the official name given to this tree by Verne Luvall was simply 'Monster', but everyone else in the chestnut community refers to it as "Luvall's Monster', in tribute to Verne.

Eaton

Originated from a seedling given to Frederick Eaton of Wallingford, CT by Arthur Graves. Suspected seedling of 'Sleeping Giant'. Has excellent flavor, raw or roasted. Considered by many to be one of the best tasting chestnuts around.

Amy, Gideon, and Peach

These cultivars originated as seedlings in a 1972 planting at Greg Miller’s farm in Carollton, Ohio. They are all cold hardy consistent producers of large easy to peel chestnuts.

Many other cultivars exist and are used in commercial production, including: AU Super, Kohr, Jenny, Liu, Benton Harbor, and others. However, it should be noted that research into chestnut genetics has shown that many existing cultivars have a complex history of hybridization between species and their genetic makeup is often not fully understood[102].


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