RESPONSES TO REVIEWER'S COMMENTS FOR THE PAPER:

Modelling post-fire vegetation recovery in Portugal

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Responses to Referee #2

We have made an effort to answer to all the issues raised by the reviewer. In order to facilitate the reading we have split and numbered all different items raised by the reviewer.

RC 1 – "Fire damage is defined as the difference in NDVI value between pre-fire (May before fire) and one year later, that is May of the following year. This one-year difference includes the impact of fire severity, the erosion processes that may be produced short after fire, and the recovery of vegetation in autumn and part of spring during this first post-fire year. As this early recovery of vegetation can be very diverse depending on the ecosystem type (and other factors), the concept of "fire damage" include early plant regeneration in a way that is difficult to interpret. It is not surprising that fire damage relates to recovery time (section 5.2) as high fire damage itself includes low initial vegetation recovery. I would suggest trying to get an index of fire severity immediately after fire."

We understand the reviewer's concern regarding the usage of NDVI (May) in the definition of fire damage. Nevertheless it may be noted that the proposed definition of fire damage as a normalised difference between post-fire (May after the fire) and pre-fire (May before the fire) NDVI values represents an improvement of the definition of fire damage as proposed in Gouveia et al. (2010), which consisted simply in the evaluation of NDVI fields in May of the year following the fire. Choice of this month to estimate fire damage (respecting to fires occurred in 2003) is justified in Gouveia et al. (2010), where it is stated (last paragraph of p.681):

> *In fact, the median of NDVI in May, during the pre-fire period ($NDVI_{MEDIAN}$), may be viewed as an indicator of vegetation density of a given pixel, whereas the field of NDVI in May 2004 ($NDVI_{2004}$) may be considered as a measure of fire damage, in particular, its impact on the new phenological cycle. This latter aspect has, in fact, motivated the choice of $NDVI_{2004}$ instead of either lack of greenness immediately after the fire event (i.e. parameter a of Eq. 3) or NDVI in October 2003. Furthermore, $NDVI_{2004}$ presents the advantage of being free from the influence of ashes and charcoal that could be misleading with low vegetation activity during the months immediately following the fire season.*

However, taking into account the reviewer's comments, the authors realize now that a justification for our choice should be explicitly included in the revised version of the manuscript (lines 16-17, p.4569), which now reads:

> *(…) where $NDVI_{PRE}$ and $NDVI_{POST}$ correspond to the mean NDVI value evaluated in May of the year of the fire event and of the following year, respectively. The evaluation of NDVI in May has the advantage of evaluating the impact of fire in the new phenological cycle, while minimizing the influence of ashes and charcoal on observations (Gouveia et al., 2010).*

RC 2 – "page 4561, line 4: Why "agriculture mechanization" could have contributed to the increase of wildfires? I don't see the direct relationship."

There is an indirect relationship, since changes in agricultural practices in northern Mediterranean (e.g. the increase of intensive (industrial) agriculture in recent decades) led to the abandonment of less productive lands as well as to the homogenization of landscape, and have promoted the progression of shrubland and forests, especially pines, which are more flammable (Barbero et al., 1990). These changes, when combined with decreases in grazing and wood gathering, lead to fuel pile-up, increasing fire risk and establishing the conditions for larger wildfires (Pausas and Vallejo, 1999; Moreira et al., 2001; Pérez et al., 2003).

RC 3 – "p. 4562, l. 7: Nutrient losses probably do not reduce plant cover in most of the cases, by the contrary the lack of plant cover facilitates nutrient losses (and soil erosion)."

We agree with the reviewer comment, which we believe to be consistent with the following sentence in the original manuscript (lines 1-2, p.4562):

> *The most important impacts consist on (i) soil impoverishment through loss of nutrients during the fire event or throughout the post-fire period, by runoff; (ii) loss of plant cover and consequent erosion;*

Reference to nutrient losses was accordingly removed from the sentence (p. 4562, lines 5-9) which now reads:

> *If, in the long term, vegetation recovery decreases post-fire runoff and erosion, in the short term, autumn rainstorms increase erosion after summer fires and therefore reduce plant cover (De Luís et al., 2001).*

RC 4 – "p. 4562, l. 24-26. The finding of decreasing trend in precipitation in inland areas (De Luís et al. 2001) do not necessarily apply in general, this was just demonstrated in Eastern Spain."

We agree with the reviewer and the sentence has been accordingly changed. The sentence at the end of the last paragraph of p.4562 (lines 24-29) now includes an explicit reference to Eastern Spain:

> *Strong or frequent droughts increase water stress during regeneration, and more concentrated rainfall intensity may intensify erosion and nutrient loss (De Luís et al., 2003), affecting short-term ecosystem development. Furthermore, De Luís et al. (2001) have observed that**, in Eastern Spain,** changes in the precipitation regime, such as decreases in rainfall volume and increases in rainfall concentration seem to be occurring in dry, inland areas, where most forests are located.*

RC 5 – "p. 4567, l. 15. Please explain how do you estimate GY."

Estimation of the Gorgeous Year (GY) is based on the definition provided in Gouveia et al. (2010). GY consists on an ideal annual cycle whose monthly means are computed by selecting the maximum value of NDVI for each month (relative to the entire pre-fire period).
This definition has been included in the new version of the manuscript, namely in the first paragraph of section 3.2 (lines 14-16, p.4567), that now reads:

> *Estimation of vegetation recovery rates is based on the mono-parametric model developed by Gouveia et al. (2010)* ***which relies on the so called Gorgeous Year (GY) defined as an annual vegetative cycle associated to an ideally healthy state of vegetation whose monthly means are computed by selecting the maximum value of NDVI in the pre-fire period for each month.***

RC 6 – "p. 4576, l. 16-18. It is surprising that the lowest NDVI is found 3 months after fire in RVII. The interpretation that delayed mortality would be the reason is unlikely. Right after fire, brown needles could remain in the pine canopy if fire severity was not very high, and these needles fall down during next months, probably changing the reflectance of the burned forest. During these 3 months, a large part of the blackish ashes on the ground are leached out or incorporated into the soil, and there is some plant regeneration, mostly though resprouting. Therefore, all together makes difficult to interpret the decrease of greenness in the burned forest several months after the fire. This deserves further analysis."

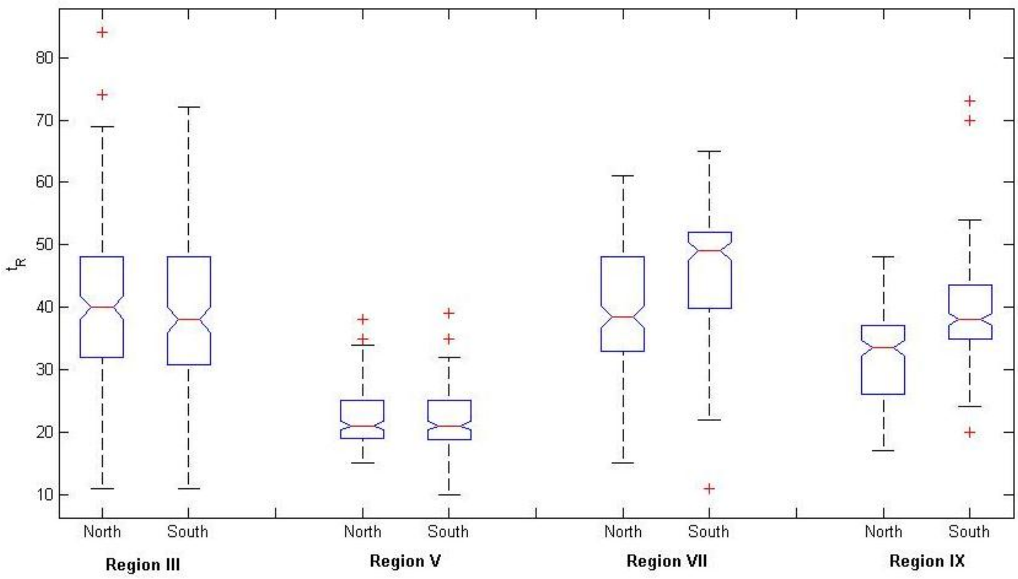
We agree with the reviewer that the first months following the fire are characterized by several changes, as those pointed by the referee, whose overall effects in soil reflectance would rather suggest an increase in NDVI than the observed decrease.
However, the influence of post-fire disturbances, such as herbivory and weather conditions, in delayed post-fire mortality is known (Whelan, 1995). De Luís et al. (2001) have studied the combined effect of fire and rainstorm in short-term ecosystem response in Eastern Spain and observed an increase in mortality rates as a consequence of rainfall. Catry et al. (2010) have studied post-fire tree mortality in mixed forests in Portugal and found that most coniferous died in the first year following the fire event, mostly due to crown injury, while the large

majority of broad-leaved survived. They have further pointed the effect of the severe drought of 2005 in increased tree mortality in Portugal, emphasising the interaction between fire and climate in this context. Furthermore, post-fire management practises in Portugal include frequently the removal of dead or injured biomass, in periods depending both on vegetation type and on the industrial use of the biomass. In this regard, it is worth mentioning that the DGRF guidelines for post-fire forest management recommending the removal until December of residuals of Pinus pinaster and other resinous species from fires were issued in the previous summer (DGRF, 2005b).

Thus, the decrease observed in NDVI over the first months following the fire may be due to a diversity of factors which cannot be assessed with the available data.

7 – "p. 4576-4577, on the spatial variability of regeneration. It would be very interesting to complement this analysis with the incorporation of topography (using GIS) and some field work."

We are in total agreement with the reviewer about the importance of topography in the analysis of spatial variability of regeneration. Several authors have studied the influence of terrain characteristics on post-fire vegetation recovery, such as a altitude, slope or aspect (Pausas and Vallejo, 1999, 2004; Vázquez and Moreno, 2001; Wittenberg et al., 2007; Carmo et al., 2011). In fact, the authors have been developing work on that subject and are preparing results for publication. Preliminary results from a study that is currently being undertaken by us suggest that, in some regions, topographic features do have influence on vegetation recovery. The example shown in the figure below respects to regions RIII, RV, RVII and RIX. Results suggest that for regions RVII and RIX vegetation recovery is influenced by terrain aspect. Results require however further analysis which the authors believe to be beyond the scope of the present paper.



Recovery time (in months) distribution over each slope aspect (North and South) for Regions III, V, VII and IX. Red lines indicate median values; blue boxes indicate the 25% and 75% interquartile ranges and black whiskers encompass the 1.5% and 98.5% interquartile ranges. Red crosses represent outliers.

8 – "The conclusions section is too long, it is an extended summary of the paper. I suggest making it more synthetic."

The authors agree with the reviewer and section 6 (Conclusions and final remarks) was accordingly reduced.