Degradation of Visible Autumn Icons and Conservation Opportunities: Trends in Deciduous Forest Loss in the Contiguous US

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Key Points:

- Temperate deciduous forests aesthetics attract visitors to experience nature, but degradation and loss can hinder connections.

- US ecoregions with the greatest leaf-peeping opportunities are underrepresented in the protected areas and vulnerable to additional losses.

- Differences in predictions scenarios emphasize the importance of conservation action, which may be linked to human connections with nature.

Abstract

Temperate deciduous forests are one of the most visible biomes on Earth because of their autumn aesthetics and because they harbor some of the most heavily populated regions. Their ability to attract visitors may increase opportunities for people to experience nature, which has been linked to greater conservation action. Identifying regions with high leaf-peeping opportunities and regions where color has been lost to landscape conversion may help to inform these connections. We use spatial overlay analyses to quantify temperate deciduous forest coverage, disturbance, and protections in each U.S. ecoregion. We evaluated recent (1984-2016) and predicted (2016-2050) disturbance under extreme future scenarios. Almost all ecoregions saw a decline in deciduous forest cover between 1985 and 2016. Some ecoregions with the greatest opportunities for leaf-peeping are also underrepresented in the protected areas network and vulnerable to additional losses. Under economic-growth forecasting scenarios, losses are predicted to continue. However, environmentally focused scenarios suggest there is still opportunity to reverse deciduous forest loss in some ecoregions. Differences in forest loss between predictions scenarios emphasize the importance of human approaches in securing environmental stability. Increasing public exposure to temperate forests may help ensure conservation of more natural areas and preserve the quantity and quality of autumn forest viewing.

1 Introduction

Accelerating landscape change threatens biodiversity and climate stability worldwide, with significant implications for society through a degradation of nature's benefits to people (i.e., "ecosystem services"; Carvahlo and Szlafsztein, 2019; Colvin et al., 2019; Diaz et al., 2020; Gómez-Baggethun et al., 2019; IPBES, 2019; Sweeney et al., 2004). The science makes clear that transformative action is needed to address the threats to nature, with major initiatives being developed at national and international levels (e.g., Convention on Biological Diversity, 2020; Udall, 2020). While preservation and restoration are common strategies for addressing these crises (e.g., Clancy et al., 2020; Dinerstein et al., 2019, 2020; Minin et al., 2017; Peng et al., 2019; Scolozzi et al., 2014), approaches may also include increasing opportunities for people to experience natural environments: when people connect with nature they are also more likely to act in ways that benefit the Earth (Ives et al., 2016). Axiological relationships are often tied to

44 feelings of duty and stewardship and previous research suggests a similar connection between a

45 person's bond with nature and the probability of them taking conservation action (Cooper et al.,

46 2016). Connections with nature can happen emotionally, physically, intellectually, and

47 spiritually, but most often, through direct experience (Wang et al., 2016). Identifying highly

48 visible environments and understanding past and future changes that people have or will

49 experience is therefore important to understanding one social dimension of conservation.

50   Although they only cover ~7.5% of Earth's terrestrial land surface, temperate forests

51 harbor exceptional biodiversity and carbon stores (Hofmeister et al., 2019; Keith et al., 2009; Pan

52 et al., 2011; Thurner et al., 2013) and provide key ecosystem services such as water filtration

53 (Brandt et al., 2014; DellaSala et al., 2011). Further, temperate forests are one of the most visible

54 biomes because heavily populated and developed regions, including in the United States, are

55 located in or near the biome (Haddad et al., 2015). At the same time, a long history of settlement

56 and development has had dramatic impacts on the forest ecosystems and their biological

57 diversity (e.g., Gunn et al., 2019; Pennington et al., 2010; Thompson and Jones, 1999). Although

58 most of the major land changes may have occurred in the past, more recent anthropogenic

59 landscape modifications mean continued forest loss, biodiversity loss, and degradation of

60 ecosystem services. Understanding recent and predicted temperate forest conversion can help

61 identify spatial patterns and clarify the critical role of human perceptions of change that may

62 affect forest conservation.

63   Among the ecosystem services provided by temperate forests, the biome provides a

64 unique aesthetic appeal with economic benefits. About 15% of the tree species of the temperate

65 regions of the world change their leaf color from green to yellow or red in autumn, a percentage

66 that can reach 70% of species in some regions of the US (Archetti et al., 2013). In this respect,

67 deciduous forests are very visible cultural icons. Autumn aesthetic is often described in terms of

68 its "complex", "reassuring", and "soothing" qualities, attracting outsiders seeking beauty and

69 relaxation in special landscapes (Eroglu and Demir, 2016). As such, many U.S. cultures and

70 economies rely on autumn traditions and 'leaf-peeping' tourism, which contributes billions of

71 dollars each year - up to a quarter of annual tourism profit - to state economies of the eastern US.

72 (Sandifer et al., 2015). Continued landscape conversion threatens to reduce the autumn color

73 display directly (i.e., tree removal) or indirectly through increased forest stress, and introduces

74   concerns for reduced future aesthetic values and tourism revenues. Ultimately, fewer visitors to

75   these forests also means fewer opportunities to connect people and nature.

76   Given the current global biodiversity and climate crises, more conservation action is

77   needed and there is much to gain with temperate forests as a connection between people and

78   nature. The reverse - using personal connections with nature to specifically emphasize

79   conservation of temperate forests - could also result in major contributions to biodiversity

80   conservation and climate mitigation. In the U.S., temperate forests are home to high species

81   endemism and hotspots of imperiled species biodiversity (Rosa and Malcom, 2020).

82   Additionally, intact temperate forests remove sufficient atmospheric CO_2 to reduce national

83   annual net emissions by 11% and may be a significant contributor to global climate stabilization

84   (Dinerstein et al., 2020; Moomaw et al., 2019). Studies suggest that U.S. temperate forests are

85   likely to act as carbon sinks for decades to come (Finzi et al., 2020). However, most remaining

86   examples of natural ecosystems are fragmented and highly modified with intensive human

87   activities, posing continued threats to biota, carbon sequestration, and ecosystem aesthetics.

88   General trends in temperate forest land use emphasize continuing rural residential

89   development largely driven by aesthetics, climate and access to recreation. Beyond the direct

90   impacts of forest loss and expanding anthropogenic land cover, biodiversity and ecosystem

91   functions are likely to suffer from fragmentation; forests are smaller, more isolated, and have a

92   greater area located near the edge. This includes degraded ecosystem processes, reduced species

93   diversity, and changes in species all of which affect autumn foliage viewing quality (Haddad et

94   al., 2015; Zhang et al., 2017; Zhang et al., 2019). Fragmentation of the forested landscape may

95   also contribute to the degradation of autumn foliage viewing in a way that is less apparent than

96   with outright forest loss: viewers may fail to notice the creeping change in viewing quality until

97   it is too late (i.e., boiling frog theory; Soga and Gaston, 2018).

98   Given the importance of temperate forests as a symbol for nature and its beauty, forest

99   conversion is among the most distinct impacts of human activity on the forest environment and

100 aesthetic. Here, we identify to what extent each U.S. ecoregion is characterized by deciduous

101 forest and quantify recent (1984-2016) and predicted (2016-2050) forest disturbance. The ability

102 to identify regions with high leaf-peeping opportunities and regions where color has been lost to

103 landscape conversion will help to inform connections between people and the forested landscape.

104 Additionally, understanding patterns of temperate forest loss is also critical to guide efforts in

105 biodiversity conservation and climate mitigation: new calls to expand the protected areas

106 network will benefit from this and subsequent knowledge that builds upon these findings.

107 **2 Materials and Methods**

108 We used spatial overlay analyses to estimate temperate forest losses and predicted

109 changes across the U.S., summarized by EPA Level 2 ecoregions (EPA, 2006). Two main

110 datasets were used for these calculations. First, the National Land Cover Database (NLCD,

111 MRLC) uses digital change detection methods to identify land cover, changes and trends for the

112 United States (Homer et al., 2020). The recently released NLCD 2016 database offers improved

113 cyclical updating of U.S. land cover and associated changes, greatly advancing large-area land

114 cover monitoring through an updated suite of products (Yang et al., 2018). Forest disturbance

115 date is a key addition that provides opportunities to examine US forest cover change patterns

116 from 1985-2016. This product combines information from the NLCD 2016 change detection,

117 land cover classification, and the LANDFIRE Vegetation Change Tracker (VCT) disturbance

118 product to assess where disturbance occurred for forest areas every 2-3 year interval.

119 NLCD classifications for deciduous forest and mixed forest were included in areal

120 calculations for available years between 1992 - 2016 (1992, 2001, 2004, 2006, 2008, 2011, 2013,

121 and 2016). Modelled historical land use and land cover for the contiguous US were used for

122 estimating forest cover prior to 1992 (Sohl et al., 2018). Similarly, all forest change identified in

123 the forest disturbance date dataset between 1985-2016 that occurred on deciduous and mixed

124 forest land cover types was used in calculations of forest loss for each ecoregion.

125 Second, we used spatially explicit predictive models of 2050 land cover to estimate future

126 forest losses (Sohl et al., 2014). The most extreme forecasting scenarios which were developed

127 based on characteristics consistent with the Intergovernmental Panel on Climate Change (IPCC)

128 Special Report on Emission Scenarios were used to understand the variability in predictions. The

129 economic-growth scenario assumes rapid economic development and very high population

130 growth globally (15 billion by 2100). Initial estimates of this scenario suggest over 500,000 km^2

131 of deciduous/mixed forests would be lost in the contiguous US between 2005 and 2100 (Sohl et

132   al., 2014). The sustainability scenario reflects an emphasis on environmental protection and

133   social equity with lower rates of global human population growth and intermediate levels of

134   economic development. In contrast, over 59,000 km2 of forests may be gained between 2005

135   and 2100 under the environmental protection scenario (Sohl et al., 2014).

136   Data on protected areas are from the PADUS 2.0 database. We use U.S. Geological

137   Survey's Gap Analysis Program (GAP) codes, which are specific to the management intent to

138   conserve biodiversity. GAP 1 and 2 areas are managed in ways typically consistent with

139   conservation and are considered 'protected' in this context. We used ArcGIS v. 10.7 (ESRI,

140   USA) to produce maps and run analyses. Maps use the Albers Equal Area Conic projection.

141   3 Results

142   Fourteen out of 20 contiguous US ecoregions have >1% of their area in deciduous or

143   mixed forest, where deciduous forests are the majority ecosystem for two ecoregions (Table 1).

144   The ecoregions with the greatest proportion of deciduous forest cover include the Atlantic

145   Highlands in New England (62.0%), the Ozark/Appalachian forests (61.0%), and the mixed

146   wood shield and plains in the upper Midwest (36.9%) (Figure 1a). Almost all ecoregions saw a

147   steady decline in deciduous forest cover between 1985 and 2016, with exception of two prairie

148   ecoregions and the central plains. In general, ecoregions with less forest cover saw greater

149   percent change in deciduous forest area in the past two decades (logarithmic relationship, $r^2 =$

150   0.14) with highest percentage changes in the upper Gila Mountains (-82.2%), Tamaulipas

151   (Texas) semi-arid plains (-79.9%), and Western Sierra Madre Piedmont (-70.8%) (Figure 1a).

152   Overall, changes ranged from -82.2% to +2.25% for ecoregions and totaled -17.5% for the

153   contiguous US.

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158 Table 1. Percent deciduous/mixed forest cover from 1985-2050 for ecoregions in the contiguous United States.

159 Percent of the ecoregion that falls within protected areas managed consistently with biodiversity conservation

160 (USGS PADUS, 2018; GAP code 1 or 2) is included. For projected forest coverage, 2050a represents the economic-

161 growth scenario and 2050b represents the sustainability scenario.

162

Ecoregion	Area	% Deciduous/Mixed Forest Cover												% Protected
Level II	(ha)	1985	1988	1991	2001	2004	2006	2008	2011	2013	2016	2050a	2050b	(PADUS)
Atlantic Highlands	1.51E+07	68.64	68.89	69.07	62.01	63.28	62.82	62.59	62.23	62.27	62.02	63.42	68.24	13.00
Ozark/Appalachian Forest	5.21E+07	65.12	65.18	65.16	60.12	61.39	60.93	60.87	60.68	60.93	60.97	57.57	63.75	8.61
Mixed Wood Shield	2.14E+07	43.29	43.52	43.76	38.72	37.08	36.86	36.95	37.00	37.11	36.94	38.14	42.22	22.85
SE Plains	1.03E+08	36.96	37.28	37.50	27.19	26.60	26.26	26.02	25.81	26.00	25.86	30.54	38.69	2.47
Mixed Wood Plains	3.92E+07	36.37	36.72	37.09	31.68	32.82	32.67	32.63	32.52	32.54	32.45	31.15	38.36	2.94
Central Plains	2.26E+07	8.37	8.68	9.24	9.90	10.04	9.98	9.98	9.95	9.95	9.93	7.59	9.59	1.53
SE Coastal Plains	3.40E+07	7.65	7.69	7.64	2.78	2.64	2.59	2.60	2.64	2.66	2.66	6.42	7.80	8.73
Mediterranean CA	1.64E+07	7.36	7.38	7.38	5.29	4.50	4.44	4.14	4.13	4.13	3.99	7.40	7.43	10.25
TX/LA Coastal Plain	7.36E+06	7.32	7.36	7.35	3.00	3.03	2.97	2.95	3.00	3.04	3.03	6.33	9.49	5.23
Marine West Coast	3.64E+07	6.18	6.19	6.19	3.35	3.06	2.99	2.97	2.99	3.02	3.05	5.86	6.14	63.33
Temperate Prairies	5.22E+07	6.16	6.17	6.18	6.01	6.58	6.55	6.54	6.53	6.54	6.55	5.61	6.15	2.37
Western Cordillera	8.22E+07	6.04	6.04	6.03	4.95	4.61	4.58	4.57	4.57	4.58	4.60	5.93	5.93	22.70
Semiarid Plain	5.31E+06	3.22	3.20	3.20	0.61	0.65	0.65	0.64	0.65	0.65	0.65	2.75	3.03	0.32
South Central Prairies	9.97E+07	3.21	3.19	3.16	3.32	3.35	3.31	3.29	3.26	3.26	3.28	2.73	3.08	0.88
Upper Gila Mtns	1.09E+07	1.00	1.00	0.99	0.21	0.22	0.22	0.22	0.21	0.18	0.18	0.97	0.97	11.24
West-Central Prairies	5.91E+07	0.79	0.79	0.79	0.59	0.57	0.57	0.57	0.57	0.57	0.57	0.79	0.80	2.43

Western Sierra Madres	4.31E+06	0.70	0.70	0.70	0.28	0.28	0.28	0.28	0.20	0.20	0.20	0.70	0.70	12.97
Cold Deserts	1.01E+08	0.65	0.65	0.65	0.58	0.56	0.55	0.55	0.55	0.54	0.55	0.65	0.65	12.45
Warm Deserts	4.08E+07	0.14	0.14	0.14	0.02	0.12	0.12	0.12	0.09	0.09	0.09	0.14	0.14	36.62
Everglades	2.20E+06	0.00	0.00	0.00	0.07	0.37	0.36	0.36	0.36	0.36	0.36	0.00	0.00	38.06

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164   Predictions of deciduous forest cover depended heavily on the scenario employed. The

165   "economic growth scenario" resulted in higher rates of forest loss due to urban increase,

166   agricultural expansion, and higher demand for forest products. Most ecoregions remain in

167   decline by 2050 with the exception of deserts, Mediterranean California and Western Sierra

168   Madre Piedmont. For the top leaf-peeping ecoregions, predicted percent change in forest cover is

169   nearly equivalent to declines from 1985-2016 (Figure 1b). Under the "sustainability scenario,"

170   more than half of the ecoregions would have increasing forest cover by 2050. Generally, highest

171   percent increases would occur in ecoregions with relatively low forest cover (logarithmic

172   relationship, $r^2 = 0.12$).

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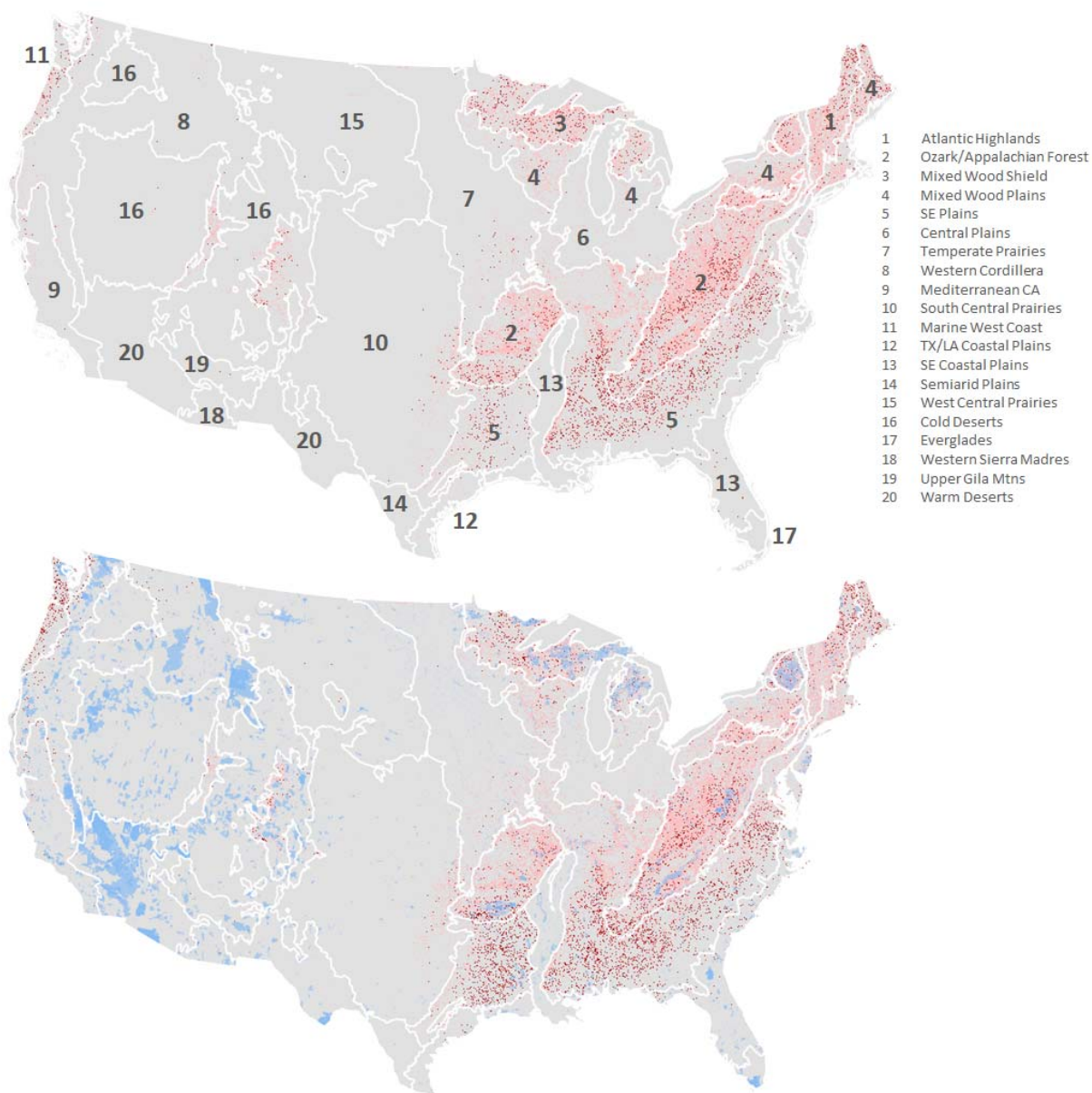
Fig. 1 Ecoregions of the contiguous United State with deciduous/mixed forest cover (pink) and disturbed forest (red) from a) 1985-2016 and b) models projecting forest cover in 2050. Numbers indicate rankings of ecoregions by proportion of forest cover in 2016. Blue areas represent protected areas managed consistently with biodiversity conservation (USGS PADUS GAP code 1 or 2).

Ecoregions for which deciduous forests make up at least a quarter of the land cover have anywhere between 2.5% and 22.8% protected areas coverage. Declines in forest cover between 1985 and 2050 (economic-growth scenario) exhibited a logarithmic relationship with protected

181   areas coverage across ecoregions, with ecoregions undergoing greater proportional losses having

182   greater forest area and being more often underrepresented in the protected areas network (Figure

183   2; $r^2 = 0.35$, $p = 0.03$). Under the "sustainability scenario," ecoregions with higher forest cover,

184   but low representation in the protected areas network (i.e., mixed wood plains and southeast

185   plains) will see relatively higher gains in deciduous forest.

186

187   **Fig. 2** Percent change in deciduous/mixed forest cover in an ecoregion from 1985 to projections for 2050 as a

188   function of forested area and the percent of the ecoregion that is protected as of 2018 (USGS PADUS GAP code 1

189   or 2; y = 0.14(protected) - 2.9E-11(forest) - 8.01, $r^2 = 0.35$, $p = 0.03$).

190

5 Conclusions

192   Forests are an essential component of the natural environment that offer profound

193   aesthetic and spiritual benefits to humanity. As such, forests offer a unique and powerful way to

194   connect people with environmental issues like the biodiversity and climate crises (Ives et al.,

195   2018). Loss of forests, either in large tracts or piecemeal, results in a degradation of these

196   benefits and decreases opportunities for quality experiences in nature (Nisbet et al., 2008; Soga

197   and Gaston, 2016; Zylstra et al., 2014). Here we documented extensive temperate forest loss

198 through the context of fall color change. These losses may be changing how people experience

199 nature, such as through the awe inspired by leaf peeping.

200   Cumulatively, we found that just under 55 million acres of deciduous or mixed forest

201 were disturbed between 1985 and 2016. All ecoregions with deciduous forests incurred losses,

202 but some were more dramatic than others. As expected, the extent of loss was related to the

203 proportion of the ecoregion that is managed as multi-use or is lacking conservation mandates.

204 Underrepresentation in the U.S. protected areas network means that temperate forests are

205 susceptible to continued fragmentation and modification. Under worst-case forecasting

206 scenarios, losses are predicted to continue. However, environmentally focused scenarios suggest

207 there is still opportunity to reverse deciduous forest loss in some ecoregions. Increasing public

208 exposure to temperate forests may help ensure conservation of more natural areas and preserve

209 the quantity and quality of autumn forest viewing.

210   The top ecoregions for autumn aesthetics are experiencing relatively higher forest losses

211 and are also relatively under-protected. Collectively, ecoregions with greater than a quarter of

212 their area covered by deciduous/mixed forest saw a 16.5% decline in forest area. For these

213 ecoregions, 93% of their lands are currently unprotected suggesting they may face further

214 disturbance or fragmentation. The top ecoregions are also concentrated east of the Mississippi

215 River, where there is less public land and more human disturbance, elevating the importance of

216 restoration efforts (Jenkins et al., 2015; Rosa and Malcom, 2020). Spatial incongruities in

217 protected areas and forested ecoregions also impact other ecosystem values. For example,

218 previous research indicates that the siting for current protected areas is often discordant with

219 diversity-rich or carbon-rich areas of the country (Jenkins et al., 2015; Rosa and Malcom, 2020).

220 This means the remaining natural habitats in these areas are significantly under-protected;

221 elevating their protections could contribute to both climate mitigation and biodiversity

222 conservation. In particular, states across the Southeast harbor high levels of biodiversity and

223 very few protected areas.

224   Additionally, trends show that ecoregions with lower forest cover generally experienced

225 greater rates of decline in the past two decades; this suggests that the few cultural and habitat

226 resources that deciduous forests provide in these areas are dwindling relatively fast. In the United

227 States, conversion of privately owned rural lands into low-density residential development (i.e.,

228 exurban development) has increased five- to seven-fold between 1950 and 2000 and is the fastest

229   growing type of land use (Suarez-Rubio et al., 2013). Exurban development is prominent in

230   forested ecoregions with dispersed, isolated housing units embedded within a forest matrix. At a

231   more local scale, topography will likely remain a significant constraining factor in development,

232   allowing some areas to persist in forest cover while agricultural, residential and urban uses are

233   concentrated in specific portions of the landscape (Wear and Bolstad, 1998). However, land use

234   may intensify without associated changes in land cover if development occurs under the forest

235   canopy: in some cases, forest cover is increasing (rather than declining) with an increase in

236   human population density and development. This suggests that estimates of forest cover and

237   ecosystem impacts derived from satellite imagery are conservative and presents limitations to

238   continued tracking and prediction of future trends in forest disturbance.

239   Projected land use patterns suggest spatial variability in continued anthropogenic

240   landscape modifications. Some ecoregions, mostly prairies and plains, may continue to see forest

241   losses regardless of scenario. But for some, like the mixed wood plains (32.5% deciduous/mixed

242   forest cover), which covers regions of the northeastern coast and upper Midwest, human

243   behaviors could mean the difference between continued forest losses or reversal to gains. Models

244   under the sustainability scenario suggest there is still time to reverse declining trends in

245   deciduous forest loss; 21.5% increase in forest cover is projected for the top five forested

246   ecoregions, collectively. However, even if forest loss is projected to slow or reverse, this may not

247   directly equate to impacts to cultural ecosystem values because of lag times in forest responses to

248   stress (Alexander et al., 2018). Additionally, these are net changes and do not capture spatial

249   changes at a local level where the loss and gain of forest may be disjunct, ultimately resulting in

250   more cumulative forest area, but also more fragmented forest patches. Ecoregions that lack

251   protections will continue to experience greater forest disturbances, which is consistent with

252   global analyses (d'Annunzio et al., 2015). These disturbances (e.g., exurban developments) are

253   often close to protected areas and natural amenities raising concern about their ecological

254   consequences, this is one of many stressors that deciduous forests will continue to face.

255   Centuries of exploitation demonstrate the resilience of temperate forests, but how much

256   disturbance can be tolerated and what it may mean for forest health and fall colors is still under

257   investigation. Currently, the majority of science on autumn colors focuses on the variation of

258   color pigments and senescence timing with nutrient availability, gene expression, herbivory, and

259   climatic factors. Additionally, there are studies on the impacts of fragmentation and degradation

260   on other forest values such as habitat, but any connections to be made between these stressors

261   and autumn aesthetic will be inferential at best given the current lack of science focused on direct

262   relationships. Understanding the indirect impacts of exurban development and forest

263   fragmentation on fall colors could be one way to generally quantify impacts to cultural

264   ecosystem values without the extra complication of estimating monetary values. For example,

265   under future climate change projections, greater summer heat-stress will cause abbreviated leaf

266   coloration seasons for most tree species (Xie et al., 2018). However, temperature discrepancies

267   which would typically be exacerbated by fragmentation may be dampened by the obscured edges

268   between exurban and forest land covers, highlighting the importance of local☐ and

269   landscape☐scale features on microclimate heterogeneity (Arroyo-Rodriguez et al., 2017; Latimer

270   and Zuckerberg, 2016). In addition to landscape conversion, forests are experiencing increasing

271   frequency, extent, and severity of natural disturbances, anthropogenic climate change, and a

272   burgeoning global human population that imposes escalating demands on forests. However, the

273   current body of literature fails to present a strong understanding of their synergistic impacts. For

274   example, stressed trees may senescence earlier than others, but research also suggests that

275   climate warming can delay timing (Faticov et al., 2019; Schaberg et al., 2003). Research

276   demonstrates increased vulnerability of temperate forests to disease and invasion during periods

277   of stress, but impacts to autumn aesthetics are unknown. More research is needed to determine

278   how forest loss and fragmentation relate to spatiotemporal changes in autumn color vibrancy and

279   to the quality of human-nature connections.

280   The large difference in forest loss estimates in the predictions scenarios emphasizes the

281   importance of human approaches to economic growth and sustainability in securing

282   environmental stability. Scenic aesthetic is the most direct and immediate aspect via which

283   people perceive and begin to value landscapes (Gobster et al., 2007; Sargolini, 2013). Visually

284   appealing and healthy ecological landscapes evoke positive emotions and promote the desire to

285   protect such landscapes (Gobster et al., 2007; Lee, 2017). Growing opportunities for U.S.

286   conservation could work to forge deeper connections between humans and nature and motivate

287   the public to take protective actions against detrimental environmental changes. In response to

288   current global biodiversity and climate crises, science-driven guidance to protect 30% of global

289   lands and seas by 2030 have made its way into US federal and state policy proposals. These

290   proposals call for achieving more equitable access to public land, nature and a healthy

291   environment for all communities. Given this framework, the potential benefits of protecting

292   deciduous forests is manifold. In addition to preserving the visual aesthetics and spiritual

293   connections that people make during autumn senescence, conserving temperate forests also

294   means protecting many of the U.S.'s biodiversity hotspots and areas of high carbon potential.

295   Additionally, forest conservation ensures more ecosystems will be more resilient to climate

296   stresses (Xu et al., 2019). Therefore, encouraging the public to experience temperate forest

297   autumn foliage may in turn have broad reaching conservation implications for the future.

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Acknowledgments, Samples, and Data

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