Fire severity and tree size affect post-fire survival of Afrotemperate forest trees

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FIRE SEVERITY AND TREE SIZE ARE SIGNIFICANT DETERMINANTS OF POST-FIRE SURVIVAL OF AFROTEMPERATE FOREST TREES, WHILE SPECIES VARY IN THEIR TOLERANCE TO FIRE

After a severe fire in 2018, large tracts of forest had edge damage of only a few metres. Of the trees that burned, most had the capacity to resprout and tree size was important for survival, with better survival in larger trees. This work shows that resprouting from the stem is a primary means of post-fire recovery in Afrotemperate forest trees.

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Indigenous forest covers around 0.1% of land surface area in South Africa. Afrotemperate forest in the Southern Cape is the largest closed-canopy forest complex in southern Africa (60 560 ha), of which the largest single patch, 25 706 ha, is located in the Garden Route National Park. Fire is a natural disturbance agent in the region and maintains the distribution of Afrotemperate forest in otherwise flammable fynbos. These forests seldom burn due to their position in the landscape and other physiological characteristics. However, under specific climatic conditions, forest is susceptible to fire, which spreads from adjacent fynbos. Further, the current climate of the southern Cape region is drier than the more mesic conditions that promoted the expansion of forest during the late Holocene.

Mature Afrotemperate forest has a defined structure. Disturbance is usually in the form of small canopy gaps caused by windfalls, senescence and lightning strikes or larger gaps due to fires. Regrowth in larger, fire-created gaps tends to be slower than in smaller gaps. Gaps are important for maintaining species diversity and successional dynamics.

A 70 000 ha fire in the mountains between the towns of George and Knysna in 2018 burnt 4 628 ha of Afrotemperate forest, of which 1 500 ha burnt at medium to high severity. The fire was driven by high fire danger weather and preceding drought conditions desiccated available fuel, increased flammability and allowed fire to enter forest. We assessed the effect of fire severity and tree size on the post-fire survival of a comprehensive set of Afrotemperate forest tree species in the largest contiguous portion of the fire scar.

Fire severity affects the survival of forest trees and is determined by fire intensity, fuel consumption and residency time. Stem circumference and bark thickness are traits that may influence a tree's ability to survive fire. Larger tree size results in a larger surface area, which reduces the chance of cellular death around the entire stem and prevents mortality. Stem circumference is correlated with bark thickness. Bark is a good insulator and thicker bark increases the protection of a tree's cambium from fire. Stem circumference may thus be an important factor in post-fire survival.

There are 47 canopy and 40 sub-canopy tree species in coastal, plateau and mountain Afrotemperate forests. Mountain forest generally experiences more severe and frequent fires compared to coastal and plateau forest. We demarcated survey plots of 20 m x 20 m (corresponding with pixel size of satellite-derived burnt areas in mountain and plateau forest) and measured trees with a stem diameter of > 10 cm at breast-height. Fire severity was visually assessed by damage to the main stem to 2 m above ground for light, medium, or high damage. We considered trees to have survived if they had any green foliage.

The post-fire survival rate of all trees collectively (n = 1 378) was 45%. Logistic regression results showed that tree size had a significant positive effect on survival. Tree species had different post-fire survival responses. All species surveyed were capable of resprouting from the stem, except *Canthium mundianum*, *Maytenus acuminata*, *Mystroxylon aethiopicum*, *Psydrax obovata* and *Virgilia divaricata*. Dominant canopy species with strong resprouting (> 70% of individuals) were *Ocotea bullata* and *Lachnostylis hirta*. Those showing poor resprouting (< 20% of individuals) were *Podocarpus latifolius*, *Olea capensis* subsp. *macrocarpa*, and *Afrocarpus falcatus*.

Fire severity and tree size had no significant effect on the survival of *Curtisia dentata* and *Elaeodendron croceum*. However, fire severity had a significant negative effect on the survival of *Afrocarpus falcatus, Gonioma kamassi, Olea capensis* subsp. *macrocarpa, Pterocelastrus tricuspidatus, Podocarpus latifolius, Olinia ventosa* and *Ocotea bullata*, while tree size had a significant positive effect on the survival of *Rapanea melanophloeos, Ocotea bullata, Olinia ventosa*, and *Podocarpus latifolius*. *Ocotea bullata* had 100% survival in low and medium fire severity, but survival was reduced to 50% when exposed to high fire severity. Large *Ocotea bullata* trees (diameter > 30 cm) survived much better than smaller individuals. *Olea capensis* subsp. *macrocarpa* had low survival probability (< 20%) across all fire severity classes and showed no significant increase in survival with tree size.

This study provides the first assessment of the resprouting ability of Afrotemperate forest trees, and finds that for species that were surveyed in sufficient numbers, all exhibited the ability to resprout. This finding is in contrast with previous assertions that several common species, including *Podocarpus latifolius, Afrocarpus falcatus* and *Rapanea melanophloeos* are unable to resprout. Thirty-two percent of trees surveyed, irrespective of species, resprouted. It appears that resprouting from the stem is a primary means of post-fire recovery in Afrotemperate forest trees. Species with high survival rates can be deemed fire tolerant and will likely dominate forest margins and mountain forest, while species with low survival rates are less fire tolerant and will likely be restricted to forest core and plateau forest. For example, *Podocarpus latifolius* and *Olea capensis* subsp. *macrocarpa*, had the lowest survival rates post-fire and are slow growing and shade tolerant. However, they are dominant canopy species, and undergo mast seeding events resulting in good regeneration when conditions are favourable.