Culture and silviculture: origins and evolution of silviculture in Southeast Europe

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SUMMARY

Silvicultural practices are generally developed to meet societal objectives given the constraints of the site. This simple premise is a foundation of modern silviculture. However, silviculture may vary for other reasons related to cultural factors. This paper reviews the differences in silviculture in the twelve countries that comprise southeastern Europe, an area that includes a variety of cultures, and a complex history. The silviculture generally follows three models: coppice systems that are largely unregulated, even-aged stands that include former coppice stands and other reforested sites, and systems to develop and maintain complex stand structures. Plantation management is not common. Cultural and historic drivers have affected the development of silviculture in this region. Additional drivers include forest access, the importance of wood for fuel, and proximity to central Europe. It is anticipated that European Union membership of countries in the region will lead to greater regional and international exchange and cooperation in the future.

Keywords: Balkans, selection silviculture, coppice systems, Austrian-Hungarian Empire, Ottoman Empire

Culture et sylviculture: origines et évolution de la sylviculture dans l'Europe du sud-est

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Les pratiques de sylviculture sont en général développées pour atteindre les objectifs sociaux suivant les contraintes du site. Cette simple prémisse est la fondation de la sylviculture moderne. Cette dernière peut toutefois varier pour d'autres raisons, liées aux facteurs culturels. Cet article examine les différences dans la sylviculture des douze pays formant l'Europe du sud-est, une région comprenant une variété de cultures ainsi qu'une histoire complexe. La sylviculture suit généralement trois modèles: des systèmes de taillis, pour la plupart non surveillés, des peuplements d'arbres d'âge semblable incluant d'anciens peuplements de taillis et d'autres sites ayant connu une reforestation, et des systèmes mis en place pour maintenir et développer des structures de peuplements complexes. La gestion des plantations n'est pas répandue. Des courants culturels et historiques ont affecté le développement de la sylviculture dans la région. Des pressions supplémentaires comprennent l'accès à la forêt, l'importance du bois comme combustible et la proximité de l'Europe centrale. On anticipe que les pays membres de la Communauté Européenne de cette région vont conduire un échange régional et international accru et à une plus grande coopération dans le futur.

Cultura y Silvicultura: Orígenes y evolución de la silvicultura en el sudeste de Europa

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Las prácticas silvícolas han evolucionado generalmente para satisfacer objetivos sociales, dadas las limitaciones de cada sitio. Esta simple premisa es una de las bases de la silvicultura moderna. Sin embargo, la silvicultura puede variar debido a otras razones relacionadas con factores culturales. Este artículo analiza las diferencias en la silvicultura de los doce países que componen el sureste de Europa, la cual es un área que cuenta con una variedad de culturas, y una historia compleja. La silvicultura sigue, en general, tres modelos: sistemas de monte bajo que en su mayoría no están regulados; rodales coetáneos, que incluyen rodales que previamente fueron monte bajo y otras áreas reforestadas; y sistemas para desarrollar y mantener las estructuras de rodales complejas. La gestión de las plantaciones no es algo habitual. Ciertos factores culturales e históricos han afectado el desarrollo de la silvicultura en esta región. Otros factores adicionales incluyen el acceso a los bosques, la importancia de la madera como combustible, y la proximidad a Europa central. Se prevé que la pertenencia a la Unión Europea de los países de la región dará lugar a un mayor intercambio y cooperación regional e internacional en el futuro.

INTRODUCTION

Silviculture, or the culture of stands and forests, is traditionally regarded as the outcome of integrating site conditions with management objectives (Hawley 1921, Troup 1928). "Site conditions" refers to a long-standing and central tenant in silviculture and includes the environmental conditions, the species present, the site productivity, and the operational limitations of the site. Management objectives result from social drivers that may range from societal concerns over management to small landowner needs. A management objective may be related to timber production in one stand and managing for protection functions in another. Hence the management of two stands with identical site conditions may be different if the management objectives are different. Likewise, two forest stands managed for the same objective on identical sites would, in theory, receive the same silvicultural regime. The variation in silvicultural treatment over a large area can therefore usually be accounted for with the product of site conditions and management objectives. This relatively simple approach to silviculture and meeting management objectives dates back many decades (Hawley 1921, Troup 1928, Matthews 1989, Smith *et al*. 1997, Nyland 2002).

Silviculture may vary for other reasons. One factor is the forest policy regulations that limit silvicultural activities in one country or state as compared to a neighboring country. These range from regulations to protect environmental resources to those that prohibit certain silvicultural practices. For example, some silvicultural practices may be prohibited in entire countries or states, or simply restricted to certain sites where slope or soil conditions are limiting. Certification systems also encourage certain silvicultural practices. As a result, the practices under one certification system may vary from a neighboring forest under a different certification system despite similarities in site conditions and management objectives. Harvest systems and economics may also limit silviculture through road densities or capital available for investment in silvicultural activities or advanced harvest systems.

Other factors that may affect silviculture include historical events that are independent of, but nevertheless affect, forestry in either direct or subtle ways. For example, political boundaries between nations often divide similar forest sites and similar cultures, but may result in different silviculture. There may also be differences in the way people from different countries look upon their forests and other "natural" places that may affect silvicultural practices. Some people may view forests as a source of natural resource extraction and others may view forests in a more spiritual way where protecting forest structures is a primary goal. The affluence of a population may influence silvicultural practices depending on the importance of those resources for local economies. Finally, there may be regional differences in the development of silvicultural practices. For example, one region may experiment with new practices where another similar region is less inclined to make changes. Similarly, silviculture may also be influenced by the educational pedigrees or international experiences of silviculture academicians and researchers. This is particularly true in selection silvicultural systems to produce multiaged stands where key historical figures – such as Gurnaud, Biolley, Hufnagl, Leibundgut, and others – have affected silviculture outside their own region (O'Hara 2014).

This synthesis examines how silviculture is affected by a combination of environmental, historical, and cultural factors, thereby providing insights to managers and researchers about the development of silviculture and the management objectives that drive it. The development of silviculture in southeastern Europe was selected to serve as a case study to answer this question. Southeastern Europe is a highly suitable location for this analysis because it includes a diversity of relatively small countries, forest types that cross political boundaries, complex historical influences and interactions, and other religious, cultural, and political contrasts that have affected forestry. Our primary objective was to examine how history, social factors, and the political context influence silviculture in ways beyond those traditionally represented by management objectives or regulatory restrictions on silvicultural practices. A secondary objective was to describe the current status and variations in silviculture throughout southeastern Europe.

TABLE 1 *Primary and secondary drivers affecting the use of different silvicultural systems across southeast Europe*

Silvicultural system	Primary drivers	Secondary drivers
Coppice	fuelwood needs	tradition
Even-aged and plantations	timber production, restoration	central planning models
Irregular shelterwood	timber production, forest access and transportation systems, protection functions, regulatory restrictions, land ownership	forestry education, scientist pedigree, international exchange
Group selection	timber production, forest access and transportation systems, protection functions, regulatory restrictions, land ownership	forestry education, international exchange
Single tree selection	timber production, forest access and transportation systems, protection functions, regulatory restrictions, land ownership	forestry education, scientist pedigree, international exchange, historical connections with central Europe, tradition

METHODS

This synthesis reviews information from the peer- and non-peer-reviewed literature, and European Union reports on forest area by country and management systems. The collective experience of the authors was also a major component as they represent each of the twelve countries in the region. The synthesis first describes the region, its history, and reviews the status of forestry in each of the individual countries. We then describe current silvicultural practices that result in regular, irregular, and complex stands.

A key data source in our analysis was the United Nations Food and Agriculture Organization/European Forestry Institute report "Forest Europe, 2015: State of Europe's Forests 2015" (Forest Europe 2015). This report provided information on total area and total forest area for individual countries. Information for other countries and information on area by regeneration method was provided by the authors. Silvicultural systems used in the region were assigned to five classes primarily due to data availability in previous classifications (e.g., Forest Europe 2015). Five classes were recognized and were the basis for assessing the relative importance of different cultural factors on silviculture in the different countries: coppice systems, even-aged systems and plantations, irregular shelterwood, group selection, and single tree selection.

The primary and secondary drivers for implementation of different silvicultural systems are shown in Table 1. Primary drivers include the fuelwood needs that promote coppice culture or the regulatory restrictions that prevent even-aged systems in some countries. Secondary drivers are the more subtle factors that influence silviculture such as traditions that encourage different systems, or the transfer of technology between some countries and not others. Certain drivers were examined in greater detail including: origins of silvicultural systems, forest planning models, wood usage, and infrastructure, the pedigrees of leading silviculturists, forestry education programs, and others.

THE SOUTHEASTERN EUROPE REGION

In this analysis, southeastern Europe was defined as including the countries of Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo[1], the Republic of Macedonia (henceforth FYR Macedonia), Montenegro, Romania, Serbia, Slovenia, and the European (Thrace) part of Turkey (Figure 1). Other geographical and political classifications have been applied to this region. For example, the Forest Europe (2015) definition of "South-East Europe", includes Cyprus but not Kosovo or Romania. The region, also known as the Balkan Peninsula, is a triangular peninsula surrounded by the Adriatic, Aegean, Mediterranean, and Black Seas with a long northern border that separates the region from Italy, Austria, Hungary, Ukraine and Moldova.

The region's rugged physical geography has played an important role in its history by separating, and affecting the development of, these cultures (Figure 2). Mountains dominate much of southeast Europe. The term "Balkan" comes from the Balkan range that extends across Bulgaria from Serbia to the Black Sea. Other important ranges include the Dinaric Alps that extend along the eastern spine of southeast Europe from Slovenia through Albania, the Carpathians in Romania and Serbia, the Rhodopes in Bulgaria and Greece, and the Pindus Mountains in Albania and Greece. Much of these mountain ranges are of karst parent materials (i.e., limestone or dolomite), particularly in the Dinaric Alps. The Pannonian plain extends down into Serbia and Croatia, and `along the Danube River through the Wallachian and Danubian Plains to the Black Sea. Topography has also defined land use with forests converted to agriculture on the flat, valley bottom sites that are typically more fertile with forests primarily in the mountains.

The history of humans in southeast Europe dates to antiquity. The location between the Middle East, Asia, and Europe has made it a crossroads for migration, trade, and cultural exchange. It was the pathway for the first human entry into

[1] This designation is without prejudice to positions on status, and is in line with UNSC Resolution 1244 and the ICJ Opinion on the Kosovo Declaration of Independence.

FIGURE 1 *Political map of southeastern Europe. In this analysis, this region included Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Kosovo, Macedonia, Montenegro, Romania, Serbia, Slovenia, and the European part of Turkey (image used under license from MapsforDesign.com)*

Europe and for the Crusaders' journeys to the Middle East. The region was the first place to have agriculture in Europe and the site of the earliest human writing. Parts of southeastern Europe were at one time within the Greek, Roman, Persian, Byzantine, Venetian, Ottoman, and Austrian-Hungarian empires, as well as satellites of the Soviet Union. This region was also the site of the separation of Orthodox and Catholic Christianity and an intersection between Christianity and Islam (Mazower 2000).

Beginning in the 19th century, individual states in southeast Europe gained their independence from the Ottoman and Austrian-Hungarian Empires to form new states. Many of the current nations, or nation states (Figure 1), were formed between 1821 and 1912: Greece was formed in 1830, Romania and Serbia in 1878, Bulgaria in 1908, and Albania in 1912. The two Balkan Wars (1912–1913, and 1913) resulted in the Ottoman Empire retaining eastern Thrace. Immediately after World War I, the State of Slovenes, Croats and Serbs was established from territories of the former Austrian-Hungarian Empire. Only 33 days later, the unification of the State of Slovenes, Croats and Serbs with the Kingdom of Serbia formed the Kingdom of Serbs, Croats and Slovenes, and in 1929 renamed as the Kingdom of Yugoslavia. After World War II, The Kingdom of Yugoslavia became the Socialist Federal Republic of Yugoslavia. All countries in the region were socialist or communist during the Cold War except Greece and Turkey. Coincident with the decline of the Soviet Union in the early 1990s, Albania, Bulgaria and Romania adopted democratic reforms and privatized their economies. Over the period of 1991–2008, Yugoslavia split into the present independent states of Bosnia and Herzegovina, Croatia, Kosovo, FYR of Macedonia, Montenegro, Serbia, and Slovenia with democratic reforms and market economies. These transitions are still underway in Kosovo (Bideleux and Jeffries 2007, Lampe 2014).

The transition from communist and socialist regimes has also resulted in dramatic changes in land ownership in southeast Europe. Following the dissolution of these regimes, land previously held by states, communities, or collectives was generally retained as state-owned, or returned to previous owners or their heirs. In some cases, reform involved restitution of property owners, and in others, land was distributed to rural households. However, land reform or decollectivization has been highly variable throughout Eastern Europe, in both the processes used and the amount of land transferred to private individuals (Swinnen 2001). This process often fragments landscapes into small holdings and places forest ownership in a new generation of citizens that may have little knowledge about sustainable forest management. The development of institutions to assist forest owners also varies with some countries providing forest management planning to most forest owners and other countries providing no assistance.

The forests of southeastern Europe are as varied as the topography and climate. The region was a refugium during previous glacial periods and hosts much greater plant diversity than central or northern Europe. Many forests are also very productive but others exist on poor quality sites or in a degraded state due to over-exploitation in the past from removal of forest cover through harvesting, grazing, or conversion to agriculture. The region includes mixed stands dominated by silver fir (*Abies alba* Mill.), Norway spruce (*Picea abies* (L.) Karst.), and European beech (*Fagus sylvatica* L.) that are found primarily in the north or higher elevations. Black or Austrian pine (*Pinus nigra* Arnold) stands are concentrated in the west and on shallow soils or carbonate substrates. Mixed broadleaved forests are common at lower elevations, along rivers or plains. Important broadleaved species include European beech, Oriental beech (*F. orientalis* Lipsky.), small-leaved linden (*Tilia cordata* Mill.), sycamore maple (*Acer pseudoplatanus* L.), European ash (*Fraxinus excelsior* L.), Turkish hazel (*Corylus colurna* L.), pedunculate oak (*Quercus robur* L.), sessile oak (*Q. petraea* Liebl.), Hungarian oak (*Q. frainetto* Ten.), Turkey oak (*Q. cerris* L.), and downy oak (*Q. pubescens* Willd.). In the areas furthest south, greater Mediterranean influences, a history of anthropogenic site degradation, and warmer and drier conditions leads to woodlands and maquis vegetation including Holm oak (*Q. ilex* L.), and kermes oak (*Q. coccifera* L.), strawberry tree (*Arbutus unedo* L.), tree heath (*Erica arborea* L.), and many others.

FIGURE 2 *The physical environment in southeastern Europe showing the many moutain ranges (image used under license from Shutterstock.com)*

THE COUNTRIES

Albania

Albania is situated on the Adriatic Coast and encompasses a wide range of ecological systems derived primarily from its rugged and varied topography. Forests vary with elevation and distance from the coast, and cover about 60% of the country. Productive mixed conifer-broadleaved forests are found in the Dinaric Mountains, mixed oak forests at middle elevations, and maquis vegetation at lower elevations (Metaj *et al*. 2015). The predominant silvicultural system is coppice culture in the mid-elevation oak and sweet chestnut forests that follows centuries of similar cutting on these sites. Many forested areas also have a long history of grazing. At higher elevations, even-aged planted forests and forests of natural origin are found (Table 2). These upper elevation forests, which are generally most productive, may be managed with a variety of methods such as clearcutting for coppice forests and shelterwood systems for high forests. The area under selection management in Albania is negligible. Due to historical over-cutting, Albania instituted a moratorium on timber harvests in 2016.

Several forestry professors in Albania have been educated in central Europe and are credited with transferring even-aged systems, such as the uniform shelterwood system for European beech, to Albania. Recently, there has been recognition that traditional even-aged systems may not emulate natural processes as well as selection systems (Meyer *et al*. 2003).

Albania has a centrally controlled forest administration that is still evolving to find effective policies for forestry. Presently, the top-down policies are typically more punitive rather than incentive-based.

TABLE 2 *Total forestland by country (in million ha) and percent of forestland managed with different regeneration methods (Forest Europe 2015). Regeneration methods are classified as "coppice": short rotation systems of predominantly sprouting species; "regular even-aged and plantations" are even-aged natural and planted stands; "irregular shelterwood" is a system of expanding gaps resulting in multiaged or uneven-aged stands; "group" and "single tree selection" are classical uneven-aged systems (Matthews, 1989; Helms, 1998); and "other" are generally non-managed forest areas*

Country	Land area	Forest area	Coppice	Regular even-aged and plantations	Irregular shelterwood	Group selection	Single tree selection	other
	million ha	million ha	Percent of total forest land					
Albania	2.8	1.5	42	30	-	-	-	29[1]
Bosnia and Herzegovina	5.1	2.9	24	5	-	43		28[2]
Bulgaria	10.9	3.8	48[3]	51	1.4	<1	<1	-
Croatia	5.6	2.4	22	43	3.3	0.3	10	21[1]
Greece	12.9	3.4	65	35	-	-	-	-
Kosovo[4]	1.1	0.5	84	16	-	-	-	-
FYR of Macedonia	2.5	1.0	70	16	-	-	14	-
Montenegro	1.4	1.0	48.9	14	22.6	14.5		-
Romania	23.0	6.5	4	66	-	5[5]	1	24[6]
Serbia	8.7	2.1	69	29	-	1.7		-
Slovenia	2.0	1.2	3	9	79	5		4
Turkey - Thrace	3.4	0.6	41[3]	59	-	-	-	-

[1]Shrubland or maquis

[2]Includes both non-productive land and land inaccessible due to land mines

[3]Designated for transformation to high forests

[4]This designation is without prejudice to positions on status, and is in line with UNSC Resolution 1244 and the ICJ Opinion on the Kosovo Declaration of Independence. The area of Kosovo is from https://ask.rks-gov.net/media/2362/kosova_shifra-2015-ang.pdf

[5]Includes transformation treatments to develop multiaged structures.

[6]Includes restoration cuttings (to restore stand productivity or stand natural composition), conservation treatments, and low intensity interventions meant to maintain continuous canopy cover in protection forests.

Bosnia and Herzegovina

Bosnia and Herzegovina is a nearly landlocked country that ranges along the Dinaric Alps and extends into the Pannonian Plain to the northeast (Figure 1). Over 50% of the land area is forested with productive conifer and broadleaved stands. A variety of silviculture was used in the past, but at present, single tree forms of selection systems are most common (Table 2). Coppice forests are a common source of fuelwood. Clearcutting was banned in the 1980s when Bosnia and Herzegovina was part of Yugoslavia. In degraded stands, clearings are permitted to a maximum of one ha. Most even-aged forests in Bosnia and Herzegovina originate from afforestation of open areas or areas that were afforested after degradation in the past; hence, only a small area is presently managed with even-aged systems (Table 2). Hans Leibundgut, the Swiss silviculturist, visited in 1957 and noted that Bosnia and Herzegovina was rich in forests of low quality. Matić *et al*. (1971) reported similar conclusions with high levels of low quality trees in both pure high beech and in mountainous mixed forests. This situation persists today with many forests in a degraded condition from coppice management and other areas that cannot be managed because they have not been cleared of mines from the Bosnia War in the 1990s (FAO 2015).

The data in Table 2 represent both present conditions and the application of different silvicultural systems in the past. For example, relatively large areas are classified as coppice forests. However, Keren *et al*. (2016) noted that at present coppice forests are rarely managed with the coppice system: instead they are managed for conversion to high forests, or neglected and left to natural development. Cutting pressures on coppice forests have declined in recent decades as rural populations move to urban centers. Such trends are similar to those reported in other European regions (see Ciancio *et al*. 2006, Nocentini 2009).

Although silviculture during the past had certain flaws, it did not dramatically change Bosnian forests (Keren *et al*. 2017). Most forests were treated with single tree removals, hence the largest change was the decrease in quality of standing timber. In response, Matić (1947) proposed a control method for single tree selection system that was adopted and applied rigorously in all forest types, even in forests composed of shade-intolerant species (Pintarić 1997). Matić

(1947) recognized advantages but also some drawbacks of this system, and hence in the year 1973 proposed the introduction of a "group-selection" system. This system resembled Swiss irregular shelterwood system. Since the late 1970s, Matić's group-selection system has been prescribed for most forest types. Nevertheless, single tree selection is still common using a system with ten-year cutting cycles.

The continued popularity of single tree systems may be rooted in negative results from use of other systems in previous centuries, and also in an increased social appreciation of forests which served as a refuge to escape atrocities of previous wars. The consistent application of single tree selection system in Bosnian high forests since the 1940's has improved timber quality, but still many forests remain in a degraded condition (Bašić and Govedar 2003). Single tree selection focuses primarily on tree species composition with a strong emphasis on attaining a reverse-J diameter distribution, at least at the multi-stand level. Group selection has been used since the 1970s. Cutting cycles are approximately 10 years in length.

Bulgaria

Bulgaria has a long history of being heavily forested. Historical accounts of the large extent of forests date to the Macedonian empire. The First Crusaders described them as "Magna Silva Bulgarica" or the great Bulgarian forests. These forests were cut heavily during the Ottoman period. After the Russian-Turkish war ended in 1878 and the liberation of Bulgaria, the first forest law was enacted in 1883. It established forest nurseries for reforestation and afforestation, and controlled harvesting on public forestlands. Forest legislation in the following three decades was largely focused on forest protection and limiting erosion and flooding resulting from reduced forest cover. In 1947, under a new socialist government, forests in Bulgaria were placed under state ownership. Following the end of the socialist period in 1997, Bulgaria has gone through a period of land restitution with improvement of forest practices. A new forest law in 2011 imposed new requirements of forest owners and improved planning and management processes.

At present, Bulgaria has the second highest total area of forest land of any country in southeastern Europe (Table 2). Nearly all of this forest land is in coppice structure or even-aged stands and plantations. The current forest plan calls for converting most of the coppice forests to high forests. Another priority is developing stands with greater species diversity.

Bulgaria has a history of interaction with central Europe, including with forestry. Bulgaria's King Ferdinand was of Austrian aristocratic heritage and, along with his son Boris the II, ruled Bulgaria from the end of the nineteenth century to 1943. Ferdinand and Boris were credited with bringing ideas about selection silviculture from central Europe where they were implemented at small scales. Bulgaria's commitment to forestry began after the end of Ottoman rule in 1978, and in 1923 with the founding of the first forestry education program.

Croatia

Croatia has highly heterogeneous topography stretching from the Pannonian plain, over the Dinaric Alps to the Adriatic Coast, and extending from Slovenia to Montenegro (Figure 1). Forests cover 42% of Croatia. These forests range from mixed oak along the Sava, Drava, and Danube rivers to mixed conifer and broadleaved forests in the mountains. Much of the forest land along the Adriatic Coast was deforested beginning in the Roman period. However, large scale reforestation efforts, some dating to the Venetian control of these lands, have restored forest cover, often dominated by black pine (Kranjc 2009). Croatia is characterized by a long history of organized forestry: the first forest inventory and mapping were made in 1764, the first Forest Office was established in 1765, the first Forest Law was adopted in 1769, and the first higher education program in forestry was established in Zagreb in 1898.

Forest cover in Croatia is primarily even-aged stands, coppice forests, and degraded forms of forests such as shrubland and maquis which dominate in the coastal area (Table 2). The irregular shelterwood system is rarely used in Croatia. A more traditional shelterwood approach is used in the oak forests along the Sava River floodplain. It includes a long rotation of at least 140 years, intensive tending of stands from an early age and regeneration in three fellings.

The selection system has been used in mixed silver fir and European beech forests in the Dinaric Alps since 1881. In 1960, Dušan Klepac, professor at the Faculty of Forestry in Zagreb, established the selection system that is in use today. Selection systems are typically managed on 10-year cutting cycles with 22–25% of volume removed in each harvest that corresponds to the 10-year increment. For a moderate site, growing stock may range from 300 to 400 m^3/ha from the beginning to end of each cutting cycle. The target structure for both single tree and group selection distributes volume among three diameter size classes: 10–30 cm: 20%, 30–50 cm: 30%, and >50 cm: 50% (Matić *et al*. 2001).

Greece

Forests in Greece are strongly influenced by the Mediterranean climate in the south and the effects of elevation on temperature and precipitation. Forests are primarily located in the north at higher elevations. Forests in Greece are also affected by centuries of human activities that have degraded many sites. As a result, many current forest management activities are associated with restoration or rehabilitation of forests (Soutsas *et al*. 2004, Dafis 2011, Huss 2017).

Approximately 65% of the forests in Greece are coppice systems including coppice with standards systems (Table 2), although many are in conversion to high forests. The remaining forest area is primarily even-aged high forests and plantations. Forests include both conifer- and broadleaved-dominated stands. In general, high forest systems are used in conifer forests at higher elevations and coppice systems in lower elevation broadleaved forests. Coppice culture typically uses rotations of 20–35 years in oak-dominated forests.

Modern Greece was formed after removal of the Ottomans in the 1820s and formation of a monarchy led by the Bavarian prince Otto. There was a strong Bavarian influence on the new government including forestry (Zagas *et al*. 1999). The first forestry education program started in 1896 in Vytina and the second in 1917 in Athens.

Kosovo

Kosovo is a mountainous country with forests that range from mixed broadleaved to conifer forests at higher elevations. It is a partially recognized state formed in 2008 from the southwestern part of Serbia (Figure 1). Forest policies are therefore still evolving. Forested area represents approximately 44% of the country, approximately 62% is publically owned and the remainder is private. Coppice culture dominates forest activities in Kosovo (Table 2), and the vast majority of this is illegal to meet fuelwood needs. Harvest treatments that leave less than 40% cover were banned to eliminate clearcutting. As a result, most legal coppice cutting is done in groups or coupes with some residual trees left (Kola 2014). Other silvicultural systems include some high forests with natural regeneration and plantations.

Forestry in Kosovo is controlled by a central ministry with two branches: one develops policy and the other manages public lands and enforces regulations on all forests. In contrast to many countries in southeast Europe, Kosovo has not had significant change in landownership as it transitioned to a market economy. With the primary energy source being wood and a high proportion of forest in public lands, there is pressure on all forest lands, particularly publicly owned land, to meet fuelwood needs. There is also little experience with other management systems. As the ongoing development of forest regulations continues, there are divergent interests in managing Kosovo's forests from banning coppice culture to developing community-based systems to better implement forms of coppice culture.

FYR of Macedonia

The FYR of Macedonia is characterized by heterogeneous topography dominated by a central valley drained by the Vardar River, surrounded by mountain ranges. Forests are highly variable resulting, in part, from many centuries of degradation particularly near populated areas (Velkovski and Lozanovska 2015). These forests are characteristic of the southern Balkan Peninsula. Macedonia has 40% of cover in forests that include deciduous and evergreen broadleaved species, maquis, and some conifers (Melovski *et al*. 2013). Coppice systems dominate management using large clearcuts and short rotations in primarily oak stands to produce fuelwood (Table 2). These sites are largely degraded with low yields due to past overharvesting. Uneven-aged systems include both group and single tree selection that focus on stand improvement through positive tree selection.

Ownership of forests in Macedonia is 90% public and 10% private. Central planning began in 1952 while Macedonia was a part of Yugoslavia. A more current forest law was passed in 2009 that encourages management, restoration, and protection of forests under all ownerships. There has also been some restitution of forest land since 2006.

Montenegro

Montenegro extends from the Adriatic Sea into the Dinaric Mountains featuring a highly varied topography that is approximately 60% forested. Forests are divided between high and coppice forests (Table 2). These forests are primarily young with over 60% being in pole stage or younger. Approximately 85% are described as "semi-natural" in Forests Europe (2015), and forests are approximately half publicly-owned and half privately-owned (Curovic *et al*. 2011).

Management in Montenegro is dominated by coppice culture with smaller amounts of even-aged and multiaged systems (Bončina *et al*. 2014). Group selection is used more often than individual tree selection. However, it is common to use a small-scale irregular shelterwood system that is more difficult to classify. Žarko Miletić, the Professor of Silviculture from Belgrade was a key influence.

Romania

Romania's physiography is dominated by the Carpathian Mountains which represent an important region for forestry and one of the more pristine areas of Europe. The Carpathians were also the approximate boundary separating the Austria-Hungarian and Ottoman empires through much of the 17th through 19th centuries, thereby affecting the development and application of silviculture on either side of this border.

Forestry practices have been strongly limited by central government controls in Romania since the late 1800s, long before the more recent formation of the current boundaries. Romania uses a variety of regeneration methods (Table 2), and has a long history of systems that have moved in-and-out of common usage. In the mid-19th century, based on the Austrian forestry law, all mountain high forests of high elevations were managed only as selection forests (Sabău 1946). A centralized forestry code (1881) set in place at about the time of Romania's independence from Ottoman rule (1878) promoted single tree selection, but was essentially a lower diameter-limit system (Giurescu 1976, Duduman 2011). It is not clear how successful efforts to implement single tree selection systems were during subsequent decades. Meda (2013) noted 50 years of transformation treatments had not achieved target structures in mixed Carpathian stands. However, the modified forestry code (1921) imposed target diameters of at least 40 cm (public estates) and 30 cm (private estates) in selection forests (Sabău 1946). By 1935, selection systems were restricted to protection forests and production forests that included silver fir.

Following the end of the Austrian-Hungarian Empire in 1918, forestry practices were more varied. The period between the World Wars was also characterized by greater interest in selection systems, and included a 1935 law that encouraged selection systems mainly in protection forests. However, the area with prescribed selection systems never

reached more than 5% of the forestland, and is presently only about 1% (Duduman 2011, Carcea *et al*. 2013). Between 1948 and 1991, all forests belonged to the state, and the use of selection systems was sought mainly for ecological reasons, not economic reasons (i.e. continuous timber production was ensured by the total area of forestland owned by the state). As these ecological protection functions can be attained by even-aged or other structures, there was no need to invest in selection systems. Additionally, before nationalization, forests belonging to individuals represented 23% of the total and those of local communities and other legal entities represented 49% of the total in Romania (Marinchescu *et al*. 2014). The Soviet influence post-WWII helped reinforce the detailed guidelines for forestry, as well as providing forestry education opportunities for some Romanian foresters in Russia. There have also been strong linkages with central European universities since the mid- 1850's with scores of Romanian foresters educated in France, Germany and Austria (Anon. 1938).

At present, Romania has a highly centralized control of forest practices with "technical norms" that include standards for silvicultural practices. These technical norms limit the types of systems used and, generally discourage flexibility or innovation. For example, irregular shelterwood is only used in rare cases, and selection systems have become very uncommon. The low road density also hinders development of selection systems. These technical norms are a relic of Romania's socialist past and do not represent the needs of the present land ownership structure which, according to Marinchescu *et al*. (2014), is very diverse and includes many small holdings.

Serbia

The northern part of Serbia is dominated by the Pannonian Plain and the southern part by hills and various mountain ranges. About 29% of Serbia is forested ranging from European beech forests to mixed-species conifer forests (Banković *et al*. 2009, Medarević *et al*. 2014). Approximately half the forest land in Serbia is owned by the state with the remaining held in small holdings by private owners. Both the public and private forest lands are predominantly managed by the state. Most forests are managed as coppice forests, or even-aged shelterwood and plantation forests (Table 2). Very little is managed with selection systems.

One of the key individuals in Serbia silviculture was Žarko Miletić who was a professor at the University of Belgrade during the middle of the 20th century. He received his Ph.D. in Zagreb, and worked with Henry Biolley in Switzerland. Miletić published two books on selection silviculture around 1950 and was the primary architect of the variant of Biolley's "control method" that became the Goč selection method where all trees are remeasured and harvested on a 10-year cutting cycle (Medarević *et al*. 2010). The method focuses on retaining and developing healthy trees and achieving a negative exponential diameter frequency distribution. The ideal species composition was a species ratio of 70:30 silver fir: European beech. The expense of the 100% inventory of the Goč selection method made it an undesirable method and contributes to the small area where it is applied. Testing is underway to develop a method based on a permanent plot inventory system.

Slovenia

Slovenia is a mountainous country dominated by the Alps and the Dinaric Mountains, and extends to the Pannonian plain in the east (Figure 2). Karst parent materials dominate, particularly in the southwest. These Karst soils are susceptible to erosion which has affected the development of silvicultural practices. Clearcutting was banned in Slovenia in 1949, and present silviculture consists primarily of selection and irregular shelterwood systems (Table 2). In the 1960s, Dušan Mlinšek, from the University of Ljubljana, introduced the irregular shelterwood system from Switzerland. Much like neighboring Croatia, the coastal forest along the Adriatic was deforested centuries ago. The successful restoration of these sites (Kranjc 2009) has resulted in many even-aged stands that are transitioning to more diverse stand structures.

Because of its proximity to central European forestry universities in Austria, Germany, France, and Italy, Slovenia has historically had high levels of interaction, particularly when it was part of Austria. However, regulated selection silviculture (i.e., Hufnagl and Schollmayer approach) developed independently in Slovenia at about the same time as in other regions in the late 19th century (Bončina 2011). The potential for erosion and the vast extent of beech-dominated forests in the Kočevje region of southern Slovenia was an apparent catalyst at the end of the 19th century for the selection system developed by Leopold Hufnagl. His method was improved by Schollmayer, who introduced the "check or control method" of forest management in Postojna region (Gašperšič 2008). Hufnagl, who was educated in Vienna, developed a system where stocking in uneven-aged stands was controlled by diameter classes where initially uncut forests were used as a target diameter distribution (Mlinšek 1972, Bončina 2011). Hufnagl's method spread outside Slovenia to Croatia and Bosnia, and as far as Turkey.

Forests in Slovenia are divided into compartments, which represent stable units for long-term planning. Subcompartments and stands, within compartments are more flexible management units. Forest planning is conducted by a state-supported public forest service. Harvest levels can exceed planning levels providing more flexibility than in most countries in the region.

Turkey

The Thrace part of Turkey is relatively flat and dominated by broadleaved forests, particularly oak and Oriental beech mainly along the Black Sea, and oak sp. and Calabrian pine (*Pinus brutia* Ten.) in the south. Around 1960, Turkey switched from primarily even-aged systems to selection systems. Initially, Biolley's control method was used, but in 1963 Turkey switched to Hufnagl's method. Soon thereafter, selection silviculture was abandoned and is not in common use at present, except for fir species included in Anatolian

region of Turkey. In addition to the influences of Biolley and Hufnagl, there was a strong German influence on silviculture and forest planning in Turkey. Fikret Saatçioğlu, the founder of modern silviculture in Turkey, completed his forestry education in the 1930s at Munich University and is credited with developing silviculture for Turkey's unique tree species.

Coppice culture and shelterwood systems dominated in the past (Table 2). Beginning in 2006, nearly all coppice forests are being converted to high forests. Currently the shelterwood method is still the main silvicultural system, except for Calabrian pine which is often clearcut followed by spreading of cone-bearing branches on the regeneration area. There is also some clearcutting associated with conversions of degraded sites to productive forests (Boydak and Çalışkan 2014).

Forest planning has been centralized but recently shifted from Ankara to several regional offices. Turkey's new planning model called as Ecosystem Based Functional Planning is attempting to integrate demands for wood as well as other uses and environmental concerns (Zengin *et al*. 2013). An emphasis on timber production is apparent in the 2016 plans for Thrace where all productive and suitable forest lands were designated as industrial forest plantations sites for Calabrian and black pines with thirty years rotations.

SYNTHESIS

Southeastern Europe has been one of the most turbulent regions in the world over the past several centuries. The conflicts, migrations, occupations, religions, nationalities, economic systems, political systems, and many languages all affect land use, including forestry. There are also steep environmental gradients across the region that interact with cultural factors to influence forestry. All of these factors have interacted to drive the types and frequencies of different types of silviculture across the region. Despite the often tumultuous history of this region, it includes some of the more pristine forests, in places like the Dinaric and Carpathian mountains, in all of Europe. It also includes degraded forestlands such as the over-grazed maquis communities along the Mediterranean and extensive areas of coppice forests, but also excellent examples of uneven-aged forests, managed in this manner for decades.

In recent conflicts, and perhaps throughout the history of this region, the forests of southeast Europe have served as a refuge for persecuted groups and resistance movements (Hehn 1971). For many countries in this region, these forests therefore have a traditional spiritual or emotional importance that affects current management and the value of forests for current residents. For example, during World War II, forests were a refuge for people in Bosnia and Herzegovina, afterwards there was a strong emphasis on using single tree selection to maintain the complex structures that were capable of serving as refuges (Hehn 1971).

Coppice forests may be the most common harvest treatments across the region (Zlatanov and Lexer 2009). For example, coppice culture comprises the majority of silviculture in Greece, Kosovo, Macedonia, and Serbia, and nearly half in Albania, Bulgaria, and the European part of Turkey (Table 2). This is the result of a combination of economic, historical, and environmental conditions since fuelwood is of great importance in these countries, but also because of the prevalence of forests that include oaks and other sprouting species (Mazzoleni *et al*. 2005, Stajic *et al*. 2009). Even-aged systems are also common across the region: even-aged stands result from both intentional even-aged culture, and from regrowth following agricultural land abandonment or restoration efforts on degraded sites. Although management for increased forest complexity is a current international trend (O'Hara 2016), in southeast Europe there has been a long-standing tradition of natural forest management. Hence there is widespread and long-term interest in silviculture to encourage and maintain more heterogeneous stand structures and using different forms of selection systems.

Countries may have similar environmental conditions but different silviculture due to restrictions on forest practices, political factors, or history. For example, historical linkages between central Europe and the countries such as Slovenia and Croatia, that were less affected by Ottoman rule, resulted in stronger connections. Some countries in southeast Europe have moved from state-controlled to market economies in recent decades. The forestry sectors have often been maintained under centralized planning agencies with control over national forest planning and management. These central planning models result in the development of rules, harvest levels, and selection of silvicultural activities by government branches with little contact with local landowners or stakeholders. This has resulted in missed expectations and forest degradation in some countries due to over-cutting, forest removal, or over-grazing by livestock. For example, after land restitution in Romania, around 300.000 ha of forest land belonging to small private owners were illegally cut due to inefficient state control and the lack of financial incentives for sustainable management on small holdings (World Bank 2000).

Alternatively, there have also been changes in forest policy in some countries in the last century that limited harvests or grazing, and resulted in large increases in standing volume. Central planning models also discourage experimentation with new silvicultural approaches thereby exacerbating differences in silviculture between countries where different rules may affect silviculture in similar or adjacent forests. A related issue arose from the restitution that followed the socialist period in some countries. These sudden changes in land ownership overwhelmed existing administrative abilities under these central planning models. In Romania management of forests must be carried out by specialized administration entities (i.e. forest districts) authorized by the national forest authority (Stancioiu *et al*. 2010). Additionally, ten-year management plans approved by the national forest authority are required for ownerships larger than 10 ha. When forests were restituted during a period of economic hardship and weak political framework, new owners sought short-term economic goals (Nichiforel and Schanz 2011) rather than sustainable management. Hence the central planning models common in this region have not always been sufficiently capable of responding to recent changes.

Selection systems are not a major component of silviculture in the southeast Europe region (Table 2). However, these varied systems – that result in multiaged stands (O'Hara 2014) – were a primary focus in this analysis because they use procedures that are often refined and developed through local experience or are easily identified because they were transferred between regions and countries. Hence they provide insights into how silviculture has developed that are not possible with many even-aged systems, particularly plantations.

The sharing or dispersion of silviculture ideas and technologies often occurs over political boundaries because of international exchanges of scientists or managers. Two prominent individuals who were credited with the development of selection silviculture were Henry Biolley in Switzerland and Leopold Hufnagl in Slovenia (Schütz 1994, Bončina 2011, Schütz *et al*. 2012). Their influence on selection silviculture in southeast Europe was also apparently independent of each other. The Serbian Žarko Miletić worked with Biolley in Switzerland and was credited for introducing the "check system", a system focused on a consistent reverse-J diameter distribution, to a major part of Yugoslavia. In Bosnia-Herzegovina, Vasilije Matić, a professor at the Faculty of Forestry in Sarajevo, introduced new management systems during the 1960s and 1970s. He was also credited with development of the national forest inventory in Bosnia (Matić 1964), based on the Swedish national inventory system. Hufnagl's influence was primarily in Slovenia, Bosnia and Herzegovina, and Croatia (Bončina 2011), but also in Turkey. Similarly, the introduction of the irregular shelterwood, or Femelschlag, system in southeast Europe is credited to the Slovene Dusan Mlinšek around 1960 who was also one of the founders of the close-to-nature silviculture movement (Mlinšek 1972, 1996). Another important figure was Hans Leibundgut, the Swiss silviculturist, who was influential in southeast Europe in the 1960s and 1970s and a leader in the development of alternative silvicultural systems (Bachmann *et al*. 1994). Leibundgut directed Mlinšek's Ph.D. work as well as the work of Spyros Dafis, a prominent Greek silviculturist. The dispersal of ideas related to silvicultural practice is an important means of expanding knowledge and improving practices. However, the dispersal of ideas and technology appears to be more limited by political boundaries and their effects on silvicultural practice than by ecological factors.

Forest access and transportation systems are critical variables that have affected the historic exploitation of forests and their current level of use. Forests near communities were always the first to be used. Forests in parts of the Carpathian and Dinaric mountains were remote and largely inaccessible until later. Forests on fertile land suitable for agriculture were often converted to agriculture. For Bosnia and Herzegovina, Begović (1985) described exploitation during the Ottoman Empire as primarily close to settlements. Later, during the Austrian-Hungarian Empire and the Kingdom of Yugoslavia, exploitation expanded into mountainous forests. Similar patterns of land use occurred through the region. These ancient patterns of land use affect current forests and their management. Forests near communities that are dependent on wood for fuel will often use coppice systems whereas the remote areas will often be managed with objectives to retain complex structures. However, forests near communities are more likely to be privately owned and remote forests owned by the state. There are efforts to convert coppice forests to high forests, but these are limited to the areas where cutting can be controlled. The availability of alternative energy sources is also a factor in movement from coppice systems. In Turkey, availability of natural gas to cities and towns has been a major factor influencing conversion of coppice forests to high forests (Şahin 2014). Roads are a necessary component of modern forestry. They provide access for multiple forest uses and for timber extraction. Current management is therefore dependent upon these road systems. The intensive selection systems practiced in Croatia and Slovenia, for example, would not be possible without roads. Forest accessibility varies across southeastern Europe due to historical land use, current land use, and the feasibility of road construction and maintenance costs. It also is a primary factor affecting silviculture (Table 2). Hence, infrastructure to support silvicultural activities is often the result of decades and centuries of land use history, establishing traditions in land use management that affect contemporary silviculture.

Forestry education is an important means to maintain forestry traditions and introduce new ideas and science. Most of the countries of southeastern Europe have forestry education programs dating to the first half of the 20th century and these programs largely exist today. In Bulgaria, a forestry program was established at the University of Sofia in 1923, and in its present University of Forestry in 1994 (Milev *et al*. 2010). The school at Thessaloniki, Greece was founded in 1927 after 10 years in Athens. A forestry program was established in the University of Thrace (Greece) in 1999. Under the Austrian-Hungarian Empire, a forestry program was initiated in Zagreb, Croatia in 1898. The The Kingdom of Serbs, Croats and Slovenes, which was renamed into Kingdom of Yugoslavia in 1929, initiated a forestry program in Belgrade in 1920. After World War II, programs were initiated in Ljubljana, Sarajevo, and Skopje between 1947 and 1948 in the Socialist Federal Republic of Yugoslavia. An additional program was initiated in Banja Luka, Bosnia and Herzegovina in 1992. Kosovo and Montenegro do not have forestry schools. Albania has a program at the Agricultural University of Tirana established in 1951. Ankara Higher Education Institute was Turkey's first forestry program in 1934 but closed in 1948. After this closure, the Faculty of Forestry joined Istanbul University, where they succeeded a program taught in French established in Istanbul in 1857. In Romania, the programs were started in 1948 (Brasov) and 1990 (Suceava), having succeeded an older program in Bucharest dated to 1883 (Giurescu 1976). However, in recent decades an additional six programs have been started in Romania. With the exception of the recent surge in Romania, forestry programs throughout southeast Europe have remained relatively stable for the past 50 years despite the turmoil and political changes that have occurred in the region. Forestry education plays a critical role in formulating and transferring technologies and influencing silvicultural, although probably less important than many other drivers (Table 1). Historically, connections

between universities in this region – particularly those within the former Yugoslavia – and between this region and central Europe, have promoted interaction and sharing of technologies.

Silviculture may also become bound by tradition. Inertia may develop for using existing practices rather than exploring new options because change incurs costs such as for training and new operations. Some of these trends can be traced to factors such as education, regulations, or the pedigrees of leading silviculturists. Foresters are also, by nature, conservative given the long time scales inherent to managing slowly-changing resources. Making changes is often very difficult and, in combination with political or economic restrictions, may inhibit silvicultural development at different rates in neighboring countries.

Although even-aged systems are relative common, the plantation culture characterized by intensive management of single-species stands on relatively short rotations that has developed in other regions in the world is not common in southeast Europe (Table 2). Instead, management of high forests has focused on retaining more complex structures. Coppice forests are primarily used to meet local demands for fuelwood because of the economic efficiency of the coppice system. The influence of preeminent silviculture leaders from central Europe may have been a key variable in the range of silviculture, primarily in the northern countries (Table 2). However, industrialization and mechanization of forestry may lead to changes in silvicultural systems towards regularity.

Nearly all countries in southeast Europe have strong central planning models for forestry due, in part, to their socialist histories and the need to improve degraded forests in the late 20th century. Although strong central planning models may limit flexibility or adaptive management approaches and possibly hinder the advancement of silvicultural practices, this was not evident across the entire region. Instead, some countries, such as Croatia and Slovenia, have more silvicultural flexibility than others due, in part, to strong monitoring programs that were linked to planning. These examples may be cases where the proximity to central Europe and the reduced influence of the Ottomans were factors in how forestry was approached.

CONCLUSIONS

Historical and cultural factors have affected silviculture in a variety of ways that may, or may not, cross the political boundaries that currently or historically have divided ecosystems. The variation in silviculture across the southeastern Europe region demonstrates a complexity that is due to far more than simply being a function of management objectives and site conditions. Instead, this region is characterized by a long history of forest land use that has affected current forests and their management. Important drivers that have affected silviculture include economic health of regions/countries, politics, general resistance to change, the tendency for central planning in the region, and relationships with other countries outside this region.

There have been several centuries of exchange between central and southeastern Europe. Looking forward, the effect of modern communication systems and increasing inclusion of southeastern European countries into the European Union may reduce political and cultural barriers between countries and encourage cooperation which may result in greater similarities in silvicultural practices across the region. For example, EU support of road infrastructure may encourage more selection systems across the region. If this is indeed a step toward achieving the best silviculture, protocols to enhance regional and international cooperation and sharing should be encouraged.

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