Reforestation challenges in Southeast Europe facing climate change

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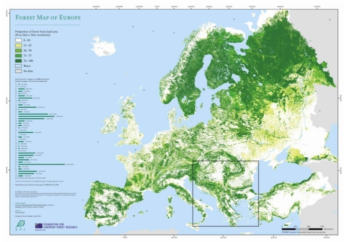

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Abstract

Projections of the regional climate model for Southeast Europe generally predict an increasing of temperature and a decrease in precipitation, with some local variations. Higher frequency of extreme weather events and increased flooding can also be expected. This climate change will, among other things, result in changes in habitats and species distribution, and a decrease in biodiversity. In most cases, forest ecosystems will be unable to adapt fast enough to keep pace with changes in climate. Extreme weather events and low precipitation during the growing season will cause high mortality of seedlings after planting. New forests will face the whole range of these changes because of the long lifetime of trees. Reforestation programs must take projections of climate change into consideration. In the long term, new guidelines for site-species matching, provenance selection, and genetic diversity need to be adopted. In the short term, site preparation, planting techniques, and post planting protection need to be improved. In addition, seedling quality (morphological, physiological, and genetic) and planting time need to be specific for each site. New site preparation, planting, and post-planting protection methods are useful tools for short term success measured in seedling survival and initial growth. Seedling quality is essential for short and long term success. Different strategies, such as assisted migration and increased genetic diversity of planting material, can provide better chances for long term success measured in growth, fitness, and capability to produce the next, better adapted generation.

Keywords

Climate Change, Assisted Migration, Seedling Quality, Planting, Seedling Protection, Seedling Field Performance

Contents

1 Introduction

Reforestation challenges are many. Except in industrial plantations, we are witnessing a global trend of reduced investments in reforestation. Overexploitation, land-use politics, forest fragmentation, and urbanization are threats to existing forests. In addition to the human factor, we are witnessing more frequent extreme weather events, the conquest of habitats by invasive tree species, migration and areal spread of pests and diseases, and the maladaptation of tree populations transferred to new sites.

Afforestation, reforestation, and deforestation avoidance are three types of climate change mitigation projects in the forestry sector (Reyer et al. 2009). Facing climate change, future management plans need to integrate adaptation and mitigation approaches (Millar et al. 2007). Climate change mitigation is not a part of this review and we will focus on management approaches available in changed climate. In changed climate, a number of adaptation strategies are available, and need to be involved in current and future afforestation/reforestation projects. Forest tree populations can extirpate in a rapidly changing environment or can persist thorough migration or adaptation (Aitken et al. 2008). “Migration and adaptation are considered as alternative responses to environment changes because evolution allows populations to adapt to novel conditions without migrating, whereas migration lets populations track favorable conditions without evolving” (Kremer et al. 2012). Reforestation and restoration programs facing climate change need to consider and to promote both strategies.

Looking into the future, climate change and the uncertainty of the environment following this change will be the most important challenges to reforestation success. It is the regeneration phase that will initially be susceptible to the changed climate (Spittlehouse and Stewart 2003) and additional efforts need to be invested in artificial regeneration of forests. To improve reforestation success, selection of species and genetic material as well as nursery cultural practices must focus on overcoming planting stress on harsh restoration sites. This can be done by enhancing the ability of seedlings to withstand drought, frost, vegetative competition, nutrient deficits, and animal damage (Jacobs et al. 2015). Additionally, planting techniques (pre planting, planting, and post planting operations) need to be improved in order to provide better chances for seedlings to survive the critical establishment phase.

The Southeast Europe (SEE) region ranges from sea level at coastal areas and plains, to river valleys, karstic area, and high mountains, resulting in rich biodiversity and natural resources. Many SEE regions belong to the areas of Europe most vulnerable to climate change, where we can expect the highest future impacts of climate change to ecosystems, with associated impacts on biodiversity (Laušević et al. 2008).

In this paper, we review the scale of reforestation in SEE, discuss theoretical predictions of climate change and its potential influence on reforestation success, and finally review the literature on seedling production and planting strategies and actions as a response to challenges presented by climate change. Seedling survival after field planting is a keystone to any reforestation project. This short-term success can be diminished in subsequent decades due to changing environment, especially when mistakes occur in the planning phase. This is why, following our review on challenges, we first pay attention to long-term actions that promote short-term success during the seedling establishing phase.

1.1 Definitions – The frame

SOUTHEAST EUROPE: SEE is defined in different ways, geographically and politically. For this review, SEE includes: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, the Former Yugoslav Republic (FYR) of Macedonia, Montenegro, and Serbia (Fig. 1). This covers all countries of the Southeast Forest Country Group (Forest Europe 2015) except Slovenia and Turkey.

REFORESTATION, AFFORESTATION, AND ARTIFICIAL REGENERATION: Definitions for the terms of reforestation, afforestation, artificial regeneration are used differently in different disciplines and areas of research. For the purpose of this review, keeping in mind that all of these terms result in planted forests (Ivetić and Vilotić 2014) we will refer to these terms the same, as reforestation.

CLIMATE CHANGE AND EMISSION SCENARIO: For this review, we adopted definitions on climate change and emission scenarios from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Climate (IPCC 2014). We adopted A2 as one of the extreme scenarios with upper limits of human-induced global warming (up to 250% more greenhouse gas emissions in year 2100 compared with the reference period 1961-1990).

SEED SOURCE: Trees within an area from which seeds are collected (OECD 2015).

ORIGIN: For an indigenous seed source or stand, the origin is the place in which the trees are growing. For a non-indigenous seed source or stand, the origin is the place from which the seed or plants were originally introduced (OECD 2015). The origin of a seed source or stand may be unknown.

PROVENANCE: The place in which any seed source or stand of trees is growing (OECD 2015).

SEED ZONE: Geographically delineated areas within which seed can be transferred with little risk of loss of productivity and forest health issues due to maladaptation (Bower et al. 2014).

REGION OF PROVENANCE: For a species or sub-species, the Region of Provenance is the area or group of areas subject to sufficiently uniform ecological conditions in which stands showing similar phenotypic or genetic characters are found (OECD 2015).

FOREST REPRODUCTIVE MATERIAL: This includes any material that can be used for reforestation: seeds (cones, fruits and seeds that are intended for the production of plants), parts of plants (stem-, leaf- and root-cuttings, buds, scions, layers, and any parts of a plant that are intended for the production of plants), and intact plants (plants raised by means of seeds or parts of plants; also includes plants from natural regeneration) (OECD 2015).

1.2 Reforestation in Southeast Europe – The stage

According to the global forest resource assessment (FAO FRA 2015), the total forest area in SEE countries is 17.3 million ha, with forest cover rate ranging from 28% in Albania to 62% in Montenegro (Fig. 1, Tab. 1).

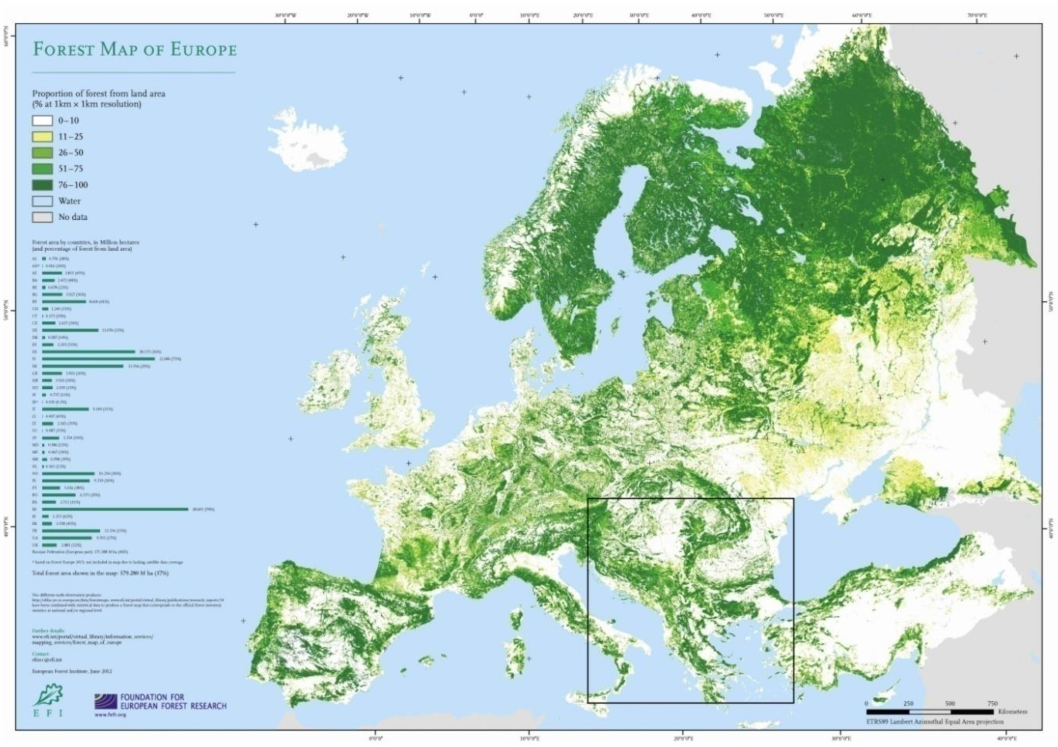


Figure 1. Forest cover rate in Europe – SEE is in square (adapted from Gunia et al. 2012 – permission by authors): http://www.efi.int/portal/members/membership_service/benefits/forest_map_of_europe

Table 1. Forest cover rates and afforested/reforested areas in SEE countries (Source: FAO FRA 2015).

Country	**Forests**		**Afforestation (1,000 ha)**				**Reforestation – artificial (1,000 ha)**			
	Area (1,000 ha)	**Cover rate (%)**	**1990**	**2000**	**2005**	**2010**	**1990**	**2000**	**2005**	**2010**
Albania	772	28.2					2.9	0.1	0.2	
Bosnia and Herzegovina	2,185	42.8								
Bulgaria	3,823	35.2	5.8	2.7	6.0	0.3	20.3	4.1	2.8	2.3
Croatia	1,922	34.3	1.6	0.8	0.5	0.9		0.7	0.6	1.5
Greece	4,054	31.5								
FYR Macedonia	998	39.6					4	1.8	1.3	
Montenegro	827	61.5				0.2				0.1
Serbia	2,720	31.1	12	1.7	1.1	2.1				0.2
TOTAL	**17,301**									

Except Serbia and Greece, the area of planted forests in all SEE countries has decreased during the last 25 years (Tab. 2). These data should, however, be used cautiously. For example, in Serbia, comparing the FAO assessment with the last national forest inventory (Banković et al. 2009) showed a similar total area of planted forests; but positive trend with an inconceivable increase in the area of planted forests during the last 10 years. Similar caution should be used when examining trends on planted forests in Bosnia and Herzegovina and FYR Macedonia.

Table 2. Trends of forest planting in SEE countries (Source: FAO FRA 2015).

Country	Planted forests (1,000 ha)	Portion in total forest area (%)	Planted forests (1,000 ha)					Trend
			1990	2000	2005	2010	2015	
Albania	90	11.7	103	96	98	94	90	-0.5
Bosnia and Herzegovina	999	45.7	1,043	999	999	999	999	-0.2
Bulgaria	1,600*	29.3*	1,032	933	874	817		
Croatia	75	3.9	92	81	76	70	75	-0.8
Greece	140	3.5	118	129	134	140	140	+0.7
FYR Macedonia	105	10.5	105	105	105	105	105	0
Montenegro	8	1				8	8	
Serbia	215	7.9	39	39	39	180	215	+7.1
TOTAL	**3,232**							

*Ionov et al. 2000

2 Climate change – The challenge

2.1 Range

The climate of SEE ranges from subtropical to continental, with a temperature range from 2 to 25°C and a precipitation range from 19 to 7,000 mm (Tab. 3). Precipitation levels follow a clear annual pattern in Albania, with the maximum in winter and the minimum in summer (Diku 2011). Other SEE countries followed that pattern, except Bulgaria and Serbia, where the maximum precipitation level is in spring and the minimum occurs in summer (Önol and Semazzi 2009).

Projections of the regional climate model for SEE predict an increasing of temperature and a decreasing of precipitation, with some local variations. According to the A2 scenario, the mean maximum temperature across SEE is projected to increase between 2.4 and 7°C. Except for a projected increase in some regions of Serbia of plus 5%, a general decrease of precipitation is predicted for other SEE countries; Croatia may see 54% less precipitation (Tab. 3). According to projected simulations, the maximum decrease of precipitation (in percent) in all SEE countries will be in summer (Önol and Semazzi 2009), which will significantly increase the fire risk in SEE and Mediterranean areas (Moriondo et al. 2006).

Table 3. Current and projected (A2 scenario) climate in SEE.

Country	Latitude	Altitude		Current		Prediction for 2100	
	(°)	(m)	Climate	T	P	Tp	Pp
Albania	39-43	0-2,764	S to M	7-16	600-3,000	2.9-5.3↗	-16.2 to -8.8
Bosnia and Herzegovina	42-46	2,386	M to C	2-20*	800-2,000	2.6-6.9↗*	-2.2 to - 50.5*
Bulgaria	43	2,925	M to C	2.8-22.5*	500-2,500	2.8 to 3.2↗	-3.9 to -37.3*
Croatia	42-47	1,831	M to C	3-17	300-1,200	2.7-7↗*	-2.7 to -53.7*
Greece	34-42	2,918	M to A	6.6-25.3*	19-316*	2.4-5.6↗*	-9.2 to -48.8*
FYR Macedonia	40-43	2,764	M to C	8-15	400-1,000	2.7-5.4↗	-5 to -21
Montenegro	41-44	2,534	M to C	5-16	800-7,000	1.6-3.4↗	-10 to -50
Serbia	41-47	17-2,169	S to C	3-13	600-1,000	2.4-3.8↗	-15 to 5
RANGE	**34-47**	**0-2,925**					

*(Önol and Semazzi 2009)

Abbreviations: S – subtropical, C – continental, M – Mediterranean, A – alpine, T – temperature (°C), P – precipitation (mm), Tp – predicted increase of temperature (°C), P – predicted change of precipitation (%).

In addition to the significant increase of air temperature and decrease in precipitation, the biggest challenge to reforestation success will be the frequency, duration, and severity of extreme weather events. Further decreases of precipitation during summer, which already sees the minimum precipitation levels, will further increase chances for drought. We may already be witnessing some of these extreme events. From years 1958 to 2000 in the Eastern Mediterranean, the most significant temperature trends were revealed for summer, where minimum and maximum temperature extremes show statistically significant warming trends, together with increasing trends for an index of heat wave duration (Kostopoulou and Jones 2005). Out of seven events of the most relevant heat waves that hit the Carpathian Region (including Serbia and Croatia) from years 1961 to 2010, four occurred from 2000 to 2010 (Spinoni et al. 2015). Summer 2007 was abnormally warm for many areas of SEE with deviations from the seasonal means exceeding 4°C in some areas but also distinct periods of extremely hot weather (Founda and Giannakopoulos 2009). During summer 2007 the maximum temperature reached 44.9°C, the record value ever recorded in Serbia (Hydrometeorological Service of Serbia 2015) since regular measurements started in 1848. In year 2011, only 65% of normal, average precipitation for the period 1971-2000 was recorded in Serbia (Ivetić 2015). The summer of 2012 was very hot and dry in SEE (Sippel and Otto 2014). At 19 main meteorological stations in Serbia (of 29) the summer of 2012 was the hottest since measurements began (Hydrometeorological Service of Serbia 2013). In spring 2014, heavy rains caused floods and landslides in Serbia and Bosnia and Herzegovina, resulting in loss of human lives and severe damages to infrastructure and habitats. Hydrometeorological hazard has changed in SEE including a distinct increase in the frequency of summer heat waves (Sippel and Otto 2014).

2.2 Space and time – The race

Following climate change, the current environmental conditions on which forest populations are adapted will move northward and upward (Ledig and Kitzmiller 1992; Loarie et al. 2009; Gray and Hamann 2013). These changes are expected to be faster than ever before (Kirschbaum and Fischlln 1996). The main concern is that migration of forest populations and genes cannot keep the pace with these changes.

The SEE region lies between latitudes 34° and 47° N, with a distance from south to north of approximately 1,100 km. Elevation ranges from 0 m by the coastline to 2,925 m at Musala peak in Bulgaria. Large mountain ranges running from north-west to south-east cover most of the region. In the southern part of the region, evergreen vegetation is predominant, whereas in the north, oak and beech forests are dominant at lower elevations with spruce, fir, and pine in the mountains. Tree line rises from 1,800 m in the north to 2,300 m in the south.

With projected warming of between 0.1 and 0.35°C per decade, tree species would have to migrate 1.5-5.5 km northward per year or to increase elevation by 1.5-5.5 m per year in order to remain within similar climatic conditions (Kirschbaum and Fischlln 1996). Many studies of past changes have estimated natural rates of migrations of trees ranging from 1.26 to 1,000 m per year (Tab. 4).

Table 4. Natural range of tree migrations.

Range ($m \cdot yr^{-1}$)	Method	Notes	Source
1.26	Forest Inventory		Bodin et al. 2013
22-57	Forest Inventory	*Quercus ilex* L.	Delzon et al. 2013
<100	Chloroplast DNA surveys		McLachlan et al. 2005
130	Numerical model		Lazarus and McGill 2014
180	Fossil pollen data	*Fagus grandifolia* Ehrh.	King and Herstrom 1996
156		*Tsuga canadensis* (L.) Carrière	
100-200	Model prediction		Iverson et al. 2004
60-260	Macrofossil and palaeoecological	From northern refugia	Feurdean et al. 2013
115-550		From southern refugia	
<250	Current haplotype distribution	*Abies alba* Mill.	Cheddadi et al. 2014
>700	Fossil pollen alone		
500-1,000	Palinological records		Kremer 2010
1,000	Forest inventory		Woodall et al. 2009

The maximum migration distance during a given time period depends on: 1) number of dispersal events in that time period and 2) distance covered by each event (Corlett and Westcott 2013). On one hand, the rate of present-day tree migrations is frequently slower than expected (Renwick and Rocca 2015). Bodin et al. (2013) found that only 2 out of 31 tree species studied were migrating fast enough to keep pace with temperature changes. On the other hand, estimates on long distance gene flow suggest that genes can move over spatial scales larger than habitat shifts predicted under climate change within one generation (Kremer et al. 2012).

Estimations on speed of climate changes and migration rate of tree species vary depending on input data and methodology. From the literature, we conclude that most tree species in SEE will not be able to keep pace with climate change under current scenarios. The region's geography is one obstacle to migration of tree species. Even if the Carpathian Mountains provide a natural corridor for migration to the north-east, the Pannonian Basin is an obstacle for migration of mountain tree species northward. Additional obstacles will include habitat fragmentation, unsuitable soil conditions (both depth and nutrients), and absence of beneficial microorganisms, such as mycorrhizae.

3 Long-term strategies – Theoretical actions

3.1 Goals and objectives: Site specific or species specific projects?

Setting the right goals and choosing an appropriate strategy to achieve them is essential for long-term reforestation success. In this sense, we need to distinguish site specific from species specific projects. Preserving a forest at a specific site will differ from translocation of specific species for conservation purposes. The main difference is that in site specific projects we need to match appropriate species and provenance with the focal site, whereas in species specific projects we need to find the best site for focal species. Although both types of projects rely on site-species matching, tools and available materials differ.

3.2 Site-specific projects

Site specific projects generally occur when the goal is afforestation of bare land or reforestation following harvesting or disturbances such as forest fire. Artificial or assisted natural regeneration also can be considered as site specific projects. In these types of projects, selection of the most appropriate species is essential for success and the only way this can be properly done is by investigating all environmental conditions on the site at the very beginning.

Despite a wide range of forest functions, the main goal of a site specific project can be prevailing productive, conservative or ameliorative. However, the uncertainty of future conditions will bring these goals closer together. The main goal determines the selection of appropriate planting material (species, provenance, level of genetic diversity).

In the case of a productive goal, the new genes (species, provenances) can be introduced with the aim to exploit the focal site production capacity to the highest amount. Many examples show higher productivity of non-local provenances (Schmidtling and Myszewski 2003; Ivetić et al. 2005; Krakowski and Stoehr 2009) and non-native species (Heryati et al. 2011; Kawaletz et al. 2013; Guo and Ren 2014; Kjær et al. 2014) compared to local populations at a specific site. Non-native species could play an important role in cases where they provide short-term benefits to ecosystem function and promote the potential for longer-term succession to native species, but this practice is controversial and debated vigorously (Thomas et al. 2014; Jacobs et al. 2015).

In the case of a conservative goal, the goal, priority is to maintain the existence and sustainability of the forest ecosystem. The usual practice is to reintroduce the same species using local forest reproductive material because that material is best adapted to the local conditions. Maintaining the current state or restoring a previous forest composition will be difficult in a changing environment. This is why the primary objective of forest restoration should be focused on functional ecosystems at the landscape level (Stanturf et al. 2014).

In case of an ameliorative goal in SEE, degraded forest is usually removed by a clear-cut harvesting and traditionally planted with fast-growing pioneer species (usually *Pinus nigra* Arnold) with a goal of facilitating the introduction of late-successional hardwoods (Stilinović 1991). Plantations established on sites more productive than that actually needed to support *Pinus nigra* are characterized by rapid succession dynamics of mainly broadleaved species (Zlatanov et al. 2010).

3.2.1 Species selection

Most forest sites can support more than one tree species, which allows selection of the best species to meet project goals. Species selection in a reforestation project is a complex decision that should be based on site conditions, environmental issues, economic criteria, and climate change predictions. “Species choice in large-scale reforestation programs should be determined by the maintenance of the realized niche under most climate change scenarios, avoiding potential exposure of forest trees to pests and diseases under a continued warming trend” (Gray and Hamann 2011).

Species biological characteristics should be considered as well. For example, the water-acquisition strategy of tree root systems can determine the survival capacity under severe drought. Deep-rooted species are highly recommended for reforestation in dry conditions, even under low soil water availability (Ovalle et al. 2015). The hydric model of plant water use behavior is potentially useful in selecting appropriate species in arid to semi-arid conditions (Kjelgren 2010). *Quercus ilex* trees, which showed a more anisohydric behavior, replace *Pinus sylvestris* L., which showed a typical isohydric behavior in a montane Mediterranean forest in association with recent episodes of drought-induced mortality (Aguade et al. 2015).

Table 5. Heat degrees (coordinate E) as combination of slope and aspect (Lujić 1960).

Aspect	Slope (%)	Coordinate E	Aspect	Slope (%)	Coordinate E
N	0-7	7	**NNE, NNW**	0-12	7
	8-23	6		13-29	6
	24-38	5		30-44	5
	39-55	4		45-65	4
	56-75	3		66-90	3
	76-107	2		91-133	2
	108-183	1		134-173	1
NE, NW	0-18	7	**ENE, WNW**	0-25	7
	19-36	6		26-55	6
	37-58	5		56-93	5
	59-90	4		94-148	4
	91-133	3		149-173	3
	134-173	2	**ESE, SSW**	0-143	7
E, W	0-47	7		144-173	6
	48-119	6	**SSE, SSW**	0-14	7
	120-173	5		15-173	8
Flat	0	7	**S**	0-12	7
SE, SW	0-13	7		13-51	8
	14-52	8		52-107	9
	53-60	7		108-173	8

Table 6. Heat degrees (coordinate V) based on altitude (Lujić 1960).

altitude	0-199	200-399	400-599	600-799	800-999	1,000-1,199	1,200-1,399	1,400-1,599	1,600-1,800
coordinate V	9	8	7	6	5	4	3	2	1

In Serbian reforestation programs, species selection is usually based on: 1) potential vegetation, 2) ecological differentiation, and 3) local heat potential. Species selection based on potential vegetation is limited to a small area with uniform environmental conditions. This method requires recognition of natural vegetation in nearby surroundings and reconstruction of potential natural vegetation at the focal site (Tomić et al. 2011). Species selection based on ecological differentiation is multidisciplinary approach relying on basic forest types — ecological units (Jović et al. 1998) — defined by three coordinates: dominant species, current vegetation, and soil properties. The local heat potential combines heat coordinates of slopes/aspects and altitude (Lujić 1960) and is usually used for afforestation of bare lands. The first heat coordinate (E) covers all possible combinations of slope and aspect, grouped in nine heat degrees, according to total annual sum of solar radiation (Tab. 5). The second heat coordinate (V) depends on altitude, with coldest sites on tree line (Tab. 6). As the result, the coldest sites will have values of coordinates of 1,1; and the warmest site will have combination of 9,9. When local heat potential is defined for focal planting site, it is necessary to find sites with the same local heat potential and natural vegetation. It is assumed that the dominant tree species at site with similar value of local heat potential will be well adapted for focal planting site.

Species selection is even more complicated when establishing mixed forests. For species with similar light requirements, small climate-induced differences in sapling growth can lead to significant differences in future species composition, but in mixtures of species with different light requirements, shade-tolerance has a more decisive effect (Ameztegui et al. 2015). In order to offer some tool for species selection, a hybrid Delphi-AHP methodology is proposed for species selection for reforestation in the Mediterranean region of Spain, which provides an optimal percentage distribution of the appropriate species to be used in reforestation planning (Curiel-Esparza et al. 2015).

3.2.2 Provenance selection

Long-term reforestation success depends on appropriate seed source (provenance) selection. Variation between populations may be clinal or ecotypic and knowledge on pattern of variation is important for seed transfer. Forest tree species are highly heterozygous and the most of total genetic variation can be found within populations (provenances). Provenances can, however, respond differently to climate change. *Pseudotsuga menziesii* (Mirb.) Franco growth response to climate change was dependent on seed source climate, with the mean temperature of the coldest month as the most sensitive indicator (Leites et al. 2012). The same study showed that all populations had optimum height growth when transferred to climates with warmer winters. Population differentiation (with high levels of genetic variation within populations) along temperature gradients is generally stronger for cold adaptation traits than for other quantitative traits and allozymes, indicating that these traits appear to be under strong natural selection (Howe et al. 2003).

Current seed transfer guidelines are based on the assumption that local tree populations are optimally adapted to environments in which they occur; this does not consider climate. However, this key assumption may no longer be valid (Gray and Hamann 2011). Changing climate conditions will complicate efforts to match seed sources with the site environments to which they are best adapted (Potter and Hargrove 2012). Two approaches for matching provenances to planting site facing climate change are suggested: climate envelope models and empirical response functions.

Climate envelope models compare the climate of seed sources and potential planting sites. Beaulieu and Rainville (2005) proposed a methodology combining a biophysical site index model and a seed source transfer model based on temperature and precipitation for identifying the most productive seed source of *Picea glauca* (Moench) Voss. Gray and Hamann (2011) used bioclimatic modeling and multivariate approaches to identify the best matching seed sources for current and projected climates in Alberta, Canada. Potter and Hargrove (2012) developed quantitative ecoregion outputs in the form of similarity maps that can be used in cases of: 1) unidirectional seed transfer from a given location toward colder climate conditions, and 2) composite provenancing, for finding sources ecogeographically matched to focal site. In their meta-analysis based on long-term growth data of 2,800 provenances transferred to 120 European test sites, Isaac-Renton et al. (2014) used bioclimate envelope models developed for North America to guide assisted migration under climate change to retrospectively predict the success of these provenance transfers to Europe, with partial success. The model was generally successful in predicting the best performing provenances along north-south gradients in Western Europe, but failed to predict provenances with superior performance in Eastern Europe (Isaac-Renton et al. 2014). "An important criticism of bioclimate envelope models is that many wide-ranging species consist of locally adapted populations that may all lag behind their optimal climate habitat under climate change, and thus should be modeled separately" (Gray and Hamann 2013). For 15 wide-ranging forest tree species in western North America, Gray and Hamann (2013) found that on average populations already lag behind their optimal climate niche by approximately 130 km in latitude, or 60 m in elevation. They suggest using a general formula where a 100 km shift northward is equivalent to an approximately 44 m shift upward in elevation to guide assisted migration of planting stock in reforestation programs. This emphasizes the need for knowledge on species genetic variability at the provenance level and the importance for further research on tree species of SEE.

Empirical response functions are based on correlations of quantitative traits with climate variables using climate-response functions. This approach combines genetic and geographic information by analyzing geographic patterns of adaptive and neutral genetic variation. Wang et al. (2010) presented a single "universal response function" (URF), which integrates genetic and environmental effects, to predict the performance of any population of *Pinus contorta* Douglas growing in any climate. They concluded that URF can be used as a mechanistic model to predict population and species ranges for the future and to guide assisted migration of seed for reforestation, restoration, or afforestation and genetic conservation in a changing climate. Hamann et al. (2011) used multivariate regression tree analysis in two case studies for *Populus tremuloides* Michx. and *Alnus rubra* Bong. and concluded that this approach enabled a better-informed subjective decision on how seed transfer should be regulated. Finally, after comparison of the growth performance of the selected best performing populations with URF to populations identified through a climate envelope approach, Chakraborty et al. (2015) concluded that population recommendations based on empirical approaches were preferred.

In addition to matching the provenance to the focal site, many other provenancing strategies have been suggested as response to predicted climate change (Tab. 7). Breed et al. (2012) developed a decision tree for selection of a provenancing strategy (local, predictive, composite, and admixture) based on confidence surrounding climate change distribution modeling and data on population genetic and/or environmental differences between populations. No single strategy is likely to work universally, so selection of provenancing strategy should consider species genetic variation and local adaptation combined with climate projections for focal site.

Table 7. The synopsis on provenancing strategies.

Strategy	Short description	Advantages	Disadvantages	Best to use	Source
Local provenancing	Collection of seeds very close to the focal site. Risk level depends on original population size.	No risk of maladaptation and outbreeding depression. Low failure rates.	Risk of genetic drift. Low production of new genotypes. Conditions driving local adaptation can change.	Where only local populations remain and no large change of distribution is predicted.	Broadhurst et al. 2008; Breed et al. 2012; Sgró et al. 2011
Predictive provenancing	Use of genotypes that are determined to be adapted to projected conditions. Requires data on local adaptation of many populations. Requires climate projections for the target species and planting site.	Low risk of maladaptation, inbreeding depression and outbreeding depression. Low risk of failure if seed source is matched well with predicted environments.	High risk of failure if seed source is poorly matched with predicted environments. Lack of data on local adaptation for most species. Uncertainty of climate change predictions.	For species expressing local adaptation to environmental variables.	Sgró et al. 2011; Breed et al. 2012
Composite provenancing	Mimic natural gene flow patterns by use of seed mixture from populations at various distances to the focal site.	Encourages production of new genotypes, potentially facilitating rapid adaptation to novel conditions.	Using seed from distant source may result in maladaptation to local conditions. Outbreeding depression risk.	Where no significant range shifts is predicted and only small local populations remain.	Broadhurst et al. 2008; Breed et al. 2012
Admixture provenancing	Collection of seeds from wide array of provenances, capturing a wide selection of genotypes from various environments with no spatial bias towards the focal site.	Build evolutionary resilience, by introduction of more additive genetic variation.	Risk of introducing invasive genotypes. High risks of introducing maladapted seed. High risk of outbreeding depression.	Where drastic changes are confidently predicted, but growth data is lacking.	Breed et al. 2012
Climate-adjusted provenancing	Combine genetic diversity and adaptability, targeting projected climate change directions. Collection of seeds biased toward the direction of predicted climatic change, but not exclusive to it.	Enhance climate-resilience of planting material by mixing genotypes from a climatic gradient, including local genotypes as well.	Risk of outbreeding depression. Risk of disruption of local adaptation to non-climatic factors.	Where data on inter-population genetic variation are available.	Prober et al. 2015

In SEE, additional research on genetic variation and local adaptation of targeted species is required, especially for those with small populations and limited or disjunctive ranges. Due to limited area and restricted south to north distances in SEE countries, foresters need to “look over the fence” in search of the best provenance to match with their focal sites. Seed transfer guidelines should allow and encourage movement of forest reproductive material across administrative and state borders.

3.3 Species-specific projects

Although species-specific projects are usually related to industrial tree plantations, we will focus on species translocation for conservation purposes. In these types of projects, the search is for the best site for focal species according to soil characteristics and projections of future climate. Facing climate change, the biggest challenge will be to match species to site, both spatially and temporally. For long-term success, future species and their sites must be selected based on predicted conditions that will support the species, realizing that conditions on those future sites may currently limit seedlings survival.

Species-specific projects often require colonization of new sites and areas where focal species are not currently found. This is possible thanks to fact that for many tree species the fundamental niche (conditions that a species can tolerate) is much larger than the realized niche (conditions where it is naturally established) (Gray and Hamann 2011). Realized niche of trees may be determined by the ability of seedlings to survive, but tree species can be successfully grown on new areas given to cultural treatments (Gray and Hamann 2011), which will be discussed in the section discussing short-term actions.

In SEE, long-lived, rare, geographically and genetically isolated species like *Picea omorika* (Pančić) Purk. and *Pinus heldraichii* H. Christ, are the most vulnerable to climate change. At the worst case scenario for them, the most appropriate sites should be found and colonized in order to prevent their expiration in the following decades.

3.3.1 Assisted migration

Assisted migration has been defined in the literature with number of terms (for detail review see Dumroese et al. 2015). For purpose of this paper, we will adopt definition of the assisted migration as intentional movement of forest reproductive material facing climate change. The practice of transferring forest reproductive material has a long tradition. Seed zones and regions of provenances have been established and seed transfer guidelines developed for most of the important tree species in SEE, but these will need to be adapted to meet projections of future climate change. Assisted migration can occur within a species current range, but species specific projects may require using assisted migration to rescue a species (Pedlar et al. 2012) or to transfer a species just beyond its current range (assisted range expansion) or quite distant from its current range (assisted species migration) as defined by Williams and Dumroese (2013).

Although assisted migration is controversial (Pedlar et al. 2012), its use has already been adopted by some forest administrations. The Canadian provinces of British Columbia, Alberta, and Quebec have altered seed transfer rules to allow assisted migration (Pedlar et al. 2011). Similar to any transfer of forest reproductive material, risks of maladaptation in assisted migration increase with movement distance. This distance can be geographic, climatic, and/or temporal and will depend on goals, the target species and populations, location, projected climatic conditions, and time (Williams and Dumroese 2013). In order to reduce risks, Gray et al. (2011) propose that three conditions should be met before implementing assisted migration in reforestation programs: (1) evidence of a climate-related adaptational lag, (2) observed biological impacts, and (3) robust model projections to target assisted migration efforts.

Assisted migration is an appropriate strategy for facing climate change in the SEE, considering the differences in the pace of climate change and the natural migration of tree species. Large scale assisted migration is unlikely due to limitations in northwards and upwards distances but this strategy should be implemented in a small scale. Legislation changes will be needed to allow and define application of assisted migration at regional level, but these changes need to be supported by more research results for tree species growing in SEE.

4 Short-term tactics – Field actions

The long-term success of reforestation depends on field success of planting material. All long-term strategies and planning are wasted if seedlings fail to survive. Because of that, seedling survival rate is usually used as a measure of initial success of reforestation during the establishment phase (Ivetić 2015). This is why propagation and field establishment techniques must promote survival through seedling stress resistance and site preparation (Jacobs et al. 2015). In this section we offer a review of techniques that can promote seedling survival in SEE reforestation programs.

4.1 Planting material

High quality planting material (genetically, physiologically, and morphologically) improves the likelihood of reforestation success with the uncertainty of changing environments. Selection of planting material for any reforestation program depends on management goals, site conditions, and planting conditions, but unfortunately is too often solely based on the material available in nurseries. Between these selection criteria, site conditions will have a decisive effect on seedling survival. In afforestation projects, environmental conditions at the planting site can be diametrically opposed, e.g. rocky terrain and abandoned agricultural land. In reforestation projects, differences between site conditions are less pronounced, with the largest differences occurring between a mature forest site before and after clear-cut harvesting. Primary ecosystem functions such as energy, hydrologic, and nutrient cycles are altered in transition from climax forest to a clear-cut forest regeneration site (Grossnickle 2000), and this change can increase differences in environmental conditions between sites. These differences in site conditions should define the main goals of nursery production: vigorous, site adapted, and project specific seedlings.

Selection of the appropriate stocktype is important, especially on harsh site conditions. Stocktype basically describes a seedlings' age and production method, but generally production method has the stronger effect on seedlings quality and field performance. In their review on bareroot versus container stocktypes, Grossnickle and El-Kassaby (2016) found that container seedlings have a higher survival in a predominant number of trials (61%) than bareroot trials (15%). However, stocktype had a minimal effect under optimal site conditions (Sloan et al. 1987; South et al. 2005), while container seedlings generally have greater survival and growth on harsh sites (Barnett and McGilvray 1993; South et al. 2005).

The Target Plant Concept (Landis 2011; Dumroese et al. 2016) should be adopted and implemented in reforestation programs in SEE. This means that a project specific definition of seedling quality and nursery culture must be made to produce seedling with attributes that promote field survival and growth. Although physiological attributes can provide more accurate evaluation of seedling quality (Jacobs et al. 2004[a]; Davis and Jacobs 2005), in SEE nursery operation and reforestation programs, a seedling quality assessment is almost exclusively based on morphological attributes.

4.1.1 Morphological seedling quality attributes and field performance

Many studies show the relationship between seedlings morphological attributes at planting time and after planting success (Thompson 1985; Mexal and Landis 1990; Noland et al. 2001; Villar-Salvador et al. 2004[a]; Mexal et al. 2009; Oliet et al. 2009; Grossnickle 2012). Morphological attributes can forecast seedling field performance (Tab. 8) with different reliability and for different numbers of years after planting (Jacobs et al. 2005; South et al. 2005; Tsakaldimi et al. 2012; Ivetić et al. 2016).

Table 8. The synopsis of morphological seedling quality attributes effect on field performance.

Morphological attribute	Effect	Source
Shoot height	Positive.	Kaczmarek and Pope 1993; Dey and Parker 1997; Puertolas et al. 2003; Gould and Harrington 2009; Oliet et al. 2009; Cuesta et al. 2010; Pinto et al. 2011; Villar-Salvador et al. 2012
	Negative.*	Larsen et al. 1986; Boyer and South 1987; Tuttle et al. 1988; Rietveld and Van Sambeek 1989; van den Driessche 1991; Thompson and Schultz 1995; McTague and Tinus 1996; Ivetić et al. 2016
Root collar diameter (RCD)	Positive.	Dey and Parker 1997; South and Mitchell 1999; Ward et al. 2000; South et al. 2005; Mexal et al. 2009; Oliet et al. 2009; Tsakaldimi et al. 2012; Ivetić et al. 2016
Root system size	Positive.	Thompson and Schultz 1995; Rose et al. 1997; Ward et al. 2000; Davis and Jacobs 2005; Jacobs et al. 2005; Wilson et al. 2007; Ivetić et al. 2016
Height:RCD ratio	Positive.	Li et al. 2011; Tsakaldimi et al. 2012
	Negative.	Johnson and Cline 1991; van den Driessche 1991; Bayley and Kietzka 1997; Sharma et al. 2007; Ivetić et al. 2016
Shoot-to-root dry weight ratio	Negative.	Larsen et al. 1986; Boyer and South 1987; van den Driessche 1991; Ivetić et al. 2016
Dickson quality index	Positive.	Tsakaldimi et al. 2012; Ivetić et al. 2016

* on droughty sites

A higher survival of shorter seedlings on droughty sites was explained by reduced water stress (Rose et al. 1993; Stewart and Bernier 1995) due to their lower shoot-to-root ratio (Grossnickle 2005a; Grossnickle 2012) and larger root systems (Burdett 1990; Grossnickle 2005b). Root collar diameter is a seedling attribute that forecasts survival and growth (Thompson 1985; Mexal and Landis 1990; Mattsson 1996) and reported as a better measure of seedling quality than shoot height (Chavasse 1977; Dey and Parker 1997; Ivetić et al. 2013). Larger RCD indicates larger root system size (Ritchie 1984; Grossnickle 2000; Grossnickle 2012) and this combination of plant attributes can provide resistance against drought and heat damage (Grossnickle and

Folk 1993). Root system size determines the potential for water uptake prior to new root growth (Carlson 1986), which is a central process in overcoming transplant (water) stress and seedling establishment (Burdett 1990).

4.1.2 Nursery culture that promote target seedlings attributes

Better understanding and implementation of nursery cultural practices to improve seedling quality will enable better matching of seedlings to forest sites (Duryea 1984). In Table 9 we offer a synopsis of suitable nursery cultural practices for SEE nurseries that promote target seedling attributes and field performance. Some of these practices differ between species and stocktypes, e.g. between hardwoods and conifers and between bareroot and container seedlings.

Table 9. The synopsis of morphological seedling quality attributes effect on field performance.

Practice	Effect	Source
Early spring sowing	Increase seedling size.	Duryea 1984; Thompson 1984; Mexal and South 1991; Viherä-Aarnio et al. 2005
Lower seedbed/container densities	Increase root collar diameter, with or without reducing height, increase dry weights and decrease shoot-to-root ratio, improve field performance.	Shipman 1964; Menzies et al. 1985; Barnett and Brissette 1986; Nebgen and Mayer 1986; Rowan 1986; Ward and Johnston 1986; Mexal and Simpson 1991; South 1993; Simpson 1994; Peterson 1997; Jinks and Mason 1998; South et al. 2005; Williams and Stewart 2006; Carneiro et al. 2007; Ivetić and Škorić 2013; Aghai et al. 2014
Drought conditioning	Improve water status, stomatal conductance, and reduce transplant shock by inducing morphological changes and acclimating the seedlings to field conditions.	Duryea 1984; Chirino et al. 2009; Vilagrosa et al. 2003; Guarnaschelli et al. 2006; Villar-Salvador et al. 2004[b]
Fall fertilization and nutrient loading	Increase field survival and growth by improved shoot and root growth, and the overall nutritional status of seedlings; increase frost resistance.	Duryea 1984; Timmer and Aidelbaum 1996; Timmer 1997; Villar-Salvador et al. 2005; Oliet et al. 2005; Oliet et al. 2009; Chirino et al. 2009; Cuesta et al. 2010; Villar-Salvador et al. 2012; Andivia et al. 2014; Jacobs 2014; Li et al. 2016
Wrenching and root pruning	Induce budset and hardening, decrease height and increase root system size, decrease shoot-to-root ratio, and increase in survival rate.	Tanaka et al. 1976; Duryea 1984; Stein 1984; Hobbs et al. 1987; Buse and Day 1989; Kainer and Duryea 1990; Mexal and South 1991; Hipps et al. 1996; Grossnickle 2012
Transplant seedlings	Increase root system fibrosity, increase root collar diameter, decrease shoot-to-root ratio.	Duryea 1984; Owston 1990; Deans et al. 1990; Rose et al. 1993
Larger and deeper containers	Increase root growth, decrease root system deformity, promotes survival on droughty sites.	Chirino et al. 2008; Haywood et al. 2012; Jelić 2012; Pinto et al. 2011; Pinto et al. 2012; Ivetić and Škorić 2013; Regan et al. 2015; Pinto et al. 2016
Hydrogel amendment	Improve seedling water status and photosynthetic performance of drought-stressed seedlings.	Chirino et al. 2011; Jamnická et al. 2013
Inoculation with mycorrhizal fungi	Improve seedling growth; improve field performance.	Querejeta et al. 1998; Dominguez et al. 2006; Rincon et al. 2007
Inoculation of seed with plant growth promoting rhizobacteria	Improve seedling growth*; promote mycorrhization.	Chanway and Holl 1991; Duponnois and Garbaye 1991; Shishido et al. 1996a; Shishido et al. 1996b; Dunstan et al. 1998; Dominguez et al. 2012

*Emergence-stimulating bacteria have species specific effect (Enebak et al. 1998) and may inhibit subsequent seedling growth of *Picea glauca* (O'Neill et al. 1992).

4.2 Pre-planting-site preparation

Site environmental conditions have a decisive influence on seedling field performance during the establishment phase (Hobbs 1992; Grossnickle 2000). The key to successful reforestation is quality site preparation followed by planting (Ehrentraut and Branter 1990). Pre-planting site preparation should provide advantage to the seedlings after planting, by controlling competitive vegetation, and by promoting access to water and root growth. A seedling's ability to overcome planting stress is affected by its root system size and distribution, root–soil contact, and root hydraulic conductivity (Grossnickle 2005^{b}), which emphasizes the importance of proper soil preparation and water harvesting. It is a generally accepted principle in SEE that the objectives of site preparation should be achieved with minimal disturbance.

REMOVING OBSTACLES AND HARVEST RESIDUES: Removing obstacles (i.e. stones) and residue (i.e. stumps) enables planting the total area with a regular layout and spacing, thus allowing easy movement on the site. Removing obstacles and residue can be done mechanically or manually; organic residuals after harvesting are usually burned either on-site or chipped and removed for energy production, which can reduce site preparation cost and generate extra revenue (Yoshida et al. 2015). As an alternative to their removal, rearrangement of obstacles and harvest residuals can promote seedling survival by creating the favorable micro-site conditions. Seedling shaded by a stump, log, or large rock tend to grow better on dry sites than those not shaded (Landis et al. 2010). The survival of *Pinus sylvestris* and *P. nigra* was remarkably higher when planted on the north side of spiny shrubs (Castro et al. 2002).

VEGETATION CONTROL: Competitive vegetation can be controlled chemically, mechanically, and manually. Chemical vegetation control in forest is limited or restricted in many regions. Vegetation management by non-chemical means is most critical and effective during site preparation as well as after crop establishment (Ehrentraut and Branter 1990). Mechanical site preparation often results in improved seedling survival and growth, but only intensive methods with much soil disturbance are an effective tool for controlling competing vegetation (Löf et al. 2012)**.** Mechanical and chemical site preparation combined provides the best results. After five years of weed control treatment, site preparation by plowing and harrowing did not result in increased growth of *Quercus macrocarpa* Michx., but growth was superior when this mechanical site preparation was combined with a simazine herbicide application (Cogliastro et al. 1997).

SOIL PREPARATION: The usual methods of soil preparation in SEE countries are subsoiling, mechanical terracing, and mechanical or manual preparation of planting holes. On karst terrains in Croatia, afforestation by *Pinus nigra* and *P. pinaster* Aiton after subsoiling resulted in higher survival and growth rates compared to planting in pickaxe, and mechanically drilled holes (Tomašević 1994). Subsoiling with a bulldozer promoted higher survival of *Pinus halepensis* Miller (Barberá et al. 2005; Jelić 2012), *Quercus ilex* (Palacios et al. 2009, Jelić 2012), *Cupressus sempervirens* var. *pyramidalis* L., *Pinus pinaster*, and *Pinus pinea* L. (Jelić 2012) than holes made with an excavator in reforestation of a semiarid Mediterranean ecosystem. On some extreme sites with a shallow soil layer, explosives can be used for breaking the bed rock and creating an initial opening for a planting hole. At planting time, these holes are filled with soil from nearby forests. Used for afforestation of container *Pinus nigra* seedlings in Serbia, reported first year survival rate was 100% (Škorić et al. 1997) and 15 years after planting, this afforestation is considered successful (Fig. 2).

Figure 2. Successful afforestation at Mt Goč in Central Serbia, following creation of planting holes using explosives.

WATER HARVESTING: Many techniques for harvesting water are described (Critchley and Siegert 1991; Prinz 1996; Mishra et al. 2011). In most of them, the basic principle is to make a reverse slope, usually done by different versions of bench terracing. Reverse slopes made during soil and planting spot (or hole) preparation can intercept runoff and redirect water to the seedling, and reduce runoff erosion by creating sinks along the slope (Fig. 3). Furthermore, the bench terraces significantly increase soil carbon stock compared to the soils between the bench terraces and soils planted by manual hole preparation (Lukić et al. 2015).

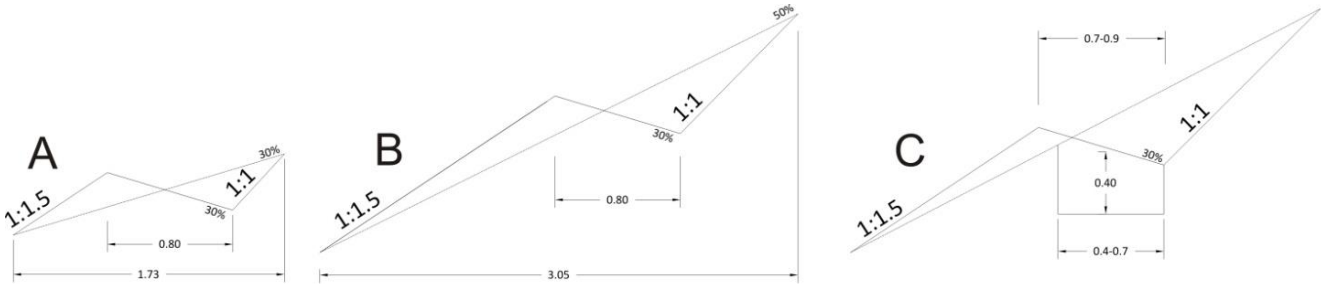


Figure 3. The most used water harvesting techniques in SEE are reversed slope terraces called gradoni (adapted from Lujić 1973): Gradoni at different slopes (A and B) and with manual prepared planting hole (C). During planting hole preparation, soil layers are inverted.

Gradoni, a version of bench terracing, is a technique of soil preparation for afforestation used since the end of the 19th century in France (Andrejević 1959) and Italy (Mercurio and Schirone 2015), and it was widely practiced in Serbia and FYR Macedonia. This method was used in Grdelica gorge in Serbia and provided more efficient soil erosion control compared to afforestation using planting holes without terracing (Lukić 2013). In addition, some different techniques, like diamond shaped negarim micro-catchments (Critchley and Siegert 1991, Prinz 1996), characterized by small earth mounds, with an infiltration pit at the lowest corner, should be tested in SEE conditions.

FACILITATION BY NURSE PLANTS: Some plants benefit from closely associated neighbors (Tab. 10), a phenomenon known as facilitation (Padilla and Pugnaire 2006). Nurse plants have been mainly used to restore vegetation in arid and sub-arid zones in recent years (Ren et al. 2008).

Table 10. Reported positive effects of nurse plants to seedlings survival and growth.

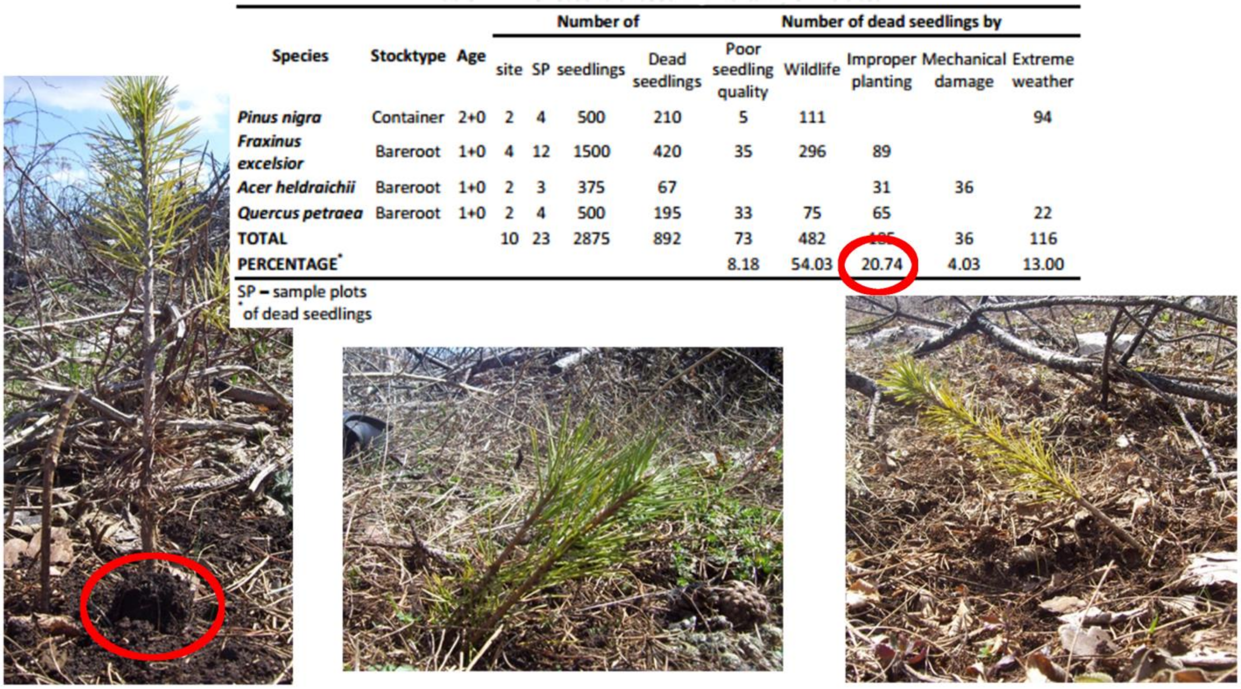
Effect	Source
Protect seedlings from frost.	Stilinović 1991; LePage and Coates 1994
Reduce soil water evaporation, lower soil and air temperature, and decrease the amount of radiation reaching the plants by shading.	Padilla and Pugnaire 2006; Endo et al. 2008
Improve the availability of water through the process known as "hydraulic lift".	Padilla and Pugnaire 2006
Improve nutrient availability by nitrogen transfer between legumes and non-leguminous plants.	Franco and Nobel 1989; Padilla and Pugnaire 2006; Rodríguez-Echeverría et al. 2016
Promote the development of differentiated soil microbial communities.	Duponnois et al. 2011; Rodríguez-Echeverría et al. 2016
Promote survival and growth by mycorrhization.	Bai et al. 2009; Bauman et al. 2012
Soil stabilization.	Endo et al. 2008; Rodríguez-Echeverría et al. 2016

In reforestation of Mediterranean mountains, *Pinus sylvestris* and *P. nigra* survival was remarkably higher and growth unaffected when planted under individuals of the shrub *Salvia lavandulifolia* Vahl (Castro et al. 2002). Three years after planting, association between *Cupressus atlantica* Gaussen and *Lavandula stoechas* L. lead to a higher growth of *C. atlantica* and better soil microbial characteristics compared to the control treatment (Duponnois et al. 2011). Gómez-Aparicio et al. (2004) conducted a meta-analysis with seedling survival and growth data for the first year after planting at experimental reforestations with more than 18,000 seedlings of 11 woody species planted under 16 different nurse shrubs throughout a broad geographical area in southeast Spain. They concluded that facilitative effect was consistent in all environmental situations explored; but with differences in the magnitude of the interaction, depending on the seedling species planted as well as the nurse shrub species involved. Additionally, they found that nurse shrubs had a stronger facilitative effect on seedling survival and growth at low altitudes and sunny, drier slopes than at high altitudes or shady, wetter slopes. At dry sites with full sunlight, creating shadow by nurse plants can promote survival but reduce photosynthetic rate. Although shade enhances the probability of *Pinus pinea* survival, carbon assimilation reaches maximum values on more open sites (Calama et al. 2015).

On sites where no suitable nurse plants are already present, the simultaneous planting of targeted tree species and nurse-planting seedlings is recommended (Blanco-García et al. 2011). However, the selection of nurse plant species is not a simple task. The use of nurse plants is a dynamic system and what could start out as a beneficial strategy may turn detrimental with nurse plant strategy could become a vegetation management issue with unforeseen consequences and costs (Grossnickle, personal communication). Thus, nurse plant species should be featured by limited resources demands and growth. This indicates the need for research of nurse plants effect on tree species used in the range of environmental conditions specific for SEE.

4.3 Planting

All efforts invested in the selection and production of planting material and in site preparation can be rewarded or depreciated during planting. The full effect of the planting method may not be visible until the first stress event, even 10 or more years after planting (Stilinović 1991). Improper planting is one of the main reasons of reforestation failures in Serbia (Ivetić 2015; Fig. 4). A number of planting methods can be used (Stilinović 1991; Kloetzel 2004; Landis et al. 2010; Ivetić 2013), depending on tool and seedling stocktype. Assuming that appropriate planting is applied (e.g. putting seedling into the hole in an appropriate manner), several techniques are available to promote seedling survival and growth.



Species	Stocktype	Age	Number of				Number of dead seedlings by				
			site	SP	seedlings	Dead seedlings	Poor seedling quality	Wildlife	Improper planting	Mechanical damage	Extreme weather
Pinus nigra	Container	2+0	2	4	500	210	5	111			94
Fraxinus excelsior	Bareroot	1+0	4	12	1500	420	35	296	89		
Acer heldraichii	Bareroot	1+0	2	3	375	67			31	36	
Quercus petraea	Bareroot	1+0	2	4	500	195	33	75	65		22
TOTAL			10	23	2875	892	73	482	185	36	116
PERCENTAGE*							8.18	54.03	20.74	4.03	13.00

SP – sample plots
*of dead seedlings

Figure 4. Improper planting was observed with more than 20% of the total number of dead seedlings at 10 sites (Ivetić 2015). These seedlings are found dead after one growing season because of shallow planting and poor root contact with soil.

INCREASE OF PLANTING DEPTH: Dimensions of the planting hole and seedling positioning depend on site conditions, species, and stocktype. Planting depth (i.e., distance between the root-collar and the groundline as defined by South 2005) can effect seedling survival. Heat, often confused with drought, and shallow planting are probably the most over looked causes of death of planted bareroot seedlings (Stroempl 1990) and shallow planting, regardless of taproot form, can promote seedling mortality (South 2005). Without rain, deeply planted *Pinus echinata* Mill. seedlings (11 cm below ground line) survived significantly better than seedlings planted with the root-collar slightly below the groundline (South et al. 2012). Deep-planting techniques promote seedling establishment by immediate exploitation of capillary fringe moisture (Dresen and Fenchel 2010). Effect of planting depth is species specific and the native habitat of a species should be considered (Bryan et al. 2010). Additional research on effect of planting hole dimensions and planting depth are needed for species and site conditions specific to SEE.

INCREASE OF NUTRIENT AVAILABILITY: Field fertilization can improve performance of planted seedlings. An organic amendment significantly improved seedlings growth (Grossnickle and Reid 1983; Roldan et al. 1996; Barberá et al. 2005) with no apparent negative influence on seedling mycorrhization (Querejeta et al. 1998). Effect of organic amendment can be species specific. Grossnickle and Reid (1982) found that root system of 5-year-old *Pinus flexilis* James was not affected by the sewage sludge and wood-chips fertilization, but root system development of *Pinus concorta* and *Picea engelmannii* Parry. ex Engelm. was dramatically reduced. This reduction, however, was result of water stress rather than nutrient stress; because this ersatz soil created low soil bulk density conditions and reduced soil water movement to newly planted seedlings root systems (Grossnickle and Reid 1984). There is a concern that fertilization will stimulate competitive vegetation. Because of that, fertilization should not be broadcast over the site, but rather only applied close to the seedling root system. Field fertilization using controlled-release fertilizer has emerged as an effective means of promoting early growth of planted seedlings (Jacobs 2014). In order to use controlled-release fertilizers successfully, their formulation, release behavior, and environmental interactions must be understood (Rose et al. 2004). At dry sites, fertilization can result with root dehydration and limited water uptake, because of increased fertilizer salts in the soil solution (Jacobs et al. 2004[b]). Decision about field fertilization in any reforestation project should consider many variables, including soil conditions, competitive vegetation, site drought level, and seedling species demands. These variables, as well as ephemeral nature of field site fertilization (Grossnickle 2000), further emphasize that the decision making process must by project specific.

INOCULATION WITH MYCORRHIZAL FUNGI AND PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR): Inoculation of seedlings with mycorrhizal fungi and PGPR can improve seedling survival and growth on sites with shallow or no soil profile. A combination of soil terracing, urban solid refuse amendment, and mycorrhization could be successfully applied in afforestation programs in semiarid and degraded sites (Roldan et al. 1996). Seedling mycorrhization at planting correlated positively with growth (Duñabeitia 2004) and survival (Óskarsson 2010). A simple and cost efficient technique for promoting mycorrhization is addition of forest soil to the planting hole. Although nursery inoculation with mycorrhizal fungi resulted in a faster growth rate, addition of forest soil to the planting holes to promote mycorrhization improved field growth of *Pinus halepensis* (Querejeta et al. 1998). Seedling performance can be significantly enhanced through PGPR inoculation of root systems (Chanway 1997), especially when moving from favorable to harsh sites (Chanway and Holl 1993; Chanway and Holl 1994). Additionally, seedling inoculation with PGPR is beneficial on contaminated soils (Babu et al. 2014; Karličić et al. 2016). Inoculation of *Robinia pseudoacacia* L. and *Pinus sylvestris* seedlings with PGPR increased seedling growth in coal mine overburden (Karličić et al. 2015). PGPR have a short-term, site specific effectiveness for reforestation of conifer seedlings, which necessitate matching PGPR strains to outplanting sites for effective growth promotion (Chanway et al. 2000). Although use of mycorrhizal fungi and PGPR has the potential to benefit seedling during establishment phase, the seedling-microorganism relationship does not always yield improved field performance (Grossnickle 2000).

AMENDMENT OF SUPERABSORBENT POLYMERS: Evidence suggests that application of superabsorbent polymers (hydrogels) during planting promotes seedling field performance. Polymer increased survival and leaf water potential of *Pinus pinea* seedlings in field conditions (Pery et al. 1995) and hydrogel combined with mycorrhizal inoculation promoted *Picea abies* (L.) Karst. resistance to drought stress (Višnjić et al. 2004). An innovative soil conditioner, comprising 23 ingredients including a new complex of hydro absorbent polymers, significantly enhanced tree growth in conditions of poor precipitation and/or thick textured soil with poor water holding capacity (Coello-Gomez et al. 2015). Šijačić-Nikolić et al. (2011) found that application of 5 g of polymer per planting hole increased two-year survival and growth of *Pinus nigra* and *P. sylvestris* seedlings. However, an excessive application of hydrogel increased mortality of *Pinus sylvestris* seedlings (Sarvaš et al 2007). Because contradictory results are reported, it is recommended that growers or planters conduct small trials to determine whether there are benefits to using hydrogels under their specific conditions (Landis and Haase 2012).

PLANTING LAYOUT AND DENSITY: Irregular planting pattern can complicate silviculture operations, but it can promote seedling survival and provide a close surrogate to successful natural regeneration that provides a more natural appearance of a landscape. Choosing the best planting spot is critical and more important than exact spacing (Landis et al. 2010), because initial seedling performance is related to microsite performance. On sites with harsh conditions, planting in groups on deeper soil is recommended, regardless of adopted regular planting pattern (Stilinović 1991). The risk of seedling mortality is not constant, but varies with tree species, planting density, tree age, and site conditions (Gadow and Kotze 2014). In most SEE reforestation programs, the prescribed planting density is 2,500 seedlings per hectare regardless of species characteristics and site conditions. The decision on planting layout and density should, however, be project specific with aim to promote survival and reforestation success.

4.4 Post-planting

The aim of post-planting silviculture during the establishment phase of plantation development is to promote success by improving microsite conditions and protecting planted seedlings. Post-planting treatments are essential for the success of seedlings establishing in droughty conditions (Klossas et al. 2012), but also on higher quality sites with risk of competitive vegetation and browsing.

VEGETATION (WEEDS) CONTROL: At the planting site, weeds are those herbaceous and woody species that compete with planted seedlings for energy, water, and nutrients. However, not all existing vegetation at planting sites should be considered weeds (see Facilitation by Nurse Plants above), and not all of them should be controlled. At planting site, herbaceous vegetation control has more effect than woody vegetation control (Rose et al. 1999). Effect of existing vegetation on planting site can be twofold. *Betula papyrifera* Marshall reduces growth of shade-intolerant conifers but facilitates growth of shade-tolerant conifers (Simard and Vyse 2006).

Due to high costs and environmental issues (especially with herbicide use), decisions about vegetation control application should be based on a cost-benefit analysis. For example, growth and yield simulations using treatment-specific site index curves suggested that site preparation or post-planting vegetation control could reduce rotation length of *Picea glauca* by 12–16 years, but untreated areas were predicted to produce an equivalent volume if left to grow to mean annual increment culmination age (Boateng et al. 2009). Knowledge of the maximum (a level of vegetation cover where additional control will not increase tree performance) and minimum (a level of vegetation cover that must be reached before additional control will increase tree performance) response thresholds can be used to improve herbicide prescriptions (Wagner et al. 1989). A minimum response threshold level of 20% cover has been suggested (Wagner 2005). The response thresholds are species and site specific. *Pinus contorta* Dougl. var. *latifolia* Engelm. height and diameter growth and *Picea glauca* × *Picea sitchensis* diameter growth increased dramatically when cover of *Rubus parviflorus* Nutt. was below 5%, suggesting a response threshold (LePage and Coates 1994). Mortality of *Betula pendula* Roth and *Pinus sylvestris* seedlings increased significantly once the cover of competing vegetation reached 60% (Hytönen and Jylhä 2005; Jylhä and Hytönen 2006). Such thresholds should be considered during the decision making process on application of any method of vegetation control.

Another issue to consider is how many years after planting vegetation control is beneficial to seedlings performance. Intensive vegetation control in first couple of years after planting is critical for seedling field performance. The critical period in the establishing phase differs with species: 1-2 years after planting for shade-intolerant *Pinus banksiana* Lamb. and *Pinus resinosa* Sol. Ex Aiton*,* 1-4 years for more shade-tolerant *Picea mariana* (Mill.) B.S.P. and *Pinus strobus* L. (Wagner et al. 1999). Rose and Ketchum (2003) found no observable effect of vegetation control in third year after planting on *Pseudotsuga menziesii* growth. Additional time aspect to consider is duration of vegetation control effect. Positive effect of weed control with herbicides last up to 11 (Hytönen and Jylhä 2005) and 30 (Wagner 2005) years after planting.

Vegetation control generally has a positive effect on seedling performance but efficiency depends on method and size of the control area. Competitive vegetation can be controlled physically by mulching, mechanically by cultivation, and chemically by herbicides (Tab. 11).

Table 11. Reported positive effects of vegetation control to seedlings survival and growth.

Type	Method	Positive effect on survival (S) and growth (G)	Source
Physical	Mulching	S	Navaro Cerrillo et al. 2005; Hytönen and Jylhä 2005; Ceacero et al. 2014
Mechanical (M)	Cultivation	S	Navaro Cerrillo et al. 2005; Ceacero et al. 2014
	Removal	G	Klossas et al. 2012
Chemical (C)	Herbicide	S	Navaro Cerrillo et al. 2005; Ceacero et al. 2014
		G	Balneaves et al. 1996; Rosner and Rose 2006; Klossas et al. 2012
		S+G	Hytönen and Jylhä 2005; Hytönen and Jylhä 2008
M + C		G	Sutton 1995

Chemical vegetation control significantly improved seedling growth compared to the manual cutting (LePage and Coates 1994), tillage (Groninger et al. 2004), mulch and cover crop (Jylhä and Hytönen 2006). Combination of weed control methods can result in synergic effect. Rey Benayas et al. (2005) found a clear positive synergic effect of shading and weed mowing on seedling performance of three *Quercus* species (*Q. coccifera* L.*, Q. ilex,* and *Q. faginea* Lam.).

Increasing in area of vegetation control has positive effect on seedling growth. Mean stem volume, basal diameter, and height of seedlings increased significantly with increasing area of vegetation control, and the magnitude of difference between treatments increased with time (Rose and Ketchum 2002).

The vegetation control efficiency depends on seedling stocktype as well: promoting survival of small and growth of large seedlings. Although the highest stand volumes of 15-years old *Picea abies* were obtained with the combination of large bareroot seedlings (4-year-old) and effective vegetation control, 2-year-old container seedlings because of their smaller size benefited more from vegetation control in terms of survival (Hytönen and Jylhä 2008). The volume return from increased weed control is maximized by planting the largest possible seedlings (Rosner and Rose 2006). On sites released from competitive vegetation larger seedlings grow quickly and occupy site resources during establishment due to greater level of incoming radiation and their greater photosynthetic capability (Grossnickle 2005[a]).

Chemical control of herbaceous competition in the first couple of years after planting promotes small seedlings survival and large seedlings growth. Decision on type, method, area, and number of applications should be made on species specific response thresholds and site specific conditions (e.g. vegetation cover, environmental restrictions, and erosion control).

MULCHING: Mulching is the spreading of material around planted seedlings to cover the soil with a goal of mitigating extreme temperatures, reducing evaporation and moisture loss, controlling weeds, and perhaps, enhancing soil structure and fertility. Some mulches are effective in some environments, some are not (McDonald and Helgerson 1990). *Pseudotsuga menziesii* seedlings grew best with treatments that promoted the most efficient use of available microsite water, either by reducing soil surface evaporation or vegetation competition (Flint and Childs 1987). The effect of mulching depends on material, size, cost, and longevity. Mulching positive effect on seedling growth increase with mulch size (McDonald et al. 1994; Harper et al. 1998). Although mulch mats controlled vegetation around trees as well as conventional herbicides, they were 7X more expensive (McCarthy et al. 2007).

Table 12. Effect of different mulch materials on seedling field performance.

Material	Positive effect on survival (S) and growth (G). (NE) = no effect.	Source
Organic material + sand layer	G	Yohannes 1999
Wood chips	G	Siipilehto 2001
Fibres (natural, synthetic, and mixture)	G	Haywood 1999
Wastepaper fibre slurry	NE	Siipilehto and Lyly 1995
Paper sheets	S+G	Bradley 1962
Fibre board	S	Hytönen and Jylhä 2005
Porous, and perforated plastic	G	Walker and Mclaughlin 1989; Harper et al. 1998
Polyetilene sheets	G	Stepanek et al. 2002; Chaar et al. 2008
Plastic strips	G	Cogliastro et al. 1997

A variety of materials are used for mulching and they have a range of biological effects (Tab. 12). On one hand, the improvement of seedling survival and growth by mulching is stronger on high quality sites where seedlings can better utilized the rich soils, higher soil moisture contents, and reduced weed competition (Coello-Gomez et al. 2015). On the other hand, mulching can promote browsing. *Quercus rubra* L. seedlings grown with fabric mats had a greater frequency of deer browsing and a greater chance of dying than seedlings grown without mats, indicating that fabric mats should not be used in restoration projects with large deer populations (Stange and Shea 1998).

In addition to biological effect and price, the selection of appropriate mulching for reforestation programs in SEE should consider possible socio-economic effects. Some mulches, like those made of cardboard packaging (Fig. 5), can be easily produced in rural communities or by children in local schools helping their economics and raising awareness on environmental issues.

Figure 5. Mulch made of cardboard packaging.

USE OF TREE SHELTERS: Tree shelters provide physical protection and modify the environment conditions of planted seedlings. Tree shelters have proven to be a highly effective complement to vegetation control treatments (Navaro Cerrillo et al. 2005; Ceacero et al. 2014) (Fig. 6) and many studies report the positive effects of tree shelters on seedling performance: survival (Stange and Shea 1998; Oliet et al. 2005) and growth (Stange and Shea 1998; Chaar et al. 2008; McCreary and Tecklin 2001). Until the seedling grows above the shelter, height growth is favored compared to stem diameter (Oliet et al. 2005). Once this rapid, short term growth (Barberá et al. 2005) brings the terminal above the top of the shelter average height growth diminishes and diameter growth increases (McCreary and Tecklin 2001).

The effect of tree shelters depends on design, color, and size. Solid-wall shelters outperform screen cages (McCreary and Tecklin 1997), mesh or fabric sleeves (Ward et al. 2000), wire, and nylon mesh (Klossas et al. 2012). Shelter color can have a pronounced effect. For shade-tolerant *Picea engelmannii* planted at high elevation, the lighter-colored, solid-wall shelters yielded higher two-year survival (95 to 99%) than control seedlings (58%; shading seedlings using logging slash, stumps, and vegetation within the site) and the darkest, solid-wall shelter (5%); height and diameter growth followed the same pattern (Jacobs and Steinbeck 2001). Bellot et al. (2002) found that a 30-cm tall, brown plastic, solid-wall protector was most beneficial for total biomass growth of *Quercus coccifera* seedlings.

Various effects of tree shelters on seedlings physical environment are reported. Shelters increased maximum temperature by up to 10°C and decreased light intensity by 50% or more (Ward et al. 2000). In contrast, tree shelters color and venting did not influence air temperatures and only affected vapor pressure deficit late in the growing season (Devine and Harrington 2008). However, Laliberté et al. (2008) found that facilitation of hardwood growth was not caused by an improvement of tree water relations, but rather to an optimization of light levels inside the shelter: “low enough to lead to a photosynthetic system less costly to maintain due to a greater specific leaf area but high enough to have no adverse effects on photosynthetic rates”. Environmental factors such as light availability need to be considered to optimize the effect of tree shelters. Tree shelters increased growth when shading by surrounding herbaceous vegetation was low, but reduced growth when surrounding vegetation blocked a substantial quantity of light (Laliberté et al. 2008). Shelters can increase water supply through dew harvesting. Both single and double wall design shelters had higher dew point temperature and lower minimum temperatures resulting in increased dew formation, but a significant increase in soil moisture was registered only with a single-wall shelter (del Campo et al. 2006). Even so, “seedling height growth in the single walled shelter was smaller indicating that only when soil moisture becomes over 6% does affect growth” of *Pinus halepensis seedlings* (del Campo et al. 2006).

Solid-wall, light-colored tree shelters can optimize light levels inside the shelter, initiate dew harvesting, and provide physical protection to seedlings during critical establishing phase of development. Given the wide variety of tree shelters on the market, shelters of different characteristics should be tested for specific combinations of species and site conditions.

Figure 6. Solid wall tree shelters on weed free site planted with *Quercus robur* L. seedlings (left) and at site under strong vegetation competition planted with *Fraxinus excelsior* L. seedlings (right).

BROWSING CONTROL: Success or failure of reforestation often depends on control of animal damage. Compared to favorable sites where seedlings can resume normal growth more readily, the negative impact of animal damage persists longer on harsher sites because of slower growth. A variety of techniques have been used for browsing control, which generally can be divided into physical protection or chemical repellents. Although planted trees can be protected by fencing the planting site, individual seedling protection is prevailing in reforestation programs in SEE. Many tree shelters (plastic tubes) and guards (meshes, wires, etc.) are available on the market for individual seedling protection. Protectors were consistently effective in preventing browse damage without reduced survival or height growth (Schaap and DeYoe 1985). The use of plastic tree shelters prevented deer browsing and reduced the mortality rate of *Quercus rubra* seedlings from 35% to 3% (Stange and Shea 1998). "No *Quercus pagoda* Raf. seedlings in the tree shelters were browsed" (Dubois et al. 2000).

An additional, positive effect of tree shelters is promoting height growth (see Use of *Tree Shelters* above). Tree shelters can greatly reduce the time required by seedlings to grow above the browse line (McCreary and Tecklin 1997), after which the danger of animal damage is significantly decreased.

An alternative to physical protection is the use of chemical repellents that generally rely on fear, conditioned avoidance, pain, or taste (Nolte and Wagner 2000, Trent et al. 2001) (Tab. 13). New products are continually developed with variable efficiency depending on active ingredient, method of application, durability, and animal species. In general, repellents using fear as a mode of action were more effective than products using other modes of action (pain, taste, and aversive conditioning) and topical repellents were more effective than area repellents (Wagner and Nolte 2001).

Table 13. Delivery systems of chemical repellents (Adapted from Nolte and Wagner 2000).

Effect	Active ingredients
Fear of predator	Compounds that indicate predator activity emitting sulfurous odors (such as predator urine, meat proteins, or garlic).
Conditional avoidance	Compounds that cause nausea or gastrointestinal distress.
Pain	Compounds that cause pain or irritation, like: capsaicin, allyl isothiocyanate, and ammonia.
Taste	Bittering agents.

Although commercial repellents are effective for some species, they may not be cost-effective for most situations due to high cost (Wagner and Nolte 2000). Low cost kitchen recipes can, however, be used as alternative (Fig. 7). These repellents are less effective and durable, but easy and inexpensive to produce.

Figure 7. A homemade repellent from ingredients found in a local market. The basic ingredients are grained paprika containing capsaicin, and eggs. Milk, garlic, and other amendments can also be used. Hand sprayers with range of capacity can be used for application.

5 Conclusions

In the SEE, every reforestation project faces different challenges, due to uncertainty of climate change predictions and wide range of environment conditions. The biggest challenge to reforestation success will be frequency, duration, and severity of extreme weather events. Most of the tree species currently in SEE cannot keep pace with changes in environmental conditions on which forest populations are currently adapted. We reviewed a number of strategies and techniques that may promote reforestation success in changing environment. The toolbox is well-equipped and offers plenty of solutions.

Although we distinguish site specific from species specific projects, both rely on correctly matching site and species, and require different approaches to make that decision. Matching provenances to a planting site facing climate change requires additional research on genetic variation and local adaptation of targeted species, especially for those with small populations and limited or disjunctive ranges. Assisted migration is an appropriate strategy for facing climate change, considering the difference in pace of climate change and tree species natural migration rates, but large scale assisted migration is unlikely due to limitations in northwards and upwards distances available in SEE. This strategy should be implemented on a small scale. Seed transfer guidelines should allow and encourage movement of forest reproductive material across administrative and state borders.

A number of nursery cultural practices are available for SEE nurseries that promote target seedling attributes and field performance, depending on species and stocktypes, e.g. between hardwoods and conifers and between bareroot and container seedlings. Proper site preparation and planting techniques promotes reforestation success. Seedling benefits from microsite improvement by water harvesting, and facilitation by nurse plants. Inoculation of seedlings with mycorrhizal fungi and plant growth promoting rhizobacteria (PGPR), and application of superabsorbent polymers (hydrogels) during planting offer a variety of tools for promoting seedling's field performance; but require site/species specific testing.

Vegetation (weed) control during first couple of years after planting is the post-planting treatment the most beneficial to seedling performance, but not all existing vegetation at the planting site should be considered competition. Complement techniques are mulching, tree sheltering and browsing control; with many available products available but still plenty of room for innovations and home-made solutions.

The need is constant for finding new solutions and testing existing strategies and techniques in conditions of SEE because no single solution or tool is best for all situations. Selection of appropriate strategies and techniques to achieve reforestation goals should combine knowledge on target species biological characteristics with focal site environment conditions and with climate change predictions.

6 References

Aghai MM, Pinto JR, Davis AS (2014) Container volume and growing density influence western larch (*Larix occidentalis* Nutt.) seedling development during nursery culture and establishment. New Forest 45: 199-213.

Aguade D, Poyatos R, Rosas T, Martinez-Vilalta J (2015) Comparative drought responses of *Quercus ilex* L. and *Pinus sylvestris* L. in a montane forest undergoing a vegetation shift. Forests 6: 2505-2529.

Aitken SN, Yeaman S, Holliday JA, Wang T, Curtis-McLane S (2008) Adaptation, migration or extirpation: climatic changes outcomes for tree populations. Evol Appl 1: 95-111.

Ameztegui A, Coll L, Messier C (2015) Modelling the effect of climate-induced changes in recruitment and juvenile growth on mixed-forest dynamics: The case of montane-subalpine Pyrenean ecotones. Ecological Modelling 313: 84-93.

Andivia E, Fernández M, Vázquez-Piqué J (2014) Assessing the effect of late-season fertilization on Holm oak plant quality: Insights from morpho-nutritional characterizations and water relations parameters. New Forest 45: 149-163.

Andrejević M (1959) Are gradoni new in our country? [In Serbian: Да ли су градони новина за нашу земљу?]. Šumarstvo 5-6: 268-272.

Babu GA, Shea JP, Byung-Taek O (2014) *Trichoderma* sp. PDR1-7 promotes *Pinus sylvestris* reforestation of lead-contaminated mine tailing sites. Sci Total Environ 476-477: 561–567. doi:10.1016/j.scitotenv.2013.12.119.

Bai S-L, Li G-L, Liu Y, Dumroese RK, Lv R-H (2009) *Ostryopsis davidiana* seedlings inoculated with ectomycorrhizal fungi facilitate formation of mycorrhizae on *Pinus tabulaeformis* seedlings. Mycorrhiza 19: 425–434.

Balneaves J, Menzies M, Hong S (1996) Establishment practices can improve longer – term growth of *Pinus radiata* on a dry-land hill forest. New Zealand Journal of Forestry Science 26: 370-379.

Banković S, Medarević M, Pantić D, Petrović N, Šljukić B, Obradović S (2009) The growing stock of the Republic of Serbia - state and problems. Bulletin of the Faculty of Forestry 100: 7-30.

Barberá GG, Martínez-Fernández F, Álvarez-Rogel J, Albaladejo J, Castillo V (2005) Short- and intermediate-term effects of site and plant preparation techniques on reforestation of a Mediterranean semiarid ecosystem with *Pinus halepensis* Mill. New Forest 29 (2): 177-198. doi:10.1007/s11056-005-0248-6.

Barnett JP, Brissette JC (1986) Producing southern pine seedlings in containers. New Orleans (LA): USDA Forest Service, Southern Research Station. General Technical Report SO-59. 71 p.

Barnett JP, McGilvray JM (1993) Performance of container and bareroot loblolly pine seedlings on bottomlands in South Carolina. South J Appl F 17: 80-83.

Bauman JM, Keiffer CH, Hiremath S (2012) Facilitation of American chestnut (*Castanea dentata*) seedling establishment by *Pinus virginiana* in mine reclamation. International Journal of Ecology 2012: 1-12.

Bayley AD, Kietzka JW (1997) Stock quality and field performance of *Pinus patula* seedlings produced under two nursery growing regimes during seven different nursery production periods. New Forest 13: 341-356.

Beaulieu J, Rainville A (2005) Adaptation to climate change: genetic variation is both a short- and a long-term solution. Forest Chron 81: 704-709.

Bellot J, Ortiz De Urbina JM, Bonet A, Sánchez JR (2002) The effects of tree shelters on the growth of *Quercus coccifera* L. seedlings in a semiarid environment. Forestry 75: 89-106.

Blanco-García A, Sáenz-Romero C, Martorell C, Alvarado-Sosa P, Lindig-Cisneros R (2011) Nurse-plant and mulching effects on three conifer species in a Mexican temperate forest. Ecol Eng 37: 994-98. doi:10.1016/j.ecoleng.2011.01.012.

Boateng OJ, Heineman LJ, Bedford L, Harper JG, Linnell Nemec FA (2009) Long-term effects of site preparation and postplanting vegetation control on *Picea glauca* survival, growth and predicted yield in boreal British Columbia. Scand J Forest Res 24:111-129. doi:10.1080/02827580902759685.

Bodin J, Badeau V, Bruno E, Cluzeau C, Moisselin J-M, Walther G-R, Dupouey J-L (2013) Shifts of forest species along an elevational gradient in Southeast France: Climate change or stand maturation? J Veg Sci 24: 269-283. doi.org/10.1111/j.1654-1103.2012.01456.x

Bower AD, St Clair JB, Erickson V (2014) Generalized provisional seed zones for native plants. Ecol Appl 24: 913-919.

Boyer JN, South DB (1987) Excessive seedling height, high shoot-to-root ratio and benomyl dip reduce survival of stored loblolly pine seedlings. Tree Planters' Notes 37: 19-21.

Bradley FR (1962) Survival of planted Douglas-fir seedlings on severe sites using the paper sheet mulch planting method. Accessed at: http://ir.library.oregonstate.edu/xmlui/handle/1957/10023. Jan 14th 2016.

Breed MF, Stead MG, Ottewell KM, Gardner MG, Lowe AJ (2012) Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. Conserv Genet 14: 1-10.

Broadhurst LM, Lowe A, Coates DJ, Cunningham SA, McDonald M, Vesk PA, Yates C (2008) Seed supply for broadscale restoration: maximizing evolutionary potential. Evol Appl 1: 587-597.

Bryan DL, Arnold MA, Volder A, Watson WT, Lombardini L, Sloan JJ, Valdez-Aguilar LA, Cartmill AD (2010) Transplant season, irrigation, and planting depth effects on landscape establishment of bald cypress and sycamore. Arboriculture and Urban Forestry 36: 57-65.

Burdett AN (1990) Physiological processes in plantation establishment and the development of specifications for forest planting stock. Can J Forest Res 20: 415-427.

Buse LJ, Day RJ (1989) Conditioning three boreal conifers by root pruning and wrenching. Tree Planters' Notes 40: 33-39.

Calama R, Puértolas J, Manso R, Pardos M (2015) Defining the optimal regeneration niche for *Pinus Pinea* L. through physiology-based models for seedling survival and carbon assimilation. Trees 29(6): 1761–1771. doi:10.1007/s00468-015-1257-5.

Carlson WC (1986) Root system considerations in the quality of loblolly pine seedlings. Sout J Appl For 10: 87-92.

Carneiro JGD, Barroso DG, Soares LMD (2007) Growth of bare root *Pinus taeda* L. seedlings cultivated under five densities in nursery. Sci Agr 64: 23-29.

Castro J, Zamora R, Hódar JA, Gómez JM (2002) Use of shrubs as nurse plants: a new technique for reforestation in Mediterranean mountains. Restor Ecol 10: 297-305.

Ceacero CJ, Navarro-Cerrillo RM, Díaz-Hernández JL, Del Campo AD (2014) Is tree shelter protection an effective complement to weed competition management in improving the morphophysiological response of holm oak planted seedlings? iForest 7: 289-299.

Chaar H, Mechergui T, Khouaja A, Abid H (2008) Effects of treeshelters and polyethylene mulch sheets on survival and growth of cork oak (*Quercus suber* L.) seedlings planted in northwestern Tunisia. Forest Ecol Manag 256: 722-731. doi:10.1016/j.foreco.2008.05.027.

Chakraborty D, Wang T, Andre K, Konnert M, Lexer MJ, Matulla C, Schueler S (2015) Selecting populations for non-analogous climate conditions using universal response functions: The case of Douglas-fir in central Europe. PLoS ONE 10(8): e0136357. doi:10.1371/journal.pone.0136357

Chanway CP (1997) Inoculation of tree roots with plant growth promoting soil bacteria: An emerging technology for reforestation. For Sci 43: 99-112.

Chanway CP, Holl FB (1991) Biomass increase and associative nitrogen fixation of mycorrhizal *Pinus contorta* seedlings inoculated with a plant growth promoting *Bacillus* Strain. Can J Bot 69: 507-511. doi:10.1139/b91-069.

Chanway CP, Holl FB (1993) First year field performance of Spruce seedlings inoculated with plant growth promoting Rhizobacteria. Can J Microbiol 39: 1084-1088.

Chanway CP, Holl FB (1994) Growth of outplanted Lodgepole pine seedlings one year after inoculation with plant growth promoting Rhizobacteria. For Sci 40: 238-246.

Chanway CP, Shishido M, Nairn J, Jungwirth S, Markham J, Xiao G, Holl FB (2000) Endophytic colonization and field responses of hybrid Spruce seedlings after inoculation with plant growth-promoting Rhizobacteria. Forest Ecol Manage 133: 81-88. doi:10.1016/S0378-1127(99)00300-X.

Chavasse CGR (1977) The significance of planting height as an indicator of subsequent seedling growth. New Zeal J Forest 22: 283-296.

Cheddadi R, Birks HJB, Tarroso P, Liepelt S, Gömöry D, Dullinger S, Meier ES, Hülber K, Maiorano L, Laborde H (2014) Revisiting tree-migration rates:*Abies alba* (Mill.), a case study. Veg Hist Archaeobot 23: 113-122. doi:10.1007/s00334-013-0404-4

Chirino E, Vilagrosa A, Vallejo VR (2011) Using hydrogel and clay to improve the water status of seedlings for dryland restoration. Plant Soil 344: 99-110.

Chirino E, Vilagrosa A, Hernández E, Matos A, Vallejo V (2008) Effects of a deep container on morpho-functional characteristics and root colonization in *Quercus suber* L. seedlings for reforestation in Mediterranean climate. Forest Ecol Manag 256: 779-785.

Chirino E, Vilagrosa A, Cortina J, Valdecantos A, Fuentes D, Trubat R, Luis VC, Puertolas J, Bautista S, Baeza J, Penuelas JL, Vallejo VR (2009) Ecological restoration in degraded drylands: the need to improve the seedling quality and site conditions in the field. In: Grossberg SP (ed), Forest management, Nova Publisher, New York, pp 85-158.

Coello-Gomez J, Fuentes-Boix C, Pique M (2015) Innovative soil conditioning and mulching techniques for forest restoration in Mediterranean conditions. In: Ivetić V, Stanković D (eds) Proceedings: International conference Reforestation Challenges, 03-06 June 2015, Belgrade, Serbia, pp 201-210.

Corlett RT, Westcott DA (2013) Will plant movements keep up with climate change? Trends Ecol Evol 28: 482-488. doi.org/10.1016/j.tree.2013.04.003

Cogliastro A, Gagnon D, Bouchard A (1997) Is site preparation necessary for bur oak receiving post-planting weed control? Ann For Sci 54:107-116. doi:dx.doi.org/10.1051/forest:19970108

Critchley W, Siegert K (1991) Water Harvesting – A manual for the design and construction of water harvesting schemes for plant production. FAO, Rome.

Cuesta B, Villar-Salvador P, Puértolas J, Jacobs DF, Rey Benayas JM (2010) Why do large, nitrogen rich seedlings better resist stressful transplanting conditions? A physiological analysis in two functionally contrasting Mediterranean forest species. Forest Ecol Manag 260: 71-78.

Curiel-Esparza J, Gonzalez-Utrillas N, Canto-Perello J, Martin-Utrillas M (2015) Integrating climate change criteria in reforestation projects using a hybrid decision-support system. Environ Res Lett 10: 1-13. doi.org/10.1088/1748-9326/10/9/094022

Davis AS, Jacobs DF (2005) Quantifying root system quality of nursery seedlings and relationship to outplanting performance. New Forest 30: 295-311.

Deans JD, Lundberg C, Cannell MGR, Murray MB, Sheppard LJ (1990) Root system fibrosity of Sitka spruce transplants: Relationship with root growth potential. Forestry 63: 1-7. doi:10.1093/forestry/63.1.1

Del Campo DA, Navarro MR, Aguilella A, González E (2006) Effect of tree shelter design on water condensation and run-off and its potential benefit for reforestation establishment in semiarid climates. Forest Ecol Manag 235: 107-115. doi:10.1016/j.foreco.2006.08.003.

Delzon S, Urli M, Samalens JC, Lamy JB, Lischke H, Sin F, Zimmermann EN, Annabel JP (2013) Field evidence of colonisation by Holm oak, at the northern margin of its distribution range, during the anthropocene period. PLoS ONE 8(11): e80443. doi:10.1371/journal.pone.0080443

Devine DW, Harrington AC (2008) Influence of four tree shelter types on microclimate and seedling performance of Oregon white oak and western redcedar. Res. Pap. PNW-RP-576. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 35 p.

Dey DC, Parker WC (1997): Morphological indicators of stock quality and field performance of red oak (*Quercus rubra* L.) seedling underplanted in a central Ontario shelterwood. New Forest 14: 145-156.

Diku A (2011) The impact of climate change on food production/selected crop yields in Albania. In: Ivanyi Z (ed) The impacts of climate change on food production in the Western Balkan Region, Report Regional Environmental Center for Central and Eastern Europe. pp 1-23.

Dominguez JA, Martin A, Anriquez A, Albanesi A (2012) The combined effects of *Pseudomonas fluorescens* and *Tuber melanosporum* on the quality of *Pinus halepensis* seedlings. Mycorrhiza 22:429-436. doi:10.1007/s00572-011-0420-0.

Domínguez JA, Selva J, Rodríguez JA, Saiz de Omeñaca JA (2006) The influence of mycorrhization with *Tuber melanosporum* in the afforestation of a Mediterranean site with *Quercus Ilex* and *Quercus faginea*. Forest Ecol Manag 231: 226-233. doi:10.1016/j.foreco.2006.05.052.

Dreesen DR, Fenchel GA (2010) Deep planting techniques to establish riparian vegetation in arid and semiarid regions. Native Plants Journal 11(1): 15-22.

Dubois MR, Chapplka AH, Robbinson E, Somers G, Baker K (2000) Tree shelters and weed control: effects on protection, survival and growth of Cherrybark oak seedlings planted on a cutover site. New Forest 20: 105-118.

Dumroese RK, Williams MI, Stanturf JA, St Clair JB (2015) Considerations for restoring temperate forests of tomorrow: forest restoration, assisted migration, and bioengineering. New Forest 46: 947-964. doi.org/10.1007/s11056-015-9504-6

Dumroese RK, Landis TD, Pinto JR, Haase DL, Wilkinson KW, Davis AS (2016) Meeting Forest Restoration Challenges: Using the Target Plant Concept. Reforesta 1: 37-52.

Duñabeitia M, Rodríguez N, Salcedo I, Sarrionandia E (2004) Field mycorrhization and its influence on the establishment and development of the seedlings in a broadleaf plantation in the Basque country. Forest Ecol Manag 195: 129-39. doi:10.1016/j.foreco.2004.02.038.

Dunstan WA, Malajczuk N, Dell B (1998) Effects of bacteria on mycorrhizal development and growth of container grown *Eucalyptus diversicolor* F. Muell. seedlings. Plant Soil 201: 241-249. doi:10.1023/A:1004329626763.

Duponnois R, Garbaye J (1991) Effect of dual inoculation of Douglas fir with the ectomycorrhizal fungus *Laccaria laccata* and mycorrhization helper bacteria (MHB) in two bare-root forest nurseries. Plant Soil 138: 169-176. doi:10.1007/BF00012243.

Duponnois R, Ouahmane L, Kane A, Thioulouse J, Hafidi M, Boumezzough A, Prin Y, Baudoin E, Galiana A, Dreyfus B (2011) Nurse shrubs increased the early growth of cupressus seedlings by enhancing belowground mutualism and soil microbial activity. Soil Biol Biochem 43: 2160-2168. doi:10.1016/j.soilbio.2011.06.020.

Duryea ML (1984) Nursery cultural practices: Impacts on seedling quality. In: Duryea ML, Landis TD (eds) Forest nursery manual: Production of bareroot seedlings, Martinus Nijhoff/Dr W. Junk Publishers, The Hague/Boston/Lancaster, The Netherlands. pp 143-164.

Endo M, Yamamura Y, Tanaka A, Nakano T, Yasuda T (2008) Nurse-plant effects of a dwarf shrub on the establishment of tree seedlings in a volcanic desert on Mt. Fuji, Central Japan. Arc Antarct Alp Res 40: 335–342. doi:10.1657/1523-0430(07-013)[ENDO]2.0.CO;2.

Enebak SA, Wei G, Kloepper JW (1998) Effects of plant growth-promoting rhizobacteria on Loblolly and Slash pine seedlings. For Sci 44: 139-144.

Ehrentraut G, Branter K (1990) Vegetation management by manual and mechanical means in Alberta boreal forests, For Chron 66: 366-368.

FAO FRA (2015) Global forest resources assessment 2015 Desk reference. Food and agriculture organization of the United Nations, Rome. 253 p.

Feurdean A, Bhagwat SA, Willis KJ, Birks HJB, Lischke H, Hickler T (2013) Tree migration-rates: Narrowing the gap between inferred post-glacial rates and projected rates. PLoS ONE 8(8): e71797. doi:10.1371/journal.pone.0071797

Flint LE, Childs SW (1987) Effect of shading, mulching and vegetation control on Douglas-fir seedling growth and soil water supply. Forest Ecol Manag 18: 189-203. doi:10.1016/0378-1127(87)90160-5.

Forest Europe (2015) State of Europe’s Forests. 314 p.

Franco AC, Nobel PS (1989) Effect of nurse plants on the microhabitat and growth of cacti. J Ecol 77: 870-886.

Gadow K, Kotze H (2014) Tree survival and maximum density of planted forests – Observations from South African spacing studies. Forest ecosystems 1: 21. doi.org/10.1186/s40663-014-0021-4

Gómez-Aparicio L, Zamora R, Gómez JM, Hódar JA, Castro J, Baraza E (2004) Applying plant facilitation to forest restoration: a meta-analysis of the use of shrubs as nurse plants. Ecol Appl 14: 1128-1138. doi:10.1890/03-5084

Gould PJ, Harrington CA (2009) Root morphology and growth of bare-root seedlings of Oregon white oak. Tree Plant 53: 22-28.

Gray LK, Hamann A (2011) Strategies for reforestation under uncertain future climates: Guidelines for Alberta, Canada. PLoS ONE 6(8): e22977. doi:10.1371/journal.pone.0022977

Gray LK, Hamann A (2013) Tracking suitable habitat for tree populations under climate change in western North America. Climatic Change 117: 289-303.

Gray LK, Gylander T, Mbogga MS, Chen P, Hamann A (2011) Assisted migration to address climate change: Recommendations for aspen reforestation in western Canada. Ecol Appl 21: 1591-1603.

Groninger WJ, Baer GS, Babassana DA, Allen HD (2004) Planted green ash (*Fraxinus pennsylvanica* Marsh.) and herbaceous vegetation responses to initial competition control during the first 3 years of afforestation. Forest Ecol Manag 189: 161-170. doi:10.1016/j.foreco.2003.07.039.

Grossnickle SC (2000) Ecophysiology of northern spruce species: the performance of planted seedlings. NRC Research Press, Ottawa, Ontario, Canada. 407 p.

Grossnickle SC (2005a) Seedling size and reforestation success. How big is big enough? In: Colombo SJ (Compiler), The thin green line: a symposium on the state-of-the-art in reforestation, Forest Research Information Paper 160, Ontario Forest Research Institute, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada. pp 138–144.

Grossnickle SC (2005b) Importance of root growth in overcoming planting stress. New Forest 30: 273-294.

Grossnickle SC (2012) Why seedlings survive: Importance of plant attributes. New Forest 43: 711-738.

Grossnickle SC, Reid CPP (1982) The use of ectomycorrhizal conifer seedlings in the revegetation of a high-elevation mine site. Can J For Res 12: 354-361.

Grossnickle SC, Reid CPP (1983) Ectomycorrhiza formation and root development patterns of conifer seedlings on a high-elevation mine site. Can J For Res 13: 1145-1158.

Grossnickle SC, Reid CPP (1984) Water relations of Engelmann spruce seedlings on a high-elevation mine site: an example of how reclamation techniques can alter microclimate and edaphic conditions. Reclam Reveg Res 3: 199-221.

Grossnickle SC, Folk RS (1993) Stock quality assessment: Forecasting survival or performance on a reforestation site. Tree Plant 44: 113-121.

Grossnickle SC, El-Kassaby YA (2016) Bareroot versus container stocktypes: a performance comparison. New Forest 47: 1-51.

Guarnaschelli AB, Prystupa P, Lemcoff JH (2006) Drought conditioning improves water status, stomatal conductance and survival of *Eucalyptus globulus* subsp. *bicostata* seedlings. Annals For Sci 63: 941-950.

Guo Q, Ren H (2014) Productivity as related to diversity and age in planted versus natural forests. Global Ecol Biogeogr 23: 1461-1471.

Hamann A, Gylander T, Chen P (2011) Developing seed zones and transfer guidelines with multivariate regression trees. Tree Genet Genomes 7: 399-408.

Harper GJ, Comeau PG, Biring BS, Reid WJ, Fielder P (1998) A comparison of mulch mat and herbicide treatments for reducing grass competition in the IDFww. B.C. Ministry of Forests, Research Branch, Victoria, BC. Exten. Note 27.

Haywood DJ (1999) Durability of selected mulches, their ability to control weeds, and influence growth of Loblolly pine seedlings. New Forest 18: 263-76. doi:10.1023/A:1006699910149.

Haywood DJ, Sung SJS, Sword Sayer MA (2012) Copper root pruning and container cavity size influence longleaf pine growth through five growing seasons. South J Appl For 36: 146-151.

Heryati Y, Abdu A, Mahat MN, Abdul-Hamid H, Majid NM, Heriansyah I, Ahmad K (2011) Assessing forest plantation productivity of exotic and indigenous species on degraded secondary forests. American Am J Agric Biol Sci 6: 201-208.

Hipps NA, Higgs KH, Collard LG (1996) The effect of irrigation and root pruning on the growth of sycamore (*Acer pseudoplatanus*) seedlings in nursery beds and after transplantation. J Hortic Sci 71: 819-828.

Hobbs SD (1992) Seedling and site interactions. In: Hobbs SD (ed) Reforestation practices in Southwestern Oregon and Northern California, Forest Research Laboratory, Oregon State University, Corvallis, OR, USA. pp. 114-135.

Hobbs SD, SG Stafford, Slagle RL (1987) Undercutting conifer seedlings: effect of morphology and field performance on droughty sites. Can J Forest Res 17:40-46.

Howe TG, Aitken NS, Neale BD, Jermstad DK, Wheeler CN, Chen HHT (2003) From genotype to phenotype: unraveling the complexities of cold adaptation in forest trees. Can J Forest Bot 81: 1247-1266.

Hydrometeorological Service of Serbia (2013) http://www.hidmet.gov.rs/podaci/meteorologija/ciril/l2012.pdf (Accessed online: 24.12.2015)

Hydrometeorological Service of Serbia (2015) http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_temp_rezim.php (Accessed online: 11.11.2015)

Hytönen J, Jylhä P (2005) Effects of competing vegetation and post-planting weed control on the mortality, growth and vole damages to *Betula pendula* planted on former agricultural land. Silva Fenn 39: 365-380.

Hytönen J, Jylhä P (2008) Fifteen-year response of weed control intensity and seedling type on Norway spruce survival and growth on arable land. Silva Fenn 42: 355-368.

Ionov N, Plugtschieva M, Milev M (2000) Afforestation programmes in Bulgaria. In Weber N (ed) NEWFOR – New Forests for Europe: Afforestation at the Turn of the Century, EFI Proc. 35, Joensuu: EFI. pp 213-220.

IPCC (2014) Climate Change 2014: Synthesis Report. In: Pachauri RK, Meyer LA (eds) Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, , IPCC, Geneva, Switzerland. 151 p.

Isaac-Renton MG, Roberts DR, Hamann A, Spiecker H (2014) Douglas-fir plantations in Europe: A retrospective test of assisted migration to address climate change. Global Change Biol 20: 2607-2617. doi.org/10.1111/gcb.12604

Iverson LR, Schwartz MW, Prasad AM (2004) How fast and far might tree species migrate in the eastern United States due to climate change? Global Ecology Biogeogr 13: 209-219.

Ivetić V (2013) Handbook on Seed production, seedling production and afforestation [On Serbian: Praktikum iz Semenarstva, rasadničarstva i pošumljavanja]. University of Belgrade – Faculty of Forestry, Belgrade, Serbia. 213 p.

Ivetić V (2015) Reforestation in Serbia: Success or failure? In: Ivetić V, Stanković D (eds) Proceedings: International conference Reforestation Challenges, 03-06 June 2015, Belgrade, Serbia. pp 1-12.

Ivetić V, Škorić M (2013) The impact of seeds provenance and nursery production method on Austrian pine (*Pinus nigra* Arnold) seedlings quality. Ann For Res 56(2): 297-305.

Ivetić V, Vilotić D (2014) The role of plantation forestry in sustainable development. Bulletin of the Faculty of Forestry – Special Edition: 157-180.

Ivetić V, Isajev V, Šijačić-Nikolić M (2005) Results of fourteen year's old Norway spruce provenance test in Serbia. Proceedings of Symposium Forest and Sustainable Development, Brasov, Romania. pp 65-71.

Ivetić V, Davorija Z, Vilotić D (2013) Relationship between morphological and physiological attributes of hop hornbeam seedlings. Bulletin of the Faculty of Forestry 108: 39-50.

Ivetić V, Grossnickle S, Škorić M (2016) Forecasting the field performance of Austrian pine seedlings using morphological attributes. In Press

Jacobs DF (2014) Advances in fertilization for forest regeneration. In: Wilkinson KM, Haase DL, Pinto JR, (technical coordinators), National Proceedings: Forest and Conservation Nursery Associations—2013. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-72. pp 3-5.

Jacobs DF, Steinbeck K (2001) Tree shelters improve the survival and growth of planted Engelmann Spruce seedlings in southwestern Colorado. West J Appl For 16: 114-120.

Jacobs DF, Wilson BC, Davis AS (2004a) Recent trends in hardwood seedling quality assessment. In: Riley LE, Dumroese RK and Landis TD (technical coordinators), National Proceedings: Forest and Conservation Nursery Associations-2003. USDA Forest Service Rocky Mountain Research Station Proceedings RMRS-P-33. pp 140-144.

Jacobs DF, Rose R, Haase D, Alzugaray P (2004b) Fertilization at planting im-pairs root system development and drought avoidance of Douglas-fir (*Pseudotsuga menziesii*) seedlings. Ann Forest Sci 61: 643-651.

Jacobs DF, Salifu KF, Seifert JR (2005) Relative contribution of initial root and shoot morphology in predicting field performance of hardwood seedlings. New Forest 30: 235-251.

Jacobs DF, Oliet JA, Aronson J, Bolte A, Bullock JM, Donoso PJ, Landhäusser SM, Madsen P, Peng S, Rey-Benayas JMR, Weber JC (2015) Restoring forests: What constitutes success in the 21st century? New Forest 46: 601-614.

Jamnická G, Ditmarová Ľ, Kurjak D, Kmeť J, Pšidová E, Macková M, Gömöry D, Střelcová K (2013) The soil hydrogel improved photosynthetic performance of beech seedlings treated under drought. Plant Soil Environ 59: 446-451.

Jelić G (2012) Effects of container type and field preparation on afforestation success in Mediterranean area [In Croatian: Utjecaj vrste kontejnera i pripreme tla na uspjeh pošumljavanja u sredozemnom području]. Doctoral Thesis. University of Zagreb - Faculty of Forestry.

Jinks R, Mason B (1998) Effects of seedling density on the growth of Corsican pine (*Pinus nigra* var. *maritime* Melv.), Scots pine (*Pinus sylvestris* L.) and Douglas-fir (*Pseudotsuga menziesii* Franco) in containers. Ann Forest Sci 55: 407-423.

Johnson JD, Cline ML (1991) Seedling quality of southern pines. In: Duryea ML, Dougherty PM (eds) Forest regeneration manual. Kluwer, Dordrecht, The Netherlands. pp 143–162.

Jović N, Tomić Z, Burlica Č, Jovanović B, Jović D, Grbić P, Jović P, Jovković R (1998) Ecological basis for afforestation of bare lands in Central Serbia. [In Serbian: Ekološke osnove za pošumljavanje neobraslih šumskih površina središnje Srbije]. Institute for multidisciplinary research University of Belgrade, Faculty of Forestry, Belgrade. 55 p.

Jylhä P, Hytönen J (2006) Effect of vegetation control on the survival and growth of Scots pine and Norway spruce planted on former agricultural land. Can J Forest Res 36: 2400–2411. doi:10.1139/x06-053.

Kaczmarek DJ, Pope PE (1993) Covariate analysis of northern red oak seedling growth. In: Proceedings of 7th biennial southern silvicultural research Conference, 1992 Novermber 17-19, Mobile, AL. Gen. Tech. Rep. SO-93. US Department of Agriculture, Forest Service, Southern Forest Experiment Station. New Orleans, LA, USA. pp 351-356.

Kainer KA, Duryea ML (1990) Root wrenching and lifting date of slash pine: effects on morphology, survival, and growth. New Forest 4:207-221.

Karličić V, Golubović Ćurguz V, Raičević V (2016) The alleviation of reforestration challenges by beneficial soil microorganisms. Reforesta 1:238-259.

Karličić V, Radić D, Jovičić Petrović J, Golubović-Ćurguz V, Kiković D, Raičević V (2015) Inoculation of *Robinia pseudoacacia* L. and *Pinus sylvestris* L. seedlings with plant growth promoting bacteria causes increased growth in coal mine overburden. In: Ivetić V, Stanković D (eds) Proceedings: International conference Reforestation Challenges, 03-06 June 2015, Belgrade, Serbia, pp 42-49.

Kawaletz H, Mölder I, Zerbe S, Annighöfer P, Terwei A, Ammer C (2013) Exotic tree seedlings are much more competitive than natives but show underyielding when growing together. J Plant Ecol 6: 305-315.

King GA, Herstrom AA (1996) Holocene tree migration rates objectively determined from fossil pollen data. In: Huntley B, Cramer W, Marsa AV, Prentice IC, Allen JRM (eds) Past and future environmental changes: the spatial and evolutionary responses of terrestrial biota, New York, USA: Springer Verlag. pp 91-102.

Kirschbaum M, Fischlln A (1996) Climate change impacts on forests. In: Watson R, Zinyowera MC, Moss RH (eds) Climate change 1995 - Impacts, adaptations and mitigation of climate change: scientific-technical analysis. Contribution of Working Group to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge a.o. pp 95-129.

Kjær ED, Lobo A, Myking T (2014) The role of exotic tree species in Nordic forestry. Scand J Forest Res 29: 323-332. doi:10.1080/02827581.2014.926098

Kjelgren R (2010) Isohydric and anisohydric water use considerations in species selection for the great green wall of Africa. In Dia A, Duponnois R (eds) Le projet majeur africain de la Grande Muraille Verte: Concepts et mise en œuvre. IRD Éditions. Tiré de http://books.openedition.org/irdeditions/2115.

Kloetzel S (2004) Revegetation and restoration planting tools: an in-the-field perspective. Native Plants Journal 5: 34-42.

Klossas G, Kyriazopoulos A, Koukoura Z (2012) Post-planting treatments and shading effects in a *Fraxinus angustifolia* Vahl. silvopastoral system. Ann For Res 56: 179-186.

Kostopoulou E, Jones PD (2005) Assessment of climate extremes in the Eastern Mediterranean. Meteorol Atmos Phys 89: 69-85.

Krakowski K, Stoehr M (2009) Coastal Douglas-fir provenance variation: patterns and predictions for British Columbia seed transfer. Ann For Sci 66:811-821.

Kremer A (2010) Evolutionary responses of European oaks to climate change. Irish For 67: 53-65.

Kremer A, Ronce O, Robledo-Arnuncio JJ, Guillaume F, Bohrer G, Nathan R, Bridle JR, Gomulkiewicz R, Klein EK, Ritland K, Kuparinen A, Gerber S, Schueler S (2012) Long-distance gene flow and adaptation of forest trees to rapid climate change. Ecol Lett 15: 378-392.

Laliberté E, Bouchard A, Cogliastro A (2008) Optimizing hardwood reforestation in old fields: The effects of treeshelters and environmental factors on tree seedling growth and physiology. Restor Ecol 16: 270–80. doi:10.1111/j.1526-100X.2007.00270.x.

Landis TD (2011) The target plant concept—a history and brief overview. In: Riley LE, Haase DL, Pinto JR (technical coordinators), National Proceedings: Forest and Conservation Nursery Associations—2010. Proc. RMRS-P-65. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. pp 61-66. Available at: http://www.fs.fed. us/rm/pubs/rmrs_p065.html

Landis TD, Haase DL (2012) Applications of hydrogels in the nursery and during outplanting. In: Haase DL, Pinto JR, Riley LE (technical coordinators) National Proceedings: Forest and Conservation Nursery Associations—2011. Fort Collins (CO): USDA Forest Service, Rocky Mountain Research Station. Proceedings RMRS-P-68. pp 53-58. Available at: http://www.fs.fed.us/rm/pubs/rmrs_p068.html

Landis TD, Dumroese RK, Haase DL (2010) The container tree nursery manual. Vol. 7, Seedling processing, storage, and outplanting, Agric. Handbk. 674. Washington, DC: U.S. Department of Agriculture Forest Service. 200 p.

Larsen HS, South DB, Boyer JM (1986) Root growth potential, seedling morphology and bud dormancy correlate with survival of Loblolly pine seedlings planted in December in Alabama. Tree Physiol 1: 253-263.

Laušević R, Jones-Walters L, Nieto A (2008) Climate change and biodiversity in South-East Europe – impacts and action. REC, Szentendre, Hungary; ECNC, Tilburg, the Netherlands. 67 p.

Lazarus ED, McGill BJ (2014) Pushing the pace of tree species migration. PLoS ONE 9(8): e105380. doi:10.1371/journal.pone.0105380

Ledig FT, Kitzmiller LH (1992) Genetic strategies for reforestation in the face of global climate change. For Ecol Manage 50: 153-169.

Leites LP, Robinson AP, Rehfeldt GE, Marshall JD, Crookston NL (2012) Height-growth response to climatic changes differs among populations of Douglas-fir: A novel analysis of historic data. Ecol Appl 22: 154-165. pmid:22471081 doi:10.1890/11-0150.1

LePage P, Dave CK (1994) Growth of planted lodgepole pine and hybrid spruce following chemical and manual vegetation control on a frost-prone site. Can J Forest Res 24: 208-216. doi:10.1139/x94-031.

Li G, Wang J, Oliet JA, Jacobs DF (2016) Combined pre-hardening and fall fertilization facilitates N storage and field performance of *Pinus tabulaeformis* seedlings. iForest (early view) doi:10.3832/ifor1708-008 [online 2016-01-07]

Li GL, Liu Y, Zhu Y, Yang J, Sun HY, Jia ZK, Ma LY (2011) Influence of initial age and size on the field performance of *Larix olgensis* seedlings. New Forest 42: 215-226.

Loarie SR, Duffy PB, Hamilton H, Asner GP, Field CB, Ackerly DD (2009) The velocity of climate change. Nature 462: 1052-1056.

Löf M, Dey DC, Navarro RM, Jacobs DF (2012) Mechanical site preparation for forest restoration. New Forest 43: 825-848.

Lujić R (1960) “The local heat factor” and its role in vegetation distribution. [In Serbian: "Lokalni toplotni faktor" i njegova uloga u rasporedu vegetacije]. Bulletin of the Faculty of Forestry 18, Doctoral thesis, University of Belgrade, Faculty of Forestry. 104 p.

Lujić R (1973) Forest melioration [In Serbian: Шумске мелиорације. Уџбеник Универзитет у Београду Шумарски факултет]. University handbook – University of Belgrade – Faculty of Forestry. 415 p.

Lukić S (2013) The effects of ameliorative afforestations in Grdelička gorge and Vranjska valley. [In Serbian: Мелиоративни ефекти противерозионих пошумљавања на подручју Грделичке клисуре и Врањске котлине]. Ph D Thesis. University of Belgrade – Faculty of Forestry. 227 p.

Lukić S, Kadović R, Knežević M, Beloica J, Đukić V, Belanović Simić S (2015) Soil carbon accumulation as a response to the afforestation method used in the Grdelica gorge in southeastern Serbia. In: Ivetić V, Stanković D (eds) Proceedings: International conference Reforestation Challenges. 03-06 June 2015, Belgrade, Serbia. pp 104-116.

Mattsson A (1996) Predicting field performance using seedling quality assessment. New Forest 13: 227-252.

Mc Carthy N, Mc Carthy C, Rathaille MO (2007) Mulch mats - their potential in establishing forest and other tree crops. COFORD, Dublin. 36 p.

McCreary DD, Tecklin J (1997) Effects of seedling protectors and weed control on blue Oak growth and survival. In: Pillsbury NH, Verner J, Tietje WD (tech coord) Proceedings of a symposium on oak woodlands: Ecology, management, and urban interface issues, 19–22 March 1996, San Luis Obispo, CA. Gen. Tech. Rep. PSW-GTR-160. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. pp 243-250.

McCreary DD, Tecklin J (2001) The effects of different sizes of tree shelters on blue Oak (*Quercus douglasii*) growth. West J Appl For 16: 153-158.

McDonald MP, Helgerson TO (1990) Mulches aid in regenerating California and Oregon forests: past, present, and future. Gen. Tech. Rep. PSW-123. Berkeley, CA: Pacific Southwest Research Station, Forest Service, US. Department of Agriculture. 19 p.

McDonald PM, Fiddler GO, Harrison HR (1994) Mulching to regenerate a harsh site: Effect on Douglas-fir seedlings, forbs, grasses, and ferns. US Dep Agric For Serv, SW Res Sta, Albany, CA Res Pap psw-rp-222.

McLachlan JS, Clark JS, Manos PS (2005) Molecular indicators of tree migration capacity under rapid climate change. Ecology 86: 2088-2098.

McTague JP, Tinus RW (1996) The effects of seedling quality and forest site weather on field survival of ponderosa pine. Tree Plant 47:16-32.

Menzies Ml, Van Dorsser JC, Balneaves JM (1985) Seedling quality-radiata pine as a case study. In South DB (ed) Proceedings of the International Symposium on Nursery Management Practices for the Southern Pines, 1985. Aug. 5-9, Montgomery, Alabama, USA. pp 384-415.

Mercurio R, Schirone B (2015) Black pine reforestation of the Apennines in the Abruzzi region (central Italy): Perspectives and management. In: Ivetić V, Ćirković-Mitrović T (eds) Book of abstracts: International conference Reforestation Challenges, Belgrade 03-06 June 2015. pp 36.

Mexal JG, Landis TD (1990) Target seedling concepts: Height and diameter. In: Proceedings of Combined Meeting of the Western Forest Nursery Association Target Seedling Symposium, U.S. Department of Agriculture – Forest Service General Technical Report RM-200. Fort Collins, CO, USA. pp 17-36.

Mexal JG, South DB (1991) Bareroot seedling culture. In: Duryea ML, Dougherty PM (eds) Forest regeneration manual Kluwer, Dordrecht, The Netherlands. pp 89-115.

Mexal JG, Cuevas Rangel RA, Landis TD (2009) Reforestation success in central Mexico: Factors determining survival and early growth. Tree Planters notes 53: 16-22.

Millar CI, Stephenson NL, Stephens SL (2007) Climate change and forests of the future: managing in the face of uncertainty. Ecol Appl 17: 2145-2151.

Mishra PK, Osman M (2011) Techniques of water conservation and rainwater harvesting for drought management. In: Satendra, Venkateswarlu B (eds) SAARC Training Program, 18-29 July, 2011, Central Research Institute for Dryland Agriculture, Hyderabad, India. 714 p.

Moriondo M, Good P, Durao R, Bindi M, Giannakopoulos C, Corte-Real J (2006) Potential impact of climate change on fire risk in the Mediterranean area. Climate Res 31: 85-95.

Navarro Cerrillo RM, Fragueiro B, Ceaceros C, Del Campo A, De Prado R (2005) Establishment of *Quercus ilex* L. subsp. *ballota* [Desf.] Samp. using different weed control strategies in Southern Spain. Ecol Eng 25: 332-342. doi:10.1016/j.ecoleng.2005.06.002.

Nebgen RJ, Meyer JF (1986) Seed bed density, undercutting, and lateral root pruning effects on Loblolly pine seedling morphology, field survival, and growth. In: South DB (ed) Proceedings of International Symposium on Nursery Management Practices for the Southern Pines, Alabama Agricultural Experiment Station, Auburn University, AL, USA. pp 136-147.

Noland LT, Mohammed HG, Wagner GR (2001) Morphological characteristics associated with tolerance to competition from herbaceous vegetation for seedlings of Jack pine, Black spruce and White pine. New Forest 21: 199-215. doi:10.1023/A:1012091917395.

Nolte DL, Wagner KK (2000) Comparing the efficacy of delivery systems and active ingredients of deer repellents. Proceedings of the Vertebrate Pest Conference 19: 93–100.

O'Neill GA, Radley RA, Chanway CP (1992) Variable effects of emergence-promoting rhizobacteria on conifer seedling growth under nursery conditions. Biol Fert Soils 13: 45–49. doi:10.1007/BF00337237.

OECD (2015) OECD Forest Seed and Plant Scheme. 53 p. (Accessed online on 2015-12-21 at: http://www.oecd.org/tad/code/RuleAndRegulations_EN_2015.pdf)

Oliet AJ, Planelles R, Artero F, Jacobs FD (2005) Nursery fertilization and tree shelters affect long-term field response of *Acacia salicina* Lindl. planted in Mediterranean semiarid conditions. Forest Ecol Manage 215: 339-351. doi:10.1016/j.foreco.2005.05.024.

Oliet AJ, Planelles R, Artero F, Valverde R, Jacobs DF, Segura LM (2009) Field performance of *Pinus halepensis* planted in Mediterranean arid conditions: Relative influence of seedling morphology and mineral nutrition. New Forest 37: 313-331. doi:10.1007/s11056-008-9126-3.

Önol B, Semazzi FHM (2009) Regionalization of climate change simulations over the eastern Mediterranean. J Clim 22: 1944-1961.

Óskarsson Ú (2010) Potting substrate and nursery fertilization regime influence mycorrhization and field performance of *Betula pubescens* seedlings. Scand J Forest Res 25: 111-117. doi:10.1080/02827581003730781.

Ovalle J, Arellano E, Ginocchio R (2015) Trade-offs between drought survival and rooting strategy of two South American Mediterranean tree species: implications for dryland forests restoration. Forests 6: 3733-3747.

Owston PW (1990) Target seedling specifications: Are stocktype designations useful? In: Rose R, Campbell SJ, Landis TD (eds) Proceedings, Western Forest Nursery Association; 1990 August 13-17; Roseburg, OR. General Technical Report RM-200. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. pp 9-16. Available at:http://www.fcanet.org/proceedings/1990/owston.pdf

Padilla FM, Pugnaire FI (2006) The role of nurse plants in the restoration of degraded environments. Front Ecol Environ 4(4): 196–202.

Palacios G, Cerrillo N M R, Campo A, Toral M (2009) Site preparation, stock quality and planting date effect on early establishment of Holm oak (*Quercus ilex* L.) seedlings. Ecological Engineering 35 (1): 38-46. doi:10.1016/j.ecoleng. 2008.09.006

Pedlar JH, McKenney DW, Beaulieu J, Colombo SJ, McLachlan JS, O'Neill GA (2011) The implementation of assisted migration in Canadian forests. Forestry Chronicle 87: 766–777.

Pedlar JH, McKenney DW, Aubin I, Beardmore T, Beaulieu J, Iverson L, O'Neill GA, Winder RS, Ste-Marie C (2012) Placing forestry in the assisted migration debate. Bioscience 62: 835-842. doi:10.1525/ bio.2012.62.9.10

Pery R, Save M, Marfa O, Serrano L (1995) The effect of a hydrophilic polymer on plant water status and survival of transplanted pine seedlings. Horttechnology 5: 141–143.

Peterson J (1997) Growing environment and container type influence field performance of Black spruce container stock. New Forest 13: 329-339.

Pinto JR, Marshall JD, Dumroese RK, Davis AS, Cobos DR (2011) Establishment and growth of container seedlings for reforestation: A function of stocktype and edaphic conditions. Forest Ecol Manage 261: 1876-1884.

Pinto JR, Marshall JD, Dumroese RK, Davis AS, Cobos DR (2012) Photosynthetic response, carbon isotopic composition, survival, and growth of three stock types under water stress enhanced by vegetative competition. Can J For Res 42: 333-344.

Pinto JR, Marshall JD, Dumroese KR, Davis AS, Cobos DR (2016) Seedling establishment and physiological responses to temporal and spatial soil moisture changes. New Forest 47: 223-241.

Potter MK, Hargrove WW (2012) Determining suitable locations for seed transfer under climate change: a global quantitative method. New Forest 43: 581-599.

Prinz D (1996) Water harvesting: past and future. In: Pereira LS (ed) Proceedings: Sustainability of irrigated agriculture, NATO advanced research workshop, Vimeiro, 21-26.03. 1994, Balkema, Rotterdam. pp 135-144.

Prober SM, Byrne M, McLean EH, Steane DA, Potts BM, Vaillancourt RE, Stock WD (2015) Climate-adjusted provenancing: A strategy for climate-resilient ecological restoration. Front Ecol Evol 3: 65. doi.org/10.3389/fevo.2015.00065

Puertolas J, Gil L, Pardos JA (2003) Effects of nutritional status and seedling size on field performance of Pinus halepensis planted on former arable land in the Mediterranean basin. Forestry 76: 159-168.

Querejeta IJ, Roldán A, Albaladejo J, Castillo V (1998) The role of mycorrhizae, site preparation, and organic amendment in the afforestation of a semi-arid Mediterranean site with *Pinus halepensis*. Forest Sci 44: 203-211.

Regan DJ, Apostol KG, Davis AS (2015) Stocktype influences western white pine seedling size 6 years after outplanting. Tree Planters' Notes 58: 37-41.

Ren H, Yang L, Liu N (2008) Nurse plant theory and its application in ecological restoration in lower subtropics of China. Prog Nat Sci 18: 137-142. http://doi.org/10.1016/j.pnsc.2007.07.008

Renwick KM, Rocca ME (2015) Temporal context affects the observed rate of climate-driven range shifts in tree species. Global Ecol Biogeogr 24: 44-51. doi.org/10.1111/geb.12240

Rey Benayas MJ, Navarro J, Espigares T, Nicolau MJ, Zavala AM (2005) Effects of artificial shading and weed mowing in reforestation of Mediterranean abandoned cropland with contrasting *Quercus* species. Forest Ecol Manage 212: 302-314. doi:10.1016/j.foreco.2005.03.032.

Reyer C, Guericke M, Ibisch PL (2009) Climate change mitigation via afforestation, reforestation and deforestation avoidance: and what about adaptation to environmental change? New Forest 38: 15–34.

Rietveld WJ, Van Sambeek JW (1989) Relating black walnut planting stock to field performance. In: Rink G, Budelsky CA (eds) Proceedings of the seventh central hardwood forest conference. Gen. Tech. Rep. NC-132. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. pp 162-169.

Rincon A, De Felipe MR, Fernandez-Pascual M (2007) Inoculation of *Pinus halepensis* Mill. with selected ectomycorrhizal fungi improves seedling establishment 2 years after planting in a degraded gypsum soil. Mycorrhiza 18: 23-32.

Ritchie GA (1984) Assessing seedling quality. In: Duryea ML, Landis TD (eds) Forest nursery manual: Production of bareroot seedlings. Martinus Nijhoff/Dr. W. Junk Publishers, The Hague. pp 243-266.

Rodríguez-Echeverría S, Lozano YM, Bardgett RD (2016) Influence of soil microbiota in nurse plant systems. Funct Ecol 30: 30–40. doi:10.1111/1365-2435.12594

Roldan A, Querejeta I, Albadalejo J, Castillo V (1996) Growth response of *Pinus halepensis* to inoculation with *Pisolithus arhizus* in a terraced rangeland with urban refuse. Plant Soil 179: 35–43.

Rose R, Ketchum JS (2002) Interaction of vegetation control and fertilization on conifer species across the Pacific Northwest. Can J Forest Res 32: 136-52. doi:10.1139/x01-180.

Rose R, Ketchum JS (2003) Interaction of initial seedling diameter, fertilization and weed control on Douglas-fir growth over the first four years after planting. Ann Forest Sci 60: 625-35. doi:10.1051/forest:2003055.

Rose R, Gleason JF, Atkinson M (1993) Morphological and water-stress characteristics of three Douglas-fir stocktypes in relation to seedling performance under different soil moisture conditions. New Forest 7: 1-17. http://doi.org/10.1007/BF00037468

Rose R, Haase DL, Kroiher F, Sabin T (1997) Root volume and growth of Ponderosa pine and Douglas-fir seedlings: a summary of eight growing seasons. West J Appl For 12: 69-73.

Rose R, Ketchum JS, Hanson DE (1999) Three-year survival and growth of Douglas-fir seedlings under various vegetation-free regimes. For Sci 45: 117-126.

Rose R, Haase D, Arellano E (2004) Controlled-release fertilizers: potential for enhanced reforestation productivity. Bosque 25: 89-100.

Rosner LS, Rose R (2006) Synergistic stem volume response to combinations of vegetation control and seedling size in conifer plantations in Oregon. Can J Forest Res 35: 930-944.

Rowan SJ (1986) Seedbed density affects performance of slash and loblolly pine in Georgia. In: South DB (ed) Proceedings: International symposium on nursery management practices for the southern pines, 1985 Aug 4–9; Montgomery, AL. Alabama Agricultural Experiment Station, Auburn University, AL, USA. pp 126-135.

Sarvaš M, Pavlenda P, Takáčová E (2007) Effect of hydrogel application on survival and growth of Pine seedlings in reclamations. J Forest Sci 53: 204-209.

Schaap W, DeYoe DR (1985) Seedling protectors for preventing deer browse. Forest Research Laboratory, Oregon State University, Corvallis. Research Bulletin 54. 12 p.

Schmidtling RC, MyszewskiJH (2003) Effect of large-scale movement of loblolly pine seed on genetic integrity of the species in its natural range. In: Beaulieu J (ed.), Proceedings of the Symposium of the North American Forest Commission, Forest Genetic Resources and Silviculture Working Groups, and the International Union of Forest Research Organizations (IUFRO), September 21, Quebec City, Canada. pp 43-48.

Sgrò CM, Lowe AJ, Hoffmann AA (2011) Building evolutionary resilience for conserving biodiversity under climate change. Evol Appl 4(2): 326-337.

Sharma RK, Mason EG, Sorensson C (2007) Impact of planting stock quality on initial growth and survival of radiata pine clones and modelling initial growth and survival. New Zeal J Forest 52:14-23.

Shipman RD (1964) Low seedbed densities can improve early height growth of planted slash and loblolly pine seedlings. J Forest 62: 814-817.

Shishido M, Petersen JD, Massicotte BH, Chanway PC (1996a) Pine and Spruce seedling Growth and mycorrhizal infection after inoculation with plant growth promoting *Pseudomonas* strains. FEMS Microbiol Ecol 21: 109-119. doi:10.1111/j.1574-6941.1996.tb00338.x.

Shishido M, Massicotte HB, Chanway CP (1996b) Effect of plant growth promoting bacillus strains on Pine and Spruce seedling growth and mycorrhizal infection. Ann Bot-London 77: 433-442. doi:10.1006/anbo.1996.0053.

Siipilehto J (2001) Effect of weed control with fibre mulches and herbicides on the initial development of spruce, birch and aspen seedlings on abandoned farmland. Silva Fennica 35: 403–414.

Siipilehto J, Lyly O (1995) Weed control trials with fibre mulch, glyphosate and terbuthylazine in Scots pine plantations. Silva Fenn 29: 41-48.

Simard S, Vyse A (2006) Trade-offs between competition and facilitation: A case study of vegetation management in the interior Cedar–Hemlock forests of Southern British Columbia. Can J Forest Res 36 (10): 2486-2496. doi:10.1139/x06-150.

Simpson DG (1991) Growing density and container volume affect nursery and field growth of interior spruce seedlings. North J Appl For 8: 160-165.

Simpson DG (1994) nursery growing density and container volume affect nursery and field growth of Douglas-fir and Lodgepole pine seedlings. In: Landis TD, Dumroese RK (tech coords), Proceedings, Forest and Conservation Nursery Associations, 1994, July 11-14, Williamsburg, VA. General Technical Report RM-GTR-257. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO, USA. pp 105–115.

Sippel S, Otto FEL (2014) Beyond climatological extremes - assessing how the odds of hydrometeorological extreme events in South-East Europe change in a warming climate. Climatic Change 125: 381-398.

Sutton RF (1995) White spruce establishment: initial fertilization, weed control, and irrigation evaluated after three decades. New Forests 9: 123-133.

Stange EE, Shea LK (1998) Effects of deer browsing, fabric mats, and tree shelters on *Quercus rubra* seedlings. Restor Ecol 6: 29-34. doi:10.1046/j.1526-100x.1998.00614.x.

Stepanek LJ, Brandle JR, Harrell MO (2002) Assessment of microenvironmental conditions related to the use of synthetic sheet mulches for protecting newly planted trees in semi-arid environments. J Sustain Agr 19: 15-347.

Sloan JP, Jump LH, Ryker RA (1987) Container grown Ponderosa pine seedlings outperform bareroot seedlings on harsh sites in southern Utah. Research Paper INT-384. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, USA. 14 p.

South DB (1993) Rationale for growing southern pine seedlings at low seedbed densities. New Forest 7: 63-92.

South DB (2005) A review of the pull up and leave down methods of planting Loblolly pine. Tree Planters' Notes 51: 53-67.

South DB, Mitchell RJ (1999) Determining the "optimum" slash pine seedling size for use with four levels of vegetation management on a flatwoods site in Georgia, USA. Can J Forest Res 29: 1039-1046.

South DB, Harris SW, Barnett JP, Hainds MJ, Gjerstad DH (2005) Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, U.S.A. Forest Ecol Manage 204: 385-398.

South DB, Jackson DP, Starkey TE, Enebak SA (2012) Planting deep increases early survival and growth of *Pinus echinata* seedlings. The Open Forest Science Journal 5: 33-41.

Spinoni J, Lakatos M, Szentimrey T, Bihari Z, Szalai S, Vogt J, Antofie T (2015) Heat and cold waves trends in the Carpathian Region from 1961 to 2010. Int J Climatol 35: 4197-4209. doi.org/10.1002/joc.4279

Spittlehouse DL, Stewart RB (2003) Adapting to climate change in forest management. J Ecosystems Manage 4: 7–17.

Stanturf JA, Palik BJ, Dumroese RK (2014) Contemporary forest restoration: A review emphasizing function. Forest Ecol Manage 331: 292-323. doi.org/10.1016/j.foreco.2014.07.029

Stein IW (1984) Wrenching Douglas-fir seedlings in August: immediate but no lasting effects. Res. Pap. PNW-317 Portland, OR: U.S, Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Stewart JD, Bernier PY (1995) Gas exchange and water relations of 3 sizes of containerized *Picea mariana* seedlings subjected to atmospheric and edaphic water stress under controlled conditions. Ann Forest Sci 52: 1-9.

Stilinović S (1991) Afforestation. Naučna knjiga, Belgrade. University book. 274 p. [In Serbian]

Stroempl G (1990) Deeper planting of seedlings and transplants increases plantation survival. Tree Planters' Notes 41: 17-21.

Šijačić-Nikolić M, Vilotić D, Milovanović J (2011) Effect of polymers on Scots pine (*Pinus silvestris* L.) and Austrian pine (*Pinus nigra* Arn.) seedling development in afforestation. Global Journal of Biodiversity Science and Management 1: 11-18. ISSN 2074-0875.

Škorić M, Krsmanović I, Ristić R, Đorđević U (1997) Application of explosive in afforestation on "Ellipse". Proceeding book of the 3rd ICFWST 97, September 29th – October 3rd, 1997, Belgrade and Mt. Goč, Serbia, Yugoslavia. pp 178-181.

Tanaka Y, Walstad JD, Borrecco JE (1976) The effect of wrenching on morphology and field performance of Douglas-fir and Loblolly pine seedlings. Can J For Res 6: 453-458.

Thomas E, Jalonen R, Loo J, Boshier D, Gallo L, Cavers S, Bozzano M (2014) Genetic considerations in ecosystem restoration using native tree species. Forest Ecol Manage 333: 66-75. doi.org/10.1016/j.foreco.2014.07.015

Thompson BE (1985) Seedling morphological evaluation: what you can tell by looking. In: Duryea ML (ed) Evaluating seedling quality: principles, procedures, and predictive ability of major tests Forest Research Laboratory, Oregon State University, Corvallis, OR, USA. pp 59-72.

Thomson JR, Schultz RC (1995) Root system morphology of *Quercus rubra* L. planting stock and 3-year field performance in Iowa. New Forest 9: 225-236.

Timmer VR (1997) Exponential nutrient loading: A new fertilization technique to improve seedling performance on competitive sites. New Forest 13: 279-299. doi:10.1023/A:1006502830067.

Timmer VR, Aidelbaum AS (1996) Manual for exponential nutrient loading of seedlings to improve outplanting performance on competitive forest sites. Nat Resour Can, Canadian Forest Service-Sault Ste. Marie, ON. NODA/NFP Tech Rep TR-25. 21 p. + appendix.

Tomašević A (1994) Undermining as first stage of soil preparation for afforestation. [In Croatian: Podrivanje kao prva faza pripreme tla za pošumljavanje] Šumarski list 5-6: 173-181.

Tomić Z, Rakonjac Lj, Veselinović M, Nevenić R (2011) Species and intra-species selection for afforestation and melioration. In: Tomić Z, Rakonjac Lj, Isajev V (eds) The selection of species for reforestation and amelioration in central Serbia, Institute of Forestry, Belgrade, Serbia.

Trent A, Nolte D, Wagner K (2001) Comparison of commercial deer repellents. USDA National Wildlife Research Center - Staff Publications. Paper 572

Tsakaldimi M, Ganatsas P, Jacobs DF (2012) Prediction of planted seedling survival of five Mediterranean species based on initial seedling morphology. New Forest 44: 327-339.

Tuttle CL, South DB, Golden MS, Meldahl RS (1988) Initial *Pinus taeda* seedling height relationships with early survival and growth. Can J Forest Res 18: 867-871.

Van den Driessche R (1991) Influence of container nursery regimes on drought resistance of seedlings following planting: survival and growth. Can J Forest Res 21: 555-565.

Viherä-Aarnio A, Häkkinen R, Partanen J, Luomajoki A, Koski V (2005) Effects of seed origin and sowing time on timing of height growth cessation of *Betula pendula* seedlings. Tree Physiol 25: 101-108.

Vilagrosa A, Cortina J, Gil-Pelegrin E, Bellot J (2003) Suitability of Drought preconditioning techniques in Mediterranean climate. Restor Ecol 11: 208-216.

Villar-Salvador P, Planelles R, Enríquez E, Peñuelas-Rubira J (2004a) Nursery cultivation regimes, plant functional attributes, and field performance relationships in the Mediterranean oak *Quercus ilex* L. For. Ecol. Manage. 196: 257-266.

Villar-Salvador P, Planelles R, Oliet J, Peñuelas -Rubira JL, Jacobs DF, González M (2004b) Drought tolerance and transplanting performance of Holm oak (*Quercus ilex*) seedlings after drought hardening in the nursery. Tree Physiol 24: 1147-1155.

Villar-Salvador P, Puértolas J, Peñuelas JL, Planelles R (2005) Effect of nitrogen fertilization in the nursery on the drought and frost resistance of Mediterranean forest species. For Syst (formerly Inv Agrarias: Sist Rec For) 14: 408-418.

Villar-Salvador P, Puértolas J, Cuesta B, Peñuelas JL, Uscola M, Heredia-Guerrero N, Rey Benayas JM (2012) Increase in size and nitrogen concentration enhances seedling survival in Mediterranean plantations. Insights from an ecophysiological conceptual model of plant survival. New Forest 43: 755-770.

Višnjić Ć, Mekić F, Balić B (2004) Usage of the new techniques for the planting by afforestation of the extreme area. [In Bosnian: Upotreba novih tehnika sadnje sadnica kod pošumljavanja ekstremnih staništa. Radovi Šumarskog fakulteta, Univerziteta u Sarajevu. Br. 1 Knjiga XXXIV, Sarajevo 2004] Works of the Faculty of Forestry, University of Sarajevo, BIH, 1: 57-65.

Wagner GR (2005) Top 10 principles for managing competing vegetation to maximize regeneration success and long-term yields. In Colombo SJ (ed) The Thin Green Line: A Symposium on the State-of-the-Art in Reforestation, Ontario Ministry of Natural Resources, Forest Research Information Paper 160. pp 32-36.

Wagner GR, Mohammed HG, Noland LT (1999) Critical period of interspecific competition for northern conifers associated with herbaceous vegetation. Can J Forest Res 29: 890-897.

Wagner GR, Petersen DT, Ross WD, Radosevich RS (1989) Competition thresholds for the survival and growth of Ponderosa pine seedlings associated with woody and herbaceous vegetation. New Forest 3: 151-170. doi:10.1007/BF00021579.

Wagner KK, Nolte DL (2000) Evaluation of Hot Sauce® as a repellent for forest mammals. Wildlife Society Bulletin (1973-2006) 28: 76-83. Retrieved from http://www.jstor.org/stable/4617286

Wagner KK, Nolte DL (2001) Comparison of Active Ingredients and Delivery Systems in Deer Repellents. Wildlife Society Bulletin (1973-2006) 29(1): 322–330. Retrieved from http://www.jstor.org/stable/3784016

Walker RF, Mclaughlin SB (1989) Black Polyethylene mulch improves growth of plantation-grown Loblolly pine and Yellow-Poplar. New Forest 3: 265-274. doi:10.1007/BF00028934.

Wang T, O'Neill GA, Aitken SN (2010) Integrating environmental and genetic effects to predict responses of tree populations to climate. Ecol Appl 20: 153-163.

Ward D, Johnston TN (1986) Determination of optimum seedling bed density for bare-root Honduras Caribbean pine. In: South DB (ed) Proceedings of the International Symposium on Nursery

Management Practices for the Southern Pines. Montgomery Alabama August 4-9-1985. Auburn University, Alabama, USA. pp 118-125.

Ward JS, Gent MPN, Stevens GR (2000) Effects of planting stock quality and browse protection-type on height growth of northern red oak and eastern white pine. Forest Ecol Manage 127: 205-216.

Williams HM, Stewart T (2006) The effects of sower and bed density on bareroot loblolly pine seedling morphology and early height growth. General Technical Report SRS-92. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC, USA, pp 45-49.

Williams MI, Dumroese RK (2013) Preparing for climate change: Forestry and assisted migration. J Forest 111: 287-297.

Wilson ER, Vitols KC, Park A (2007) Root characteristics and growth potential of container and bare-root seedlings of red oak (*Quercus rubra* L.) in Ontario, Canada. New Forest 34: 163-176.

Woodall CW, Oswalt CM, Westfall JA, Perry CH, Nelson MD, Finley AO (2009) An indicator of tree migration in forests of the eastern United States. Forest Ecol Manage 257: 1434-1444.

Yohannes F (1999) Improvement of water application efficiency by moisture conservation methods for establishment of planted tree seedlings. Commun Soil Sci Plan 30: 1119-1125. doi:10.1080/00103629909370272.

Yoshida M, Fujiwara M, Sakai H (2015) A proposal of a site preparation system combined with chipping operation. In:Ivetić V, Stanković D (eds) Proceedings: International conference Reforestation Challenges, 03-06 June 2015, Belgrade, Serbia, pp 211-216.

Zlatanov T, Velichkov I, Lexer MJ, Dubravac T (2010) Regeneration dynamics in aging black pine (*Pinus nigra* Arn.) plantations on the south slopes of the Middle Balkan Range in Bulgaria. New Forest 40: 289-303.