Correspondence: Uncertainty in climate-vegetation feedbacks on fire regimes challenges reliable long-term projections of burn area from correlative models

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Abstract

Recent studies have applied simple correlative models to project an increase in future burnt area (BA) for the Mediterranean region. In one of these studies led by Marco Turco and co-workers in the journal Nature Communications (doi:10.1038/s41467-018-06358-z), the authors relate BA to regional estimates of cumulative drought surrogates derived from evapotranspiration indices (SPEI) and later, they use this relationship to infer changes derived from future climate data. However, estimates of future fire risk suffer from the critical shortcoming that negative feedbacks of climate changes on vegetation (i.e. climate may actually reduce vegetation growth and eventually decrease fire risk) are not included. To overcome this problem, these authors proposed a way around by using regional variability in the BA drought relationship (what they call nonstationary models) to account for future changes on fire regimes derived from climate effects on vegetation. Their analyses showed that sensitivity of fire activity to dry periods is stronger in cooler/productive sites and therefore, they propose to use this finding as a short cut in their BA projections using climate change scenarios. The main assumption behind this approach is that the BA-SPEI relationships under a

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given productivity gradient can be used to infer new BA-SPEI relationships arising in the future. While representing a step forward in acknowledging the pitfalls of current projections of BA, this short-cut falls short in allowing to account for the key process behind climate-vegetation-fire feedbacks. We argue that there are a series of mechanisms by which current correlations are not likely to be maintained in the future with major, overall still unknown, consequences on BA projections.

Main text

Turco et al. (2018)[1] have recently published an elegant work in which they apply a simple correlative model to project an increase in future burnt area (BA) for the Mediterranean region. In their study, the authors relate BA to regional estimates of cumulative drought surrogates derived from evapotranspiration indices (SPEI) and later, they use this relationship to infer changes derived from future climate data. However, estimates of future fire risk suffer from the critical shortcoming that negative feedbacks of climate changes on vegetation (i.e. climate may actually reduce vegetation growth and eventually decrease fire risk) are not included. To overcome this problem, Turco et al. (2018)[1] proposed a way around by using regional variability in the BA drought relationship (what they call nonstationary models) to account for future changes on fire regimes derived from climate effects on vegetation. Their analyses showed that sensitivity of fire activity to dry periods is stronger in cooler/productive sites and therefore, they propose to use this finding as a short cut in their BA projections using climate change scenarios. The main assumption behind this approach is that the BA-SPEI relationships under a given productivity gradient can be used to infer new BA-SPEI relationships arising in the future. While representing a step forward in acknowledging the pitfalls of current projections of BA, this short-cut falls short in allowing to account for the key process behind climate-vegetation-fire feedbacks. We argue that there are a series of mechanisms by which current correlations are not likely to be maintained in the future with major, overall still unknown, consequences on BA projections.

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First, the BA-SPEI is known to be affected by ecosystem productivity [2,3]. However, climate drivers of productivity are not universal and often difficult to capture[4]. In their study, Turco et al. 2018, found that temperature proved to be the best predictor of regional variability in the BA-SPEI relationship. We appeal that temperature might not be the most appropriate variable to relate productivity changes in vegetation to fire activity in the Mediterranean[5]. For instance, Pausas and Ribeiro (2013) [2] pointed to an increase of net primary productivity with temperature across the range of temperatures included in Turco et al (2018)[1], suggesting that other factors beyond productivity may be behind the relationships found in their work pointing in the opposite direction. Current evidence suggests that vegetation productivity in the Mediterranean is usually constrained by precipitation rather than by temperature alone[6]. In line with this, the authors actually conducted a sensitivity analyses to account for uncertainty derived from different climate variables potentially related to productivity gradients. Then, by using a wider set of predictors including precipitations variables, the models lead to an enormous increase in the uncertainty of BA predictions (BA increase of up to ~250% in non-stationary model built with PRE-PET; Fig 5). Results suggest that these correlative models are extremely idiosyncratic in nature and that using them for future projections is, at present, extremely uncertain. In addition, the sensitivity of vegetation to fire is not always mediated by productivity. Wind-driven fire regime regions are likely to strongly affect these relationships by reducing the role of vegetation in fire spread patters [7,8]. By not including this critical climate factor in their correlative analyses, BA drought analyses may be biased, especially in regions in which these two climate characteristics co-occur.

Second, spatial variation in the BA- SPEI relationship is likely to account for the effects of lower vegetation growth in drier sites which erodes the capacity of fuel to build up rapidly and thus, reduces the dominance of larger fires[5]. Is our view that using the current estimated BA-SPEI coefficients as a shortcut falls short in accounting for the interactions we expect to drive future climate-fire-vegetation feedbacks. The direct application of BA-SPEI relationships from other regions would assume a complete shift in vegetation which is far from likely in the forthcoming years due to lags in vegetation responses to climate[9]. Under this view, we expect that the

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approach used by Turco et al. (2018)[1] based on nonstationary models would actually shift BA values closer to those obtained in their stationary models. However, since climate conditions anticipated in the future are likely to be novel in many cases, vegetation responses are highly uncertain and may involve more sudden changes falling outside the variability estimated in the paper. In these cases, large scale vegetation shifts (i.e. *Pinus* to *Quercus* [10]) triggered by fire itself, climate or a combination of both[11] may increase the sensitivity of the system to drier conditions even faster of what is assumed in the paper. Under this alternative view, the system could in fact trigger lower BA projections compared to what is expected from nonstationary models based. Overall, assumptions on specific vegetation responses to climate productivity changes for which mechanisms are not yet fully understood are likely to induce contradictory effects on future estimate of BAs.

Finally, climate-fire-vegetation feedbacks are often mediated by human factors. This human influence is likely to be especially strong for European Mediterranean forest systems[12]. Although this is explicitly recognised by Turco et al. (2018)[1], we think their projections may strongly suffer from biases associated to these human influences[13]. In contrast with the future projections showing increases in BA, they actually have observed significant negative trends (mainly derived from fire suppression) in BA independently of the BA-SPEI relationship. This indicates that contrary to the assumption that BA will be affected by spatial variation in drought alone, BA is likely to be heavily influenced by other factors with variability in fire suppression policies being an outstanding example. While Turco et al. 2018 argue that their approach does not account for future changes in fire management policies, we argue that these fire management policies are already shaping the BA - SPEI drought relationships in the region and therefore may strongly influence projections derived from these simple relationships[14].

While we share some of the worries raised by the authors in relation to the increase in climate fire-prone conditions under even mild increases in temperature (which goes in line with evidence already provided by a number of studies[15,16]), we argue that the approach used by Turco et al. (2018)[1] cannot adequately capture vegetation feedbacks expected from fire regime

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changes. Their results entail a large uncertainty preventing reliable inference on long term projections of BA. Current evidence cannot yet discard that negative feedbacks actually decreases burnt area in the long term in some regions specially when combined with high fire suppression effectiveness. Resolving this challenge will greatly benefit from the development of mechanistic models that explicitly consider the processes by which changes on vegetation derived from climate influence fire regimes. Future research focus in future modelling approaches will also require a more in depth inclusion and assessment of novel fire conditions (and especially novel wind patterns) and their relationships with vegetation responses and fire suppression effectiveness in determining future fire regimes in the region.

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