Fuel Treatment Impacts on Overstory Species Composition
in Mixed-Conifer Forests of the Sierra Nevada

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ABSTRACT

Prior to fire suppression policies, the Sierra Nevada range of California experienced high frequency, low severity fires that created a heterogeneous landscape. However, current forests are dense with trees, high in fuel loads, and changed in species composition with shade tolerant species shading out shade intolerant species. Current fires are of high severity that raises concerns for future forest structure. Fuel treatments are a method to replicate historic fire regimes and to meet desired forest management objectives. Three different fuel treatments, a prescribed burn, mechanical thinning, and a combination of the two, were applied in 2002 by the Fire-and-Fire Surrogates project to alter forest structure and data was collected in 2003, 2009, and 2016. I used a linear mixed effects model to determine changes in both the proportional basal area and individual species' basal area of the five most important mixed-conifer forest tree species in response to the fuel treatment applied and the time after initial treatment. MECH and MECHBURN treatments generally resulted in the largest and longest effects across species compared to control treatments. MECH and MECHBURN treatments also decreased the basal area of shade tolerant tree species: White Fir and Incense-Cedar. These results can be used by forest managers to determine the best management approach for their specific objective and the potential longevity of their treatment on overstory species composition.

KEYWORDS

Basal area, prescribed burning, mechanical thinning, species proportion, fuel treatment longevity

INTRODUCTION

Low to moderate severity wildfires frequently burned in the Sierra Nevada range of California prior to fire suppression policies and forest management practices in the late 1800s (Stephens and Ruth 2005, Marlon et al. 2012). Fire suppression was implemented to prevent the loss of economic resources, such as land for livestock grazing and timber harvests, as well as to protect growing urban areas (North et al. 2009). However, contrary to intentions, fire suppression and fire exclusion management practices have instead increased fire risk in California by increasing the available surface and ladder fuels (Stephens et al. 2012). This homogeneity of fuels in the forest surface and the forest canopies increases the risk of high severity fires. Rising temperatures from climate change are increasing the amount of dead fuels and may further increase the frequency and severity of wildfires (Hessburg et al. 2016). To preserve forest structure, treatment and management practices that reduce surface fuels and promote forest resiliency (i.e. the ability of an ecosystem to absorb change) rather than fire suppression are needed (DeRose and Long 2014).

Fuel treatments are focused on reducing surface fuels and in reducing ladder fuels to prevent the spread of fires into the higher canopy (Stephens et al. 2012). These fuel management practices are often approached in one of three ways: using fire (e.g., prescribed or managed wildland), mechanical thinning (which involves crown thinning and masticating small trees) or a combination of the two (Collins et al. 2014). The goal of these treatments is to manage future fire behaviors which in turns prevents high-severity wildfires which have the potential to burn though various habitat sites and through urban areas (North et al. 2009). Controlled fires also can strengthen forest resiliency for continued climate change via vertical and horizontal heterogeneity (North et al. 2009). Restoring the previous fire regime of frequent low-severity fires can also initiate ecosystem processes that were interrupted by a lack of frequent fires and the accumulation fuels (Agee and Skinner 2005, North et al. 2007). For example, the burning of surface fuels recycles nutrients into the soil, allowing for an increase in plant growth and species diversity (Moghaddas and Stephens 2007). As such, the ability to influence fires via fuel treatment is significant for forest managers to create a resilient forest for both plants and wildlife and to control fire behavior.

Although all three treatments influence forest structure by reducing available fuels, the long-term outcome of each treatment may be different in ecological trajectory. Fuel treatments impact shrub cover, tree mortality, overstory, and species composition differently over time. For example, mechanical treatments result in a lack of shrub cover important for forest heterogeneity because mechanical thinning focuses on small trees (Collins et al. 2014). Although shrub cover may be lacking, mechanical treatments also result in lower large tree mortality than fire treatments. (Collins et al. 2014). Treatments can create forest stands that are resistant to high severity fires by decreasing surface fuels and ladder fuels (Stephens et al. 2012). These studies and others reported how fuel treatments impact forest structure in the short term (1-3 years) and the mid-term (5-7) years, yet studies on the long term (10+ years) impacts of fuel treatments on forest structure are rare.

This study aims to extend the current knowledge of fuel treatments and examine the long-term effects on overstory species composition in mixed-conifer forests of the Sierra Nevada by examining changes in species composition from pre-treatment (2001) to mid-treatment (2003 and 2009) to fourteen years after treatment (2016) compared to control stands. Each treatment will be assessed to determine how the growth of the individual mixed-conifer forest tree species were impacted. The results will inform forest managers in determining what treatments are best for long-term goals regarding overstory species composition.

METHODS

Study site

The University of California Blodgett Forest Research Station is in the mixed conifer zone of the north-central Sierra Nevada Mountain Range of California, USA (38°54'45" N;120°39'27" W) (Collins et al. 2014). Blodgett Forest is approximately 20 kilometers east of Georgetown, CA with an area of 1780 hectares and is situated altitudinally between 1100 m and 1410 m above sea level (Stephens et al. 2012). Blodgett Forest experiences a Mediterranean climate with mild summer temperatures and a drought that extends into the fall. Most of the rain occurs in the winter and spring with an average precipitation of 160 cm. There are infrequent thunderstorms in the area (Stephens et al. 2012).

Tree species of Blodgett Forest include ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), Pacific madrone (*Arbutus menziezii*), Douglas-fir (*Pseudotsuga menziesii*) Franco, white fir (*Abies concolor*), incense-cedar (*Calocedrus decurrens*), California Black Oak (*Quercus kelloggii*), tanoak (*Lithocarpus densiflorus*), and bush chinkapin (*Chrysolepis sempervirens)* (Stephens et al. 2012, Collins et al. 2014). Prior to early 20th century fire suppression, fire was a common occurrence and ecosystem process in this mixed-conifer forest zone (Graham et al. 2004). In accordance with management practices in California, forests in Blodgett Forest were harvested and underwent fire suppression for the last 100 years (Graham et al. 2004).

Fuel treatments

Three different fuel treatments, along with an untreated control, were used to change forest structure so that 80% of trees would survive a wildfire from the 80th percentile of weather conditions: Mechanical-only (MECH), Mechanical-plus-fire (MECHFIRE), and Prescribed-fire-only (FIRE) (Stephens et al. 2012). These treatments were conducted in 2002 by the Fire-and-Fire-Surrogate study in collaboration with the Stephens Lab at the University of California Berkeley. Each treatment was randomly applied to 3 of 12 experimental units of 14 to 29 hectares in size, totaling the size of the experimental units to 225 hectares (Stephens et al. 2012).

The MECH treatment occurred in two stages. The first stage of the treatment began in 2001 with crown thinning. Crown spacing was maximized to retain a basal area of ~ 28-34 m2/ha and to reduce live crown overlap from dominant and codominant trees (Stephens et al. 2012). The goal was of the crown thinning was to create an even species mix (Stephens and Moghaddas 2005, Collins et al. 2014). The second stage involved mastication by excavator of 90% of understory conifers and hardwoods less than 25 cm DBH. The masticated chips were left in the area while the masticated understory trees were scattered in 0.04 to 0.20 ha clumps (Stephens et al. 2012). The MECHFIRE treatment underwent the same procedure as MECH but also had a prescribed backing fire (a fire that goes against the wind). The BURN treatment had no pre-treatment but had prescribed strip head fires (a series of fire lines ignited near fuel breaks) burned between 10/23/2002 to 11/6/2002 predominantly at night ("Strip-Head Fire" n.d., Stephens et al. 2012).

Data collection

Vegetation data was collected in 0.04 ha circular plots (0.04 ha) with a random starting point within each of the 12 experimental units by Rob York and Brandon Collins (Collins et al. 2014). This design, created by Scott Stephens and implanted by both Scott Stephens and Rob York, totals to 240 plots in which tree species (species name), DBH (cm), total height of the tree (m), height-to-live-crown-base (m), and crown position (dominant, co-dominant, intermediate, and suppressed) for trees greater than 10 cm DBH were collected (Collins et al. 2014). Status of conifers greater than 25 cm DBH was measured as live in 2001 to track mortality through time (Collins et al. 2014). These trees were numbered and then resurveyed in 2003, 2009, and 2016. Masticated trees from MECH and MECHFIRE treatments were excluded from these recurrent measurements (Collins et al. 2014). Species composition was calculated for live tree basal area proportion using species-specific regional volume equations (Collins et al. 2014). Data was organized by Daniel Foster.

Data analysis

Linear mixed effects model

Using a linear mixed effects model package on R studio (nlme) and a 2-way BACI to account for the natural variation amongst the plots of each treatment type, I determined the significant difference in the percentage of basal area for vegetation type in each treatment (R Development Core Ream 2019). I used the following general equation: Basal area per hectare ~ Treatment + Year + Treatment*Year + (1| Unit/PlotID). I adjusted my p-value using the Bonferroni procedure and set the highly significant p-value as 0.00052, the moderately significant p-value as 0.003125, and the weakly significant p-value as 0.05. The fixed effects in the model were the treatment, year and the interaction between treatment and year. I created a model for each the five most important species in mixed-conifer forests: White-fir (ABCO), incense-cedar (CADE), Sugar pine (PILA), Ponderosa pine (PIPO), Douglas fir (PSME) to determine which interactions between treatment and time were significant in influencing the total basal area of said species. I then ran a linear mixed effects model for the proportional basal area for each species

using the previous steps and ran validation checks for all linear mixed effects to ensure assumptions or normality were met.

RESULTS

Total Basal area of each species

ABCO

In general, all the MECH and MECHBURN treatments had highly significant negative effects on the basal area of white fir while the BURN treatment had one weakly significant negative effect. The interaction between the BURN treatment in 2009 had a weakly significant negative effect on the basal area of white fir of -2.07 ± 0.82 m^2. The MECH treatment had a highly significant negative effect of -3.56 ± 0.83 m^2 in 2003, -4.12 ± 0.83 m^2 in 2009, and -3.39 ± 0.83 m^2 in 2016. The MECHBURN treatment had a highly significant negative effect of -3.69 ± 0.82 m^2 in 2003, -6.70 ± 0.82 m^2 in 2009, and -7.21 ± 0.82 m^2 in 2016.

CADE

All the MECH and MECHBURN treatments had highly significant negative effects on the basal area of incense-cedar while the BURN treatment had a weakly significant negative effect in 2009 and a highly significant negative effect in 2016. The MECH treatment had a highly significant negative effect of -4.49 ± 0.71 m^2 in 2003, -4.61 ± 0.71 m^2 in 2009, and -4.98 ± 0.71 m^2 in 2016. The MECHBURN treatment had a highly significant negative effect of -4.96 ± 0.71 m^2 in 2003, -5.27 ± 0.71 m^2 in 2009, and -6.73± 0.71 m^2 in 2016. The BURN had a weakly significant negative effect of -1.93 ± 0.70 m^2 in 2009 and a highly significant negative effect of -3.36 ± 0.70 m^2 in 2016.

PILA

In general, the BURN treatment did not have a significant effect on the basal area of sugar pine while the MECHBURN and MECH treatments had weakly significant effects in the mid-treatment and post-fourteen years after treatment. The MECHBURN was the only treatment had a weakly significant negative effect on the basal area of sugar time through time. The interactions between the MECHBURN treatment and the years 2009 and 2016 weakly decreased basal area by -1.35 ± 0.66 m^2 and -1.39 ± 0.66 m^2, respectively. Unlike the MECHBURN treatment, the MECH treatment had a weakly significant positive effect on the basal area of sugar pine of 1.35 ± 0.66 m^2 in 2016.

PIPO

Similarly, to the results in Sugar Pine, the BURN treatment did not have a significant effect on changes in the basal area of Ponderosa Pine. The MECHBURN treatments had weakly significant negative effects on the basal area of Ponderosa Pine that weakened over time. The interactions between the MECHBURN treatment and the year 2003 and 2009 each had weakly significant negative effects on basal area by -1.61 ± 56 m^2 and -1.06 ± 0.56 $m^2 m^2$, respectively. In comparison, the effect of the MECH treatment became more significant over time with no significance change in basal area in 2003 and 2009 but a weakly significant negative effect of -1.05 ± 0.56 m^2 in 2016.

PSME

All treatments appeared to have a negative effect on the basal area of Douglas Fir over time. The strength of the effect of the MECH treatment weakened over time while the effect strengthened in the MECHBURN and BURN treatments. The interaction between the MECH treatment and 2003 had a highly significant negative effect on basal area of Douglas fir of -2.55 ± 0.66 m^2 and a weakly significant negative effect of -1.60 ± 0.66 m^2 in 2009. The interaction between the MECHBURN treatment and the year 2003 had a weakly significant negative effect of -1.75 ± 0.66 m^2 while in 2009 and 2016 the MECHBURN treatment had significant negative

effects of -2.69 ± 0.66 m^2 and 3.59 ± 0.66 m^2 respectively. The BURN treatment did not have significant effects until 2016 when there was a moderately significant negative effect of -2.11 ± 0.65 m^2.

Proportional basal area of each species

ABCO

The interaction between the MECHBURN treatment and the year 2009 had a moderately significant negative effect (-0.06 ± 0.02 m^2) on the proportional basal area of white fir. By 2016. The MECHBURN treatment had a weakly significant effect (-0.03 ± 0.02 m^2) on the proportional basal area in 2016. No other results were significant.

CADE

The MECH treatment had a highly significant negative effect on the proportional basal area of incense-cedar of -0.05 ± 0.01 m^2 in 2003 and in 2009. By 2016, the MECH treatment had a weakly significant negative effect of -0.03 ± 0.01 m^2. The MECHBURN treatment had a moderately significant negative effect on the proportional basal area of incense-cedar of -0.04 ± 0.01 m^2 in 2003.

PILA

There were weakly significant effects of both the MECH and MECHBURN treatments through time. The MECH and MECHBURN treatments had weakly positive significant effects on the proportional basal area of Sugar Pine of 0.03 ± 0.01 m^2 in 2003, 2009, and 2016 with the MECHBURN in 2009 having a weakly positive of 0.04 ± 0.01 m^2.

PIPO

The BURN treatment in 2016 had a moderately significant positive effect on the proportional basal area of Ponderosa Pine of $0.04 \pm 0.01 \ m^2$. The MECHBURN treatment had a highly significant positive effect on the proportional basal area of Ponderosa Pine through time of $0.05 \pm 0.01 \ m^2$ in 2003, $0.08 \pm 0.01 \ m^2$ inn 2009, and $0.07 \pm 0.01 \ m^2$ in 2016.

PSME

There were no significant results on the proportional basal area of Douglas-fir.

DISCUSSION

As wildfires grow in number and severity and climate causes interannual variability in precipitation and temperature, fuel treatments will increase in scale to create more resilient and diverse forests. It is important to understand the longevity of fuel treatments regarding species composition to determine how often a desired goal will last and how long until another treatment is needed. The goal of this study was to determine how fuel treatments impact species composition by examining the changes in the total basal area and proportional basal area of each species resulting from the treatment conducted and the years post-treatment. I found that the MECHBURN treatment had the greatest influence in changing the basal area of trees with MECH coming in second and the BURN treatment having little impact. This information can then be used by forest managers to determine the best treatment for their goals: such as increasing the proportion of fire tolerant species and decreasing the proportion of shade tolerant species.

Basal area and proportional basal Area for each species

Sugar pine and ponderosa pine

Sugar pine and ponderosa pine are shade intolerant and fire intolerant species that have been shaded out by shade tolerant species (Miller and Urban 2000, Hessburg et al. 2016, Safford

and Stevens 2017). Both ponderosa pine and sugar pine decreased in basal area in the MECHBURN treatments relative to the control while the MECH treatment had weakly significant effects on the basal area of both species in 2016. As the linear mixed effects model were run against the control units, the MECHBURN treatments decreased basal area of ponderosa pine and sugar pine relative to the control. The MECH treatments may not have had a significant difference relative to the control. This could be due to the nature of the mechanical treatments in which there was a goal to create an even species mix and less of ponderosa pine and sugar pine may have been masticated (Collins et al. 2014). The added prescribed burn in the MECHBURN treatments may have caused the decrease in basal area of both ponderosa pine and sugar pine due to fire injuries. Sugar pine and ponderosa pine may not have been significantly impacted by the BURN treatment given that the species are tolerant to low-to-moderate severity fires due to thick bark (Hessburg et al. 2016, Safford and Stevens 2017).

Both sugar pine and ponderosa pine had significant increases in their proportional basal area in the MECH and MECHBURN treatments. This may be due to the methods behind the mechanical treatments in which the goal of creating an even species mix may have decreased the basal area of shade tolerant species, opening space for the two pines. The increased crown spacing from the mechanical treatments would have increased sunlight availability and increased the growth of the sugar pine and ponderosa pine trees (Kinloch and Scheuner 1990, Safford and Stevens 2017). Ponderosa pine also had moderately significantly positive effect on the proportional basal area in the BURN treatment in 2016. Given that no other species had any significant results from the BURN treatment regarding proportional basal area, this increase may be due to a higher proportion of ponderosa pine basal area relative to the control treatment.

White fir and incense cedar

Both white fir and incense cedar are shade tolerant and fire-intolerant species and were both significantly negatively affected by the MECH and MECHBURN treatments relative to the control treatment (Conard and Radosevich 1982, Safford and Stevens 2017). Incense cedar also had a significant decrease in basal area in 2016 within the BURN treatment and both incense cedar and white fir had weakly significant negative effects from the BURN treatment in 2009. Both species are fire intolerant which explains some of the decrease within the burn treatment (Safford

and Stevens 2017). The mechanical treatments would have removed shade tolerant species, causing this decrease in basal area of white fir and incense cedar (Stephens et al. 2012). This continued decrease post treatment indicates that the initial goal of treatment (reducing shade tolerant species) succeeded and continued to cause a decrease in white fir and incense cedar basal 16 years after treatment (Stephens et al. 2012).

However, it is important to note that the change in proportion of basal area of white fir was only moderately significant in the MECHBURN treatment post 6 years after treatment (2009) and weakly significant post 14 years (2016). On the other hand, the proportional basal area of incense cedar was significantly negatively impacted by both the MECH and MECHBURN treatments through time, though the significant of the treatments weakened over time. By 2016, the MECH treatment weakly impacted proportional basal area of incense cedar and the MECHBURN treatment had no significant impact on the proportional basal area of incense cedar. These results indicate that the MECH and MECHBURN treatments did influence the relationship between tree species causing a slight decrease in white fir and incense cedar. This decrease is important as shade tolerant species, such as white fir and incense cedar, not only shade out shade intolerant species but also act as a ladder fuels (Miller and Urban 2000). The ability to slow down or decrease the growth of white fir and incense cedar may help in increasing the growth of shade intolerant species as well as decrease future fire risk. This longevity of the mechanical treatments in decreasing basal area of white fir and incense cedar may help forest managers determine the most effective treatment for reducing shade tolerant species and the longevity of said treatments.

Douglas-fir

Douglas-fir is both shade tolerant and fire tolerant (North et al. 2009, Hessburg et al. 2016, Safford and Stevens 2017). At one point in time, all treatments conducted did significantly impact the basal area of Douglas-fir trees - although the proportional basal area of Douglas-fir was not significantly impacted by any treatment. Similarly to white fir and incense cedar, Douglas-firs are shade tolerant that the mechanical treatments would have removed the higher density shade species in order to achieve the goal of an even species mix (Stephens 1998, Collins et al. 2014). As expected, the basal area of Douglas-firs was significantly negatively affected by the MECH and MECHBURN treatments. Douglas-firs are also fire tolerant that it is interesting to note the

moderately significant negative effect of the BURN treatment in 2016. This may be due to fire injuries to the trees within the BURN treatments that decreased the basal area of Douglas-fir trees relative to the basal area of Douglas-fir trees in the control (Hood and Bentz 2007). However, the proportional basal area of Douglas-firs was not significantly impacted by any treatment. This may be due to the relationships with other species. Increases in shade intolerant species, such as ponderosa pine and sugar pine, as well decreases in shade tolerant species changed the relative proportional basal area which may have not impacted the proportional basal area of Douglas-fir. The effects of time of each treatment, such as the sudden decrease in basal area of Douglas-for in the MECH treatment and the delayed decrease in the BURN treatment, may help forest managers determine the best treatment for both short term and long-term goals in influencing forest stand structure.

Limitations

Although this study focused solely on species composition in mixed-conifer forests in the Central Sierra Nevada, there were limitations on how species composition was analyzed. Each species was analyzed individually and inferences on the overall species related to one another were made based on those results. These inferences may not accurately reflect relationships, such as an increase in one species causing a decrease in another, given that I did not have an appropriate method to analyze these relationships. I also did not account for competition between the species or potential diseases, such as bark beetle attacks, that may have influenced the growth of trees. The same results may not occur in other locations, such as different forest types, or other mixed-conifer forests, due to different topographic and weather conditions. This study is limited to the mixed-conifer forest of the Blodgett Forest Research Station and does not represent all mixed-conifer forests.

Future directions

This study is limited in examining purely species composition. Future studies could examine species composition in greater depth, such as determining the interactions between species post-treatment. My proportional basal area results did provide some clues as to how the

species relate to one another, but a better method would be to run a model against two species and compare the results from the two species. Another limitation was that I did not statistically determine if the goal of an even species mixed was achieved in the mechanical thinning treatments. I made inferences rooted in my results, but a more comprehensive study could run a diversity index post-treatment to determine if the even species mix goal was achieved. Studies can also focus on other components of forest stand structure, such as overstory growth, fire behavior structure, such as fuel availability, and tree vitality, such as tree mortality. For example, a study could exam the probability of mortality of each species based on the scorch height from the prescribed burns. Mortality information can help determine future availability of dead fuels. This information can provide more insight on how fuel treatments effect mixed-conifer forests.

Conclusion

The results from this study indicate that different fuel treatments have a long-term effect on the growth of species of trees in mixed-conifer forests and understanding these differences may aid forest managers determine the best fuel treatments for their objective. Reducing the percentage of shade-tolerant trees and increasing the percentage of fire-tolerant trees will help in creating fire-resistant forests. The results from this research agrees with previous research at Blodgett and indicate a potential for treatments to have a longer duration (Stephens et al. 2012, Collins et al. 2014). In general, MECH and MECHBURN treatments influenced the overstory species composition more than the BURN treatments and had a longer lasting effect. BURN treatments appeared to have delayed effects. However, forest structure is also dependent on understory structure and this understory structure provides the surface fuels for fires. More information can only better prepare forest managers to determine the best way to create resilient forests both from climate and fires.

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APPENDIX A: RESULTS SUMMARIES

Table 1: Summary of linear mixed effects model results on total individual species basal area.

SPECIES	YEAR	MECH	MECHBURN	BURN
ABCO	2003	$-3.56 \pm 0.83\ m^2$***	$-3.69 \pm 0.82\ m^2$***	-
	2009	$-4.12 \pm 0.83\ m^2$***	$-6.70 \pm 0.82\ m^2$***	$-2.07 \pm 0.82\ m^2$*
	2016	$-3.39 \pm 0.83\ m^2$***	$-7.21 \pm 0.82\ m^2$***	-
CADE	2003	$-4.49 \pm 0.71\ m^2$***	$-4.96 \pm 0.71\ m^2$ **	-
	2009	$-4.61 \pm 0.71\ m^2$***	$-5.27 \pm 0.71\ m^2$***	$-1.93 \pm 0.70\ m^2$*
	2016	$-4.98 \pm 0.71\ m^2$***	$-6.73 \pm 0.71\ m^2$***	$-3.36 \pm 0.70\ m^2$***
PILA	2003	-	$-1.61 \pm 56\ m^2$	-
	2009	-	$-1.06 \pm 0.56\ m^2$*	-
	2016	$1.35 \pm 0.66\ m^2$*	-	-
PIPO	2003	-	$-0.05 \pm 0.01\ m^2$*	-
	2009	-	$-0.08 \pm 0.01\ m^2$*	-
	2016	$-1.05 \pm 0.56\ m^2$*	$-1.05 \pm 0.56\ m^2$*	-
PSME	2003	$-2.55 \pm 0.66\ m^2$***	$-1.75 \pm 0.66\ m^2$*	-
	2009	$-1.60 \pm 0.66\ m^2$*	$-2.69 \pm 0.66\ m^2$***	-
	2016	-	$-3.59 \pm 0.66\ m^2$***	$-2.11 \pm 0.65\ m^2$**

***Highly significant, **Moderately significant, *Weakly significant, -No significance

Table 2: Summary of linear mixed effects model results on proportional species basal area.

SPECIES	YEAR	MECH	MECHBURN	BURN
ABCO	2003	-	-	-
	2009	-	$-0.06 \pm 0.02\ m^2$**	-
	2016	-	$-0.03 \pm 0.02\ m^2$*	-
CADE	2003	$-0.05 \pm 0.01\ m^2$***	$-0.04 \pm 0.01\ m^2$**	-
	2009	$-0.05 \pm 0.01\ m^2$***	$-0.05 \pm 0.01\ m^2$***	-
	2016	$-0.03 \pm 0.01\ m^2$*	-	-
PILA	2003	$0.03 \pm 0.01\ m^2$*	$0.03 \pm 0.01\ m^2$*	-
	2009	$0.03 \pm 0.01\ m^2$*	$0.03 \pm 0.01\ m^2$*	-
	2016	$0.03 \pm 0.0\ m^2$	$0.03 \pm 0.01\ m^2$*	-
PIPO	2003	-	$0.05 \pm 0.01\ m^2$***	-
	2009	$0.05 \pm 0.01\ m^2$***	$0.08 \pm 0.01\ m^2$***	-
	2016	-	$0.07 \pm 0.01\ m^2$**	$0.04 \pm 0.01\ m^2$**
PSME	2003	-	-	-
	2009	-	-	-
	2016	-	-	-

***Highly significant, **Moderately significant, *Weakly significant, -No significance