

TREES AND SHRUBS SUITABLE FOR THE CONSTRUCTION OF AGROFORESTRY SYSTEMS IN A TEMPERATE CLIMATE AND THEIR USE IN ECONOMIC ACTIVITIES: A STUDY IN BULGARIA

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Purpose. The study aims to (i) discover the various trees and shrubs appropriate for building agroforestry systems in Bulgaria's temperate climate and their possible use in various economic activities, (ii) identify the contribution of Bulgarians' agroforestry systems to the three dimensions of sustainable development.

Results. The contributions of Bulgarians' agroforestry systems to three pillars of sustainability were pointed out. Regarding the social dimension of sustainability, the respondents highlighted the social benefits of agroforestry (e.g., raising the standard of living and the social status of the population; providing jobs and access to renewable energy; overcoming social inequality in individual regions; providing recreation opportunities for the population; give social, educational, scientific, landscape and recreational benefits to society; generate firewood for society). The contribution of agroforestry in the environmental dimension is unquestionable. Moreover, 46 trees and 15 shrubs have been presented. The use of their products in various economic activities and industries has been discussed. These trees and shrubs are appropriate for the construction of various agroforestry systems such as forest-farming, alley-cropping, and forest-pasture agroforestry systems.

Scientific novelty. A few scientific researches focus on tree species suitable for agroforestry systems in particular counties with different climates. However, there is limited research on various trees and shrubs suitable for constructing agroforestry systems in a temperate climate, especially in Bulgaria. Moreover, the use of the products of these trees and shrubs in various economic sectors and activities, which can bring additional economic value for agroforestry farmers in temperate climates, is not discussed in one paper.

Practical value. The current findings will provide farmers with additional knowledge about trees and shrubs suitable for the construction of agroforestry systems in temperate climates and the possible implementation of their products in various economic activities and industries. This will encourage them to create ecoefficient agroforestry systems using some of the 46 trees and 15 shrubs, based on their regional location and local conditions, to support sustainable development and the environment. What is more, if these tree species are promoted by decision-makers and professional/farmer associations, and adopted by the farmers can support and reinforce agroforestry in Bulgaria and regions with temperate climates.

Key words: agroforestry systems, standardization, agroforestry standards, trees, shrubs, Bulgaria.

Introduction. Agroforestry has become one of the sustainable approaches for achieving sustainable development in recent years. It refers to land use practices and land-used management systems where pasture or crops are combined with trees and shrubs [1]. Furthermore, Burgess & Rosati [2] consider agroforestry as "the practice of

deliberately integrating woody vegetation (trees or shrubs) with crop and/or animal systems to benefit from the resulting ecological and economic interactions”.

The use of agroforestry as an economic activity emerged in the 1980s. However, there is evidence that agroforestry has been practiced since ancient times [3]. By integrating different production actions, agroforestry systems (like forest-farming, alley, and forest-pasture agroforestry systems) allow the diversification of economic activities on the land, raising profitability per unit of area, and decreasing the risks of income losses caused by adverse market conditions and weather events [4]. These characteristics demonstrate their importance in agricultural sustainability, social inclusion, and climate change issues.

Review of literature. Agroforestry research is diverse. Some papers focus on agroforestry’s contribution to livelihoods and carbon sequestration [5] as well as to government policy for stimulating agroforestry in different counties [6]. Others discussed the standardization and certification of agroforestry systems [7; 8], different partnerships and cooperation [9], various agroforestry systems like forest-farming [10], alley-cropping agroforestry systems or intercropping [11], silvopastoral systems/forest-pasture agroforestry systems [12; 13]. There are differences between forest-farming, alley-cropping, and forest-pasture agroforestry systems. Forest farming is a type of agroforestry practice that cultivate high-value crops under the protection of a managed tree canopy. Alley-cropping or intercropping is another type of agroforestry practice that places trees within agricultural cropland systems in order to improve whole-farm yield. And forest-pasture agroforestry system or silvopastoral system is the practice of integrating trees, forage, and the grazing of animals in a mutually beneficial way, existences for millennia.

A few scientific researches focus on tree species suitable for agroforestry systems in particular counties (e.g., woody plant species in North-Western Himalaya, India [14] and trees and shrubs species in home gardens in Kampung Masjid Ijok Perak, Malaysia [15]). However, there is limited research on different trees and shrubs suitable for constructing agroforestry systems in a temperate climate, especially in Bulgaria. Moreover, the use of the products of these trees and shrubs in various economic sectors and activities, which can bring additional economic value for agroforestry farmers, is not discussed in one paper.

The current study aims to fulfill the above research gap and challenge by discovering the various trees and shrubs appropriate for building agroforestry systems in Bulgaria’s temperate climate and presenting their possible use in various economic activities. Furthermore, the contributions of Bulgarian agroforestry systems to sustainable development have been analyzed. The case study method has been applied to gather the necessary information. The methodology and main findings are presented in the following sections.

Materials and methods. The study aims to (i) discover the various trees and shrubs appropriate for building agroforestry systems in Bulgaria’s temperate climate and their possible use in various economic activities, (ii) identify the contribution of

Bulgarians' agroforestry systems to the three dimensions of sustainable development. Based on this research goal, the following two research questions are formulated:

Q1. How do agroforestry systems contribute to sustainable development in Bulgaria?

Q2. What are the main types of tree species suitable for building agroforestry systems in Bulgaria, a country with a temperate climate?

The case study method was chosen to investigate various agroforestry systems in Bulgaria, the suitable tree species for their constructions, and their contributions to three aspects of sustainable development [16]. The study was conducted in Bulgaria in 2019, a leading country in the European Union in agroforestry systems [17–20]. The 17 top agroforestry experts and farmers from 14 leading organizations in the agroforestry field in Bulgaria were interviewed (see Appendix 1, Table A.1). They were selected based on three key criteria: (1) their extensive experience (above 7 years) in agroforestry systems and tree species; (2) their comprehensive and in-depth knowledge of agroforestry systems; and (3) the organization in which they work, i.e., the leading organizations in the field of agroforestry located in different regions of the country have been selected.

Semi-structured interviews were conducted with the respondents to allow them to freely and unrestrictedly answer ten identical, theoretically related questions based on their experience and knowledge in the agroforestry area. Four of these 10 questions were related to types of Bulgarian agroforestry systems and used tree species in them, as well as their contribution to sustainable development and society. The average duration of each interview was about 50 minutes. Face-to-face and telephone interviews were recorded with the respondents' consent and transcribed afterward. This tactic ensures that the reliability and validity of the study increase. A significant number of secondary documents (e.g., internal press releases, presentations, reports, newspapers, plans, and case studies of agroforestry systems: 40 documents, about 600 A4 pages) were collected, which supplemented the interview information and further increased the study's reliability and validity. Additionally, the respondent from the 12th organization provided (by email) above 100 pages of primary documents containing information about Bulgarian's most famous trees and shrubs. Moreover, it was conducted a field study in regions with agroforestry systems (including in the Rhodope Mountains) in July and August 2019, and June–August 2020. Thus, it was observed the various agroforestry systems, trees, and shrubs there (see Appendix 1, Table A.2).

The gathered information is managed as follows. The contributions of Bulgarian agroforestry systems to sustainable development have been grouped into the three dimensions of sustainable development: social, environmental, and economic. The information about tree species has been carefully analyzed. As a result, the tree species are classified into three main groups: trees with short rotation (between 2–4 years), trees with medium and long rotation (from 4 to 20 years), shrubs with medium and long rotation (above 2 years).

Results and discussion. *The contribution of Bulgarian's agroforestry systems to*

sustainable development. Agroforestry and agroforestry systems fully meet the concept of sustainability in its entirety [4]. According to the respondents in the present study, agroforestry and agroforestry systems in Bulgaria contribute to the three dimensions of sustainable development as follows:

Regarding the social dimension of sustainability, the respondents highlighted the social benefits of agroforestry. Agroforestry farming contributes to “raising the standard of living and the social status of the population” (Interviewee 12), “providing jobs and access to renewable energy” (Interviewee 8), “overcoming social inequality in individual regions” (Interviewee 3). Bulgarian mountains and agroforestry systems 1) “provide recreation opportunities for the population” (Interviewee 7.1), 2) “give social, educational, scientific, landscape and recreational benefits to society” (Interviewee 7.2), and 3) “generate firewood for society” (Interviewee 9). Furthermore, there are systems of protective forest belts in Bulgaria that protect against the strong winds in the northern part of the country (Interviewee 8; Interviewee 12, Interviewee 11).

The contribution of agroforestry in the environmental dimension is unquestionable. Agroforestry farming contributes to “environmental protection and the conservation of natural resources” (Interviewee 11), “improving environmental conditions and the sustainability of ecosystems” (Interviewee 6.1), “preventing erosion, improving the microclimate through conditions of a lasting tendency to warmth and dryness in Bulgaria, filtering air and water, providing shelters and protection to wild animals and birds” (Interviewee 8).

Finally, in the economic dimension, agroforestry agriculture, by not using pesticides or chemical fertilizers, reduces production costs. Agroforestry contributes to “increase the production of timber and non-timber forest products” (Interviewee 7.1). More revenue is generated per unit area via growing several plant species in one place as each plant species generates revenue streams (Interviewee 6.1; Interviewee 6.2; Interviewee 6.3; Interviewee 4; Interviewee 11; Interviewee 12). Therefore, agroforestry production in the mid-term period is no more expensive than conventional agriculture, and still has the advantage of creating life and not destroying it [21].

Main types of trees and crops suitable for the construction of agroforestry systems in Bulgaria. Tree species for agroforestry in Bulgaria. Tree species suitable for agroforestry in Bulgaria can be divided into three main groups: trees with short rotation, trees with medium and long rotation, shrubs with medium and long rotation. These groups are discussed in detail below.

i) Tree species with short rotation. This group can be included trees like white willows (*Salix alba* L.), basket willows (*Salix viminalis* L.), white poplars and aspens (*Leuce Duby*), black poplars (*Aigeiros Duby*), balsamic poplars (*Tacamahaca Spach*), kind of white poplars (*Leucoides Spach*), white acacia (*Robinia pseudoacacia* L.), black (sticky) alder (*Alnus glutinosa* (L.) Gaertn.), eastern plane tree (*Platanus orientalis* L.), western plane tree (*Platanus occidentalis* L.), maple plane tree (*Platanus acerifolia* Willd.), paulownia (*Paulownia tomentosa* (Thunb.) Steud.) (Table 1).

Table 1

Tree species with short rotation

Tree species with short rotation	The use of tree parts in particular economic activities (examples)	Possible agroforestry system
White willows (<i>Salix alba</i> L.)	The wood/timber of the tree is used: i) for making small accessories; and ii) in the packaging. The leaves of the tree are utilized as fodder for domestic animals	Coastal protection belts, plantations for biomass production, forest-farming agroforestry systems
Basket willows (<i>Salix viminalis</i> L.)	Cultivated for extraction of basketry rods, fiber for ropes, and others	Forest-farming agroforestry systems
White poplars and aspens (<i>Leuce DUBY</i>)	The wood/timber of the tree is used in the pulp and paper industry to manufacture various objects as well as in construction	Coastal protection zones, plantations for biomass production, alley-cropping agroforestry systems
Black poplars (<i>Aigeiros DUBY</i>)	The wood/timber of the tree is used in the pulp and paper industry to manufacture various objects as well as in construction and packaging	Alley-cropping agroforestry systems, coastal protection zones, and the creation of plantations for biomass production
Balsamic poplars (<i>Tacamahaca</i> Spach)	The wood/timber of the tree is used in the pulp and paper industry to manufacture various objects as well as in construction	Farms for biomass production
Aspen (<i>Populus tremula</i> L.)	It is used in the pulp and paper industry, for the production of various objects, for making matches, in construction (for roofing constructions), and others	Alley-cropping agroforestry systems, coastal protection zones
Kind of white poplars (<i>Leucoides</i> Spach)	The wood/timber of the tree is used in the pulp and paper industry to manufacture various objects as well as in construction	Alley-cropping agroforestry systems, coastal protection zones
White acacia (<i>Robinia pseudoacacia</i> L.)	White acacia is a honey-bearing species	Plantations for the production of wood biomass, forest-farming agroforestry systems, anti-erosion protection belts
Black (sticky) alder (<i>Alnus glutinosa</i> (L.) Gaertn.)	The wood/timber of the tree is used in i) furniture production; ii) the pulp and paper industry to manufacture various objects, iii) construction. The fruits and leaves are used in medicine	Windbreaks on wet terrains, coastal protection belts, biomass plantations
Eastern plane tree (<i>Platanus orientalis</i> L.)	It is mainly used for the production of furniture. It has valuable wood	Coastal protection zones, forest-farming systems
Western plane tree (<i>Platanus occidentalis</i> L.)	It is mainly used for the production of furniture	Coastal protection zones, forest-farming systems
Maple plane tree (<i>Platanus acerifolia</i> Willd.)	It is mainly used for the production of furniture. It has valuable wood	Coastal protection zones, forest-farming systems
Paulownia (<i>Paulownia tomentosa</i> (Thunb.) Steud.)	It has valuable wood used in many industries	Plantations for biomass and wood

Sources: created by the author based on the information from the interviews and primary sources, collected via the study.

The wood/timber of some of the above mentioned trees is used in i) furniture

production (black (sticky) alder); ii) for making small objects/accessories (white willow); iii) the pulp and paper industry to manufacture various objects (e.g., poplars, aspens, black (sticky) alder); iv) in construction (e.g., poplars, aspens, black (sticky) alder); v) in the packaging (e.g., white willow, black poplar). The fruits of black (sticky) alder trees are used in medicine. The leaves of a piece of the above trees are utilized as fodder for domestic animals (white willow); dyeing, and in medicine (black (sticky) alder).

The trees, as mentioned above, can be applied in agroforestry to i) create protective belts (e.g., willows, poplars, white acacia, black (sticky) alder, the plane trees); ii) in forest-farming agroforestry systems (e.g., willows, white acacia, the plane trees, the hairy paulownia); iii) in forest-pasture agroforestry systems (the hairy paulownia); iv) in alley-cropping agroforestry systems (e.g., poplars, the plane trees, the hairy paulownia). A piece of the trees is suitable to create plantations for biomass production (e.g., willows, poplars, white acacia, black (sticky) alder, the plane trees, the hairy paulownia).

ii) Tree species with medium and long rotation. Tall trees. In the group of tall trees with medium and long rotation can be included species like orange (winter) oak (*Quercus petraea* Liebl), ash (*Fraxinus excelsior* L.), gledichiya (*Gleditsia triacanthos* L.), walnut (*Juglans regia* L.), small-leaved linden (*Tilia cordata* Mill.), large-leaved linden (*Tilia platyphyllos* Scop.), silver-leaved linden (*Tilia tomentosa* Moench.), maple (*Acer pseudoplatanus* L.), breccia (*Sorbus torminalis* (L.) Crantz.), hornbeam (*Carpinus betulus* L.), chestnut (*Castanea sativa* Mill.), birch (*Betula pendula* Roth.), ordinary persimmon (*Diospyrus lotus* L.), white pine (*Pinus sylvestris* L.), black pine (*Pinus nigra* Arn.), spruce (*Picea abies* (L.) Karst.), silver (prickly) spruce (*Picea pungens* Engelm.), (white) fir (*Abies alba* Mill.) (Table 2).

The wood/timber of some of the above-mentioned tall trees is used in i) furniture production (genus Oak (*Quercus*), walnut, maple (genus *Acer*), breccia, chestnut, birch, ordinary persimmon, coniferous species); ii) for making small objects/accessories (hornbeam) and parquet (walnut); iii) in construction (gledichiya, chestnut, coniferous species); iv) in carpentry (white alder, mahalebka, sumac); v) in turning (walnut) and carving (linden); vi) for making musical instruments (walnut, maple (genus *Acer*), breccia, chestnut, ordinary persimmon, coniferous species); shipbuilding (chestnut); vii) in the packaging (linden) and the extraction of charcoal for painting (linden). The fruits of trees are used as i) food (walnut, breccia, chestnut); ii) for confectionery, perfumery, painting (walnut); iii) in medicine and pharmaceuticals (breccia, chestnut, birch); iv) in the food industry (chestnut), chemical industry (chestnut, birch) and pulp and paper industry (birch). The leaves of a piece of the above trees are utilized as fodder for domestic animals (ash, gledichiya); dyeing, and in medicine (walnut, birch). A part of the tree's bark is obtained paint (ash) and extracted tannins/resin (birch). Some tree species' acorns are utilized to make fodder (orange (winter oak), blagun, tserat, red American oak, gledichiya). The flowers of a few trees are used for tea and in medicine (tree species of the genus linden (*Tilia*)), and as honey-bearing species (chestnut).

Table 2

Tall trees with medium and long rotation

Tall trees with medium and long rotation	The use of tree parts in particular economic activities (examples)	Possible agroforestry system
Orange (winter oak) (<i>Quercus petraea</i> Liebl)	The wood/timber of the tree is hard, very strong, and heavy with many implementations in industries. Its acorns are rich in nutrients and used as fodder for pigs and other animals	Protective forest belts, forest-pasture systems
Ash (<i>Fraxinus excelsior</i> L.)	Its wood/timber is heavy, durable, tough, and strong, and has a wide range of uses. The bark is used in folk medicine, for dyeing, and for processing leather. The leaves are good fodder	Buffer zones, forest-pasture, and alley-cropping agroforestry systems
Gledichiya (<i>Gleditsia triacanthos</i> L.)	Its wood/timber is highly valued in construction. The green mass and fruits are used for fodder	Protective belts in agricultural and pasture areas, forest-pasture systems
Walnut (<i>Juglans regia</i> L.)	Its wood/timber is highly valued in furniture production, but it is also used to make musical instruments, woodwork, parquet, and others. The fruits are used for food, in confectionery, in perfumery, in painting, and for technical purposes. The leaves are used in medicine, and the outer shell of the fruits – for dyeing	Alley-cropping, forest-pasture, and forest-farm agroforestry systems
Small-leaved linden (<i>Tilia cordata</i> Mill.)	The wood/timber is used in carving, packaging, extracting coal for painting, and others. The flowers of the tree are used for tea and in medicine	Protective belts in agricultural and pasture areas, forest-farming systems for obtaining one-species honey
Large-leaved linden (<i>Tilia platyphyllos</i> Scop.)	The wood/timber is used in carving, packaging, extracting coal for painting, and others. The flowers of the tree are used for tea and in medicine	A companion in creating windbreaks, forest-farming systems for obtaining one-species honey
Silver-leaved linden (<i>Tilia tomentosa</i> Moench.)	The wood/timber is used in carving, packaging, extracting coal for painting, and others. The flowers of the tree are used for tea	Protective belts in agricultural and pasture areas, forest-farming systems for obtaining one-species honey
Maple (<i>Acer pseudoplatanus</i> L.)	Its wood/timber is mainly used for making musical instruments and in furniture production where the specific texture of its wood is highly valued, called “bird’s eye”	Protective belts, forest-farming agroforestry systems
Breccia (<i>Sorbus torminalis</i> (L.) Crantz.)	The wood/timber is used for veneer, furniture, musical instruments, and others. The fruits are used for food and in folk medicine	Protective belts, forest-farming agroforestry systems
Hornbeam (<i>Carpinus betulus</i> L.)	Its wood/timber is very heavy, hard, and durable and is used for crafting various accessories – shuttles, planers, cobbler molds, handles of various tools, and others	Buffer zones for hedges and barriers in forest-pasture and forest-farming systems
Chestnut (<i>Castanea sativa</i> Mill.)	The wood/timber is used in construction, furniture production, shipbuilding, manufacturing of musical instruments, and others.	Alley-cropping systems

Continuation of Table 2

	The bark, leaves, domes of the fruits, and the wood contain tanning substances that are used in the chemical industry. The flowers are honey-like, and the fruits are tasty and nutritious	
Birch (<i>Betula pendula</i> Roth.)	The wood/timber is used in furniture production for veneer and in the pulp and paper industry. Tannins, birch resin, and other substances are extracted from the bark. During active vegetation from the stem can be obtained juice, which is rich in sugars, and in some northern countries, it is used as a drink. The branches, buds, leaves, and some other parts of birch are used in folk medicine and in pharmaceuticals	Alley-cropping and forest-pasture agroforestry systems, protective belts
Ordinary persimmon (<i>Diospyrus lotus</i> L.)	The wood/timber can be used to make furniture and musical instruments. It is also valued as a fruit species	Protection belts, forest-farming agroforestry systems
White pine (<i>Pinus sylvestris</i> L.)	The wood/timber of the white pine is medium heavy, contains resin, and has many good physical and mechanical properties. It is used in construction, furniture production, and others	Forest-pasture systems in foothill areas
Black pine (<i>Pinus nigra</i> Arn.)	The wood/timber is suitable for underground and underwater construction. It can be extracted resin from the black pine, its leaves are rich in vitamin C, release phytoncides, and affect air ionization	Forest-pasture systems, coastal protection zones in sunny areas
Spruce (<i>Picea abies</i> (L.) Karst.)	The wood/timber is widely used in construction, furniture production, the pulp and paper industry, mining, and others. Because of its specific acoustic properties, it is very suitable and is used for making musical tools. Tannin extracts are obtained from the bark of the stem	Ornamental species in forestry
Silver (prickly) spruce (<i>Picea pungens</i> Engelm.)	It has been introduced in urban and park environments for its decorative qualities	Ornamental species in forestry
(White) fir (<i>Abies alba</i> Mill.)	The wood/timber is used in construction, in the production of packaging, pulp, and furniture. The bark is used to obtain tannins, resin, and dye substances. Essential oils can be extracted from the leaves and cones. The leaves are rich in vitamin C and have an ionizing and phytoncide effect on the air	Ornamental species in forestry

Sources: created by the author based on the information of the interviews and primary sources, collected via the study.

Tall trees, as mentioned above, can be applied in agroforestry to i) create protective belts (orange (winter oak), breccia, blagun, tserat, red American oak, trees of the genus ash (*Fraxinus*), walnut, tree species of the genus linden (*Tilia*), tree species of the genus maple (genus *Acer*), hornbeam, birch); ii) in forest-farming agroforestry systems (walnut, breccia, tree species of the genus linden (*Tilia*), maple (genus *Acer*), chestnut, ordinary persimmon, ordinary persimmon); iii) in forest-pasture agroforestry systems (walnut, orange (winter oak), blagun, tserat, red American oak, trees of the genus ash (*Fraxinus*), birch, coniferous species); iv) in alley-cropping agroforestry systems (walnut, trees of the genus ash (*Fraxinus*), chestnut, birch). Some of the trees are suitable for creating plantations for biomass production ((field) ash) and for the cultivation of Christmas trees within forestry (coniferous species).

Medium and short trees. In the group of medium and short trees with medium and long rotation can be included species like hairy oak (*Quercus pubescens* Willd.), white alder (*Alnus incana* (L.) Moench), small-leaved elm (*Ulmus pumila* L.), mekish (*Acer tataricum* L.), manna ash (*Fraxinus ornus* L.), (wild) pear (*Pyrus communis* L.), skorusha (*Sorbus domestica* L.), rowan/mountain ash (*Sorbus aucuparia* L.), white mulberry (*Morus alba* L.), mahalebka (*Padus mahaleb* (L.) Borkh.), janka (*Prunus cerasifera* Ehrh.), almond (*Prunus dulcis* (Mill.) D. A. Webb.), elderberry (*Sambucus nigra* L.), sumac (*Cotinus coggygria* Scop.), pistachio (*Pistacia vera* L.).

The wood/timber of some of the above medium and short trees is used in furniture production (manna ash, (wild) pear, skorusha, rowan/mountain ash, white mulberry, janka), for making small objects ((wild) pear, janka), in underwater construction (white alder, elderberry) and carpentry (white alder, mahalebka, sumac), in turning (skorusha, white mulberry, mahalebka), carving (rowan/mountain ash), in cooperage (white mulberry), for making musical instruments (sumac), for heating and the extraction of charcoal (hairy oak). The fruits of trees are used as food (skorusha, rowan/mountain ash, mahalebka, pistachio), for beverages (skorusha), in medicine and pharmaceuticals (skorusha, rowan, white mulberry, almond, elderberry), in the food industry (white mulberry, almond, pistachio). The leaves of a part of the above species of trees are utilized for food by the larvae of the silkworm (white mulberry), as fodder for domestic animals (white alder, white mulberry), dyeing, and in folk medicine (manna ash, sumac). A piece of the trees' bark is obtained (black, yellow, brown) paint (pear, white alder, white mulberry, sumac).

Those as mentioned above (medium and short) trees can be applied in agroforestry (Table 3) to i) create protective belts (hairy oak, white alder, small-leaved elm, mekish, manna ash, (wild) pear, skorusha, white mulberry, mahalebka, janka (*Prunus cerasifera* Ehrh.), elderberry, sumac, pistachio), ii) in forest-farming agroforestry systems ((wild) pear, rowan, white mulberry, janka), and iii) forest-pasture agroforestry systems (white alder, (wild) pear, rowan, white mulberry, janka ((*Prunus cerasifera* Ehrh.)).

Table 3

Medium and short trees with medium and long rotation

Medium and short trees with medium and long rotation	The use of tree parts in particular economic activities (examples)	Possible agroforestry system
Hairy Oak (<i>Quercus pubescens</i> Willd.)	It is mainly used for firewood and the extraction of charcoal	Coastal protection belts and anti-erosion belts
White alder (<i>Alnus incana</i> (L.) Moench).	Its wood/timber exhibits high durability in underwater constructions. The bark is used for dyeing, and the leaves as fodder for domestic animals	Coastal protection and anti-erosion belts on floodplains, forest-pasture systems
Small-leaved elm (<i>Ulmus pumila</i> L.)	Used as a food, medicine, and source of materials	Protection zones/belts in agricultural and pasture areas
Mekish (<i>Acer tataricum</i> L.)	-	Protection belts in agricultural and pasture areas
Manna ash (<i>Fraxinus ornus</i> L.)	The wood/timber is heavy, tough, strong, and widely distributed application. The leaves are used in folk medicine	Coastal protection and erosion zones in sunny areas
(Wild) pear (<i>Pyrus communis</i> L.)	Its wood/timber is used in furniture production and for making small items. From the bark are obtained black and brown paint. The fruits contain vitamins C and B, carotene, tannins, and others	Protection zones in agricultural and pasture areas, forestry, and forest-pasture systems
Skorusha (<i>Sorbus domestica</i> L.)	It is used in furniture production, turning, etc. The fruits are used as food, beverage, and in medicine	Protection belts
Rowan/mountain ash (<i>Sorbus aucuparia</i> L.)	Its wood/timber is used in furniture production and carving. The fruits are used for food by birds and animals. They are rich in vitamin C and are used in pharmaceuticals	Forestry and forest-pasture systems in mountainous areas
White mulberry (<i>Morus alba</i> L.)	The wood/timber is used in furniture production, in cooperage, in turning, and others. The leaves are used for food from the larvae of the silkworm and as fodder for domestic animals. It gets yellow paint from them. It is also a good honey variety. The fruits are very tasty and used in the food industry and medicine	Protection zones in agricultural and pasture areas, forest-pasture systems
Mahalebka (<i>Padus mahaleb</i> (L.) Borkh.).	Its wood/timber is brownish, hard, and has a specific smell. Finds an application in carpentry and turning. The fruits are used for food (raw or processed). It is used as a rootstock for cherry	Protection zones in agricultural and pasture areas
Janka (<i>Prunus cerasifera</i> Ehrh.)	Its wood/timber is hard and heavy and is used for making small objects and furniture production. It serves as a substrate for the ennobling of plum and apricot tree varieties	Protective belts in agricultural and pasture areas, forest-pasture and forest-farming systems
Almond (<i>Prunus dulcis</i> (Mill.) D. A. Webb.)	The fruits are valued in the confectionery, pharmaceutical, and perfume industries	Forest-farming agroforestry systems
Elderberry (<i>Sambucus nigra</i> L.)	Its wood/timber is hard and very heavy. It is characterized by great strength in use in moist soil and water. The flowers and fruits are used in medicine	Buffer zones in agricultural and pasture areas
Sumac (<i>Cotinus coggygia</i> Scop.)	Its wood/timber is used for veneer, musical instruments, carpentry, inlays, and as a source of dyes and tanning substances. The leaves are used in medicine	Protective belts in agricultural and pasture areas, anti-erosion belts
Pistachio (<i>Pistacia vera</i> L.)	It is used for pistachio production	Protective belts

Sources: created by the author based on the information of the interviews and primary sources, collected via the study.

iii) *Shrubs with medium and long rotation.* There are several popular shrubs in Bulgaria like lilac (*Syringa vulgaris* L.), bird grapes (*Ligustrum vulgare* L.), hazel (*Corylus avellana* L.), narrow-leaved fragrant willow (*Elaeagnus angustifolia* L.), yellow tree acacia (*Caragana arborescens* Lam.), European (ridged) cephalopod (*Euonymus europaeus* L.), amorpha fruticosa L., golden rain (*Laburnum anagyroides* Medic), rosehip (*Rosa canina* L.), goat willow (*Salix caprea* L.), sea buckthorn (*Hippophae rhamnoides* L.), chinese Lemongrass (*Schisandra chinensis* (Turcz.) Ball.), shepherdia argentea (Pursh.) Nutt.), Japanese quince (*Chaenomeles japonica* Thun.) (Table 4).

Table 4

Shrubs with medium and long rotation

Shrubs with medium and long rotation	The use of tree parts in particular economic activities (examples)	Possible agroforestry system
Red viburnum (<i>Viburnum opulus</i> L.)	Its wood is very hard and is used to make small objects. Red viburnum is grown as an ornamental plant; it is also used in medicine	Anti-erosion protection belts on floodplains, coastal protection belts in shady places, forest-farming agroforestry systems
Lilac (<i>Syringa vulgaris</i> L.)	Its wood is hard, strong, and heavy. It is used in turning for crafting small items. Its flowers are used in perfumery and cosmetics	Protective belts in agricultural and pasture areas, anti-erosion and road protection belts, and coastal protection belts in sunny areas.
Bird grapes (<i>Ligustrum vulgare</i> L.)	It is widely used for hedges	Buffer zones in agricultural and pasture areas
Hazel (<i>Corylus avellana</i> L.)	The wood is used in carving and turning for crafting small items. The leaves are used for fodder. The fruits are very tasty and highly valued	Buffer zones in agricultural and pasture areas, coastal protection zones, forestry, forest-pasture, and alley-cropping agroforestry systems
Narrow-leaved fragrant willow (<i>Elaeagnus angustifolia</i> L.)	Its wood is used for making music tools, in turning, and carpentry. Its bark and leaves contain tannins, and fruits are rich in nutrients	Protection zones in agricultural and pasture areas
Tree yellow acacia (<i>Caragana arborescens</i> Lam.)	Its wood is used in turn to make small objects. The leaves contain vitamins A and C. Honey and silage type	Forestry and forest-pasture agroforestry systems
European (ridged) cephalopod (<i>Euonymus europaeus</i> L.)	Its wood is hard and strong, suitable for some activities	Protection zones in agricultural and pasture areas, coastal protection zones in shady terrains
Shrubby amorphous (<i>Amorpha fruticosa</i> L.)	Used like honey type	Anti-erosion belts on flooded and sunny terrains
Golden Rain (<i>Laburnum anagyroides</i> Medic)	Used like honey type	Protective belts in agricultural and pasture areas
Rosehip Willow (<i>Rosa canina</i> L.)	Fruits constitute an essential source of food and medicine for many cultures	Buffer zones in agricultural and pasture areas, coastal and erosion protection belts in sunny areas, forest-farming systems

Continuation of Table 4

Goat willow (<i>Salix caprea</i> L.)	Its wood is used for pulp production. The bark is rich in tannins. Black paint is obtained from it	Coastal protection belts, anti-erosion belts in mountainous areas
Sea buckthorn (<i>Hippophae rhamnoides</i> L.)	The wood has good mechanical qualities – hard, durable, and heavy. It is used in carving, carpentry, turning, and for making small objects. The fruits contain a lot of vitamin C, and provitamin A, which are used for food, pharmaceuticals, and cosmetics. Their main purpose is to obtain sea buckthorn oil, with a healing effect against many diseases	Forest-farming systems, coastal protection zones
Chinese Lemongrass (<i>Schisandra chinensis</i> (Turcz.) Ball.)	The stems, roots, and especially the fruits are aromatic and sour. They are used in medicine as a tonic. Used in larger quantities, they are poisonous	Forest-farming systems
Shepherdia argentea (<i>Shepherdia argentea</i> (Pursh.) Nutt.)	It is suitable for hedges	Suitable for hedges
Japanese quince (<i>Chaenomeles japonica</i> Thun.)	The fruits, leaves, and seeds are excellent raw materials for functional food production. They are used in the pharmaceutical field	Forest-farming agroforestry systems, path protection belts

Sources: created by the author based on the information of the interviews and primary sources, collected via the study.

The wood/timber of a few of the above shrubs is utilized for making small objects (red viburnum, lilac, hazel, yellow tree acacia, sea buckthorn), in carpentry (sea buckthorn), in turning (sea buckthorn), carving (sea buckthorn), in bending and carpentry (narrow-leaved fragrant willow), for making musical instruments (narrow-leaved fragrant willow), for making hedges (bird grapes). The fruits of a piece of shrubs are used as food (hazel, sea buckthorn, Japanese quince), in medicine and pharmaceuticals (sea buckthorn, Chinese lemongrass), in the food industry (hazel, Japanese quince). Some of the above shrubs' leaves are applied to produce fodder for domestic animals (hazel). A piece of the shrubs is used to obtain paint (goat willow).

The above-mentioned shrubs can be applied in i) agroforestry to create protective belts (e.g., bird grapes, hazel, yellow tree acacia, goat willow, sea buckthorn), ii) in forest-farming agroforestry systems (red viburnum, hazel, tree yellow acacia rosehip), and iii) forest-pasture agroforestry systems (hazel) (Table 4).

Conclusions. The contributions of Bulgarians' agroforestry systems to three pillars of sustainability were pointed out. Regarding the social dimension of sustainability, the respondents highlighted the social benefits of agroforestry (e.g., raising the standard of living and the social status of the population; providing jobs and access to renewable energy; overcoming social inequality in individual regions; provide recreation opportunities for the population; give social, educational, scientific, landscape and recreational benefits to society; generate firewood for society). The

contribution of Bulgarians' agroforestry systems to environmental and social dimensions was discussed.

The trees and shrubs, as mentioned above, can be used in Bulgarian agroforestry to: i) create protective belts (e.g., willows, poplars, white acacia, black (sticky) alder, the plane trees); ii) in forest-farming agroforestry systems (e.g., willows, white acacia, the plane trees, the hairy paulownia, rowan, white mulberry); iii) in forest-pasture agroforestry systems (e.g., the hairy paulownia, white alder, (wild) pear, rowan, white mulberry); iv) in alley-cropping agroforestry systems (e.g., poplars, the plane trees, the hairy paulownia, walnut, trees of the genus ash (*Fraxinus*), chestnut, birch). A piece of the trees is suitable to create plantations for biomass production (e.g., willows, poplars, white acacia, black (sticky) alder, the plane trees, the hairy paulownia, and (field) ash).

For the first time, it has been given a new insight into the trees and shrubs suitable for various agroforestry systems in Bulgaria, a country with a temperate climate. The above-mentioned knowledge of tree species with short, medium, and long rotations, and their possible use in various agroforestry systems and economic activities will support agroforestry farmers in creating efficient and sustainable agroforestry farms suitable for their region and economic industries operating there. Furthermore, the study contributes to agroforestry literature by providing knowledge on the rich palette of critical trees (46 trees) and shrubs (15 shrubs) appropriate for agroforestry systems in temperate climates. What is more, if these tree species are promoted by decision-makers and professional/farmer associations, and adopted by the farmers can support and reinforce agroforestry in both Bulgaria and regions with temperate climates.

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Appendix 1

Table A.1

Interviewees and organizations

Organization	Information for organization	Interviewee	Position in organization	A land area with agroforestry
ORG 1	The organization is engaged in the cultivation of crops with paulownia	INT 1	Farmer/Owner	100 hectares (Paulownia with different crops)
ORG 2	This organization provides consultancy and design services in the field of interior and exterior landscaping. The company owns a nursery in Septemvri (producing high-quality coniferous, broad-leaved trees and shrubs) and a garden center situated in Sofia	INT 2	Farmer/Owner	200 hectares (The assortment of ornamental plants is very rich – more than 150,000 plants of over 200 species)
ORG 3	The organization is engaged in truffle cultivation	INT 3	Farmer/Owner	5 hectares (Agroforestry and truffles cultivation)
ORG 4	The main operation of the organization is the distribution of agricultural products, auxiliary materials for agriculture, preparations for bio-agriculture, offering saplings and seedlings of fast-growing trees of the species Paulownia elongate and Paulownia tomentosa	INT 4	Farmer/Owner	10 hectares (Paulownia with different crops) + 700 hectares with organic farming

Continuation of Table A1

ORG 5	The organization is engaged in the cultivation of Bulgarian oil roses with different crops/lavender	INT 5	Farmer/Owner	6 hectares (Bulgarian oil roses with different crops)
ORG 6	The enterprise manages the state forest territories (near 934 968 ha) in seven administrative districts – Blagoevgrad, Lovech, Sofia City, Sofia District, Pazardzhik, Pernik, and Kyustendil. The company unites 36 state forestry holdings, five state hunting farms, and 67 forest nurseries	INT 6.1 INT 6.2 INT 6.3	1. Chief of Department “Resumption of Forests” 2. Chief Expert “Conservation of Forest Areas” 3. Expert in Agroforestry	4 hectares with trees and strawberries; many additional acres with trees combined with berries, herbs, beehives, and mushrooms
ORG 7	The enterprise manages the state forest territories (near 860 572 ha) in four administrative districts – Pazardzhik, Kardjaliiska, Smolyanska, Plovdivska. The planting material is produced in 37 forest nurseries	INT 7.1 INT 7.2	1. Expert in agroforestry; 2. Chief of Department “Resumption of Forests”	many hectares with trees combined with berries, forest crops (i.e., walnut), herbs, fruits, beehives, and mushrooms
ORG 8	The enterprise manages the state forest territories (near 287 892 ha) in four administrative districts – Shumen, Varna, Dobrich, and Targovishte. The company has nine forest nurseries	INT 8	Expert in Agroforestry	many hectares with trees combined with forest crops (walnut, melons, etc.), herbs, fruits and mushrooms
ORG 9	The enterprise manages the state forest territories in five administrative districts – Rousse, Silistra, Gabrovo, Veliko Tarnovo, and Razgrad. The company unites 13 state forestry holdings and four state hunting farms	INT 9	Expert in Agroforestry	many hectares with trees combined with forest crops (walnut, etc.), herbs and mushrooms
ORG 10	The enterprise manages the state forest territories in five administrative districts – Stara Zagora, Haskovo, Yambol, Burgas, Sliven. The company unites 26 state forestry holdings and five state hunting farms	INT 10	Expert in Agroforestry	many hectares with trees combined with forest crops (walnut, etc.) and herbs
ORG 11	This organization aims to train European agricultural stakeholders in agroforestry practices	INT 11	Professor / agroforestry expert	-
ORG 12	The Agrarian Faculty of Bulgarian university	INT 12	Professor / agroforestry expert	-
ORG 13	This organization is the leading research center in Bulgaria in the field of plant and agro-biotechnologies	INT 13	Professor / Director / agroforestry expert	-
ORG 14	The company has been the only one in Bulgaria providing education in forestry, landscape architecture, forest management, and wood processing	INT 14	Professor in agroforestry systems	-

Sources: created by the author.

Table A.2

The information gathered through the case study

No.	Information source	Information quantity
1	Interviews in Bulgaria	98 A4 pages with Times New Roman Font, 12 point, 1.5 spaced
2	Internal documents:	
2.1	Internal press releases, presentations, reports and speeches	26 documents, about 520 A4 pages
2.2	Websites of agroforestry organizations participation in the research	Passim
3	External documents:	
3.1	Reports, newspapers and journal articles	10 documents, 105 A4 pages
3.2	Plans and case studies of agroforestry systems	3 documents, 18 A4 pages
4	Observation notes	9 pages
5	Visits of Rhodope Mountain in Bulgaria:	
5.1	High Western Rhodopes – Batak, Dospat, Smolyan	6 days
5.2	Atoluka, Ravnogor, Peshtera	3 days

Sources: created by the author.