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# A Preliminary Investigation of the Impact of Forest Management Practices on Microhabitat Abiotic Variables in the Southern Appalachian Mountains

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# A PRELIMINARY INVESTIGATION OF THE IMPACT OF FOREST MANAGEMENT PRACTICES ON MICROHABITAT ABIOTIC VARIABLES IN THE SOUTHERN APPALACHIAN MOUNTAINS

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## ABSTRACT

Existing research has demonstrated that forest management practices (e.g., clear-cutting, planting) can dramatically impact animal communities. This is particularly the case with amphibian populations due to their sensitivity to microhabitat alterations. However, few studies have investigated the manner by which forest management practices impact the abiotic variables most relevant to healthy amphibian populations. In this study we investigated how spatially localized forest management practices (i.e., at the scale of hundreds of meters) alter the microhabitat variables that have been shown important to amphibian population distributions. We assessed the relationship between forest composition and microhabitat abiotic variables across three localities with differing management histories in Lumpkin County, Georgia. Site A consisted solely of systematically distributed planted pines, Site B was composed of planted pine and mixed hardwoods, and Site C contained only mixed hardwoods. To quantitatively assess these differences in forest composition, we conducted a point-centered quarter tree survey at each locality and measured ambient temperature, soil temperature, air humidity, light intensity, and soil *p*H daily over a 60-day period. Our results indicate that soil moisture and *p*H differ across these localities. These data suggest that even at highly resolved spatial scales, forest management practices can dramatically impact the suitability of microhabitats for amphibian populations. This localized impact should be considered more broadly, but especially in regions with particularly dense amphibian populations.

***Keywords:*** forest management, forest composition microhabitat, abiotic variables

## INTRODUCTION

Research focused on amphibian population dynamics in response to forest management practices has largely concentrated on short- and long-term changes in taxonomic diversity and abundance (deMaynadier and Hunter 1995; Loehle et al. 2005; Wolf et al. 2016). Amphibian population level changes in relation to habitat alterations have been linked to dominant tree species and stand age (Loehle et al. 2005), as well as degree of amphibian detectability (Wolf et al. 2016).

Other studies have focused on the underlying mechanisms of these broad scale patterns. It has been demonstrated that the alteration of tree composition within a forest can negatively impact amphibian populations through loss of habitat or canopy cover and/or changes in leaf litter composition, soil chemistry, and forest floor dynamics (Anderson and Johnson 2018; Bondi et al. 2016; Connette and Semslitsch 2015; Homyack and Haas 2009; Morneault et al. 2004; Reichenbach and Sattler 2007; Riedel et al. 2007; Rota et al. 2017; Semlitsch et al. 2009; Waldick et al. 1999). Otto et al. (2013) found that the proportion of downed woody materials in timber harvest systems is positively correlated with amphibian counts. Yavitt and Williams (2015) assessed the effect of tree species on soil conditions (particularly microbial activity) and found 1) evergreen leaves decay at much slower rates than those from deciduous trees, and 2) soil associated with gymnosperms produces almost twice the quantity of methane than do soils dominated by angiosperms. Finally, Wyman and Jancola (1992) found that amphibian density and diversity was lower in more acidic habitats with some amphibian species actively avoiding low *p*H environments. This interplay of all of these factors creates a framework for amphibian microhabitats and can thereby influence their spatial distribution (de Maynadier and Hunter 1995; Mourneault et al. 2004).

The southern Appalachian Mountains represent a biodiversity hotpot for amphibian populations, with 76 species of salamanders, frogs, and toads (Bishop and Haas 2009). These temperate mountain environments provide a heterogeneous landscape and subtropical microclimates, which together create an ideal setting for the success of many amphibian species (McLeod 2017; Richmond et al. 2009). Miller et al. (2018) identified an important connection between abiotic variables and amphibian distribution, and suggested that future studies need to be focused at the scale that amphibians encounter in their environment. Therefore, highly resolved environmental data collected from across dynamic ecosystems could be the key to understanding the factors that most directly contribute to amphibian population vulnerability. In this study, we attempted to better understand spatial and temporal variation in abiotic conditions across three sites in Lumpkin County, Georgia, with varying levels of historical disturbance. More specifically, we: 1) quantitatively assessed variability in soil moisture, soil *p*H, soil temperature, air temperature and humidity across sites, and (2) explored the relationship between these abiotic variables and the composition of the localized tree community within each study site.

## MATERIALS & METHODS

We collected data daily in three localities at Lumpkin County, Georgia for a seven-week period beginning on 14 May 2018 and ending on 28 June 2018. Sites A and B are located in the Hurricane Creek Research Property (HCRP) owned by the University of North Georgia (Figure 1). Hurricane Creek, a tributary of the Etowah River, flows through the center of this property. The HCRP has undergone historical logging and clear-cutting practices and was subsequently replanted with *Pinus taeda* (loblolly pine) approximately 80 years prior to the study. Site A is approximately 50 m from Hurricane Creek and from

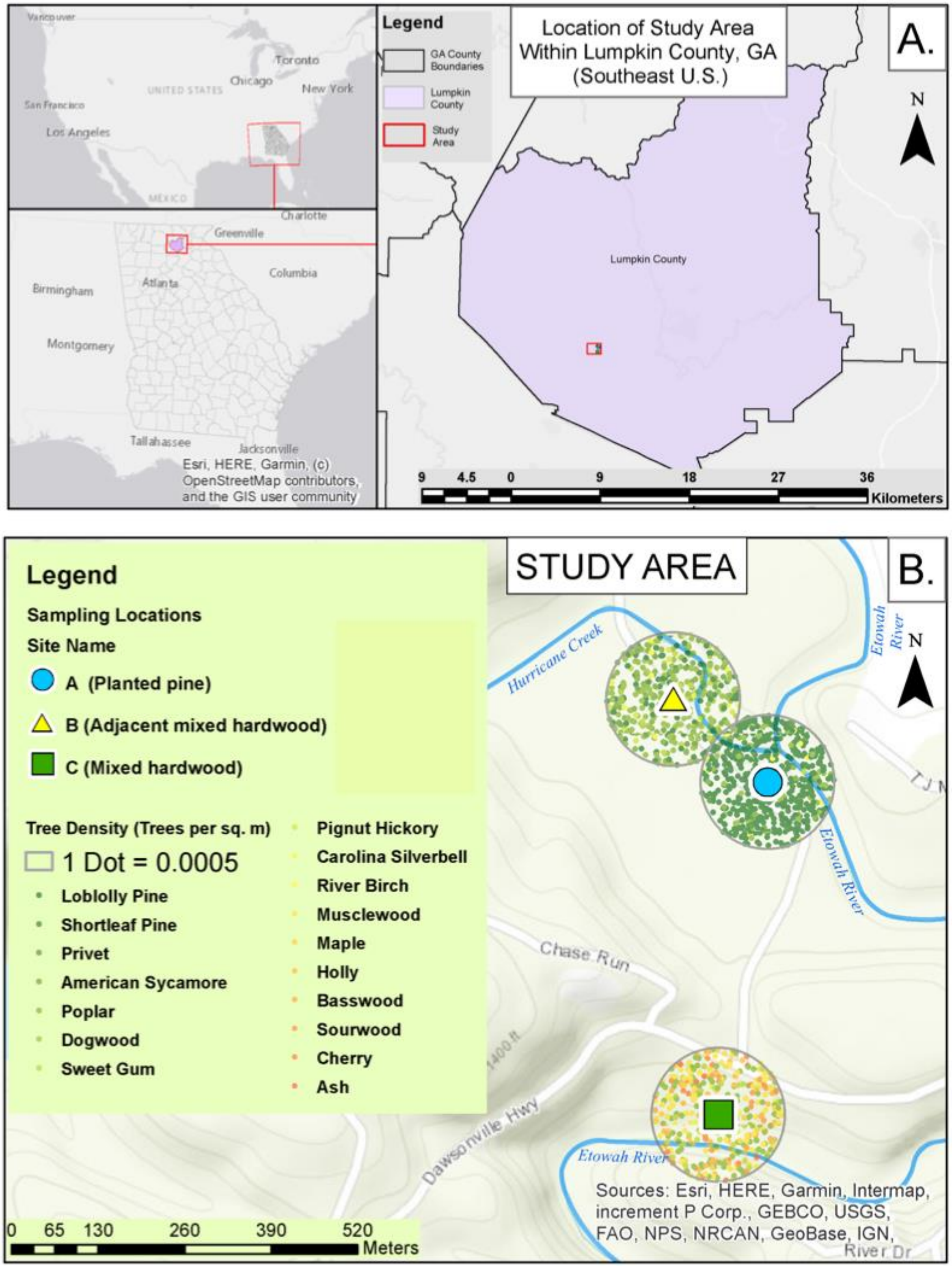


***Figure 1.*** Geographical setting of this study; **A)** Location of sampling sites in Lumpkin County, Georgia, southeast United States; **B)** Tree species identification and density.

Site B, which is in the riparian zone of the creek approximately 10 m from the bank. Site A is at the center of the clear-cut area at HCRP and is therefore the most anthropogenically-disturbed site in this study. Given its proximity to Site A, we considered Site B as moderately disturbed. Site C is approximately 400 m from the location of Sites A and B, situated 30 m from the Etowah River and is a mixed hardwood riparian forest with few pine trees and lacks a history of forest management alteration. Importantly, Site C is completely isolated from the previously logged location (Site A and B), making it the least disturbed of the three study sites.

We implemented a point-centered quarter method tree survey modified from Mitchell (2015) to investigate differences in forest composition patterns at Sites A, B, and C. First, we located a center point for each site and traversed five randomly generated distances (up to 25 m) along a north-south transect away from this center point. We divided each sampling point along the transect into 4 quarters and recorded and measured the nearest tree in each quarter. Measurements included distance to the tree, species identification, and diameter at breast height (DBH; approximately 130 cm from ground level). We required a minimum circumference of 12.5 cm DBH for inclusion in the survey. This method used an importance value index (IVI) of each tree species in each sampling area. The IVI is a summative measure that describes the importance of a particular species to the overall forest composition based upon: (1) the number of individuals of that species seen divided by the total number of trees observed (relative density), (2) the density of each species in relation to the average area taken up by that species (relative dominance), and (3) the number of times each species is sampled in relation to other observed species (relative frequency).

We measured five abiotic variables at Sites A, B, and C daily throughout the sampling period. Variables measured include ambient temperature, percent humidity, soil temperature, soil *p*H, and soil moisture levels (on a 1–8 scale). Ambient temperature and percent humidity were measured using a Springfield vertical thermometer and hygrometer (Taylor Precision Products) installed at each of the three sampling sites. We used a series of electronic probes at a depth of 10 cm to gather the remaining measurements. The probes used include General Tools MMD4E Moisture Meter (General Tools and Instruments LLC) for measuring soil moisture, Simply Silver Rapitest 1835 Luster Leaf Digital 3–way Soil Analyzer (Luster Leaf Products) for measuring soil *p*H and soil temperature, and a Yoyomax Soil Test Meter (Yoyomax Inc) for measuring soil moisture.

Forest composition analyses were completed in Microsoft Excel. All analyses of abiotic variables at Sites A, B and C were completed in R (version 3.1.1) using a one-way analysis of variance (ANOVA), and Tukey Honest Significant Differences (HSD) analyses. Differences in abiotic variables were considered significant at the $P < 0.05$ level. It should be noted that reference to significance in the following sections refers to statistical significance.

## RESULTS

Vegetation survey data indicated a spectrum of tree composition at Sites A, B, and C ranging from loblolly pine dominant to mixed hardwood dominant (Table I, Figure 1). Site A consisted primarily of loblolly pines, Site B was dominated by mixed hardwood trees and loblolly pines, and Site C was composed primarily of mixed hardwoods (Table I). In site A, loblolly pine density had an IVI of 234.56, with the second highest being

***Table I.*** Point-quarter importance value index (IVI) for each sampling site

| Site A | | Site B | | Site C | |
|---|---|---|---|---|---|
| **Species** | **IVI** | **Species** | **IVI** | **Species** | **IVI** |
| *Pinus taeda* (loblolly pine) | 234.6 | *Pinus taeda* (loblolly pine) | 129.8 | *Liriodendron tulipifera* (poplar) | 106.3 |
| *Liriodendron tulipifera* (poplar) | 38.4 | *Liriodendron tulipifera* (poplar) | 84.3 | *Carpinus caroliniana* (musclewood) | 58.9 |
| *Betula nigra* (river birch) | 9.8 | *Pinus echinata* (shortleaf pine) | 32.4 | *Acer rubrum* (red maple) | 30.7 |
| *Pinus echinata* (shortleaf pine) | 8.8 | *Ligustrum sinenese* (Chinese privet) | 18.7 | *Ilex opaca* (American holly) | 27.4 |
| *Platanus occidentalis* (American sycamore) | 8.5 | *Liquidambar styraciflua* (sweet gum) | 12.7 | *Liquidambar styraciflua* (sweet gum) | 21.6 |
| | | *Carya glabra* (pignut hickory) | 9.3 | *Prunus serotina* (black cherry) | 20.1 |
| | | *Halesia carolina* (Carolina silverbell) | 6.5 | *Oxydendrum arboreum* (sourwood) | 13.4 |
| | | *Cornus florida* (flowering dogwood) | 3.7 | *Fraxinus americana* (white ash) | 8.8 |
| | | | | *Tilia heterophylla* (white basswood) | 6.6 |
| | | | | *Halesia carolina* (Carolina silverbell) | 6.0 |

*Liriodendron tulipifera* (yellow poplar) at 38.36. In site B, loblolly pine IVI was lower (129.8), with the yellow poplar still as the second highest IVI (84.26). In site C, yellow poplar and *Carpinus caroliniana* (musclewood) had the two highest IVI, totaling to 106.34 and 58.94, respectively. Summary data are reported in Table II. Raw daily abiotic data are plotted in Figure 2. We collected soil moisture on fewer days than other variables due to a moisture probe malfunction. The ANOVA analysis indicated that soil *p*H and soil moisture were significantly different across the Sites A, B, and C (Table III). Tukey HSD post hoc results indicated significant differences in soil moisture and *p*H between Sites A and B, with soil moisture approaching significant differences between Sites A and C ($p$ = 0.08). Figure 3 depicts daily measurements of abiotic variables across sites A, B, and C.

## DISCUSSION

Due to their unique ecology and physiology (cutaneous respiration), amphibian population dynamics provide early indications of declining environmental conditions (Welsh and Ollivier 1998). Generally, our results suggest that two of the variables most important to amphibian communities (i.e., soil moisture and soil *p*H) can vary significantly at even extremely localized spatial scales (i.e., tens of meters).

Existing studies indicate that the introduction of pine species acidifies underlying soil conditions (Coile 1933; Millar 1974; Sariyildiz et al. 2005). Site A, dominated by loblolly pine (IVI = 234.56), had the greatest amount of historical disturbance (clear cut for timber harvest), and we hypothesize that the replanting of loblolly pines likely lowered soil *p*H.

***Table II.*** Summary statistics for five abiotic variables across three forest sites

| | Site A | | | Site B | | | Site C | | |
|---|---|---|---|---|---|---|---|---|---|
| | **n** | **($\bar{x}$) ± $\sigma$** | **range** | **n** | **($\bar{x}$) ± $\sigma$** | **range** | **n** | **($\bar{x}$) ± $\sigma$** | **range** |
| Air Temp (°C) | 37 | 19.9 ± 2.8 | 14.0–25.0 | 37 | 20.6 ± 2.8 | 15.0–26.0 | 37 | 20.7 ± 3.2 | 14.0–27.0 |
| Humidity (%) | 37 | 75.5 ± 5.1 | 54.0–81.0 | 37 | 73.7 ± 5.5 | 56.0–81.0 | 37 | 73.5 ± 5.8 | 56.0–82.0 |
| Soil *p*H | 37 | 6.8 ± 0.3 | 6–7 | 37 | 6.9 ± 0.2 | 6.5–7.4 | 37 | 6.8 ± 0.1 | 6.5–7.0 |
| Soil moisture (1–8) | 29 | 3.0 ± 1.1 | 1.0–5.0 | 29 | 1.8 ± 1.4 | 0.3–4.5 | 29 | 2.4 ± 1.1 | 1.0–4.0 |
| Soil temp (°C) | 37 | 20.3 ± 1.9 | 16.1–23.3 | 37 | 20.6 ± 2.0 | 16.7–23.9 | 37 | 20.3 ± 2.2 | 16.7–24.4 |

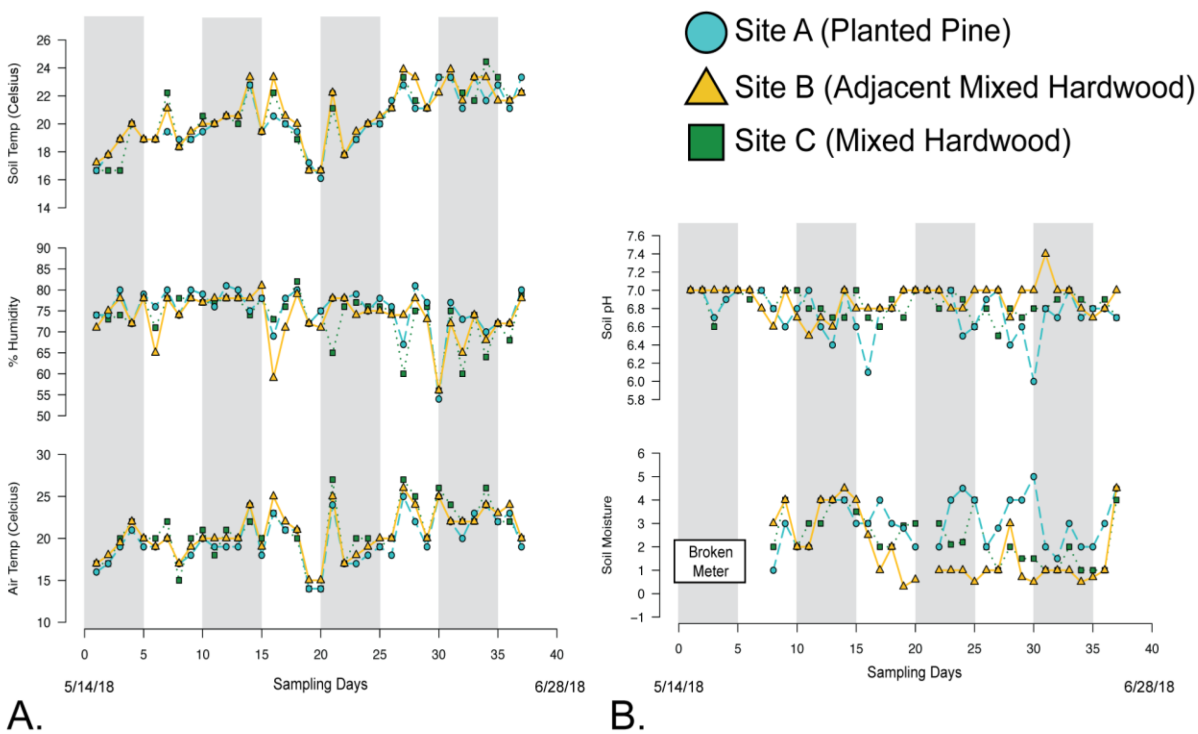


***Figure 2.*** Abiotic variables; **A)** Variables found to be consistent (not significantly different) across sites (air temperature, percent humidity, soil temperature); **B)** variables found to be significantly different (soil moisture, soil *p*H) across sites.

***Table III.*** Resulting *p*-values for ANOVA and Tukey HSD of the abiotic variables considered in this study. The two sites included in each *t* test and Tukey HSD are listed in row one. Significant *p*-values are displayed as bolded (A = planted pine, B = mixed hardwood, C = Etowah).

| | | Tukey HSD | | |
|---|---|---|---|---|
| **Abiotic Variable** | **ANOVA** | **A x B** | **A x C** | **B x C** |
| Air temperature (°C) | 0.40 | 0.50 | 0.44 | 0.99 |
| Humidity (%) | 0.23 | 0.34 | 0.27 | 0.98 |
| Soil *p*H | **< 0.05** | **< 0.05** | 0.30 | 0.46 |
| Soil moisture (1–8) | **< 0.05** | **< 0.05** | 0.08 | 0.20 |
| Soil temperature (°C) | 0.80 | 0.80 | 0.99 | 0.87 |

It is important to remember the logarithmic nature of the *p*H scale whereby small differences represent changes in orders of magnitude. While Site A did not boast extremely acidic soil (Table III), it was significantly less than Site B and lower than Site C. Given the forest composition and its segregation from the HCRP (and therefore forestmanagement practices), logic would suggest that Site C would have the highest *p*H (i.e., most alkaline) values of the sites considered here. This was not the case in that Site B had a slightly more alkaline soil when values were averaged across the period we sampled. Intriguingly, however, Site C had the smallest range of *p*H values (approximately half of that of Site A and B). This could imply more stability in soil *p*H values at Site C, potentially making it more habitable for amphibian species.

Soil water content has been demonstrated to control many different biogeochemical processes, including regulating soil microbial activity and *p*H. Specifically, as soil moisture increases, so does microbial activity and soil *p*H (i.e., becomes more alkaline; Robinson et al. 2008; Zhang and Wienhold 2002). Our data indicate that Site A had highest average soil moisture value and differed significantly from Site B and nearly significantly from Site C. There are a number of factors that could have contributed to this pattern. First, as Site A was almost exclusively composed of planted pine, the forest floor was covered with a thick layer of pine leaf litter (thicker than the ground debris at Sites B or C). Existing research indicates that evergreen leaves decay at a significantly slower rate than deciduous plant material (Yavitt and Williams 2015). We hypothesize that the greater accumulation of evergreen leaf material (as a result of slower decay rates) impeded soil water evaporation at Site A, thereby resulting in elevated soil moisture values relative to Sites B and C, which had lower amounts of leaf litter and therefore likely had higher soil moisture evaporation rates. The elevated soil moisture values of Site A are also intriguing given that this locality also had the most acidic soil. It is possible that the increased soil moisture at Site A served to prevent more acidic *p*H values. During warmer months (and therefore greater soil moisture evaporation), it is likely that Site A is characterized by even more acidic *p*H values.

Our preliminary investigation of the impact of differing levels of forest management on abiotic microhabitat variables revealed some interesting patterns that could be further explored in future analyses. First (and most obvious), passive and active amphibian sampling techniques should be employed across Sites A, B, and C to assess abundance and distribution in relation to the microhabitat patterns we describe here. Second, we recognize that the longevity of our sampling season was somewhat limited, so we recommend longer studies, particularly during the summer months, be conducted to further evaluate the relationship between forest composition, soil characteristics, and salamander abundance and distribution. Finally, more robust statistical analyses and modeling techniques could be employed in the evaluation of variation in the abiotic parameters described here.

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