

Hybrid Hazelnuts: Midwest United States Agroforestry Applications

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Executive Summary

Hazelnuts (*Corylus* spp.) are grown around the world for human food, mainly in the Mediterranean climates on steep slopes in mountainous or hilly areas. They are used mainly for confectionary purposes, but also for table nuts, and oil production. Their large, fibrous root systems are excellent for soil conservation and water quality improvement. The three largest producers of hazelnuts are Turkey (70%), Italy (14%), and the USA (4%) (Tombesi 2005).

Hazelnuts native to colder climates (*C. Americana* Marsh. and *C. cornuta* Marsh.), such as those in the Midwest section of the United States, produce smaller nuts that are excellent for wildlife habitat and food. When hybridized with the commercial hazelnut (*Corylus avellana* L.) they can produce plants that are cold-hardy, eastern filbert blight resistant, and commercially viable for areas with colder climates. Hybrid hazelnut production in the Midwest is still in its infancy as far as commercial production, but is being developed extensively.

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren 1982). Agroforestry practices include trees on cropland, perennial- crop combinations, livestock on pastures with trees, erosion-control structures, windbreaks, living fences, and snow fences.

Agroforestry has the potential to improve commodity production systems around the world. Systems utilizing hybrid hazelnuts in the Midwest are one potential application. The benefits include agricultural diversification, environmental impact mitigation, land and water conservation and rehabilitation, increased food production, sustainable use of marginal lands, natural habitat enhancement, and profitability.

International Resource Management

Hybrid Hazelnuts: Midwest United States Agroforestry Applications

Literature Review

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Introduction

Hazelnuts (*Corylus spp.*) are hardy individuals with large, fibrous root systems that are excellent for soil and water conservation. They are dense shrubs or trees that provide excellent habitat for wildlife while still producing a human food crop of high nutritional value. They can be grown in steep mountainous regions or in riparian zones. New cultivars are being developed for disease resistance and cold-hardiness. Propagation techniques are being studied to promote consistent size for mechanical harvest and uniformity in nut characteristics. Hazelnuts create opportunities for environmentally friendly production and profit (Josiah and Kemperman 1998).

Agroforestry is a hybrid between agriculture and forestry that is practiced worldwide. Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren 1982). It is an integrated management system that North America has begun to look more closely at as greater concerns over the long-term sustainability of its intensive crop monocultures arise (Lassoie and Buck 2000). The role of woody perennials in restoring and maintaining soil fertility has long been recognized. Woody perennials stabilize

soils and control erosion. The addition of organic matter through leaf and root decay is also one of the many advantages of agroforestry.

Agroforestry

Agroforestry Systems

Agroforestry has been practiced around the world for thousands of years (Elevitch 2004). The oldest systems used are shifting cultivation, taungya, and conuco (Whitmore 2001) or cunucu (Miller 1917), a clearing in the forests of Venezuela, Cuba and other Caribbean islands in the 1500's, where yucca, pineapple, sugar-cane, plaintain, banana, and cashew were planted. Agroforestry is the modern name for land-use systems combining trees, crops, and/or livestock. There are numerous definitions for these systems and three are listed below:

“Agroforestry is a term for practices where trees are combined with farming, as well as for the inter-disciplinary subject area embracing land- use systems, at a range of scales from that of field to the planet, that involve interactions amongst trees, people and agriculture. Put simply, agroforestry is where trees interact with agriculture.” (Sinclair 2004)

“Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system.” (Lundgren 1982)

“Agroforestry is an intensive land management system that optimizes the benefits from the biological interactions created when trees and/or shrub are deliberately combined with crops and/or animals.” (Association for Temperate Agroforestry 1997)

There are many types of agroforestry systems around the world. At the highest level they can be classified based on the main components (Young 2002):

Agrosylvicultural	Trees with crops
Sylvopastoral	Trees with pasture and livestock
Trees predominant	Forests with other components subordinate
Special components present	Trees with insects or fish

On the second level systems are based on their components as arranged in space and time. There are predominately agrosylvicultural systems that include rotational systems such as shifting cultivation, managed tree fallows (including relay intercropping), and taungya. Taungya is a system in which farmers are invited by government forestry departments to plant crops on forest land, while also intercropping trees on this land. They take care of the young trees and crop for one to three years until the competition for light prevents further planting of crops. The trees are then allowed to grow out their normal cycle. There are spatially mixed systems such as trees on cropland, perennial-crop combinations, and multi-strata systems where trees, shrubs, and herbaceous plants are grown together. Spatially zoned systems include boundary planting, trees on erosion-control structures, windbreaks and shelterbelts, alley cropping (also known as hedgerow intercropping), tree-row intercropping, contour hedgerows, and biomass transfer where cut-and-carry mulching is carried out (Young 2002).

Predominately sylvopastoral systems include spatially mixed systems such as trees on pastures and perennial crops with pastures (including orchards). Spatially zoned systems include hedges and live fences along with fodder banks.

In systems that are predominately tree-based there are trees for soil conservation, private woodlots and village forests, and reforestation. In special component agroforestry there is entomoforestry (trees with insects) and aquaforestry (silviculture and aquaculture being practiced within the same water resource, i.e. mangrove swamps) (Janssen 1999, Young 2002).

There are five main categories of agroforestry in the US. They are described in the table below.

Practice	Predominant Region	Uses	Associated Technologies
Riparian buffer strips	All regions	Decrease nonpoint source pollution, soil erosion, nutrient loading, and improve microhabitats	Stream bank bioengineering Constructed wetlands
Windbreaks	Great plains, midwest	Protect and enhance production of crops, control soil erosion	Living snow fences, windbreaks
Alley cropping	Midwest	Increases and/or diversifies farm crops and income	
Silvopasture	West and southeast	Economics, wildlife habitat, fire protection and forest management purposes	Pine straw harvest

Forest farming

All regions

Income diversification

(Gold et. al. 2000)

Hybrid hazelnuts are commonly used in riparian buffer strips, windbreaks, and alley cropping in the US (Badgersett 2008).

Benefits of Agroforestry

Natural resource conservation is critical to human's survival on earth. Agroforestry systems demonstrate conservation in many areas. Soil is conserved by tree roots and mycorrhizal systems that reduce nutrient leaching, bind soil, and prevent erosion. Tree leaf litter enhances soil physical, chemical, and biological processes that help reduce erosion and improve nutrient cycling. This may reduce the need for commercial fertilizers, thus reducing production costs and agricultural run-off. Trees in windbreaks are known to reduce evapotranspiration and improve crop water use efficiency (Davis 1988). Trees also provide excellent habitat for birds, insects, and other wildlife which assists in conserving biodiversity. Trees sequester a great deal of carbon, helping reduce carbon dioxide pollution and climate change (Young 2002).

Agroforestry systems can have many socioeconomic benefits also. Mixed cropping systems produce more than one product, which lessens dependence on income from only one source. More production may be harvested from one acre than if it were only a single monoculture. By combining traditional practices and production with multiple natural resource conservation measures, sustainable practices may be more profitable, acceptable, and therefore more readily adopted.

Hazelnuts

Hazelnuts are a sweet, tasty nut that can be used for confections, cooking oil, table nuts, or in a wide range of other food products such as cereals, breads, and cookies (Stahl 2007). Hazelnuts are used as coffee flavoring, liqueurs, additives in chocolate bars (Josiah 2000), for making praline, and for hazelnut butter (The Hazelnut Council 2008). Non-food uses include massage oils, essential oils, biomass production, medicinal extractions, and mulch (Stahl 2007). Hazelnut wood is used to make baskets, walking sticks, chairs, fences, and hand tools (FTG 2008).

Hazelnuts have been used around the world in cool and warm temperate agroforestry systems. In Turkey hazelnuts are likely used in alley cropping, trees/shrubs on cropland, trees/shrubs in soil conservation and reclamation, and agrosylvopastoral systems (Tolunay 2007). Italy may be using hazelnuts in alley cropping systems (Marti 2001) and as erosion control structures.

Hybrid hazelnuts are grown in a variety of agroforestry applications in the United States. New York is growing hybrid hazelnuts in alley cropping systems (Mudge 2008). Iowa has hazelnuts in windbreaks and living snow fences (Josiah and Kemperman 1998). Minnesota has hybrid hazelnuts in alley cropping, windbreaks, streamside buffer strips, living snow fences, wildlife plantings, and pick-your-own plantings (Josiah and Kemperman 1998 and Josiah 2000). Nebraska has alley cropping, living snow fences, windbreaks, riparian forest buffers, and odd corners of fields planted in hybrid hazelnuts. Wisconsin utilizes hybrid hazelnuts in alley cropping, windbreaks, snow fences, and wildlife plantings (Ebert 2007).

History of Hazelnuts

Hazelnut, the commonly used name for filbert, has evolved from European folklore and was associated with Saint Philbert's Day, August 22nd, the day that nut harvest began. Pliny, a famous Roman historian recorded that 'hazels' (filberts) were frequently gathered for food. He believed that hazels originated in Damascus, Syria, where they grew naturally in forests. However, 5000 year old fossilized hazels have been found in excavations in China. European hazelnut trees (*Corylus avellana* L.) originated in the Mediterranean region from Turkey to Spain. The name *avellana* is derived from the town of Avella in Italy. The two hazels native to North America are the American hazelnut (*Corylus Americana* Marsh.) and the beaked hazelnut (*Corylus cornuta* Marsh.). Hazelnuts have been part of the human diet for 5000 years. The first commercial nursery in the U. S. was established by Robert Prince in 1737 in Flushing, N. Y. (Malcolm 2006-2009). George Washington visited this nursery and during the Revolutionary War sent armed guards to protect it because it contained valuable American filbert trees and "Barcelona" filbert trees imported from Spain.

Nutrition

Anti-oxidant rich hazelnuts have been studied extensively in relation to their nutritive qualities. In 2003, the United States Food and Drug Administration approved a health claim that states (US FDA 2003) "[s]cientific evidence suggests, but does not prove that eating 1.5 ounces per day of most nuts, such as hazelnuts, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease." Hazelnuts are high in protein (19%) and an excellent source of vitamins E and B6 (Stahl 2007). They contain 60% oil, which is three times the oil content in soybeans. This oil is similar to olive oil, containing 70% monounsaturated fats (USDA 2003). Hazelnut oil is valued in cooking as light and flavorful, and has a long shelf life.

Species Descriptions

Hazelnuts are a member of the Betulaceae (birch) family. The European hazelnut (*Corylus avellana* L.) is a species of hazel native to Europe and western Asia, from the British Isles south to Iberia, Greece, Turkey, and Cyprus. It is also found north to central Scandinavia and east to the central Ural Mountains, the Caucasus, and northwestern Iran (Rushforth 1999). This is the species that dominates world trade. In the United States, *C. avellana* is grown in Oregon, in the Willamette Valley, and in Washington State.

The European hazelnut grows from twelve to twenty feet in height and usually forms a dense thicket of erect stems (Dirr 1998). Commercial producers in Oregon and France often train this species as a small tree (Beyhan 2007). It develops extensive shoots from its large root system. Hazelnuts are wind pollinated. The nut is about $\frac{3}{4}$ inch long, set in an involucre about as long as the nut. The nuts grow in clusters of one to five. Trees begin bearing nuts at three to five years of age and will continue to increase in yield until age eight or so (Badgersett 2008).

In the midwestern section of the United States and southern Canada, the native hazelnuts are the American hazelnut (*Corylus americana* Marsh.) and the beaked hazelnut (*Corylus cornuta* Marsh.). These species are cold hardy, small (4-10 feet high), shrubby, and resistant to eastern filbert blight, a major problem for the European hazelnut in the United States (Dirr 1998). They also produce a much smaller nut with a thicker shell. While these native plants are not commercially used for nut production, they provide excellent food and habitat for wildlife.

Hybrid Hazelnuts

Hybrid hazelnuts are being studied extensively in Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Kansas, and Ontario, Canada. Plant breeders in the United States are hoping to combine

the best characteristics of the European hazelnut, with the eastern filbert blight resistant, cold-hardy native American and beaked hazelnuts to create a hybrid suitable for commercial production in the Midwest and Northeast. These hybrids have larger nuts with thinner shells than their native cousins. They grow ten to twelve feet in height and six to eight feet in diameter (Badgersett 2008, Molnar 2006). They begin producing nuts at three to five years, increasing yield up to year eight or so, and may live longer than 30 years. Nuts are generally harvested in early September in Minnesota and Wisconsin, with some harvest time variation in other states depending on climate.

Growing Conditions

European hazelnuts are not as cold-hardy as the North American natives: American and beaked hazelnuts. European hazels grow best in climates without extremes of heat and cold. Temperatures of minus 10°C, accompanied by wind may kill both pistillate and staminate flowers, although some winter chilling is necessary to break dormancy (Tous Marti 2001b). Dormancy is nature's way of setting a time clock that allows seeds to germinate when environmental conditions are favorable for seedling growth (Evans 1999). Hazelnuts need winter chilling of two to six months to break their internal dormancy. European hazelnuts grow in United States Department of Agriculture (USDA) Zones 4-6, while native American and beaked hazelnuts grow in USDA Zones 4-8/9 (Dirr 1998). Hardiness zones are determined using the extremes in winter temperature as indicators of whether a plant can be cultivated outdoors in that particular region.

Hazelnuts can grow under a variety of conditions. They grow in cool to warm temperate climates, some in areas of high rainfall, others in more arid areas. Hazelnuts are grown on steep slopes (20%), or flatter more fertile plains (Tous Marti 2001a). They can grow

on a variety of soils with respect to pH and fertility. However, they do prefer deep, well-drained soils either neutral or slightly acidic (about pH 6), and are sensitive to root asphyxia (Tous Marti 2001b). Hazelnuts are generally planted as seedlings.

World Production

Turkey is by far the largest producer with approximately 70% of the world's production at 800,000 metric ton in-shell basis in 2006 (USDA FAS 2007). Most of their hazelnuts are grown in the Black Sea region. Italy produces about 14 % at 120,000 ton, United States at 4% with 39,000 ton, and Spain about 3% with 25,000 ton (Tombesi 2005). Virtually all of the US production comes from Oregon (99%) (Molnar 2006). Other countries producing hazelnuts are Greece, Portugal, France, the Republic of Azerbaijan, Croatia, the Russian Federation, with new markets developing in Australia, New Zealand, Chile, and Poland (Tous Marti 2001a). Turkey and Italy's largest export market is the EU (Coutts 2001). The US consumes 67% of its production and exports the rest to Europe (Coutts 2001).

Hazelnuts are sold on a shelled or an in-shell basis. The in-shell market accounts for about 10% of the world market and the other 90% are cracked and sent to processors (Tous Marti 2001a). In 2005 the price for hazelnuts in the United States on an in shell basis was \$2,240 per ton (2000 pounds) (USDA 2006). Oregon hazelnuts yielded 1960 pounds per acre in 2005. This was down from 2640 pounds per acre in 2004 when the price was \$1,440 per ton in-shell. World production ranges from 440 to 2700 pounds per acre (USDA 2006). Prices range from 40 cents to \$1 per pound on the world market (Stahl 2007). Potential for new products and expanded markets is high.

Conclusion

Agroforestry systems have been utilized around the world for centuries. These systems have a myriad of advantages in ecosystem sustainability. The world's population is estimated to reach 8 billion by the year 2030. Food demand is expected to grow at a faster rate due to increased urbanization and improved incomes. Agricultural areas of greatest grain productivity have declining rates of growth in yields. These areas will likely not be able to meet increasing demands for food. More land is going to be required. There are four major reasons why meeting increased demand for agricultural products will often require agroforestry type systems (Scheer and McNeely 2007): more food will likely be grown domestically and on more marginal or fragile lands, wild products will continue to be important for local food and income, agricultural systems will need to adapt to the changing climate, and agricultural sustainability will need to consider ecosystem management in order to slow degradation of landscapes. Agroforestry system utilization in farming practices will be an important asset for future agricultural production and sustainability. Hazelnuts can play an important role in this agricultural future.

Case Study – Turkey

The word agroforestry was accepted as a term for intermediate production techniques taking place between agriculture and forestry around the world in the late 1970's. However, traditional agricultural practices in Turkey fit into current agroforestry definitions. Practices that have been utilized in Turkey for generations are listed in Table 1. These practices are not

Table 1. Agroforestry practices in Turkey (Tolunay 2007)

Agroforestry Systems

Agroforestry Practices

Agrisilvicultural systems: combinations of crops and trees

alley cropping
multilayer tree gardens
multipurpose trees and shrubs on farmlands
homegardens
trees in soil conservation and reclamation
shelterbelts and windbreaks

Silvopastoral systems: combinations of pastures and/or animals and trees

trees on rangeland and pastures
protein banks
plantation crops with pastures and animals

Agrosilvopastoral systems: combinations of crops, pastures and/or animals and trees

homegardens involving animals
multipurpose woody hedgerows
apiculture with trees
aquaforestry
multipurpose woodlots

accepted as forestry practices by foresters, nor are they accepted as agricultural practices by agriculturalists. Agroforestry is still a new concept for academic and governmental agencies in Turkey.

Anatolia or Asia Minor encompasses most of Turkey. Anatolia's agricultural history dates back to pre-historic times. It is one of the oldest settlements in history. Anatolia's vast

forests had been destroyed early on in their history to make way for agricultural land. Herbaceous plants, such as those from the wheat and pulse families were cultivated in pre-historic times (Tolunay 2007). At the same time deforested sylvan steppes in Anatolia were found to be suitable to livestock grazing. The people then became organized into two different agricultural systems: livestock production and land cultivation. Forests, during the Ottoman Empire, were used for any purpose desired by the population, but as time went on and the government needed forest products, some regulations were enacted. During the 16th century there were many revolts and uprisings and people fled to the forests for safety. During this time, trees were needed as lumber for shelter, and clearings were made again for food production. These people developed their own production systems for both forest and agricultural production (Tolunay 2007).

Today Turkey is still a developing country. Thirty-five percent of the population (ORKOY 2002) still live in rural areas and earn the majority of their living through agricultural work. Turkey dominates the world in hazelnut production. Approximately 400,000 farms are carrying out hazelnut production in Turkey and millions of people depend on hazelnuts for their income in Turkey and Italy. The provinces of Ordu, Giresun, Trabzon, and Samsun on the Black Sea coast are ideally suited for growing hazelnuts (Kilic and Alkan 2006). Thick forests of hazelnuts grow naturally on these steep hillsides. They are excellent at soil retention with their deep, fibrous roots systems. Sakarya and Duzce are among the most efficient plains of Turkey for agricultural production. These six provinces produce 94% of the country's hazelnuts (DIE 2002, 2003, 2004) on approximately 500,000 hectares. The country produces approximately 800,000 ton annually (USDA 2006).

The main hazelnut cultivars in Turkey are ‘Tombul’ (Giresun), with 34% of the land area, followed by ‘Palaz’ (Ordu), ‘Foca’ (Trabzon), ‘Karafindik’ and ‘Mincane’ (Akcakoca). ‘Tombul’ is a very high quality processing cultivar.

Turkey’s domestic hazelnut consumption, at 70,000 tons, has been stable since the beginning of the 1980’s (Bozoglu 2005). Turkey’s largest importer is Germany at 34% of production. EU countries together import 80% of production on a shelled basis. Turkey exported 247,000 tons in 2006 (Calcagni 2008).

Case Study – Italy

Italy’s agricultural history is interesting and varied. Italians raised grain crops and livestock, and supplemented their supplies with hunting, gathering, and logging the nearby forests during the Etruscan times, about 500 A.D. Single farms were found to survive throughout the Etruscan period from 5th century B.C to 500 A.D. Wine making has a 2,000 year old history in Italy. Etruscans and Greek settlers began growing grapes and making wine long before the Romans did (Earthwatch 1997). Cultivation of hazelnuts began in the province of Viterbo in the 1950’s (Monarca 2005).

Italy is the world’s second largest producer of hazelnuts. Hazelnut plantations cover nearly 70,000 hectares (Senni 1997) and produce approximately 120,000 ton. Ninety-seven percent of Italy’s hazelnut production is concentrated in just four regions, Campania at 42%, Lazio at 30%, Piedmont at 13%, and Sicily at 12% (Tombesi 2005). Of the farms producing

hazelnuts in these regions, 67% are located in the hills, 21% in the mountain areas, and 11.5% on the plain. Only 1,170 hectares are new plantations. In Campania hazelnuts are produced mostly on small farms with other plants such as walnut, cherry, and grape in the border. These soils are volcanic in origin, fertile with neutral pH. Seventy percent of the crop is grown on steep slopes in the hills, where mechanization is difficult, and 30% is grown on the plains where mechanization can be utilized and soils are fertile. In the Lazio region production is concentrated around the Cimini Mountains, where there are high levels of production because of soils with near neutral pH, sandy soils, and a sub-Mediterranean climate with the correct combination of generally mild winters and an annual rainfall of 40 inches (Monarca 2005). Some areas in Lazio are irrigated due to dry summers. Piedmont hazelnut production is centered on small farms and located in the hilly areas of Cuneo and Asti provinces. The soils here are high in fertility with neutral to acid pH. In stark contrast to other hazelnut production areas, Piedmont has seen a 20% increase in the area cultivated on low hills, and hazelnuts have replaced other crops due to the increasing demand for quality hazelnuts for the confectionary industry there (Monarca 2005). Sicily's hazelnuts are grown in mountainous regions with varying soils.

There are a number of varieties grown in Italy, but the most important are 'Tonda Gentile delle Langhe' (TGDL) in the Piedmont; 'Tonda Romana' in the Lazio; 'Tonda Giffoni', 'Sam Giovanni', and 'Mortarella' in the Campania; and 'Santa Mar' a del Gesu' in Sicily. TGDL is known worldwide because of its superior quality nut for processing (Tous Marti 2001).

The expansion and improvement of the hazelnut sector between 1968 and 1980 was a result of favorable market conditions. The European Union does not offer strong protectionism measures for hazelnuts, so the market is based significantly on local market forces (Senni 1997).

Improvements were also made in cultivation techniques and harvesting mechanization, which lowered production costs and improved fruit quality, resulting in increased production.

Italy currently imports more hazelnuts than it exports. During the 1980's exports reached 50,000 t, about 50% of production. Since then exports have decreased and in 1994 hazelnut imports started exceeding exports. Italy now imports 1,300 t of hazelnuts in shell from the US and Turkey, and 35,000 t of shelled hazelnuts, almost all from Turkey (Tombesi 2005). Countries of the EU currently import 3,000 t of in shell hazelnuts from Italy, and Germany imports 20,000 t of shelled hazelnuts.

Marketing is different in each of the three main hazelnut producing provinces. In Campania, the supply is very fragmented and managed mostly by private businesses. There are a few grower cooperatives involved also. In Latium, three grower cooperatives manage 75% of production. In Piedmont, two thirds of production is managed by two grower associations, and 45% of the area and 6,500 t of hazelnuts have been certified "Nocciola di Piemonte", which is mainly used by the chocolate sector for high quality products (Tombesi 2005). It also supplies the local chocolate, bakery, and nougat markets.

Case Study – USA

North American agroforestry has a long history. Native Americans were practicing this type of land management long before European settlers arrived (Anderson and Nabhan 1991, Bainbridge 1997). Swidden systems (slash and burn) were common, and fire was used extensively to make hunting and gathering easier, improve wildlife food sources, and to encourage understory plants used for food and medicinal purposes. Native Americans were skilled in seed selection, planting, transplanting trees and shrubs, and utilizing trees of the forest

in many ways. They knew how to integrate many systems for long-term sustainability (Elevitch and Wilkinson 2004).

Europeans brought many agroforestry practices with them from their homelands, as well as livestock and other agricultural practices. They brought with them silvopastoral systems, intercropping crops with various trees, and home gardens. One historical European practice whose use is documented in the Midwest is the use of osage orange (*Machura pomifera*) as living fences (Baltensperger 1987). A new practice that was adapted by settlers was the use of sugar maples (*Acer saccharum*) to make maple sugar.

In the 1970's, as agroforestry was being recognized as a discipline, current practices were being acknowledged as agroforestry-related. Some of these were farm woodlot management, maple syrup production, Christmas tree plantations, and windbreaks (Gordon 1997). New practices being developed are intercropping with cash crops, silvopasture and pines with forage production in the south-east (Lewis et al. 1983), and livestock used to control weeds in conifer plantations in the west. In the Midwest, agroforestry practices utilizing hybrid hazelnuts as a food crop are being developed (Josiah 1998).

The United States is third in the world for hazelnut production, but they lag far behind Turkey and Italy with only 4% of the total, with 39,000 ton. Oregon grows 99% of the USA's crop on 12,000 hectares in the Willamette Valley. The cultivars grown there are 'Barcelona' (synonym of 'Castanyera' - 80%), 'Ennis' (11%), 'Casina' (3%), and 'Willamette' (2%) (Tous Marti 2001). Oregon's market historically has been directed toward table hazelnuts. However, as world trade has become saturated, new orchards are choosing cultivars that produce quality kernels for processing.

The hazelnut orchards in Oregon are grown on plains with fertile, well-drained, deep soils with high rainfall (1000 mm). The orchards range in size from 15-30 hectares with high mechanization and low labor inputs. Here the nuts are harvested after falling to the ground. The production techniques used are the most advanced in the world, including trees trained to a single stem (tree shape), triennial (every three years) pruning, and chemical sucker control (Tous Marti 2001). Suckers are shoots from the roots or lower part of the stem of a plant. They are undesirable because they use nutrients needed for nut production. Even with these advanced production techniques, productivity in these orchards is not the highest in the world. The main reason for this is the lack of light because of high planting densities. Too much shade from mature trees does not allow for high levels of hazelnut production.

Hybrid hazelnuts, crosses mainly between *C. avellana* and *C. Americana* or *C. cornuta*, are being grown in colder regions of the U.S., such as Wisconsin, Minnesota, Iowa, New York, and Nebraska. These hybrids have been in development for 20 years and are being grown in hopes of using them in sustainable cropping practices. These hybrids are unique because they combine the cold-hardiness and eastern filbert blight resistance of the native species, with the nut size and quality of the commercial species.

Critique of Case Studies

Turkey

Turkey's hazelnut industry does produce the greatest number of hazelnuts in the world. However, the industry is not without its problems. Many orchards are showing excessive age and are small in size (Serdar 2005). Yields per hectare are low compared to the USA and Italy. There are also difficulties in post-harvest procedures and marketing.

Historically, hazelnut orchards were only in the provinces of Ordu, Giresun, and Trabzon where the land is ecologically suited for hazelnut production. In 1964 government support policies, designed to improve farmer's incomes in these original provinces, encouraged the farmers in the fertile plains of Sakarya and Duzce to convert their production to hazelnuts. Purchase and price guarantees given by Fiskobirlik, Union of Hazelnut Sales Cooperative, contributed to this expansion. From 1964 to 2003 production increased about five times (Kilic and Alkan 2006), 65% since 1971-74 (FAO 2006). Turkey now has a hazelnut surplus. The usage change of these fertile lands has prevented the cultivation of other economically important crops. Turkey is now finding it necessary to control hazelnut production by banning new planting areas, and paying compensation to those who uproot their orchards. However, without adequate inspections little progress has been made (Kilic and Alkan 2006).

As Turkey goes through economic, social, and political development many avenues of change are explored. As in many developing countries, most people still live in rural areas and earn their living from agricultural production. Developing countries try to transform their production into a monoculture based system, with heavy dependence on intensive use of herbicides and fertilizers (Tolunay 2007). Hardships develop for the rural inhabitants because they can not afford to purchase the inputs and implements necessary for cultivation. Classic forestry practices are similarly problematic. Environmental degradation, lack of food security, and deforestation are all results of excessive adoption of mono-culture based systems.

Promoting agroforestry could help Turkey address some of these problems. A number of topics need to be addressed in order for Turkey to take advantage of agroforestry systems. They include: building a scientific knowledge base on agroforestry, establishing a network for the flow of data, analyzing the traditional agroforestry practices, involving the government in policy

problem areas, working on provenance screening and breeding of local cultivars, and publicizing information obtained nationally and internationally (Tolunay 2007).

Italy

Improvements are being made in the hazelnut industry in Italy in areas such as mechanization of harvesting and cultivation techniques. However, there are also some questionable practices being utilized in hazel production. Irrigation is used in the hilly areas of Campania to improve the first year's growth. On the plains in Campania it is used once or twice a year to overcome dry spells. In Lazio, irrigation is widespread because of the increases in production it produces, however at times too little or too much water is applied. Piedmont orchards are not irrigated because of the lack of water. Tombesi (2005) states that producers in the province of Piedmont regularly till their orchards because of the lack of water. Soil mulching can conserve water, but tillage can damage the soil's structure and the hazelnut's root system. In Campania plantation soils are tilled to 10-15 cm and at harvest the soils are compacted for ease of harvest. Lazio uses its natural weed cover to reduce dust during harvest, to reduce soil erosion, and to improve soil fertility. They keep the weeds under control by shredding.

Propagation techniques need some upgrading in order to improve genetics and disease aspects. The common method of propagation is removing suckers from the orchards and using them for new plant material. Suckers are new shoots grown from the roots or stem of the parent plant. Suckers contain the same genetic information as the parent. Propagation with suckers results in little uniformity, or consistency, in growth or production traits if the parent plants have little uniformity. This is most often the case with hazelnuts. This also limits improvements in disease resistance and pest control.

USA

Agricultural practices in the US have resulted in some of the highest crop yields in the world. Farmers have produced an enormous amount of food and fiber for the country's and world's populations. But this production has come at an environmental price. Most farmers truly desire to be good stewards of the land (Sullivan 1996), but sometimes economics get in the way. Modern, monoculture farming practices using herbicides, pesticides, fertilizers, and irrigation all have their ecological problems.

Agroforestry practices are being looked at for their many ecological benefits including: economic and agricultural diversification, environmental impact mitigation, land and water rehabilitation and restoration, increased or decreased food production, sustainable use of land, retirement of marginal or fragile land, natural habitat enhancement, and profitability (Gordon 1997). Agroforestry could be used for two primary goals, economic improvements and resource conservation.

Hazelnuts, as native perennials, have great potential to be used effectively in numerous agroforestry practices due to their lower input needs, and more effective provision of ecosystem services compared to non-native annual plants (Cox 2006). Hybrid hazelnuts can combine the best characteristics of the European hazelnut and the native beaked or American hazelnut. Hybrid hazelnuts are often grown as perennial shrubs in hedgerows, with perennial crops between the rows. This strategy enhances their value in reducing soil erosion and improving water quality. Currently, hybrid hazelnuts are open-pollinated and seed-propagated. This leads

to difficulties in producing hybrid hazelnut shrubs consistent in size and shape, maturation date, and nut size and quality, which are necessary for mechanical harvest and profitable production. Most perennial crops are vegetatively propagated, or grafted, to attain consistent genetics. This has proven to be difficult with hybrid hazelnuts due to their shrubby growth habit, and stem cuttings rooting poorly.

Very little research has been done on best management practices for hybrid hazelnuts in the Midwest. Anecdotal information collected from growers is the best information available at this time. This information suggests that hybrid hazelnuts can survive with very little management, but are more productive with higher levels of management. The most economically justified practices of management need to be determined. Research needs to be done on establishment methods, plant spacing, fertilization, weed control measures, and use of cover crops.

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