REFORESTATION IN SERBIA: SUCCESS OR FAILURE?

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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. Reforesta. pp. 1-12.

Abstract: Forests in the Republic of Serbia cover 2,252,000 ha, 29% of the country's area. Reforestation is, however, small-scale despite strategic documents encouraging more forest cover. From 2004-2013, annual reforestation and afforestation averaged 1,671 and 1,901 ha, respectively, mostly because of reduced investment in forestry. Because funding is limited, reforestation success, mainly measured by seedling survival, is imperative.
For the last 25 years, no organized monitoring of reforestation occurred in Serbia. To better understand current reforestation success, the first-year survival was measured after planting on 90 sites for nine of the most used species in Serbian reforestation programs. Effects of reforestation goal, species, stocktype, planting time, and weather conditions on survival were analyzed. In addition, on 25 of those sites, survival was monitored for five species for another 1, 2, or 3 years on 6, 7, and 12 sites, respectively. The reasons for seedling mortality were identified on 10 sites.
Average first-year survival was 78%, ranging from 85% in assisted natural regeneration to 68% in afforestation, and was strongly influenced by planting goal, species and stocktype selection, and weather conditions. Bareroot (2+0) *Pseudotsuga menziesii* seedlings had the highest survival (90%) whereas bareroot (2+0) *Pinus nigra* seedlings had the lowest (59%). Moreover, *P. menziesii* seedlings maintained high survival on three sites after four years, decreasing slightly from 87% to 82%. In contrast, bareroot (1+0) *Acer pseudoplatanus* seedlings had good first-year survival (~80%) that decreased to 25% on three sites after two years and 21% on four sites after four years. Overall, the lowest average survival rate (61%) was recorded in 2011 when growing season precipitation was only 65% of the normal 30-year average. The two most common reasons for mortality after outplanting were wildlife (54%) and improper planting (21%). Of the dead seedlings, 5% showed no evidence of root penetration into natural soil.

Key words: reforestation, afforestation, seedling survival, seedling mortality, stocktype

INTRODUCTION

In the last two centuries, forest cover in central Serbia is significantly decreased (Figure 1), from 80% in 1801 to 21.4% just after the Second World War (Aleksić and Vučićević 2006). From this lower point, forest cover rate increasing in the second half of XX century, mainly due to improved forest management, successful reforestation and large afforestation programs. Today, forests in the Republic of Serbia cover 2,252,000 ha, 29.1% of the country's area: 37.6% in Central Serbia and 7.1% in Vojvodina (Banković et al. 2009).

In Serbian forestry, planted forests (Ivetić and Vilotić 2014) are traditionally described as forest cultures or artificial established forests. Young forest, established by afforestation or reforestation (by reconstitution or substitution) is described as forest culture (Ivkov 1971, Stilinović 1991). Planting trees on land without forests is usually described by term of afforestation and planting or direct sowing of trees inside forests or on clear area immediately after harvesting is usually described by term of artificial regeneration or reforestation. Statistical Office of the Republic of Serbia in methodology for survey of forest cover recognize "artificial forests" in forests (after harvesting or on other suitable sites) and outside forests (rocks and barren land, sand, salt marsh, eroded soil, agricultural soil and other soil) both with planting of seedlings or seed sowing.

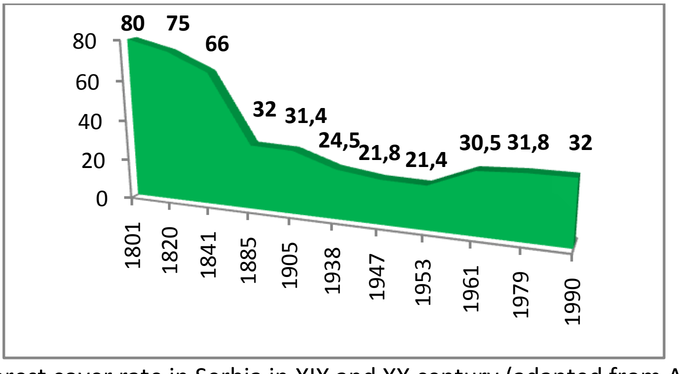

Figure 1. Forest cover rate in Serbia in XIX and XX century (adapted from Aleksić and Vučićević 2006)

Despite strategic documents encouraging more forest cover, in last three decades the reforestation is small-scale. In this paper the focus will be on: 1) reforestation, as artificial forest regeneration by planting seedlings following harvest and 2) afforestation, as way of increasing forest cover and method of restoring forests after deforestation (Stanturf et al. 2014). From 2004-2013, annual reforestation and afforestation averaged 1,671 and 1,901 ha, respectively (Table 1), mostly because of reduced investment in forestry. In same time, annual averages of 6,244,700 seedlings were planted for reforestation/afforestation. In addition, 2,115,900 seedlings were used for industrial plantations and agroforestry. In observed ten year period, the largest total planted area was in 2007, given to largest funding through National Investment Plan.

Because funding is limited, reforestation success, mainly measured by seedling survival, is imperative. Reforestation success can be defined on different fashions, from first-year survival, up to providing a profit or social and environmental benefits. In this study, success of reforestation was measured by survival rate in establishment phase (Kanowski and Catterall 2007).

Table 1: Reforestation/afforestation (ha) in Republic of Serbia, years 2004-2013*.

	Total reforestation/ afforestation	Reforestation	Afforestation	Filling	Industrial plantations	Agroforestry
2004	2.917	1.977	940	609	1.253	139
2005	2.746	1.748	998	321	1.341	119
2006	4.783	2.188	2.595	473	1.577	83
2007	10.475	1.128	9.347	209	7.365	73
2008	3.320	2.446	874	535	8.014	348
2009	2.143	1.018	1.125	309	923	348
2010	2.154	1.305	849	237	5.239	223
2011	2.821	1.834	987	240	6.547	579
2012	2.168	1.413	755	416	866	220
2013	2.194	1.651	543	259	1.149	140
∑	35.721	16.708	19.013	3.608	34.274	2.272

*Source: Statistical Office of the Republic of Serbia – Bulletin: Forestry in Republic of Serbia, release 2004-2013.

Many reforestation failures are hard to explain with data available. Reforestation failure can be result of some nursery operations, mishandling from lifting to planting (McKay 1997, Grossnickle and South 2014), improper planting technique (South 2000), site conditions and absence of seedling adaptation.

For the last 25 years, no organized monitoring of reforestation occurred in Serbia. The last organized survey of reforestation and afforestation success was done by Stilinović (1987). So, this research has two goals: 1) to measure reforestation and afforestation success in Serbia by means of survival rate and 2) to initiate a setup of organized monitoring on long term.

MATERIAL AND METHODS

The first-year survival after planting was measured on total of 90 sites, in a five-year period (2010-2014). The data were collected from forest enterprises (Stolovi, Niš, Južni Kučaj and Belgrade) in system of PE "Srbijašume" (Figure 1). In addition, on 25 of those sites, survival was monitored for five species for another 1, 2, or 3 years on 6, 7, and 12 sites, respectively.

The reasons for seedling mortality were identified on 10 sites. A one sample plot (10 m wide x 50 m long) per hectare was established and obvious reasons for seedling mortality or damage were recorded. Seedlings without visible cause of death were lifted-out for morphological examination.

Mortality was attributed to poor seedling quality in case of absence of growth (shoot and root) and in case of significant deformations. Improper planting was defined by poor planting spot preparation (depth) and wrong seedling positioning. Mortality by wildlife was differentiated from mechanical damage by symptoms of grazing. Dead, wilted plants with yellow or brown leaves and needles, appearing throughout the site are attributed to drought (Figure 1).

Figure 1: Mortality by wildlife (left), improper planting (center) and mortality by drought (right)

Effects of reforestation goal, species, stocktype, planting time, and weather conditions on survival were analyzed. Weather conditions (air temperature and precipitation) were collected for the research period (Table 2).

Table 2: Weather conditions in growing season (April-September) years 2010-2014

Year	Temperature deviation* (°C)	Days with temp. >20°C	Days with temp. >30°C	Days with temp. >35°C	Rainy days	Precipitation (mm)	Precipitation percentage of normal average*
2010	1.1	136	32	2	58	467	129
2011	1.5	149	47	8	38	239	65
2012	2.4	150	68	19	39	279	77
2013	1.2	146	41	8	46	305	84
2014	0.7	136	17	0	70	698	190

*from normal average values for the period 1971-2000.

RESULTS

The first-year survival was measured on 90 sites, with total of 340 ha. During years 2010-2014, the average first-year survival was 78%, ranging from 87.5% in 2014 to 60.8 in 2011 (Table 3).

Table 3: Survival in first year after planting in period 2010-2014

Year	Number of sites	Average site area (ha)	Survival (%)
2010	21	3.97	79.8
2011	16	3.12	60.8
2012	18	3.07	75.7
2013	17	4.12	84.6
2014	18	4.52	87.5
AVERAGE			77.7

Based on reforestation goal, average first-year survival range from 85.6% in assisted natural regeneration to 68% in afforestation. The most successful was assisted natural regeneration, with first-year survival of 80-90% (Table 4). In same time, some serious failures were recorded in amelioration (first-year survival of 30%) and total failures in reforestation after fire and afforestation (5% and 0% respectively).

Table 4: Reforestation goal and survival rate

Reforestation goal	Total area (ha)	Average area (ha)	Survival (%)	Min	Max
After fire	172.47	4.79	74.8	5*	90
Amelioration	96.57	3.58	80.6	30	95
Assisted natural regeneration	35.15	5.02	85.6	80	90
Afforestation	35.81	3.26	67.9	0***	90**

* *Pinus nigra*, 2+0 bareroot
** *Acer pseudoplatanus*, 1+0 bareroot
*** *Pinus nigra*, 2+0 container

Table 5: The first-year survival of seedlings in reforestation after fire, by species and stocktype

Species	Reforested area (ha)	Stocktype	Age	Survival (%)
Pseudotsuga menziesii	2.62	Bareroot	2+0	90
Pinus nigra	71.3	Container	2+0	66.22
	1.45	Container	3+0	87.5
	8.7	Bareroot	2+0	59.16
Acer pseudoplatanus	10.80	Bareroot	1+0	75.27
Robinia pseudoacacia	2.18	Bareroot	1+0	85
Picea abies	13.74	Plug+2	2+2	73
	21.77	Bareroot	2+1	87.5
Acer heldraichii	29.98	Bareroot	1+0	85.83
Prunus avium	6.1	Bareroot	1+0	85
Quercus petraea	2	Bareroot	1+0	85
Fraxinus excelsior	2	Bareroot	1+0	85
STOCKTYPE				
Bareroot				81.97
Container				76.86
Plug+2				73

The average first-year survival in reforestation after fire range from 90% (bareroot 2+0 *Pseudotsuga menziesii*) to 59% (bareroot 2+0 *Pinus nigra*). In most cases bareroot seedlings were used, except for *Pinus nigra*, which container seedlings survived better than bareroot. In general, bareroot seedlings survived better (Table 5).

The first-year survival in melioration ranges from 91% (container 2+0) to 65% (bareroot 2+0) both *Pinus nigra* seedlings (Table 6). Similar results were recorded for *Picea abies*, both bareroot seedlings, but survival ranged from 90% (2+2) to 66% (3+0). Container seedlings had the highest, while bareroot and Nisula seedlings had a similar survival rate.

The first-year survival in assisted regeneration ranges from 90% (bareroot 2+0, *Acer pseudoplatanus*) to 82.5% (bareroot 1+0 *Acer heldraichii*) (Table 7). Only bareroot seedlings were used.

Table 6: The firs-year survival of seedlings on reforestation for melioration, by species and stocktype

Species	Reforested area (ha)	Stocktype	Age	Survival (%)
Picea abies	17.01	Bareroot	3+0	66.25
	2.43	Bareroot	2+2	90
	18.74	Nisula	2+1	81.25
	1.12	Nisula	2+2	75
Pseudotsuga menziesii	5.52	Bareroot	2+0	80
Quercus petraea	5.50	Bareroot	1+0	88.33
Pinus nigra	10.59	Container	2+0	90.83
	4.21	Bareroot	2+0	65
Acer heldraichii	16,64	Bareroot	1+0	87.5
Prunus avium	6.03	Bareroot	1+0	87.5
STOCKTYPE				
Bareroot				80.65
Container				90.83
Nisula				78.12

Table 7: The first-year survival of seedlings after assisted natural regeneration, by species and stocktype

Species	Reforested area (ha)	Stocktype	Age	Survival (%)
Acer pseudoplatanus	2.17	Bareroot	2+0	90
	1,00	Bareroot	1+0	85
Pinus nigra	16.04	Bareroot	3+0	86.2
Acer heldraichii	13.94	Bareroot	1+0	82.5
Prunus avium	2	Bareroot	1+0	85
STOCKTYPE				
Bareroot				85.6

Table 8: The first-year survival of seedlings after afforestation, by species and stocktype

Species	Reforested area (ha)	Stocktype	Age	Survival (%)
Pinus nigra	4.86	Container	2+0	29.2
	3	Bareroot	2+0	80
	4	Bareroot	3+0	87.5
Picea abies	9.65	Bareroot	2+1	83.7
Acer pseudoplatanus	5.3	Bareroot	1+0	75
Acer heldraichii	6	Bareroot	1+0	87.5
STOCKTYPE				
Bareroot				82.74
Container				29.2*

*87.5% with two total failures excluded.

The first-year survival in assisted regeneration ranges from 87.5% (bareroot 3+0 *Pinus nigra* and bareroot 1+0 *Acer pseudoplatanus*) to 29.2% (container 2+0 *Pinus nigra*).

The average survival after afforestation of bareroot seedlings was 82.74% (Table 8). So low average survival rate of container 2+0 *Pinus nigra* seedlings is due to total failure on two sites (0%) planted on 2011. If we exclude these two outliers, average first-year survival of container 2+0 *Pinus nigra* seedlings is 87.5%.

Table 9: The first-year survival of seedlings by stocktype

Stocktype	Number of sites	Area (ha)	The first-year survival (%)
Bareroot	66	215.23	80.3
Container	19	104.1	73.1
Nisula	6	19.86	79.2

In general, bareroot seedlings are the most used stocktype in Serbian reforestation and afforestation programs. Bareroot seedlings had the highest survival rate (80.3%) followed by Nisula and container seedlings, with 79.2% and 73.1% respectively (Table 9).

Table 10: The first-year survival of seedlings by time of planting

Time of planting	Number of sites	Area (ha)	Survival (%)
Spring	47	93,79	71.29
Autumn	43	73.38	73.93

Planting on spring and autumn are equally distributed by the number of sites. The time of planting have no influence on average first-year survival (Table 10).

Table 11: Survival in the first and in following years at 25 sites

Species	Number of sites	Reforested area (ha)	Stocktype	Age	First year survival (%)	Survival in years after planting
			Four years after planting			
Picea abies	1	2.43	Bareroot	2+2	90	70
Pseudotsuga menziesii	3	4.72	Bareroot	2+0	86.67	81.67
Pinus nigra	3	7.7	Container	2+0	87.5	56.67
	1	1.45	Container	3+0	87.5	70
Acer pseudoplatanus	4	5.80	Bareroot	1+0	80.62	21.25
			Three years after planting			
Picea abies	2	9.67	Bareroot	2+1	90	50
Quercus petraea	2	3.5	Bareroot	1+0	90	62.5
Pinus nigra	1	0.3	Container	2+0	50	50
Acer pseudoplatanus	2	3.17	Bareroot	1+0	82.5	40
			Two years after planting			
Picea abies	2	1.12	Bareroot	2+2	75	60
Pseudotsuga menziesii	1	1.1	Bareroot	2+0	90	90
Acer pseudoplatanus	3	4.3	Bareroot	1+0	76.67	25

In general, survival of all species and stocktypes decreased in year's two to four after planting (Table 11). This decrease in survival is larger for bareroot seedlings. *Pseudotsuga menziesii* bareroot (2+0) seedlings maintained high survival on three sites after four years, decreasing slightly from 87% to 82%. In contrast, bareroot (1+0) *Acer pseudoplatanus* seedlings had good first-year survival (~80%) that decreased to 25% on three sites after two years and 21% on four sites after four years.

Table 12: The reasons of seedling mortality on 10 sites

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

The two most common reasons for mortality after outplanting were wildlife (54%) and improper planting (21%). Of the dead seedlings, 5% showed no evidence of root penetration into natural soil. On 10 sites, extreme weather events caused damages mostly by frost (Table 12).

DISCUSSION

After the Second World War forest cover rate in Serbia is increased, mainly due to improved forest management, successful reforestation and large afforestation programs. However, not all of these programs of reforestation and afforestation were successful. Although Ratknić and Dražić (2007) states 525,657 ha afforested/reforested in Serbia between 1945-1995 (492,256 ha in Central Serbia and Vojvodina) and Ranković (2009) states 390.965 ha between 1961-2007, according to National Forest Inventory planted forests covers only 174,800 ha or 7.8% of total forest area in Serbia; of which 6.1% are cultures and 1.7% of plantations (Banković et al. 2009). So, the question is: What was happened to these large areas of planted forests? Reasons for such large mismatch are numerous: different definitions of planted forests and survey methodologies, rotation of some stands is finished and they are naturally regenerated, as well as reforestation failure. In many cases, repeated planting following planting failure and low survival rate, are recorded as new planting, resulting with unduly increase of planted area. Origin of forest stands in last National Forest Inventory was determined (among others) on tree species and regeneration method. Based on field survey, stands were classified as high forests, coppice forests or artificial established forests. Some differences may be due to fail of recognizing the stand origin.

Average survival rate of 78% in five years period on 90 planting sites is not satisfactory, but this is the result of diverse species, reforestation goals, site conditions and weather. Reasons for planting success or failure in Serbia are numerous: site, species (and provenance) selection, nursery operations, stocktype and seedling quality, handling after lifting from bed or container, organization of planting, site preparation, planting technique, silviculture after planting (Stilinović et al. 1987). The reasons for mortality on researched sites are hard to explain with data available, but some general trends can be observed.

There is obvious effect of weather conditions on seedling survival in the first year after planting. The hottest year in observed period was 2012, with 2.4° C above normal average and the most days with temperatures above 30° C and 35° C, resulting with survival rate of 76%. However, effect of precipitation to survival is stronger compared to air temperature. The lowest survival rate was in year 2011, with precipitation of 65% of normal average (from period 1971-2000). On the other hand, the highest survival rate was in year 2014, with precipitation of 190% of normal average.

The planting goal had a strong influence on the first-year survival rate. The most successful was assisted natural regeneration, followed by melioration and reforestation after fire. This trend of reduced survival rate from assisted natural regeneration to afforestation can be expected, due to changing of environmental conditions. The lowest survival rate was in afforestation, which is expected due to harsh environment on the most of the planting sites. However, this low survival rate (67.9%) is due to two total failures of *Pinus nigra* (2+0 container) seedlings, planted in year 2011, the driest year in observed period. The lack of precipitation, combined with poor site preparation can be the reason of total failure on these sites. If we exclude these outliers, the average survival rate in afforestation is 83% which indicate that planting on non forest land can be successful when site preparation, the good quality seedlings and a proper planting technique are applied.

It is interesting that *Pseudotsuga menziesii* as introduced species have the highest first-year survival rate on reforestation after fire and maintained high survival two and four years after planting. These results indicate that this species is well adapted to new environment. *P. menziesii* is introduced to Serbia very late, at beginning of XX century (Soljanik 1968). Provenance test of reproductive material from 29 provenances which covers the most of the natural range of *P. menziesii* in North America is established in eastern Serbia (Šijačić-Nikolić et al. 2014). According to National Forest Inventory (Banković et al. 2009), *P. menziesii* counts 1,600,000 trees in Serbian forests with total of 511,150 m^3 of wood. Despite growth which usually overcomes the growth of other local or other introduced species (Marković 1950, Radulović 1960, Stojanović et al. 2010) and good results in provenance trial, in last 10 years (2005-2014) the new cultures of *P. menziesii* was established only on total of 137 ha.

In general, bareroot seedlings are the most used stocktype in reforestation and afforestation programs in Serbia. The lower survival of container seedlings, compared to other stocktypes is not expected. Container seedlings have a higher survival in a predominant number of trials (reviewed by Grossnickle and El-Kassaby 2015 – 122 trials). Results of this study show average survival rate of container seedlings on 19 sites of 73% (two total failures excluded). Since site preparation and even planting spot preparation are very similar for bareroot and container seedlings in Serbian forestry practice, this poor survival of container seedlings can be attributed to inappropriate nursery operations. The quality of container seedlings is not defined by current Serbian standard. Beside two container nurseries equipped with newest technology, the most are still growing seedlings in old designed containers with trays old between 20-30 years. Recommendations for substrate preparation, fertilization and irrigation are only general. Additional research should be conducted to found the reasons of such poor survival of container seedlings. Planting seedlings with desirable plant attributes increases chances for survival after field planting (Grossnickle 2012) and improvement of nursery operations can lead to increased survival at field.

Planting is equally distributed in two seasons – spring and autumn, with hardwoods planted in both seasons and conifers planted mainly it spring. The absence of influence of planting time in this study was similar to previously reported (Stilinović 1991, Repáč et al. 2011).

Reducing of survival rate in years after planting is worrying. Seedlings face the greatest obstacles to survival in the first year after planting (Burdett 1990, Grossnickle 2005) and their survival in following few years depends a lot on control of competing vegetation and protection from browsing. On some sites a severe damages from browsing were recorded and vegetation control was poor on large portion of planting sites. The largest reduction of survival rate in years two to four after planting was recorded in years 2011-2012, and this mortality can be attributed to drought.

Wildlife caused a half of mortality at 10 sites. These damages can be easily avoided by wildlife control and protecting from browsing. Unfortunately, there was no use of repellents, fences or tree shelters at researched planting sites. Improper planting is another reason of high mortality on planting sites which can be eliminated. Planting technique can seriously affect survival, with shallow planting as one of the most obvious reasons for seedling dying. In addition to training of planting crew, the quality control of all activities on planting site needs to be improved. On some sites planting was accepted by forestry authorities despite obvious mistakes in planting spot preparation and seedling positioning. Immediate repeating of planting is much cheaper than corrective activities in following years. On 10 sites, only 13% of mortality was attributed to drought. This result can mislead to wrong conclusion because this part of the study was conducted in 2014 – year with the precipitation almost double to the normal average.

CONCLUSION

Historically, reforestation and afforestation in Serbia after the second half of XX century can be considered as success. The increase in country's forest cover rate of 8% is equal to area of planted forests. In last five years (2010-2014) reforestation was on small-scale and average first-year survival of 78% cannot be considered as success. The lowest survival rate was recorded in year with least precipitation. May reasons of reforestation failures can be easily eliminated with improvement of planting technique and silviculture after planting. The constant survey of reforestation success is necessary to provide backward information's to nursery managers and forest contractors on planting how to improve their activities and performance.

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