Letters

Fire regimes, fire experiments and alternative stable states in mesc savannas

A response to Laris & Jacobs (2021) ‘On the problem of natural savanna fires’

In their comment on Veenendaal et al. (2018), Laris & Jacobs (2021; in this issue of New Phytologist, pp. 11–13) question the appropriateness of fire experiments to simulate effects of fire on tropical vegetation cover as well as objecting to our use of the word ‘natural’ to describe nonanthropogenic fire regimes. They also challenge some of the conclusions we drew as regards the likelihood of fire-mediated feedbacks causing alternate stable states (ASS) in forest–savanna transitions.

First we would like to note that, as has also been done by others including Furley et al. (2008) in what Laris and Jacobs describe as an ‘excellent paper’, we used the term ‘natural fire regime’ as a contrast to the often very short (annual) fire return times as used in many of the classical fire experiments. This was with a full understanding that quantification of any ‘natural’ fire return time in the field is a necessarily complex problem, depending on factors such as spatial scale of measuring, mode of detection, data analysis technique and land use/type, etc. (Archibald et al., 2010; Alencar et al., 2011; Oliveras et al., 2013; Smit et al., 2013; Giglio & Schroeder, 2014; Beringer et al., 2015; Smit & Prins, 2015). To give a range, generally, for open savannas (grasslands and shrub savannas), fire return times may oscillate between 1 and 5 yr (Oliveras et al., 2013). In savanna woodlands, fire frequencies may vary widely, but are in the range 2–10 yr for Africa (Archibald et al., 2010; Smit & Prins, 2015) and Australia (Russell-Smith et al., 1998; Spessa et al., 2005) and 6–12 yr in South America (Pereira et al., 2014). Regional variation in fire return intervals tends to be largest for tall savanna woodlands and dry forests, with commonly observed values ranging from c. 1–4 yr in West Africa to 10 yr in southern Africa (Furley et al., 2008; Janssen et al., 2018). Tropical forests usually have long fire return intervals, varying from 10 yr to decadal or even centennial/millennial intervals (Hall & Swaine, 1981; Hope & Tulip, 1994; Cochrane et al., 1999; Cochrane, 2003; Archibald et al., 2010). In short: a lot can be said about what constitutes a typical fire regime, but as specifically stated in Veenendaal et al. (2018), we used the 4-yr interval as a demonstration of a reasonable norm for fire return times in the absence of significant human intervention and at a scale where fire–vegetation interaction processes play out. Here we would also like to note that – contrary to the claims of Laris and Jacobs – there was no misquotation here as Furley et al. (2008) actually wrote that ‘natural fires typically break out in the late dry season with a mean fire return interval (1941–1996) of 4.5 years’.

In terms of the importance of our supposed neglect of anthropic regimes, we also would like to note that we stated in our paper that: ‘Indeed, perhaps we should not think of nonanthropogenic fire regimes as being in any way representative of the current fire regime of the savanna lands with, in particular in Africa, human influences on fire patterns now being the dominating effect for all but the most strictly protected areas.’ Indeed, lest Laris and Jacobs’s comment leads to any confusion pertaining to this issue, we point out that throughout Veenendaal et al. (2018) we on many occasions clearly contrasted the effect of anthropic and nonanthropogenic fire regimes on tropical vegetation structure. However, that is not what our paper was specifically about.

Of course, we do not dispute that the influence of humankind on savanna fires reaches back possibly as far as 400,000 yr. However, considering population fluctuations over this long period, human influence must have varied considerably with the magnitude of any effect also varying from continent to continent. Further, as we also noted in our paper, the often interacting effects of humans and variation in climate are inevitably difficult to disentangle and with the quantitative analysis of the exact impact of human fires in terms of vegetation structure being complex and therefore understandably lacking in Laris and Jacobs’s comment. Of relevance here and as already mentioned in our paper, many eminent scientists of the first half of the twentieth century (namely Aubreville, Stebbing and Schantz to name but a few; see also Laris & Wardell, 2006) had the impression that large parts of the African landscape would have been otherwise covered by forest were it not for long-term concerted human action. However, the associated ‘derived savanna concept’ has on many occasions been shown to be blatantly wrong (Fairhead & Leach, 1996). Indeed, any quantitative evidence for fire effects on tropical vegetation cover (on which concepts such as ‘fire derived savanna’ hinge) must necessarily come from manipulated experiments. Aubreville himself well understood this point and, contrary to what is inferred by Laris and Jacobs’s comment, although we did indeed state that most early fire experiments were designed with applied management questions in mind, we never in any way suggested that Aubreville’s original fire experiment was itself a management-orientated exercise.

We also disagree with Laris and Jacobs’s point as regards the apparent mistiming of early fire treatments in some West African experiments (Aubréville, 1953; Brookman-Amissah et al., 1980; Louppe et al., 1995) especially as their Fig. 1 puts the line indicating the timing of early fire treatment in Central Ivory Coast in the wrong place: the correct date being the 2nd half of December for Kokondeko (‘2e quinzaine de Décembre’: Aubréville, 1953). Further, their Fig. 1 with fire incidence data taken solely from areas with a mean precipitation total >1.0 m yr⁻¹ (Laris et al., 2017) fails to take into account that across the West African savanna...
region the timing of the onset of the fire season varies in a systematic way with the expansion of the Harmattan from north to south. For example, in the Red Volta experimental region in Northern Ghana (which incidentally has a mean rainfall $<1.0$ m yr$^{-1}$) November is the first major month of the fire season but for the more southerly forest–savanna transition zone area this is more typically later on in December and/or January. This is illustrated in our Fig. 1 where the seasonal trend of MODIS-derived fire occurrences are shown along with the locations of the two fire trials in question: see also Owusu-Afriyie (2008) and Janssen et al. (2018). As a rule of thumb, West African farmers start the fire season 2–4 wk after the last rainfall event, which is when the grass layer is combustible enough (a moisture content being necessary in the order of 30%) to set a self-sustaining fire to it; see for example Finney et al. (2013) – and with the main peak logically following several weeks later. The early fire treatments in the experiments in Central Ivory Coast and Northern Ghana are thus not mistimed as Laris and Jacobs claim. Rather, they are actually very well timed indeed.

The Laris et al. (2017) paper does, however, make important observations on the importance of variations in soil resources and their influence on tree density in the Kokondekro trial. These wholly support our own analysis pointing out the importance of edaphic factors as important influences interacting with precipitation regime to modulate variations in tree cover extent and the position of the forest–savanna boundary in the tropics at local, continental and/or global scales (Lloyd et al., 2015; Veenendaal et al., 2015; Ametsitsi et al., 2020; Gonçalves et al., 2021), a concept that now seems to be becoming increasingly well appreciated (see, for example, Case & Staver, 2018).

Nevertheless, it is also clear that the results of Veenendaal et al. (2018) are not in agreement with several hypotheses recently presented regarding the effects of fires as influenced by time of burning and/or precipitation regime (Laris et al., 2016, 2017). Perhaps more importantly, however, much of the ‘well-established’ evidence that Laris and Jacobs present to support their arguments (Staver et al., 2011a,b) should, in our view, be considered as little more than hypotheses arising from in silico interpretations of a remote sensing product with clear data fidelity issues: for extensive discussions of this issue see papers by Hanan et al. (2013), Staver & Hansen (2015), Veenendaal et al. (2015), Lloyd & Veenendaal (2015).

Fig. 1 Monthly fire seasonality in the dry season in West Africa in relation to the Red Volta and Kokondekro Fire experiments. The pixel burn count between November 2000 and December 2020 was retrieved from the MODIS burned area monthly product (MCD64A1; Giglio et al., 2018) at 500-m spatial resolution. The locations of two fire experiments, at Red Volta (RED) in Ghana and Kokondekro (KOK) in Ivory Coast, are indicated in blue. Thick black lines are country borders and thin black lines are vegetation zones. From north to south the vegetation zones defined are: dry savanna (DS), mesic savanna (MS), transition zone (TZ), moist and dry semideciduous forest (SDF), rain forest (RF) and coastal savanna (CS).
rigorous way and, based on that analysis, we concluded that it is unlikely that fire-mediated feedbacks can lead to critical forest–savanna transitions and ASS.

Laris and Jacobs take issue with that conclusion but with the only evidence they cite as ‘demonstrating’ that ASS are already a documented phenomenon, namely Keeley & Rundel (2005) being a palaeostudy looking at simple vegetation–climate correlations. Moreover, the only tropical example in Keeley & Rundel (2005) is for East Africa at mean annual precipitations currently < 0.6 m yr$^{-1}$ in an area where vegetation types are clearly influenced more by edaphic conditions than climate (White, 1983), and for which there is a current precipitation regime under which Laris and Jacobs themselves (amongst others) have argued that vegetation structure should be primarily determined by climate rather than ASS in any case. The corollary here seems to be that under the sort of disturbance regimes characteristic of the more mesic savannas (i.e. with mean annual precipitation ≥ 1.0 m yr$^{-1}$) the occurrence of ASS should be more likely. Nevertheless, Van Langevelde et al. (2003) have suggested the opposite trend for more arid savannas with lower tree cover, and our own analysis suggests that for more mesic vegetation types fire can only maintain open savanna grasslands under deliberate human-mediated, high-frequency, late season fire regimes.

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