Ecological Restoration Institute

Fact Sheet: *Planting to Restore Ponderosa Pine Sites Burned by High-Severity Fire*

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Planting to Restore Ponderosa Pine Sites Burned by High-Severity Fire

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Introduction

Increases in landscape-scale wildfires in frequent-fire forests over the last several decades have led to management concerns regarding long-term restoration of severely burned sites. In particular, interior areas of large, high-severity patches may lack conifer regeneration for decades (Savage and Mast 2005, Passovoy and Fulé 2006, Haire and McGarigal 2010, Roccaforte et al. 2012). A lack of tree regeneration may result in type conversion from sites historically dominated by coniferous forests to persistent non-forested areas (Figure 1) (Barton 2002, Strom and Fulé 2007). Based on these concerns, managers have at times aggressively pursued replanting of burned-over sites with conifers, with the result that many planted areas eventually become overly dense with trees to the point that eventually crown fires are bound to recur. To avoid this problem and to assure long-term restoration of forest structure including natural openings, consideration should be given to reestablishment of reference species composition, natural ranges and variability in tree densities, and spatial arrangement of trees in a functional ecosystem.

Figure 1. The Pot Fire (top) burned in 1996 and had no regeneration 11 years following the fire; the Aspen Fire (bottom) in southern Arizona burned in 2003 and has the potential of transitioning into an oak shrubfield.

This fact sheet outlines a relatively new approach—one based on ecological restoration principles—for tree planting after high-severity wildfire in southwestern frequent-fire forests. Historically, land managers were directed to reestablish full site stocking with an emphasis on future timber production. Presently, concern for restoration of long-term resilience and ecological function directs managers to consider natural ranges of variability (reference conditions) in tree density and spatial arrangement to guide replanting strategies. We use the Forest Vegetation Simulator (FVS) to demonstrate planting densities that emulate pre-fire exclusion reference conditions at the mid-scale range of 10–1,000 acres (Reynolds et al. 2013). In the absence of subsequent management, higher initial planting densities will likely lead to poor forest health and increased crown fire hazard.

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History of Ponderosa Pine Planting in the Southwest

There is a rich history of research related to tree regeneration in southwestern forests dating back to the early 20th century. The Fort Valley Experiment Station was established in 1908 to study the apparent lack of sufficient natural regeneration in ponderosa pine forests (Fletcher 1979). Research from 1912 into the 1930s helped develop detailed guidelines for planting to achieve optimal seedling survival and stocking (Larson 1957, Hayes 1961; Heidmann 1963, see also Heidmann 2008). Schubert and his colleagues (1969) summarized these recommendations and produced a simple planting guide. Although guidelines concerning planting density are presently flexible and allow silviculturists to customize planting programs to meet local objectives (USFS Region 3 2002), managers historically aimed to reestablish full site stocking. For example, Schubert (1974) recommended planting 680 trees per acre at an 8-by-8-foot spacing based on the assumption that 50 percent of the seedlings would survive and attain a diameter of five inches. These 340 surviving, 5-inch trees would be needed for a growing stock level of 80 (Schubert 1974). Studies that discussed planting arrangement always recommended even spacing insofar as possible (e.g., Heidmann et al. 1977), although Schubert (1974) noted the importance of planting in the best spots, even at the expense of consistent spacing between trees.

Funding for reforestation programs has declined in recent decades (Burch 2005), although reforestation is still mandated under the Anderson-Mansfield Reforestation and Revegetation Joint Resolution Act of 1949 (at 16 U.S.C. 581j and 581 j(note)) and the National Forest Management Act of 1976.

Using Reference Conditions to Guide Planting Decisions

Extensive research over the last few decades has indicated that tree density in southwestern ponderosa pine forests historically ranged about 20 to 50 ponderosa pines per acre prior to the widespread interruption of the frequent surface fire regime (Stoddard 2011). From a timber production standpoint, sites were understocked (Woolsey 1911). In addition, before fire exclusion, trees often showed aggregated spatial patterns, with tree groups of varying sizes and single trees surrounded by a predominant matrix of grassy openings (Sánchez Meador et al. 2011, Larson and Churchill 2012). Tree groups ranged from less than one-tenth of an acre in size to nearly one acre, with two to 72 trees per group. Frequent surface fires and grass competition sufficiently maintained open conditions with regeneration rates as low as 1.5 trees per acre per decade (Mast et al. 1999, Bailey and Covington 2002). Open forests with scattered groups of trees provided a wide range of habitats for a diversity of animals and plant life, and were resilient to frequent occurrence of fire. Today, many of these forests are overly dense with trees due to decades of fire exclusion and are degraded in terms of forest health and resilience to wildfire (Covington and Moore 1994, Dahms and Geils 1997).

Replanting severely burned areas in a pattern that emulates natural patterns of healthy forests that historically occurred on the site is one way to promote resilient forests that function within their historical range of variability. For southwestern ponderosa pine forests, this translates to planting fewer trees than the traditional full stocking approach. On many sites, this also requires planting trees in various sized groups and leaving unplanted openings, which often occupied 60 to 80 percent of the area in presettlement stands (Covington and Sackett 1992, Covington and Moore 1994). In Table 1, Forest Vegetation Simulator (FVS) projections using varying planting densities and assumed survival rates suggest that multi-resource goals are likely to be met at intermediate planting levels. Table 1 shows that, depending on site index (the potential productive quality of an area where trees grow) and assuming 50 percent survival (Schubert 1974, Ouzts 2014), planting from 60–100 seedlings per acre will, after 80 years, result in tree densities similar to those found in historical tree density studies (Stoddard 2011) and recommended by Covington et al. (1997) for restoring stands to within natural ranges of structural variability. In contrast, FVS predictions indicate that planting 300 seedlings per acre will result in tree densities well above the historical range of variability reported by Stoddard (2011). Managers should plan post-fire reforestation efforts that promote resilient future forests while recognizing that stands planted with too many seedlings have the potential to become overly dense and susceptible to crown fire.

Although FVS does not account for variations in tree spatial arrangement, use of this tool can help land managers evaluate relative differences among planting scenarios. By studying these differences, practitioners can determine strategies for reaching forest health goals over time.

Future Research and Monitoring

Monitoring and evaluation of successes and failures is needed for restoration of severe wildfire sites. Near-term monitoring should document the planting objectives and strategy, site selection criteria and site conditions, planting technique, density, and arrangement in addition to initial seedling survival and planting costs. Longer-term studies should continue to monitor tree survival but also assess responses of other important ecosystem components. An additional potential study could test drought-resistant genotypes in anticipation of climate change. Long-term monitoring will help managers strengthen adaptive management frameworks and ensure that sound, evidence-based decisions are made.

Table 1. Forest Vegetation Simulator output for ponderosa pine planting scenarios at 50 percent seedling survival. Two site index values (70 and 80) and three planting densities (60, 100, and 300 TPA) were simulated. The output shows estimates of tree density (TPA), basal area (BA (ft^2 per acre)), Reineke's (1933) stand density index (SDI), and crowning index (Crowning (mph)) for years 1 –81 from time of planting.

	Seedling Survival = 50%												
Site Index = 70													
	Planting Density = 60 TPA				Planting Density = 100 TPA				Planting Density = 300 TPA			
Year	TPA	BA	SDI	Crowning	TPA	BA	SDI	Crowning	TPA	BA	SDI	Crowning
1	30	0	0	0	50	0	0	0	150	0	0	0
11	29	0	1	364	49	0	2	255	147	1	5	122
21	29	2	6	169	48	4	10	119	144	11	31	57
31	28	6	13	119	47	10	22	85	142	27	60	41
41	28	11	22	102	46	18	35	73	139	43	88	37
51	27	17	30	96	45	26	47	71	136	60	114	36
61	27	22	38	94	45	34	58	69	134	75	137	36
71	26	28	45	94	44	41	68	69	131	90	158	37
81	26	33	51	95	43	48	77	69	129	104	177	38

Site Index = 80												
	Planting Density = 60 TPA				Planting Density = 100 TPA				Planting Density = 300 TPA			
Year	TPA	BA	SDI	Crowning	TPA	BA	SDI	Crowning	TPA	BA	SDI	Crowning
1	30	0	0	0	50	0	0	0	150	0	0	0
11	29	1	2	314	49	1	3	222	147	3	10	105
21	29	3	8	153	48	6	14	108	144	17	42	49
31	28	8	17	115	47	14	28	81	142	35	75	39
41	28	14	26	103	46	23	42	74	139	53	105	36
51	27	20	35	99	45	32	55	71	136	72	132	36
61	27	26	43	97	45	41	67	71	134	89	157	36
71	26	32	50	98	44	49	78	72	131	106	179	37
81	26	38	57	99	43	57	87	72	128	121	199	38

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