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Jay P. Sah
Southeast Environmental Research Center, Florida International University

James R. Snyder
USGS, Southeast Ecological Science Center

Michael S. Ross
Southeast Environmental Research Center, Florida International University

Danielle Ogurcak
Southeast Environmental Research Center, Florida International University

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Resampling of Permanent Pine Rockland Vegetation Plots on Big Pine Key

Final Report to U.S. Fish & Wildlife Service
FWS Agreement # 401817N040

Jay P. Sah[1], James R. Snyder[2], Michael S. Ross[1], and Danielle Ogurcak[1]

[1] Southeast Environmental Research Center, Florida International University, Miami, FL

[2]USGS, Southeast Ecological Science Center, Ochopee, FL

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1. Introduction

1.1 Background

The pine rocklands of South Florida are characterized by an herbaceous flora with many narrowly endemic taxa, a diverse shrub layer containing several palms and numerous tropical hardwoods, and an overstory of south Florida slash pine (*Pinus elliottii* var. *densa*). Fire has been considered as an important environmental factor for these ecosystems, since in the absence of fire these pine forests are replaced by dense hardwood communities, resulting in loss of the characteristic pineland herb flora. Hence, in the Florida Keys pine forests, prescribed fire has been used since the creation of the National Key Deer Refuge. However, such prescribed burns were conducted in the Refuge mainly for fuel reduction, without much consideration of ecological factors. The USGS and Florida International University conducted a research study for four years, from 1998 to 2001, the objective of which was to document the response of pine rockland vegetation to a range of fire management options and to provide Fish and Wildlife Service and other land managers with information useful in deciding when and where to burn to perpetuate these unique pine forests. This study is described in detail in Snyder et al. (2005).

In the prescribed burning experiment conducted between 1998 and 2001, three 1.0-ha plots were established in each of six blocks, and randomly assigned to the three treatments: control (unburned), summer burn, and winter burn. However, only eleven plots were burned, three in winter and eight in summer over a four-year period from 1998 to 2001(**Table 1**). While we use the original plot designations throughout this report, it should be noted whenever burning history is discussed that the Dogwood winter burn plot was never burned, the Locustberry and Buttonwood winter burn plots were actually burned in the summer, and the Orchid control plot burned in 2004.

In the three blocks in which paired summer and winter burns were successfully carried out, the mortality of South Florida slash pine trees was greater after the summer burn than the winter burn in each block, but there was rarely such a consistent pattern seen for other vegetation responses (Snyder et al. 2005). In two blocks, in which both plots were burned in the summer of 2001, tree mortality after fire was not monitored.

In all 18 permanently marked 1.0-ha plots all trees with DBH $\geq$ 5 cm were tagged and measured (>11,400 trees). In eight of the plots the location of each tree was mapped on an x-y coordinate system. Mapping of the trees allows for analysis of responses such as tree growth or mortality and their relationship to environmental factors such as fire and flooding that vary spatially within a plot.

1.2 Objective

The objective of this project was to remeasure the DBH of the trees in all the permanent plots, noting any mortality or recruitment that had occurred since the plots were established and to complete mapping of trees in the 10 plots that were not mapped in the original study. The overall goal of the project was to establish a new baseline against which to measure future changes that may occur after events such as fires and hurricanes, and to design a usable monitoring protocol which can easily be used by USFWS (US Fish and Wildlife Service) staff to document changes in vegetation over time.

2. Methods

2.1 Tree measurements

In each of the 18 1.0-ha experimental plots, all trees that were tagged and measured over a three year period from 1998-2000 during the original study were relocated and their diameters at breast height (DBH) measured with a diameter tape. If the tags were missing, overgrown, or covered with resin they were replaced. If trees were dead they were classified in one of five categories (**Table 2**). Standing dead trees showing no sign of any obvious cause of mortality was simply recorded as dead (D). However, for those dead trees, the status of snags was also recorded (**Table 3**). The classification of snags was based on the degree of deterioration, presumably related to how long the tree has been dead. Finally, if a tagged tree could not be found, i.e. there was little or no evidence of the tree, it was assumed as dead and gone (DG). For those trees, sometimes the tag was found, but often it was not.

The trees which grew into the ≥5 cm DBH size class after the first survey done between 1998 and 2000 were recorded as in-grown trees, hereafter termed as 'ingrowths'. All ingrowths were identified to species, and they were tagged the same way as the original trees, i.e. with numbered aluminum tags attached with aluminum nails at breast height (1.4 m above ground). The DBH of all the ingrowths was also measured.

2.2 Tree mapping

The trees were mapped in 8 of the 18 plots during 1998-2001 study (**Table 1**). In 2008, we mapped all ingrowths in the 8 plots and recorded their coordinates. In addition, we mapped all live trees, including originally tagged trees and ingrowths, in five of the previously unmapped plots in three blocks (**Table 1**). During the course of the current project we were unable to map the Buttonwood plots and the unburned Dogwood control and Dogwood winter plots because of the tremendous amount of time it takes to map pineland with dense understory.

In the plots that were mapped during 1998-2001 using either the interpoint method (Boose et al. 1998) or the right-angle-prism method, corrections were made to reflect the actual shape of the plot and generate geographical coordinates. The steps used in making corrections are described in Appendices I and II. In the additional 5 plots mapped in the current study, the trees were mapped using the Interpoint method. To begin, a target tree with unknown coordinates was located, its tag number was recorded, and a series of 3 consecutive clockwise distance measurements were taken from the tree to reference benchmarks with known UTM coordinates (UTM Zone 17, NAD83.). Once at least three target trees were mapped, instead of benchmarks, the known trees were used as reference trees for other unknown targets. Care was taken so that the angles between consecutive references and the target were between 20° to 120°, a fundamental requirement for using the aforementioned triangulation method. Once the references for all trees were recorded, coordinates of the trees were obtained using the INTERPNT software

(Boose et al. 1998). If there were any open triangles shown in the resulting analysis, the tree in question was re-mapped and the data were then re-analyzed. This process was repeated until there were no open triangles and all trees in a plot were mapped.

The GPS coordinates of all tree plot corners are listed in Appendix III.

2.3 Elevation

We obtained ground elevation data for both the plots and tree locations from a digital terrain model (DTM) developed by Robertson and Zhang (2007). They had developed DTM from LIDAR survey data collected over Big Pine Key for Nature Conservancy, using an Optech Airborne Laser Terrain Mapper (ALTM) 1233 LIght Detection And Ranging (LIDAR) mapping system mounted in a Cessna 337 aircraft in January 2007. The DTM was in the form of high resolution (1 x 1 m grid) raster map, and had the vertical accuracy of 0.17 m at the 95% confidence interval. For plot level ground elevation, we averaged the elevation value (z) all grid cells within a plot. In addition, we obtained ground elevation for the trees that were mapped, using the tool 'Extract Values to Points' in the Spatial Analyst Geoprocessing Toolbox in ArcGIS 9.3. The elevations were referenced to North American Vertical Datum 1988 (NAVD88).

2.4 Data analysis

2.4.1 Tree mortality

Twelve experimental plots were burned between 1998 and 2004 (**Table 1**), and some of both unburned and burned plots were impacted by Hurricane Wilma-induced storm surge in 2005. In the plots that were burned and/or impacted by storm surge, tree mortality would vary greatly among years. Also, in five burned plots trees were not surveyed until several years after the fires, in 2008. Therefore, an annual tree mortality rate was not feasible to calculate for most plots. Instead, 8-, 9-, or 10-year tree mortality was calculated depending on the years between the first survey (1998, 1999, or 2000) and the 2008 survey.

Tree mortality data was analyzed at individual tree and plot level. For individual trees, probability of mortality was calculated using a binary logistic regression model of the form:

$$P(m) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + ... + \beta_k X_k)}}$$

Where, $P_{(m)}$ = probability of mortality, X_1, …X_k are independent variables, and β_0, β_1… β_k are the regression coefficients.

For calculating the likelihood of tree mortality in the 8 plots that were mapped in 1998-2000, independent variables were tree size (DBH) and elevation. In the other 10 plots, tree size was only the independent variable. The merits of using logistic model include the predictions of binary dependent variables, having a value of 0 or 1, from continuous, nominal or ordinal independent variables, and the model does not require an assumption of normally distributed data. Logistic regression model estimates the coefficients for the independent variables using a maximum likelihood process.

One way analysis of variance (One-way ANOVA) was also used to test the differences in tree size or elevation between two groups of trees, live and dead, in each plot.

At the plot level, simple regression model was used to assess the effects of mean elevation on tree mortality. Elevation was considered as the surrogate measure of the storm surge, and was based on the assumption that the impact of storm surge on standing trees would be linearly correlated with elevation.

2.4.2 Tree growth

Since the size and status (live and dead) of trees were not measured annually, the growth rate of the trees that died of natural causes or due to the effect of fire or storm surge between the two surveys was not feasible to calculate. Instead, tree growth rate was calculated using the measurements made only on the trees that were recorded alive in the 2008 survey. The mean annual tree growth rate was calculated using the exponential growth model as $r = \ln(N_t/N_0)/t$, where N_0 and N_t are the dbh of a tree in the beginning and end of the interval t (years), respectively. A general linear model (GLM) was used to assess the effects of initial size and burning treatment on tree growth.

3. Results

Figure 1 shows the locations of plots overlaid on the digital elevation model (DTM) developed by Robertson and Zhang (2007) using LIDAR data.

3.1 Tree density and basal area

In 2008, mean live tree density was 375 (± 277) trees ha^{-1}. The density of trees varied greatly among plots, and it ranged from 22 trees ha^{-1} in Iris winter plot to 1089 trees ha^{-1} in Dogwood winter plot (**Table 4**). The plots which were burned and subsequently flooded by storm surge caused by Hurricane Wilma had very few surviving trees. Three such plots, Iris winter, Iris summer and Poisonwood summer had tree densities of <100 trees ha^{-1}.

Pine trees constituted 87% of the total trees, the remainder representing several hardwood species. The mean pine density was 327 trees ha^{-1}, and it ranged between 21 trees ha^{-1} in Iris winter plot and 983 trees ha^{-1} in Dogwood control plot (**Figure 2**). The high number of pine trees in Dogwood control plot was due to presence of large number of trees in small size classes. In this plot, 674 pine trees had dbh ≤15 cm (**Figure 3**).

Hardwood trees constituted 13% of the total trees belonging to 17 species, of which Poisonwood (*Metopium toxiferum*) was the most abundant, contributing approximately 78% of the total number of hardwood stems (**Table 5**). The species which constituted >1% of total hardwood trees were Buttonwood (*Conocarpus erectus*), Jamaica Dogwood (*Piscidia piscipula*), Sea Grape

(*Coccoloba uvifera*), Red Mangrove (*Rhizophora mangle*), Wild Dilly (*Manilkara jaimiqui* ssp. *emarginata*), and Beeftree (*Guapira discolor*). In general, hardwood tree density was much higher in unburned plots than in burned plots, supporting the hypothesis that prescribed fire helped to reduce the cover of hardwood species (**Table 5**). Buttonwood control with the hardwood tree density of 468 stems ha^{-1} had more than half of hardwood trees found in 18 plots. Dogwood control and Dogwood winter, which also were not burned had hardwood density of >100 stems ha^{-1}. Ten of 12 burned plots had hardwood densities of <10 stem ha^{-1}.

In 2008, mean tree basal area in the Big Pine key pine forests was 4.785 (± 2.425) m^2 ha^{-1} (**Table 4**). The plots such as Iris winter and Poisonwood summer, which were burned and also hard hit by the storm surge had the tree basal area <1 m^2 ha^{-1}. In contrast, Dogwood control and Dogwood winter plots that were not burned were also not hit by storm surge had higher basal area than all other plots. However, average stand diameters in these two plots were smaller than all other plots but two, Buttonwood control and Iris winter, suggesting that these plots had the large number of trees in small categories. Button control had also many (>400) hardwood stems in small (5-10, and 10-15) diameter classes (**Figure 3**).

3.2 Tree mortality

Tree mortality in pine forests in Big Pine Key varied among plots, depending on whether the plots were burned or not, and/or were impacted by hurricanes passed over the keys during the last 10 year period. In those plots, however, both pine and broad-leaved hardwood species differed in mortality. Tree mortality averaged over eighteen plots was 59.3% and 49% for hardwood species and pines, respectively.

3.2.1 Hardwood tree mortality

In South Florida Pine Rocklands, one major objective of prescribed burning is to reduce the cover of hardwood species. Between 1998 and 2008, mean mortality of hardwood species was significantly (One-way ANOVA: $F_{1,15}$ = 48.9; $P<0.001$) higher in burned plots than in unburned plots, suggesting that experimental fires killed the aboveground portions of most of hardwood trees. Though, in some cases the topkilled individual might have survived and resprouted from belowground parts. In the burned sites with a sizeable numbers (>30 individuals/ha) of hardwoods, the mortality, or topkilling, of trees ranged from 48% in the Poisonwood winter burn to 96% in Buttonwood summer burn plot. Among six unburned plots, Poisonwood control had much higher hardwood tree mortality than others (**Figure 4a**). Most of mortality of hardwood species in this unburned plot was probably due to storm surge caused by hurricane Wilma, although in general, hardwood mortality across all plots was not affected by elevation (R^2 = 0.19, p = 0.389).

3.2.2 Pine mortality

Pine trees exhibited great variation in mortality among plots. Mean pine mortality ranged between 8.1% in Dogwood control plot and 97.3% in Iris winter plot. In general, burned plots had the higher pine mortality than the unburned plots, except in Buttonwood block, where the unburned control plot had much higher pine mortality than two burned plots in 8 years (**Figure**

4b). Since large portion of Buttonwood control plot has relatively low elevation, high pine mortality in this unburned plot was probably due to storm surge in 2005.

3.2.3 Factors affecting pine mortality

Over a decade between 1998 and 2008, pulse events such as prescribed fire and hurricanes have caused pine mortality in the Big Pine Key experimental plots.

Pine tree mortality varied within and among plots, depending on wind damage, burn treatments and/or severity of storm surge in the plots. However, from the physical observation of dead trees, wind damage (either broken or uprooted) was identified as a cause of mortality for only 5% of all dead trees. For 95% of trees, the cause of mortality was not definitely identified. In a forest that does not experience a natural or anthropogenic calamity, background tree mortality rate is assumed to be consistent over a given period. In this study, three experimental plots which did not burn in 10 years and were exposed to minimal storm surge (Dogwood control, Dogwood winter and Locustberry control plots) had background rate of pine tree mortality of 1 to 2% per year.

Storm surge and pine mortality

On-site measurements of depth of storm surge caused by hurricane Wilma in 2005 were not available. Thus, mean ground elevation was considered as an indicator of the degree of storm surge. Although most of Big Pine Key was flooded by the storm surge, among 18 experimental plots, six burned and three unburned plots that have mean elevation of <1 m (**Figure 5**) were the most likely to have been severely impacted by storm surge.

Cumulative pine mortality across all burned and unburned plots was non-linearly related to their mean ground elevation (**Figure 6a**). The reason could be the confounding effects of other factors, including wind damage and prescribed fire. It is evident when tree mortality in relation to elevation was analyzed separately for burned and unburned plots. The effects of storm surge were apparent in unburned plots, in which pine mortality was strongly ($R^2 = 0.926$; $p < 0.001$) related to mean ground elevation (**Figure 6b**). Three unburned plots with mean elevation of <1m had much higher pine mortality than the other three unburned plots with mean elevation of >1 m. In 12 burned plots also, cumulative pine mortality caused by storm surge and/or fire was significantly related to elevation ($R^2 = 0.29$; $p <0.05$). Tree mortality in storm-surge impacted burned plots was relatively high. However, the relationship between elevation and total pine morality in the burned plots was also affected by the fact that all low elevation burned plots were not impacted by storm surge, mainly due to their locations within the landscape. For example, two burned plots in Orchid Block had mean elevation of <1 m, but they were not impacted by the same degree of storm surge as did the plots in Poisonwood, Buttonwood and Iris blocks The plots in Orchid Block are located north east of Key Deer Blvd, which might have acted as a barrier for the storm surge.

To test the hypothesis that fire had increased the susceptibility of pines to storm surge, pine mortality data for the plots with mean elevation of <1 m was separately examined. For this analysis we considered seven plots, 4 burned and 3 unburned, which were impacted by storm surge. Total pine mortality was not significantly different between burned and unburned plots (One-way ANOVA; $F_{1,5} = 3.09$, $p = 0.139$), indicating that there was no evidence that fire increased the susceptibility of pine trees to storm surge. However, the results need to be interpreted cautiously, as not only the number of observations in each group was low, but also within-plot variation in elevation was not addressed. If there had been on-site measurements of storm surge and periodic monitoring of trees, it would have been possible to separate storm surge-induced mortality from post-fire mortality.

Tree size and pine mortality

Pine tree mortality in Big Pine Key over a decade between 1998 and 2008 was significantly related to tree size. However, this effect differed among plots, depending on type of disturbances that killed majority of trees within the plots. In general, fire-induced mortality was higher in small tree classes, whereas storm surge effects were concentrated on large trees. Three unburned plots which were also not much impacted by the storm surge showed mixed results. Pine mortality in Dogwood control plot had no relation with DBH, whereas in Dogwood winter (unburned) and Locustberry control plots, mortality was higher in smaller size classes.

In 4 burned and 2 unburned plots which were severely impacted by storm surge, probably due to their low mean elevation and proximity to the coast, total pine mortality was significantly higher in large tree classes (**Figure 7**). The mortality of large numbers of big trees in these plots may alter fuel production, increasing the difficulty of carrying out effective prescribed fires needed to maintain pine forest and its characteristic biodiversity.

In burned plots which are located on the relatively higher ground (mean elevation > 1.0 m), and thus not much affected by storm surge, pine mortality was significantly higher in small tree classes. In these plots, the loss of small trees results in a change in size structure, shifting from exponential (inverted J) distribution towards a unimodal size distribution.

3.2.4 Tree Snags

Snags are important habitat for several wildlife species, including birds. In Big Pine Key in 2008, two thirds of trees that died in one decade were still standing in the field as snags. Among them 96.7% were pine snags. The snags were in different stages of deterioration (**Table 6**). More than half (58%) of total snags were newly created with intact bark and some small and large braches still present. Many of these trees might have died in 2005 or later when the island was severely impacted by hurricanes. Less than one percent of snags were without bark and heart wood (Category 4).

3.3 Tree growth

In Big Pine Key pine forests, mean growth of pine tree was 1.15 mm $tree^{-1}$ yr^{-1} and the growth rate varied among plots (**Table 7**). Pine tree in the Orchid sites grew slower than in other plots. The growth rate of pine tree in Poisonwood control was much higher than in other plots. A general linear model (GLM) was used to test the effects of tree size and burning treatments across all the plots. Both size of tree and burn treatments had significant effects of growth of pine trees (**Table 8**). Mean annual growth rate decreases with the size of trees, and was significantly higher in unburned plots than in burned plots (**Figure 8**). Higher tree growth rates in unburned plots may be due to relatively high number of trees in small size classes in these plots. In 13 plots which had all live trees mapped and therefore had elevation data for those trees, results of a multiple regression shows that tree growth was affected by both size of trees and elevation. Pine tree growth tends to be higher at the high grounds, though the relationship between elevation and tree growth was very weak ($r = 0.11$, $p<0.001$).

3.4 Recruitment

In between the first survey (1998-2000) and 2008, many trees, including slash pine and hardwood species grew into the size class of >5 cm dbh class. However, in the present study, not all the ingrowths were mapped in all the experimental plots. In the 8 plots which were mapped during the first survey only pine ingrowths were recorded, whereas in the other 10 plots, both pine and hardwood ingrowths were recorded. In addition, any trees which grew into the ≥ 5 cm DBH size class and died before the 2008 survey were not recorded. Despite this limitation in recording ingrowths, in the 2008 survey, a total of 650 ingrowths were measured and mapped. In the plots in which both pine and hardwood species were recorded, pine trees constituted the half of all ingrowths (**Table 9**), and rest were represented by 9 hardwood species. *Metopium toxiferum* constituted 86% of all hardwood ingrowths.

In general, ingrowths were much higher in unburned plots than in burned plots, and it stands the same for both pine and hardwood species. Depending on high likelihood of sapling and small size class trees to be killed by fire, this result is not surprising. However, it suggests that repeated burning would be necessary to control the recruitment and growth of hardwood species even though some pine young trees suffered from prescribed fires.

3.5 Change in stand structure

Over a decade, the size distribution of pine trees still shows the negative exponential (inverted J) pattern (**Figure 9**), primarily due to presence of large number of young trees. However, there was a shift in the size-class distribution of trees, such that a decrease in the proportion of trees in small (0-5) and large size classes was accompanied by an increase in intermediate-sized (10-20 cm) trees..

As a result of fire and/or storm surge-induced tree mortality, there was also a significant reduction in total basal area in 15 of the 18 (83%) experimental plots. Only three plots, Dogwood control, Dogwood winter and Locustberry control plots, which were neither burned nor influenced by storm surge showed an increase in total basal area (**Figure 10**). The highest reduction in total basal area was in Poisonwood summer plot, followed by Iris winter, Iris control, Poisonwood control and Poisonwood winter plots. All these plots have relatively low elevation (**Figure 6a**), and were severely impacted by storm surge, which killed large trees more often than the small trees. Because of higher mortality of large trees than the small trees in the storm surge-influenced plots, mean stand diameter also decreased (**Figure 11**). In contrast, mean stand diameter increased in the burned plots that were not influenced by storm surge, primarily because mortality by fire was centered in small size classes. A change in tree density in different size classes, has also affected the Stand Density Index (SDI), which basically decreased in all but two plots (**Figure 12**). This sort of event is more likely to be aggravated in future, as frequency and intensity of tropical storms are predicted to increase due to global warming.

3.6 Tree mapping

Tree mapping is now completed in 13 plots (**Figures 13-25**). In 8 plots in which mapping was competed between 1998 and 2001, in-growths were mapped during this study period in 2008. The location maps of trees in these plots include both live and dead trees by species and their size classes. Other five plots, in which trees were mapped using interpoint method in 2008, the location maps of trees include only live trees.

4. Conclusions

- Pine forests on Big Pine Key are unusual in having a balanced size (age) structure with large numbers of small trees.
- This structure has changed quantitatively over the decade, primarily due to effects of both fire and storm surge-caused tree mortality.
- Fire-induced mortality was higher in small tree classes, whereas storm surge effects were concentrated on large trees.
- Loss of large numbers of big trees due to storm surge may alter fuel production, increasing the difficulty of carrying out effective prescribed fires needed to maintain pine forest and its characteristic biodiversity.
- Distinguishing future effects of sea level rise from other natural or human disturbances is necessary for effective resource management, and requires a consistent program of inventory and monitoring.

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Use of trade, product, or firm names does not imply endorsement by the U.S. Government.

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Table 1: Years in which the 18 permanent 1.0 ha tree plots were measured, checked for mortality, and mapped.

				Year trees measured/status checked						Tree Mapping		
Site	**Treatment**	**Plot code**	**Burn date**	**Preburn**	**Post-burn Year 1**	**Post-burn Year 2**	**Post-burn Year 3**	**Post-Wilma Year 1**	**Post-Wilma Year 3**	**Mapped**	**Method**	**Year**
Orchid	Control	OC	N/A*	1998	1999	2000	2001	2006	2008	Yes	Right angle	1998
Orchid	Summer	OS	8/16/1998*	1998	1999	2000	2001	2006	2008	Yes	Right angle	1998
Orchid	Winter	0W	12/15/1998*	1998	1999	2000	2001	2006	2008	Yes	Interpoint	1998
Poisonwood	Control	PC	N/A*	1998	1999	2000	2001	2006	2008	Yes	Right angle	1998
Poisonwood	Summer	PS	8/17/1998*	1998	1999	2000	2001	2006	2008	Yes	Right angle	1998
Poisonwood	Winter	PW	12/15/1998*	1998	1999	2000	2001	2006	2008	Yes	Interpoint	1998
Iris	Control	IC	N/A	1999	2000	2001			2008	Yes	Interpoint	2008
Iris	Summer	IS	6/22/1999	1999	2000	2001			2008	Yes	Interpoint	2008
Iris	Winter	IW	12/12/2000	1999	2001			2006	2008	Yes	Interpoint	2000
Dogwood	Control	DC	N/A	1999	2000	2001			2008	No		
Dogwood	Summer	DS	7/18/2001	1999	2000	2001			2008	Yes	Interpoint	2008
Dogwood	Winter	DW	not burned	1999					2008	No		
Locustberry	Control	LC	N/A	2000					2008	Yes	Interpoint	2008
Locustberry	Summer	LS	7/19/2001	2000				2006	2008	Yes	Interpoint	2000
Locustberry	Winter	LW	7/19/2001	2000					2008	Yes	Interpoint	2008
Buttonwood	Control	BC	N/A	2000					2008	No		
Buttonwood	Summer	BS	7/18/2001	2000					2008	No		
Buttonwood	Winter	BW	7/18/2001	2000					2008	No		

* All or most of plot burned after original study on 8/02/2004

Table 2: Codes for dead trees found in the study plots.

CODE	Description	Probable cause of mortality
D	Dead and standing	Unknown
DURA	Dead tree uprooted when tree was alive	Wind damage
DURD	Dead tree uprooted after tree was dead	Unknown
DBA	Dead tree broken while tree was still alive	Wind damage
DBD	Dead tree broken after tree was dead	Unknown

Table 3: Snag categories for the Big Pine Key pine rocklands.

Category	Snag characteristics
1	Newly created, bark present and tight, large and small branches intact.
2	Low/moderate decay, bark present or not, sapwood mostly intact and sound (small cracks may be present).
3	Moderate/severe decay, bark typically absent, cracked and sloughing sapwood (often soft and crumbly).
4	Heartwood only, (gray snag), very hard and all bark and sapwood is gone.

Table 4: Summary of tree density (trees ha^{-1}), basal area (m^2 ha^{-1}), average stand diameter (cm), and stand density index in 18 experimental plots in Big Pine Key (2008)

Site	Plot	Density (trees $ha^{-}1$)	Basal area (m^2 ha^{-1})	Average stand diameter (cm)	SDI
Buttonwood	BC	629	4.116	9.1	128.3
	BS	428	5.956	13.3	153.9
	BW	420	5.046	12.4	131.6
Dogwood	DC	919	8.643	10.9	240.3
	DS	290	3.409	12.2	89.4
	DW	1089	8.823	10.2	254.7
Iris	IC	305	4.579	13.8	113.7
	IS	97	1.461	13.9	35.8
	IW	22	0.145	9.1	4.5
Locustberry	LC	481	7.652	14.2	190.2
	LS	309	6.110	15.9	145.3
	LW	175	4.057	17.2	92.3
Orchid	OC	325	5.874	15.2	142.1
	OS	324	5.393	14.6	132.5
	OW	442	6.248	13.4	158.5
Poisonwood	PC	241	4.042	14.6	96.3
	PS	43	0.684	14.2	17.0
	PW	222	3.893	15.0	92.2

Table 5: Hardwood tree species diversity and number of stems ≥ 5 cm dbh per ha in the 18 experimental plots in 2008

Species	Buttonwood			Dogwood			Iris			Locustberry			Orchid			Poisonwood		
	BC	**BS**	**BW**	**DC**	**DS**	**DW**	**IC**	**IS**	**IW**	**LC**	**LS**	**LW**	**OC**	**OS**	**OW**	**PC**	**PS**	**PW**
Metopium toxiferum	338	52	4	99	3	100	31	4	1	15				2	1	12	7	20
Conocarpus erectus	56	2					1	1						1			1	16
Piscidia piscipula	9	2	3			1	5			3								
Coccoloba uvifera	19																	
Rhizophora mangle	12																	
Manilkara jamiqui ssp. *emarginata*	11																	
(Syn. *Manikara bahamensis)*																		
Guapira discolor	9																	
Byrsonima lucida	2	1		1	1	2												1
Morella cerifera		1		3	1			2										1
(Syn. *Myrica cerifera)*																		
Pithecellobium keyense	3	1		2														
(Syn. *Pitecellobium guadalupense)*																		
Guettarda scabra	1					2												
Psidium longipes	1			1			1											
Sideroxylon salicifolium						1				1								
(Syn. *Bumelia salicifolia)*																		
Myrsine floridana	1									1								
Pisonia rotundata	1			1														
Sideroxylon celastrinum	1																	
(Syn. *Bumelia celastrina)*																		
Reynosia septentrionalis	1																	
No. of stems	465	59	7	107	5	106	38	7	1	20	0	0	0	3	1	12	8	38
No. of species	15	6	2	6	4	5	4	3	1	4	0	0	0	2	1	1	2	4

Table 6: Hardwood and pine tree snags at different stages of deterioration in 18 experimental plots in 2008.

Species	Stages of Snag deterioration	BC	BS	BW	DC	DS	DW	IC	IS	IW	LC	LS	LW	OC	OS	OW	PC	PS	PW
Byrsonima lucida	1																		1
Coccoloba uvifera	3	2	1																
Conocarpus erectus	3	2	2					1							1				
Ficus citrifolia	2	1																	
Manilkara jamiqui ssp. *emarginata (*Syn. *Manikara bahamensis)*	3		1																
Metopium toxiferum	1	1						1										2	3
	3	12	28	13	1	2									2		2	1	3
*Morella cerifera (*Syn. *Myrica cerifera)*	3	4	2																
Myrsine floridana	1				1														
Pinus elliottii var. *densa*	1	216	54	29	8	17	13	238	232	599	31	19	3	20	56	74	102	214	116
	2	102	22	30	11	6	17	24	17	30	17	36	43	52	5	23	31	69	14
	3	34	65	85	6	76	5	9	17	11	11	54	123	40	66	61	31	50	50
	4			2		4						1		2	8	6		4	2
Piscidia piscipula	3	1	5	7									1				1		
*Pithecellobium keyense (*Syn. *Pitecellobium guadalupense)*	2	1																	
	3		4	1															
Reynosia septentrionalis	2	2																	

Table 7: Mean initial diameter at breast height (DBH) of live trees and annual growth rate of pine trees in 18 experimental plots in Big Pine Key. Growth rate is based on only those trees that were alive in 2008.

Plot	Mean Initial DBH (cm)	Interval between two surveys (years)	Abs. Annual growth rate (cm/year) [m=(1/t)*(Nt-N0)]	Exponential growth rate [r=ln(Nt/N0)/t]
BC	9.1	8	0.122	0.014
BS	12.4	8	0.132	0.011
BW	11.3	8	0.111	0.011
DC	10.1	9	0.091	0.010
DS	11.0	9	0.125	0.013
DW	9.3	9	0.080	0.008
IC	12.8	9	0.106	0.008
IS	13.3	9	0.103	0.009
IW	8.3	9	0.111	0.014
LC	12.8	8	0.113	0.010
LS	14.1	8	0.142	0.011
LW	14.7	8	0.188	0.015
OC	13.5	10	0.110	0.009
OS	13.1	10	0.073	0.006
OW	12.0	10	0.066	0.005
PC	12.3	10	0.163	0.017
PS	11.4	10	0.123	0.014
PW	13.6	10	0.118	0.010

Table 8: Results of general linear model (GLM) used to test the effects initial diameter at breast height (DBH_T_0) and burning treatments (Burn_Unburn) on pine tree growth in 18 experimental plots.

	SS	Degrees of Freedom	MS	F	p
Intercept	0.384967	1	0.384967	2125.022	0.000000
DBH_T_0	0.106254	1	0.106254	586.526	0.000000
Burn_Unburn	0.002607	1	0.002607	14.390	0.000150
Error	0.996918	5503	0.000181		

Table 9: Hardwood and pine ingrowths (stems ≥ 5) in the 18 experimental plots in 2008.

Species	BC	BS	BW	DC	DS	DW	IC	IS	IW	LC	LS	LW	OC	OS	OW	PC	PS	PW
Coccoloba uvifera	9																	
Conocarpus erectus	7	1					1	1										
Manilkara jamiqui ssp. *emarginata (*Syn. *Manikara bahamensis)*	5																	
Metopium toxiferum	106	19	1	50		48	11	3		5								
Morella cerifera (Syn. *Myrica cerifera*)				1	1			1										
Piscidia piscipula	1					1	1											
Pisonia rotundata				1														
Pithecellobium keyense (Syn. *Pitecellobium guadalupense*)	2																	
Rhizophora mangle	3																	
Pinus elliottii var. *densa*	21	6	27	94	39	63	9	10	3	14	8	6	6	13	13	24	1	11
Total number of stems	154	26	28	146	40	112	22	15	3	19	8	6	6	13	13	24	1	11

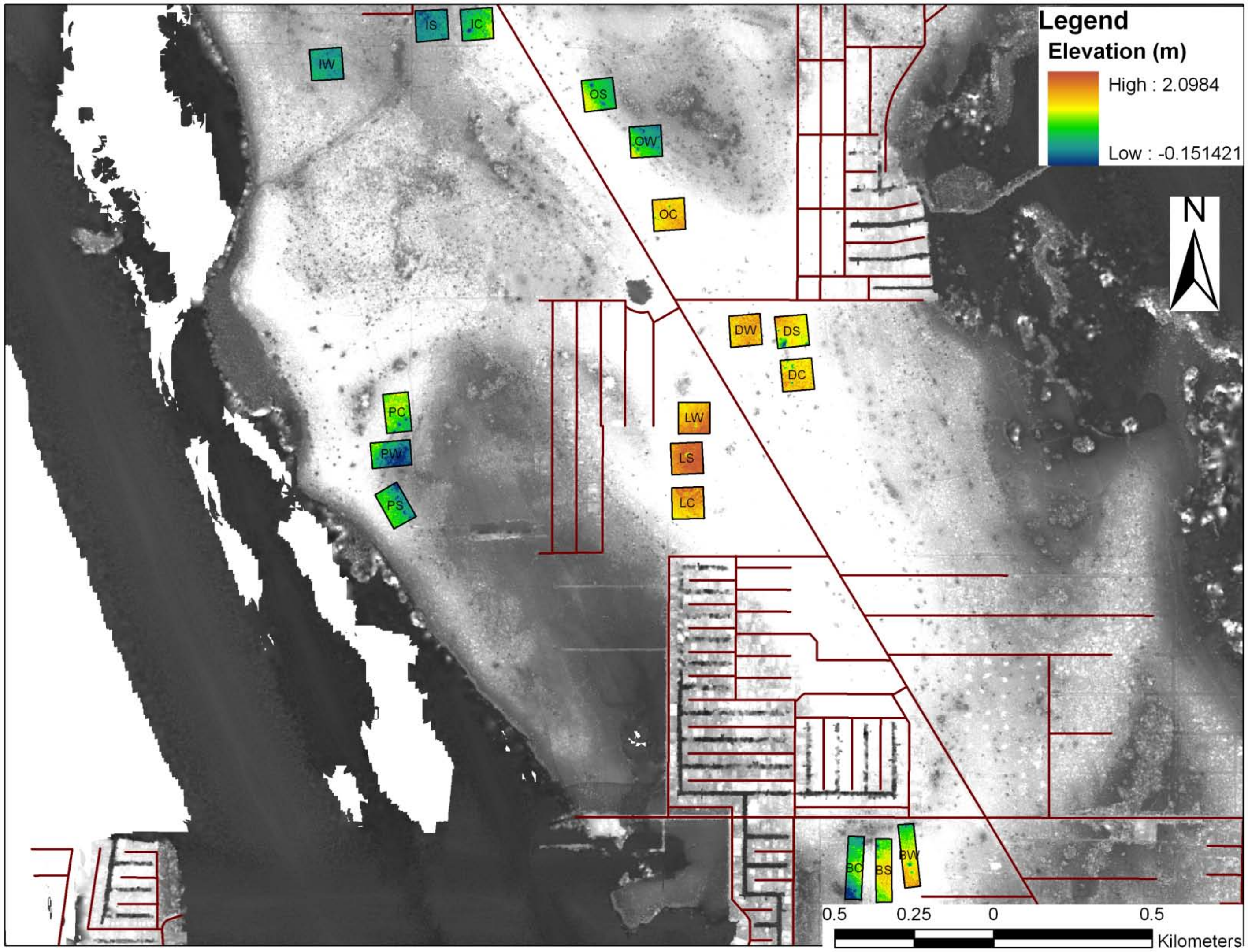


Figure 1: Map showing the locations and elevation of 18 experimental plots in Big Pine Key.

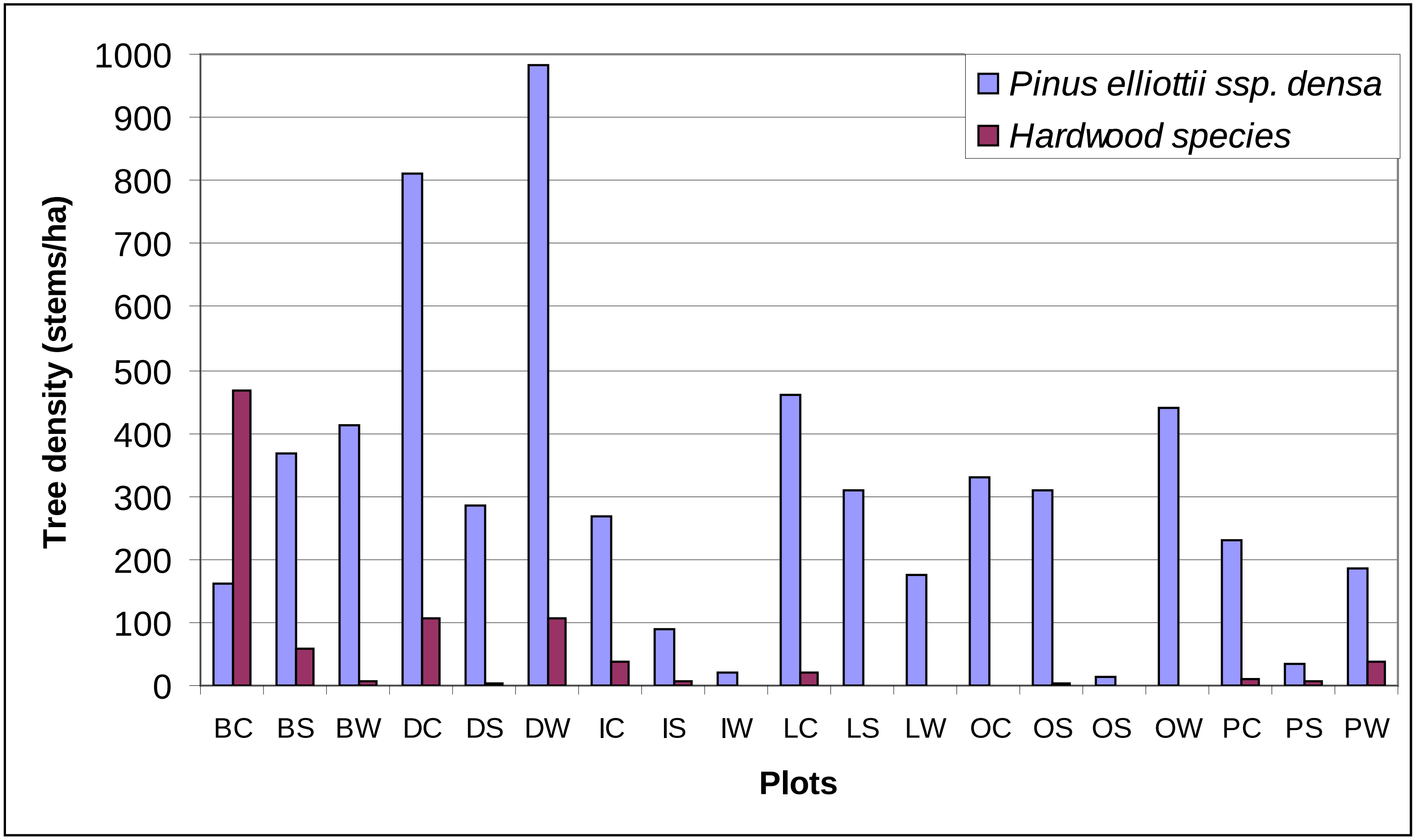


Figure 2: Density of pines and hardwood species in the 18 experimental plots in 2008

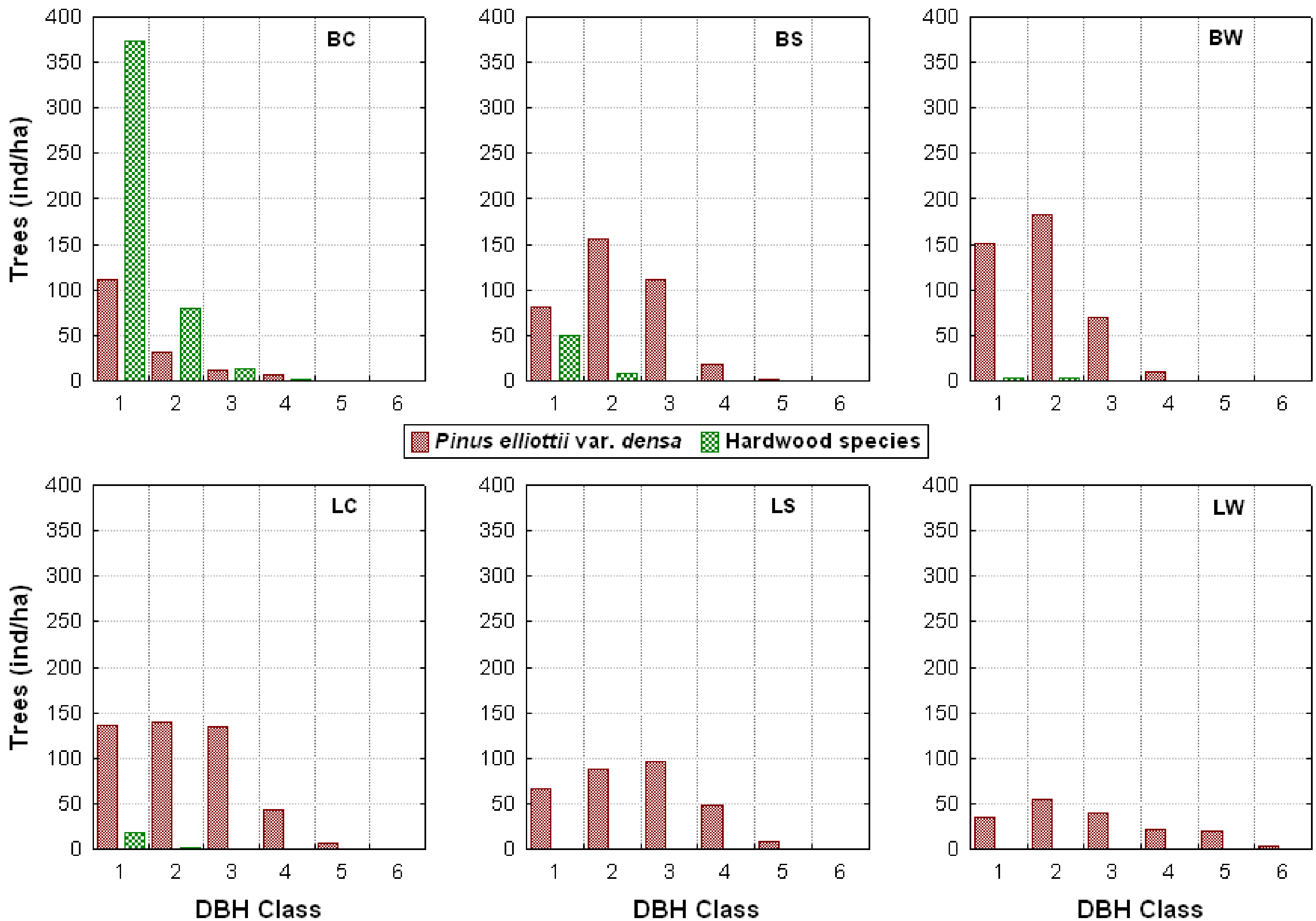


Figure 3: Size class distributions of pines and hardwoods in 18 experimental plots in 2008. DBH class 1 = 5.0-10.0 cm, 2 = 10.1-15.0, 3 = 15.1-20.0 cm, 4 = 20.1-25.0 cm, 5 = 25.1 to 30.0 cm, and 6= >30 cm.

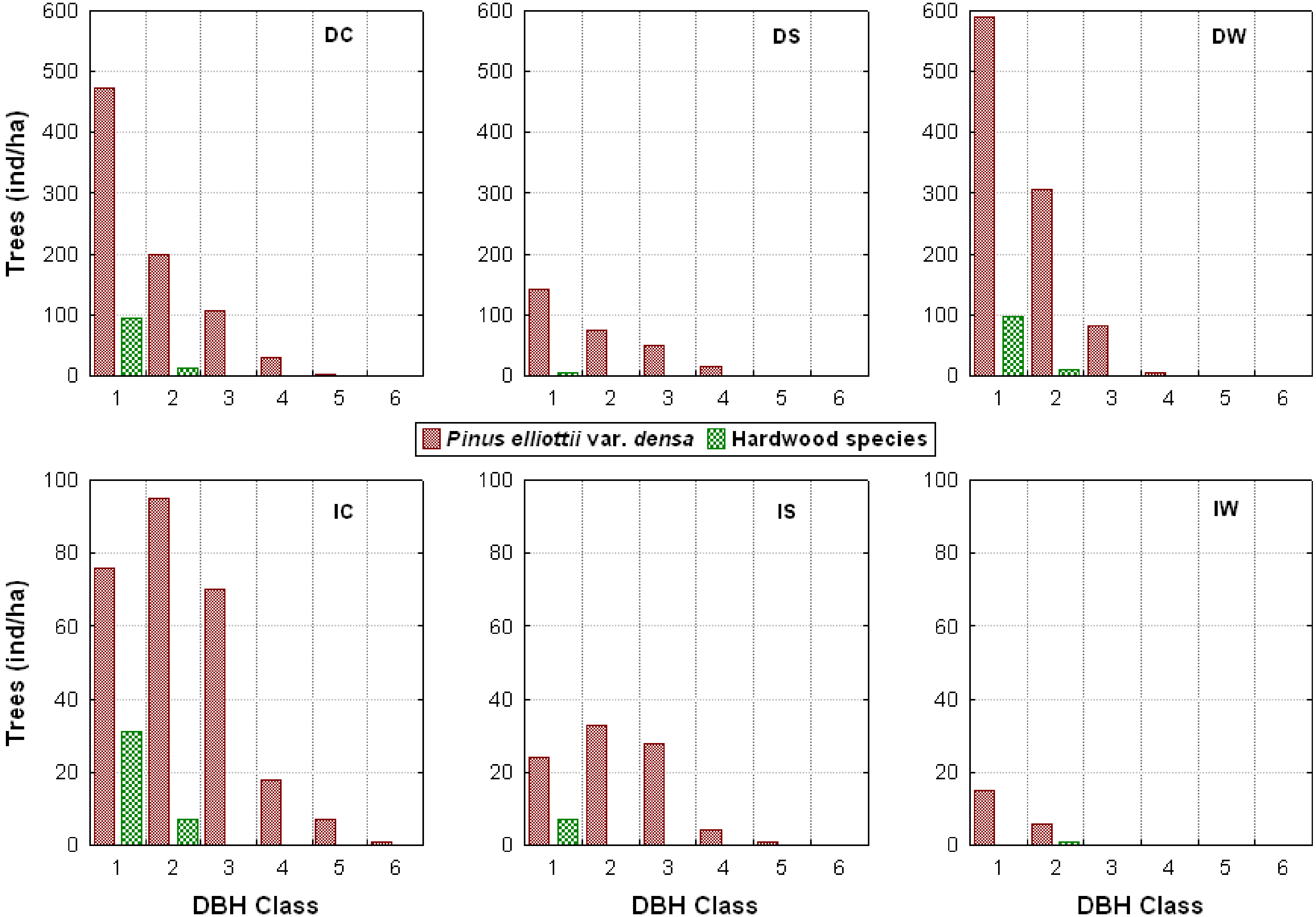


Figure 3: continued.

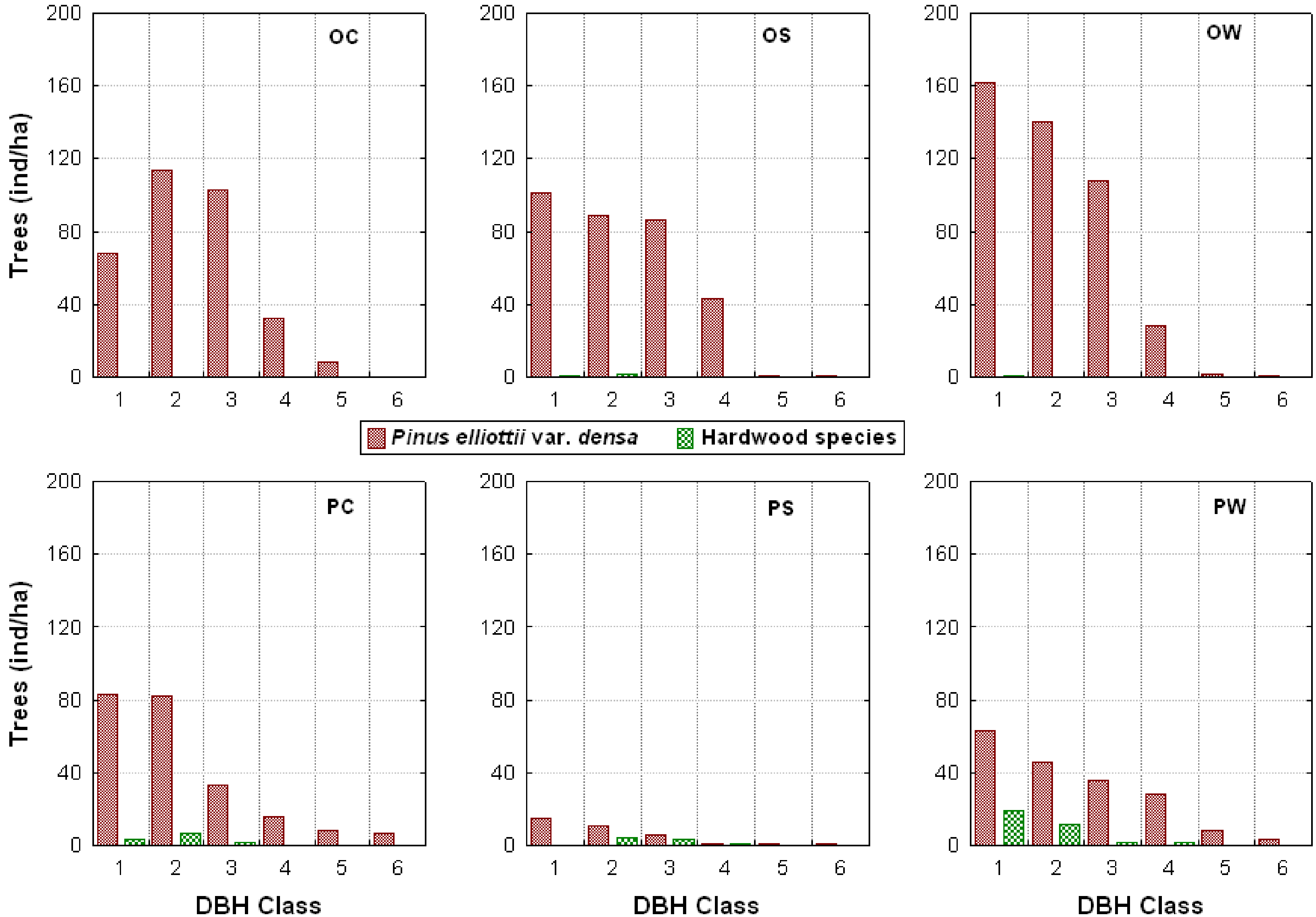


Figure 3: continued

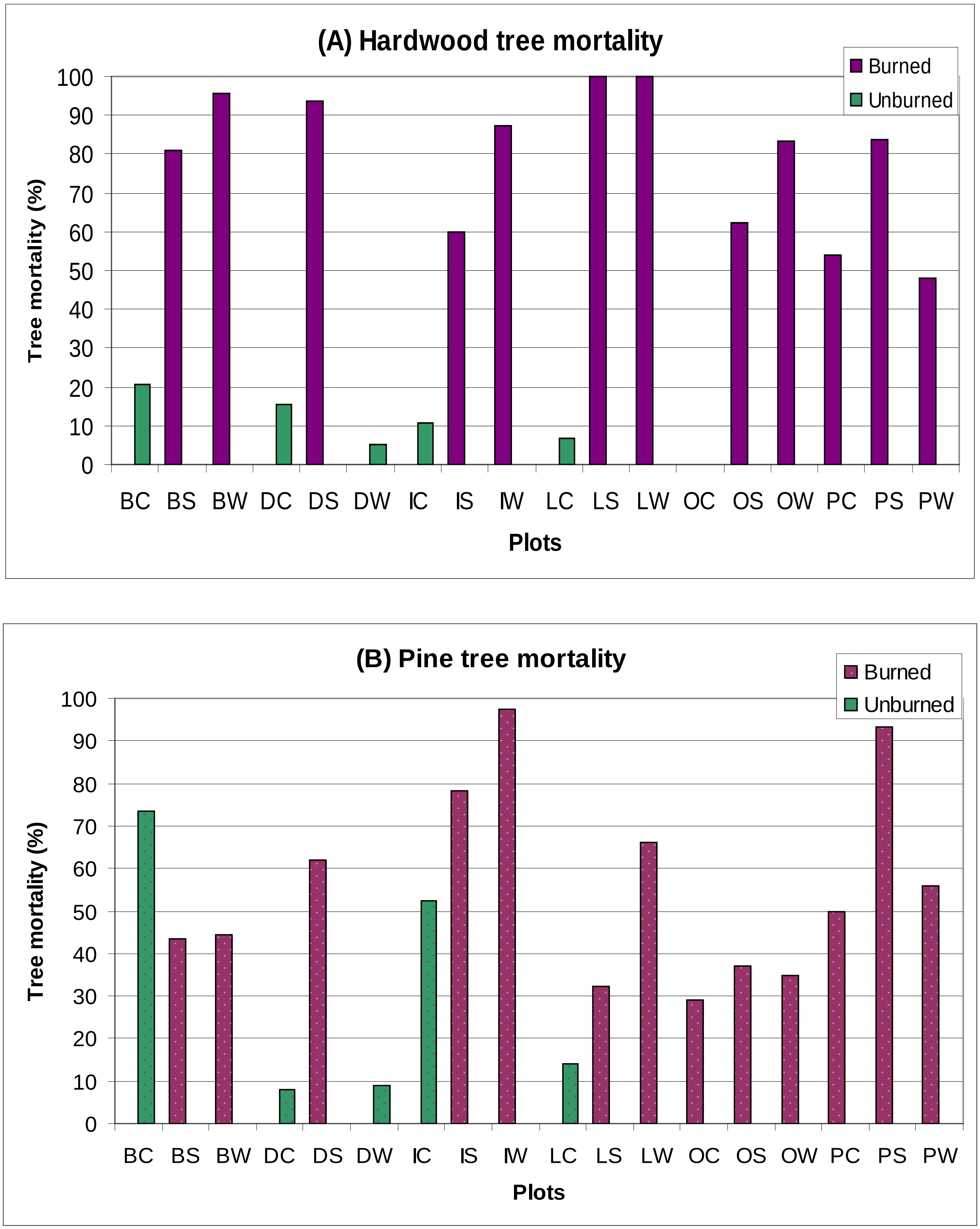


Figure 4: (A) Hardwood and (B) Pine tree mortality in 8, 9 or 10 years (8 years in Buttonwood and Locustberry; 9 years in Dogwood and Iris; and 10 years in Orchid and Poisonwood) in the 18 experimental plots.

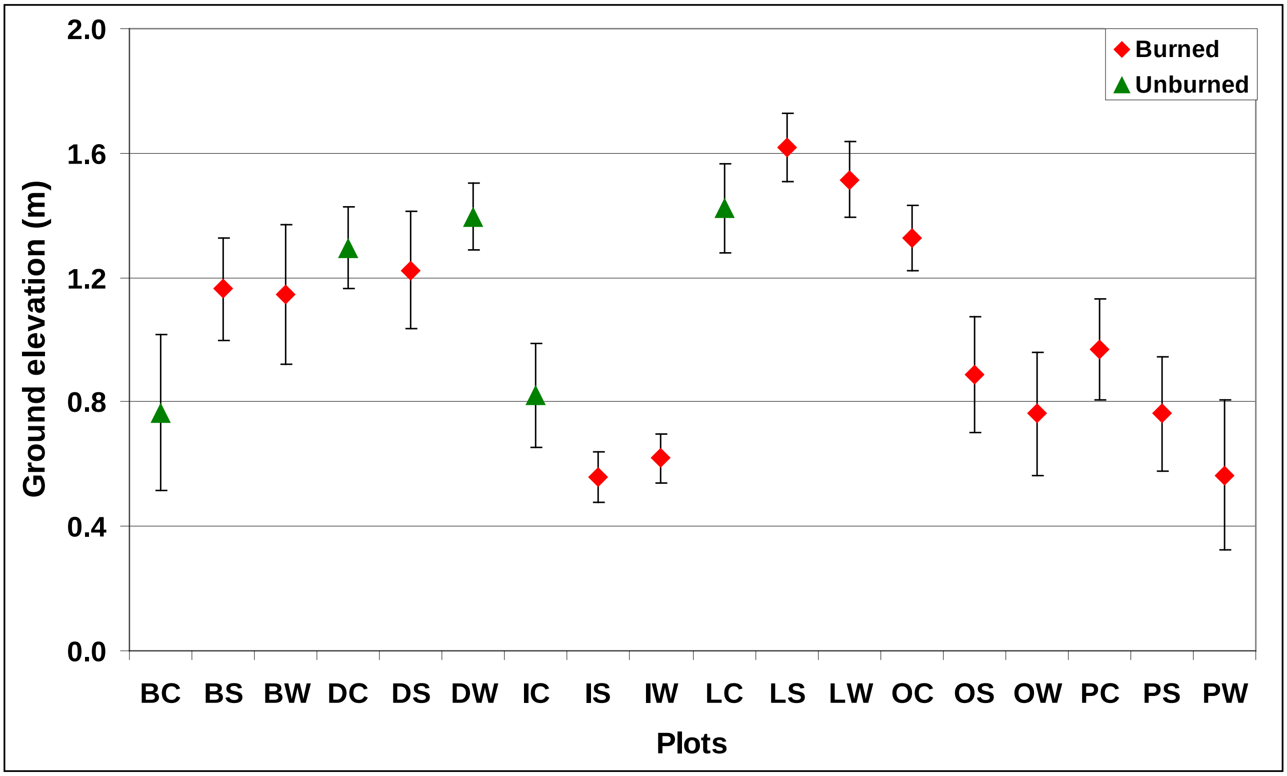


Figure 5: Mean ground elevation (m) of 18 experimental plots in Big Pine Key.

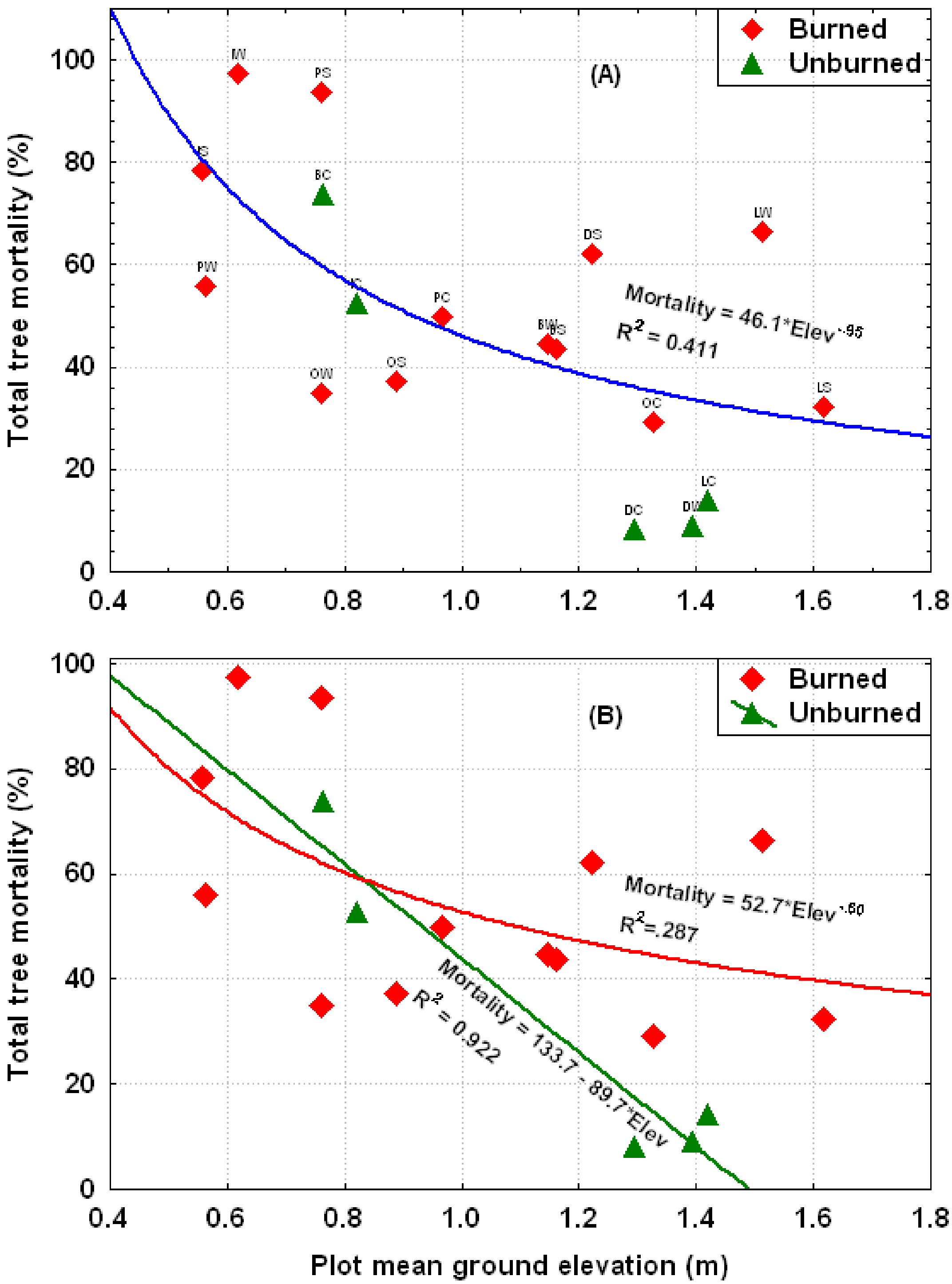


Figure 6: Relationship between mean ground elevation and cumulative pine tree mortality in 18 experimental plots in Big Pine Key. (A) Non-linear regression model across all burned and unburned plots, (B) Two separate models for unburned (Linear model) and burned plots (Negative exponential model).

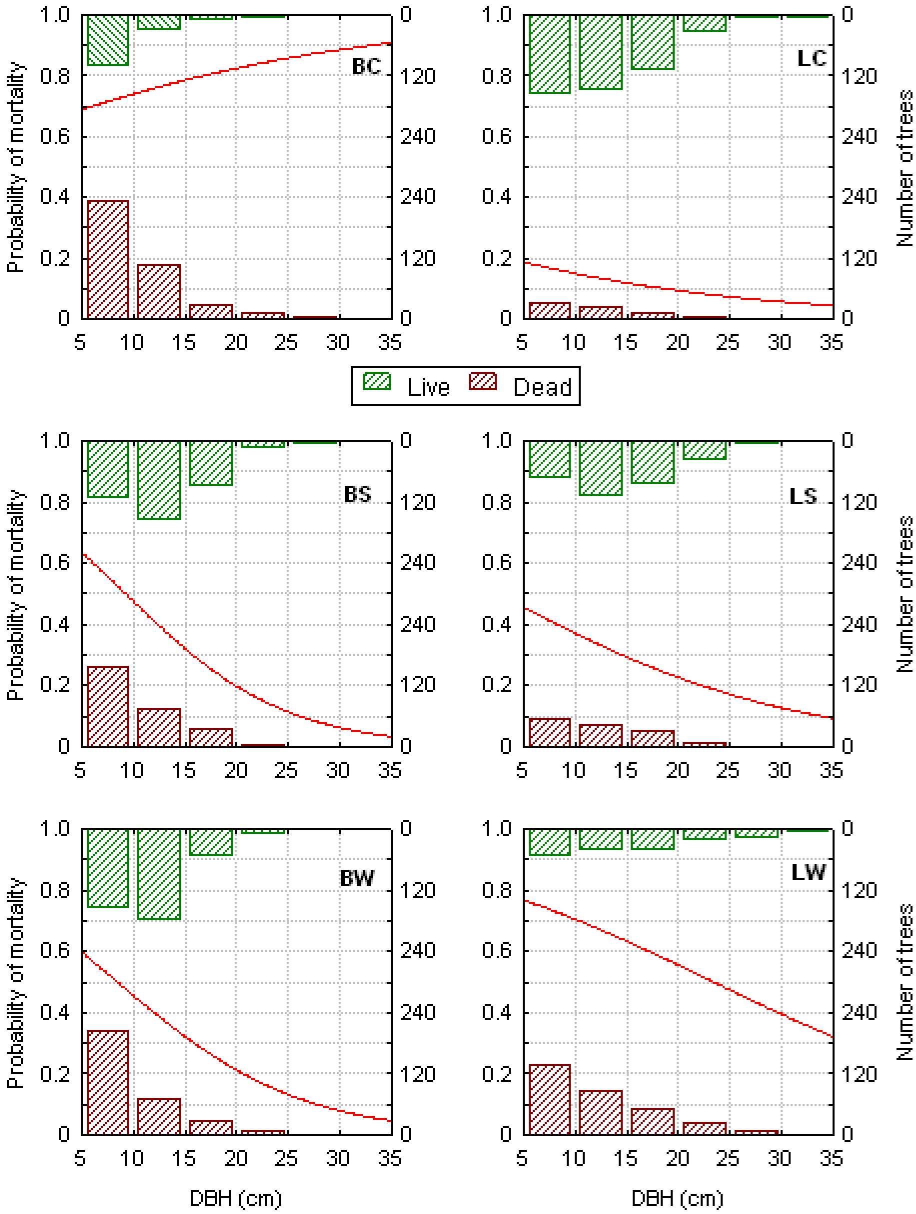


Figure 7: Logistic regression models predicting the probability of pine tree mortality as a function of initial tree dbh (diameter at breast height) in 18 experimental plots. Bars represent the numbers of dead (attached to x-axis) and live (hanging from top) trees in different size (dbh) classes.

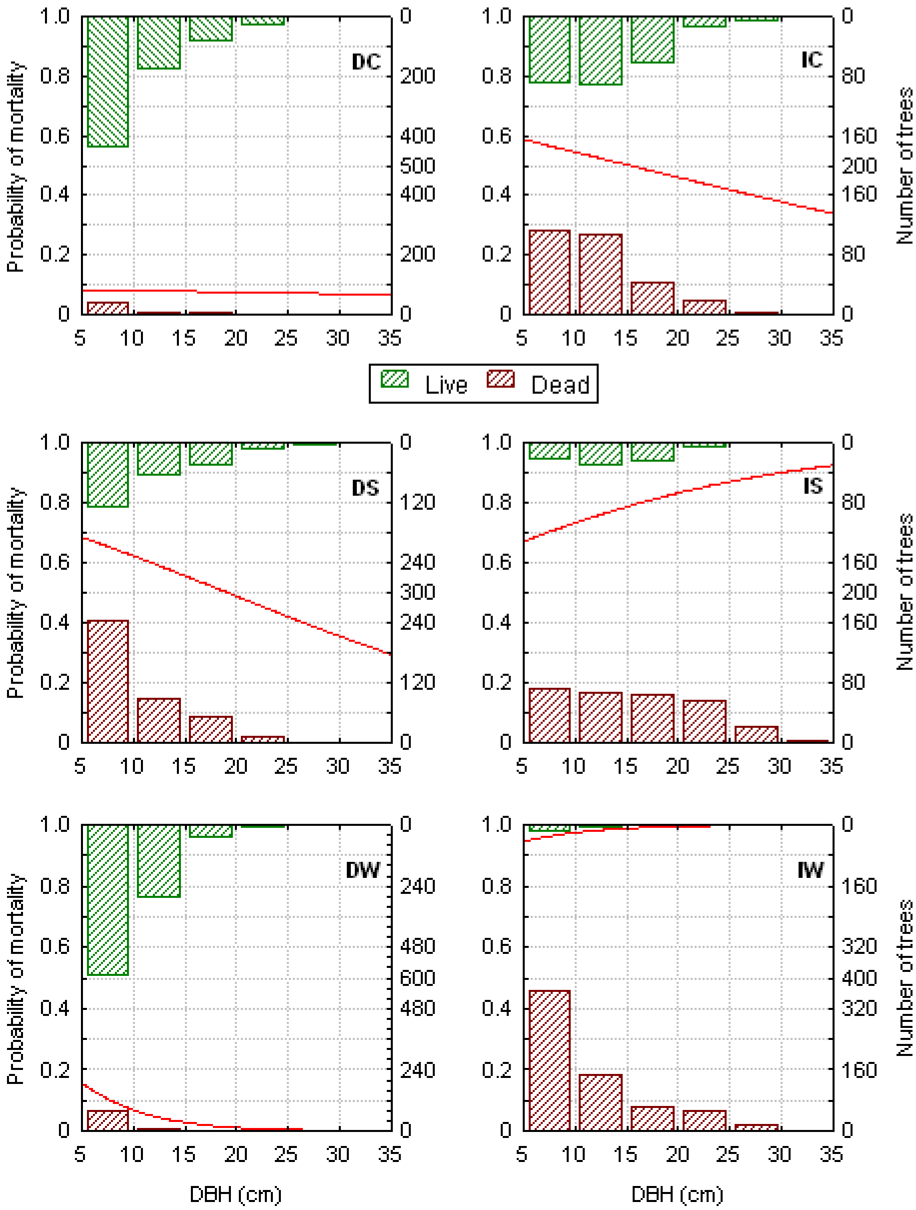


Figure 7: continued.

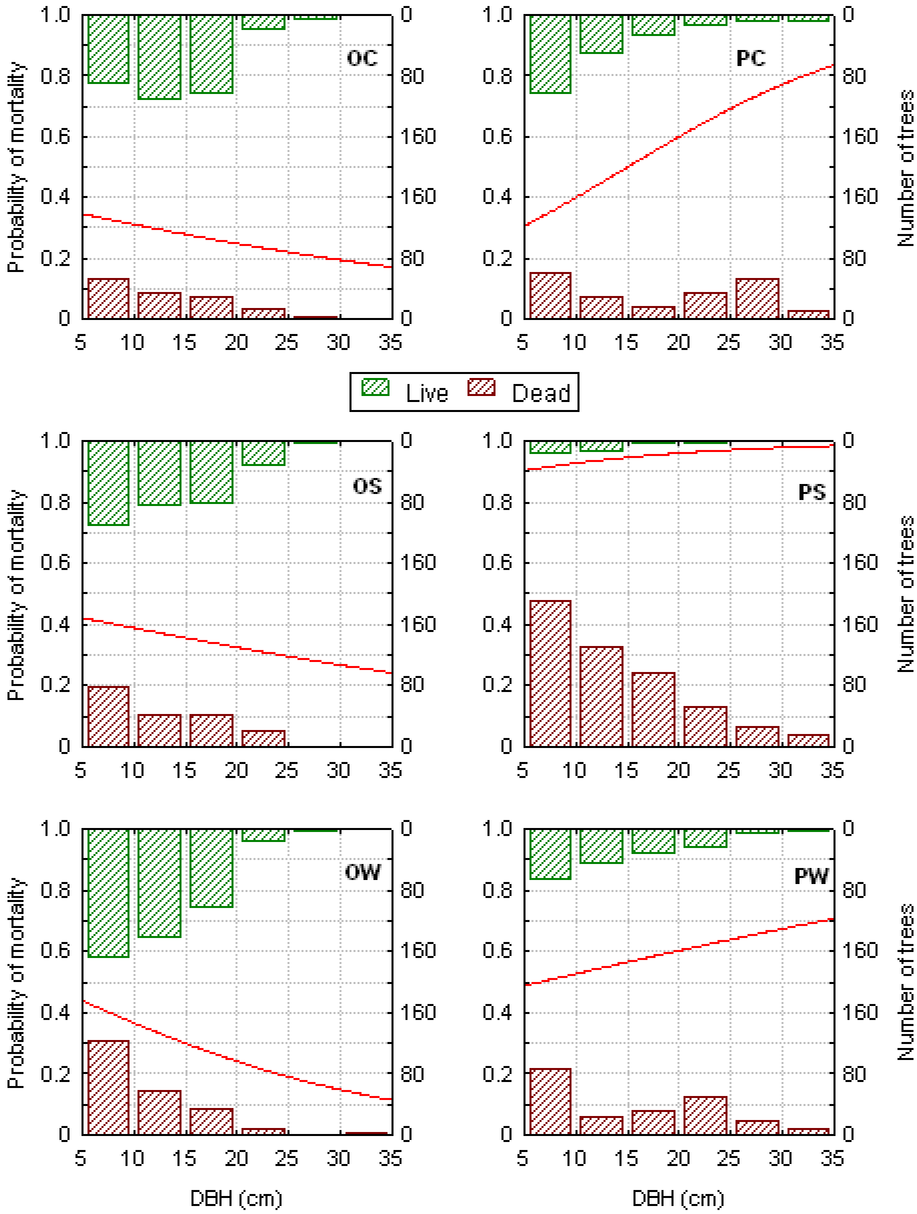


Figure 7: continued.

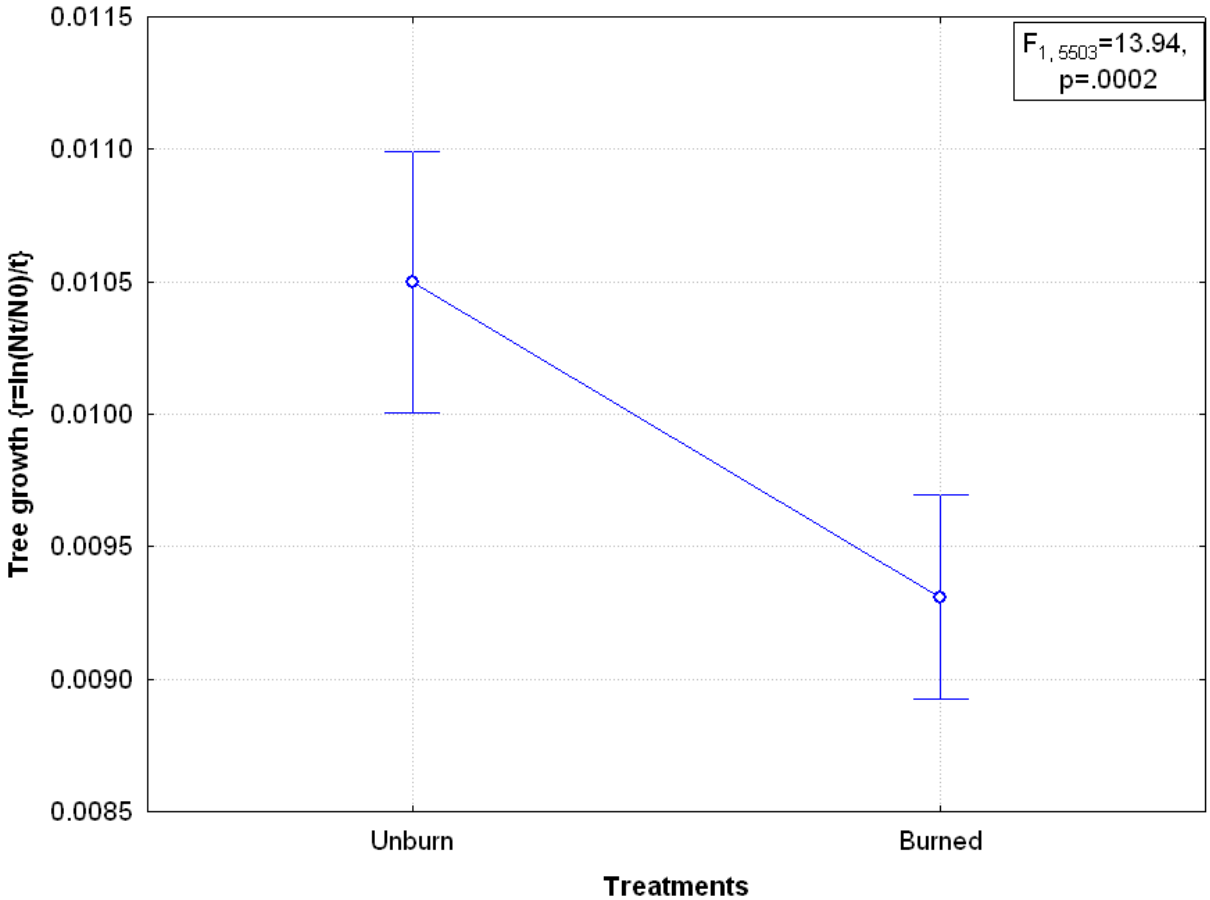


Figure 8: Mean growth rate of pine trees in unburn and burned plots in Big Pine Key. Growth rate is based on the trees that were alive in 2008 survey.

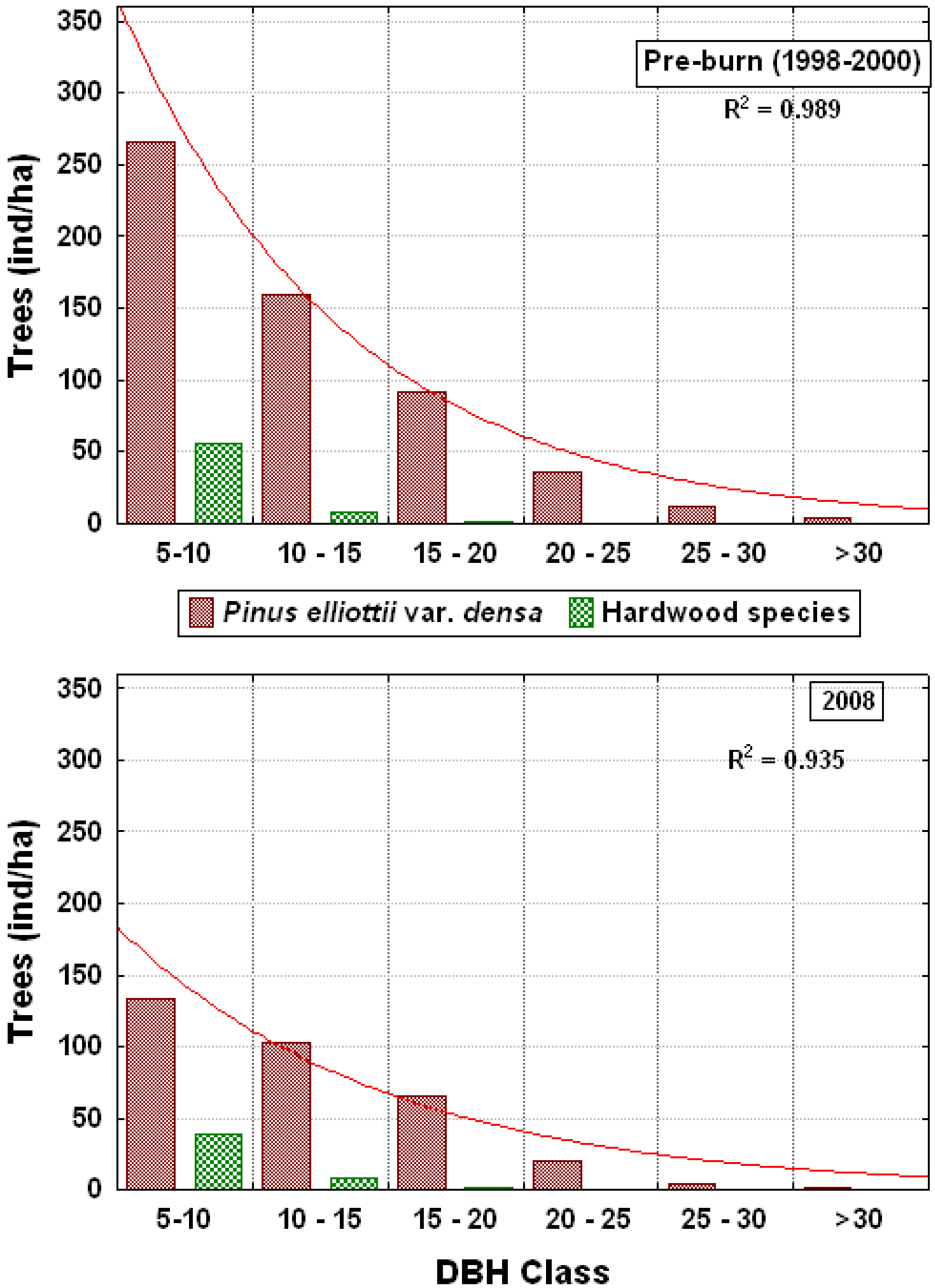


Figure 9: Size class distributions of pines and hardwoods in 18 experimental plots: A: 1998-2001 survey, (B) 2008 survey. Negative exponential models were fitted for the pine tree density in different size classes. DBH class 1 = 5.0-10.0 cm, 2 = 10.1-15.0, 3 = 15.1-20.0 cm, 4 = 20.1-25.0 cm, 5 = 25.1 to 30.0 cm, and 6= >30 cm.

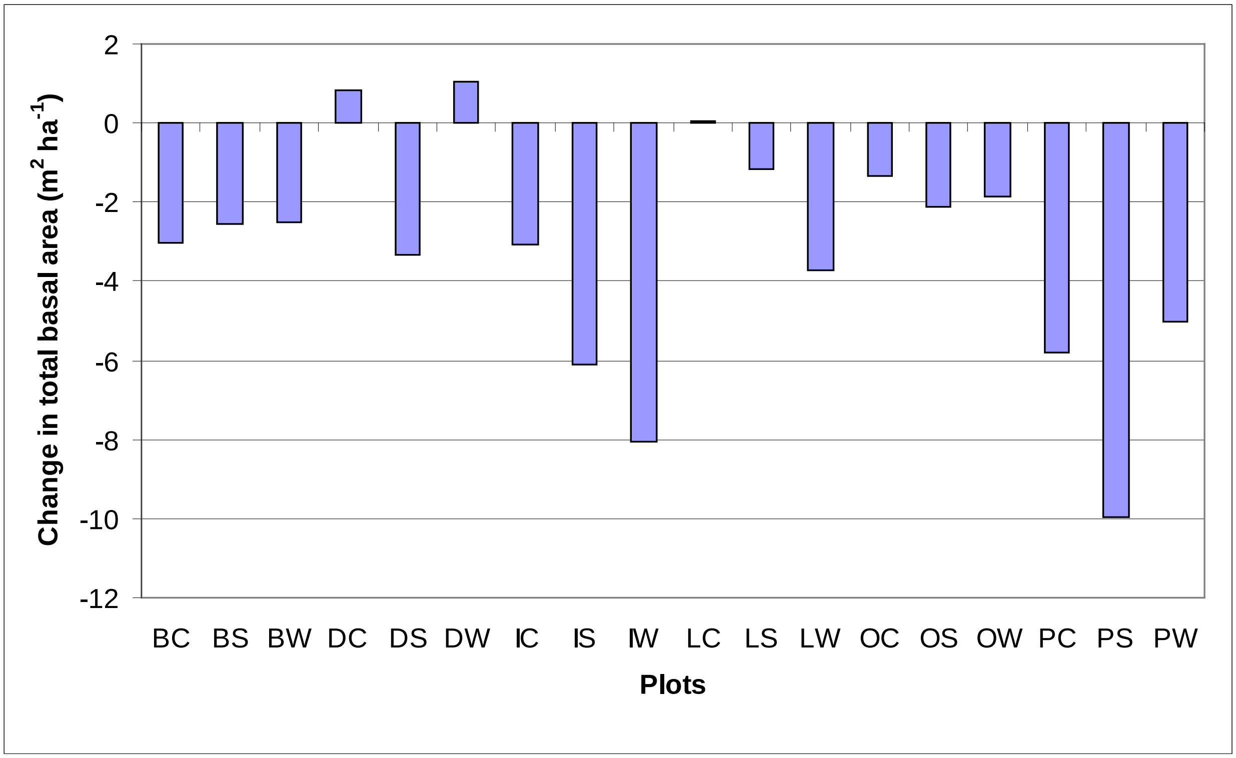


Figure 10: Change in total basal area ($m^2\ ha^{-1}$) in 8-10 years in 18 experimental plots.

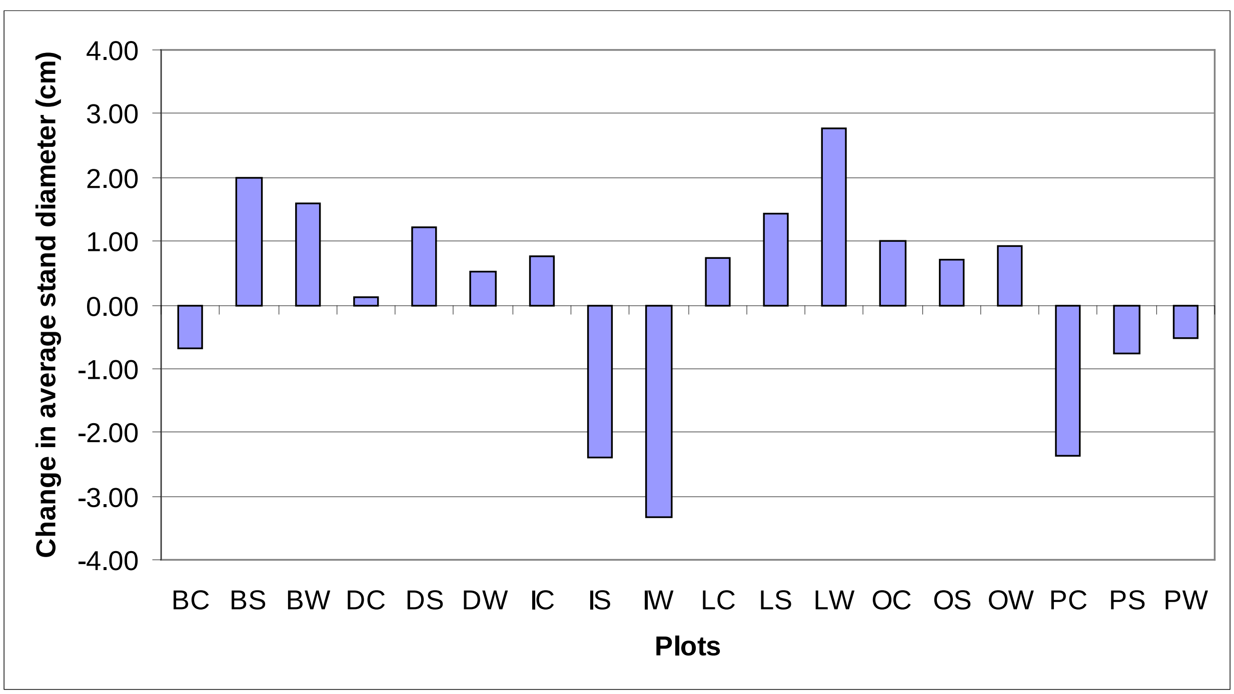


Figure 11: Change in average stand diameter (cm) in 8-10 years in 18 experimental plots.

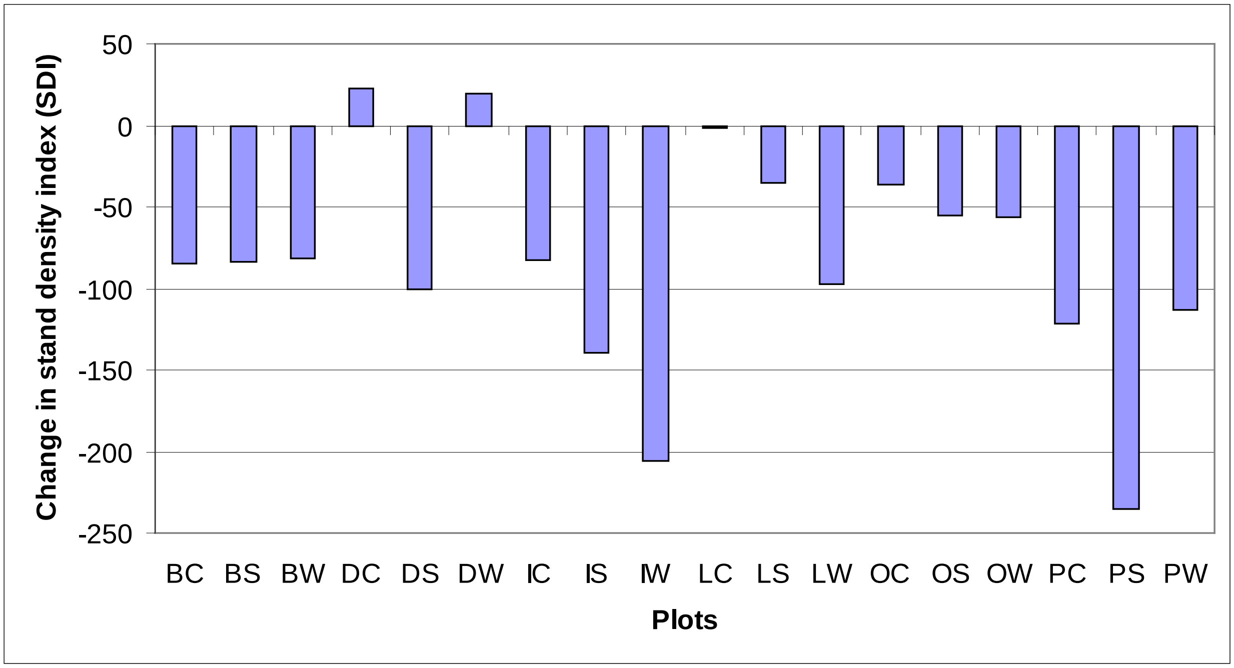


Figure 12: Change in stand density index (SDI) in 8-10 years in 18 experimental plots.

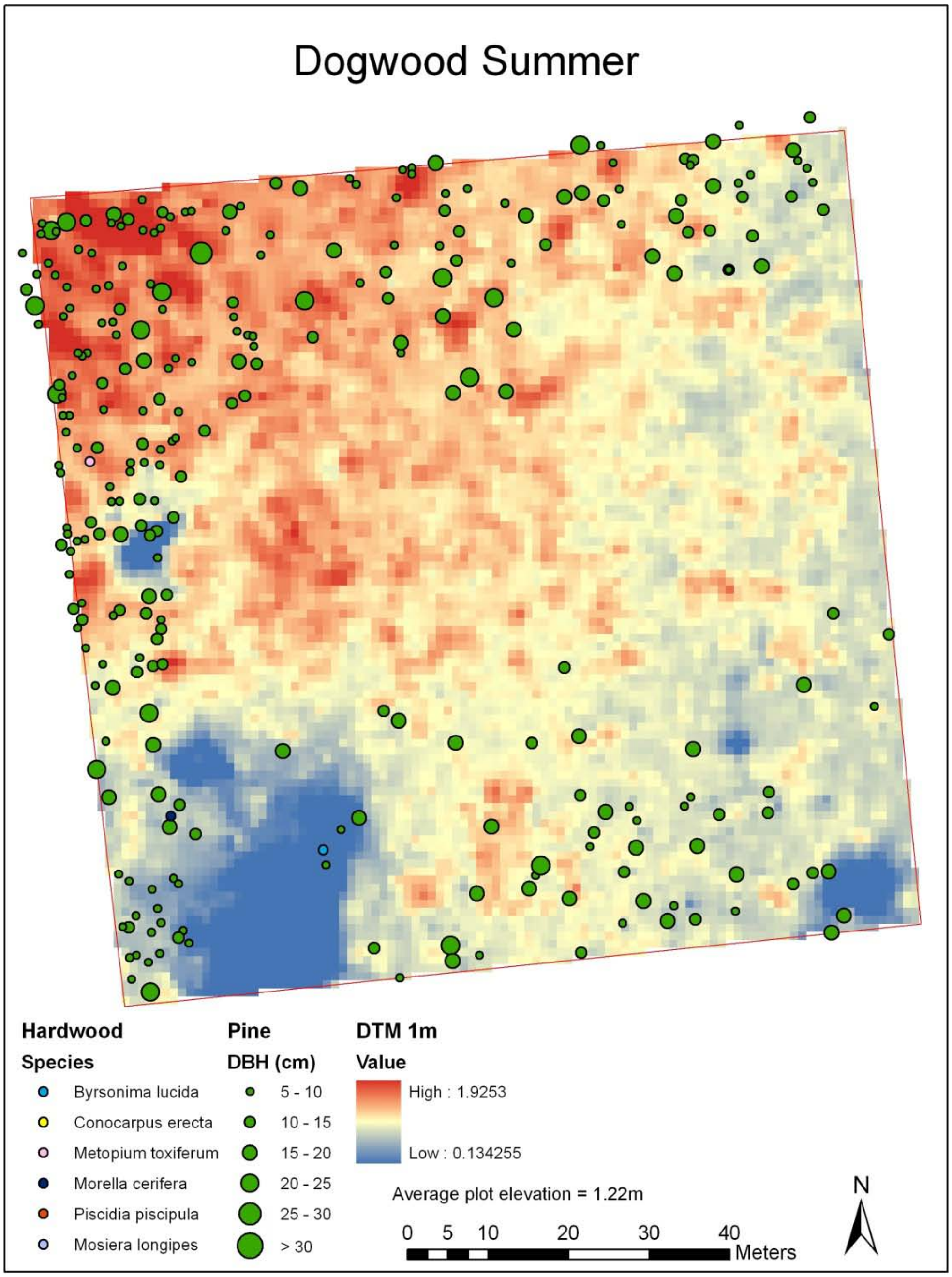


Figure 13: Map showing the locations of live trees of different size classes overlaid on ground elevation in Dogwood Summer (DS) plot in 2008.

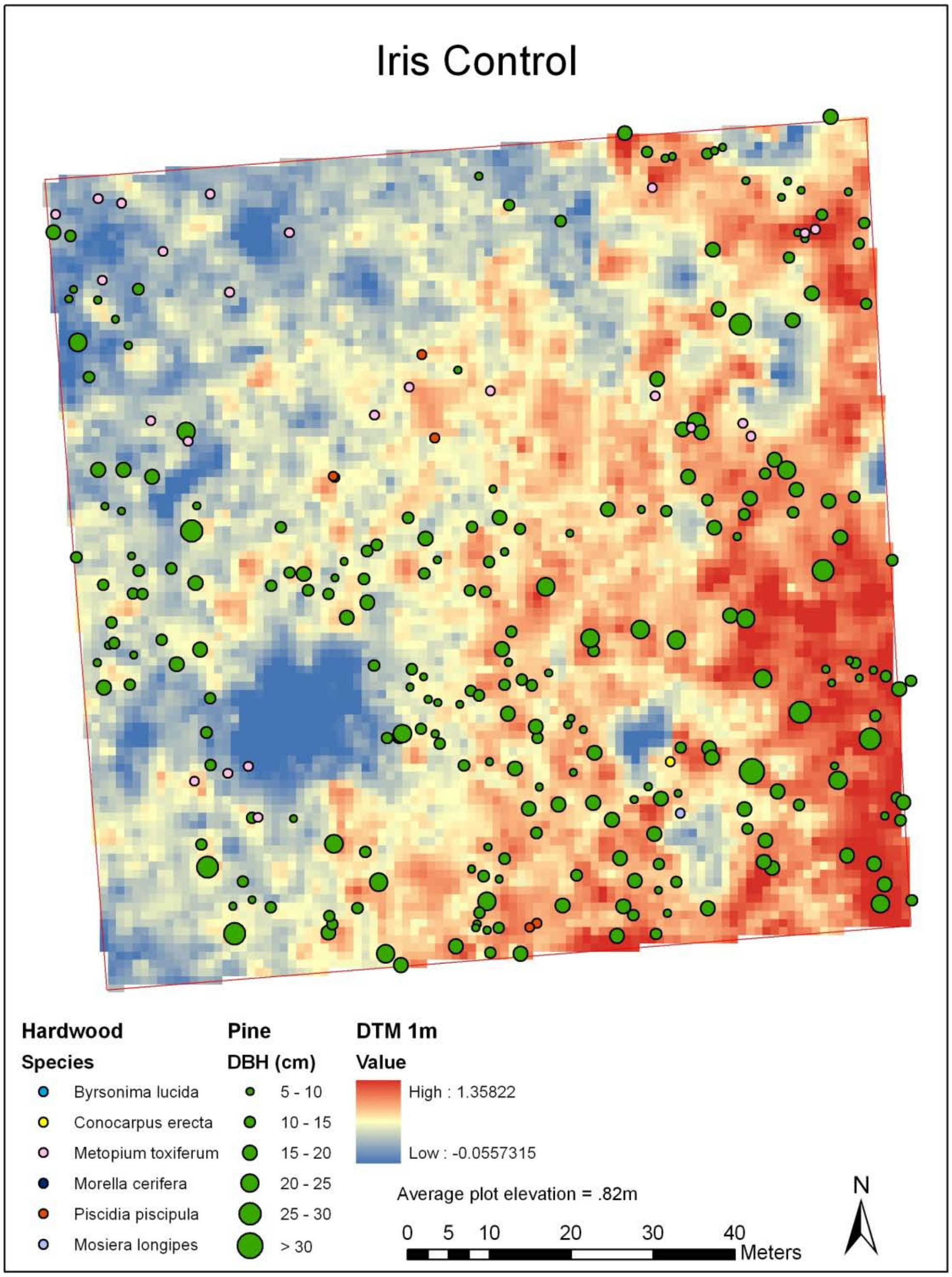


Figure 14: Map showing the locations of live trees of different size classes overlaid on ground elevation in Iris Control (IC) plot in 2008.

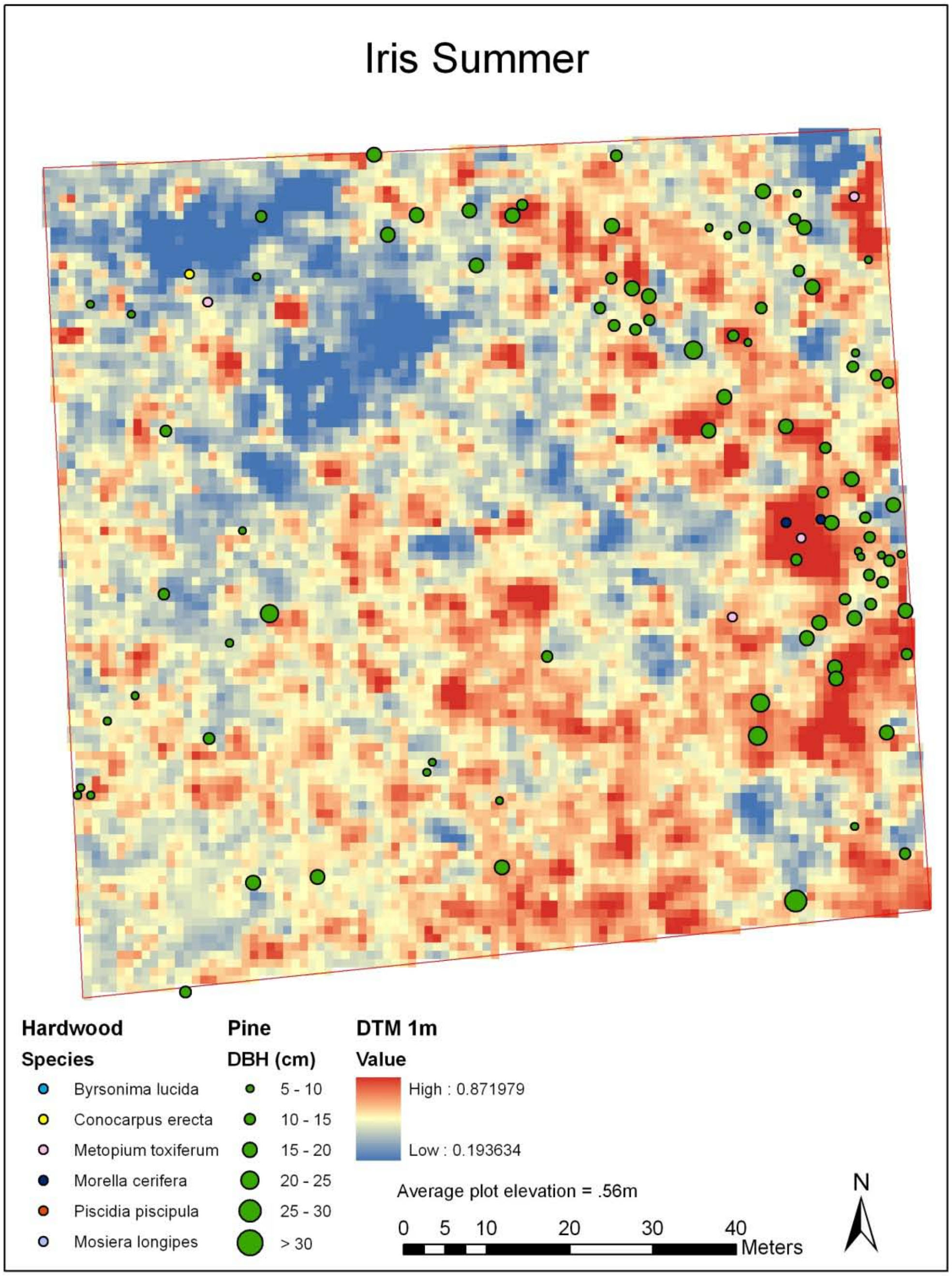


Figure 15: Map showing the locations of live trees of different size classes overlaid on ground elevation in Iris Summer (IS) plot in 2008.

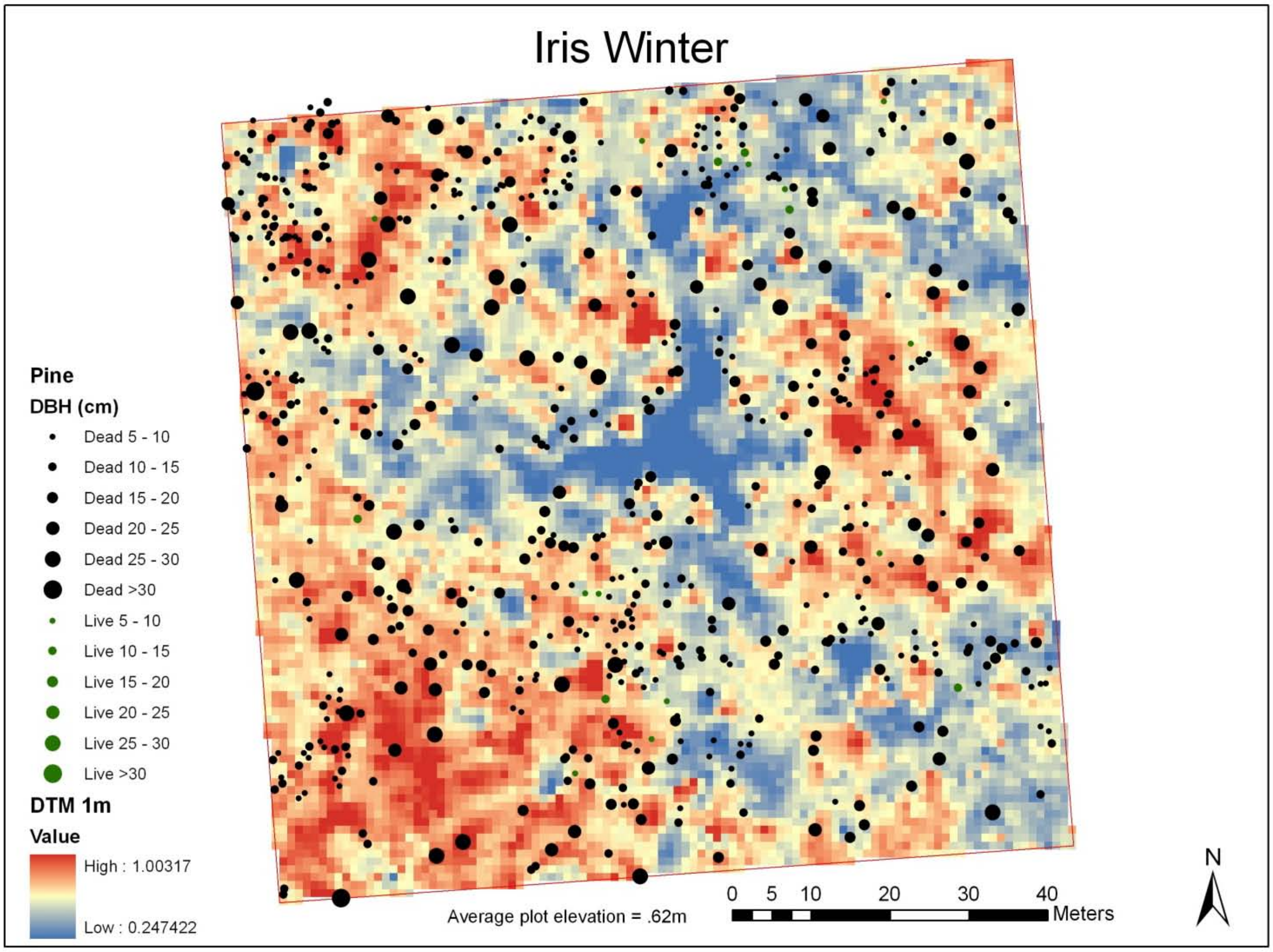


Figure 16: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Iris Winter (IW) plot in 2008.

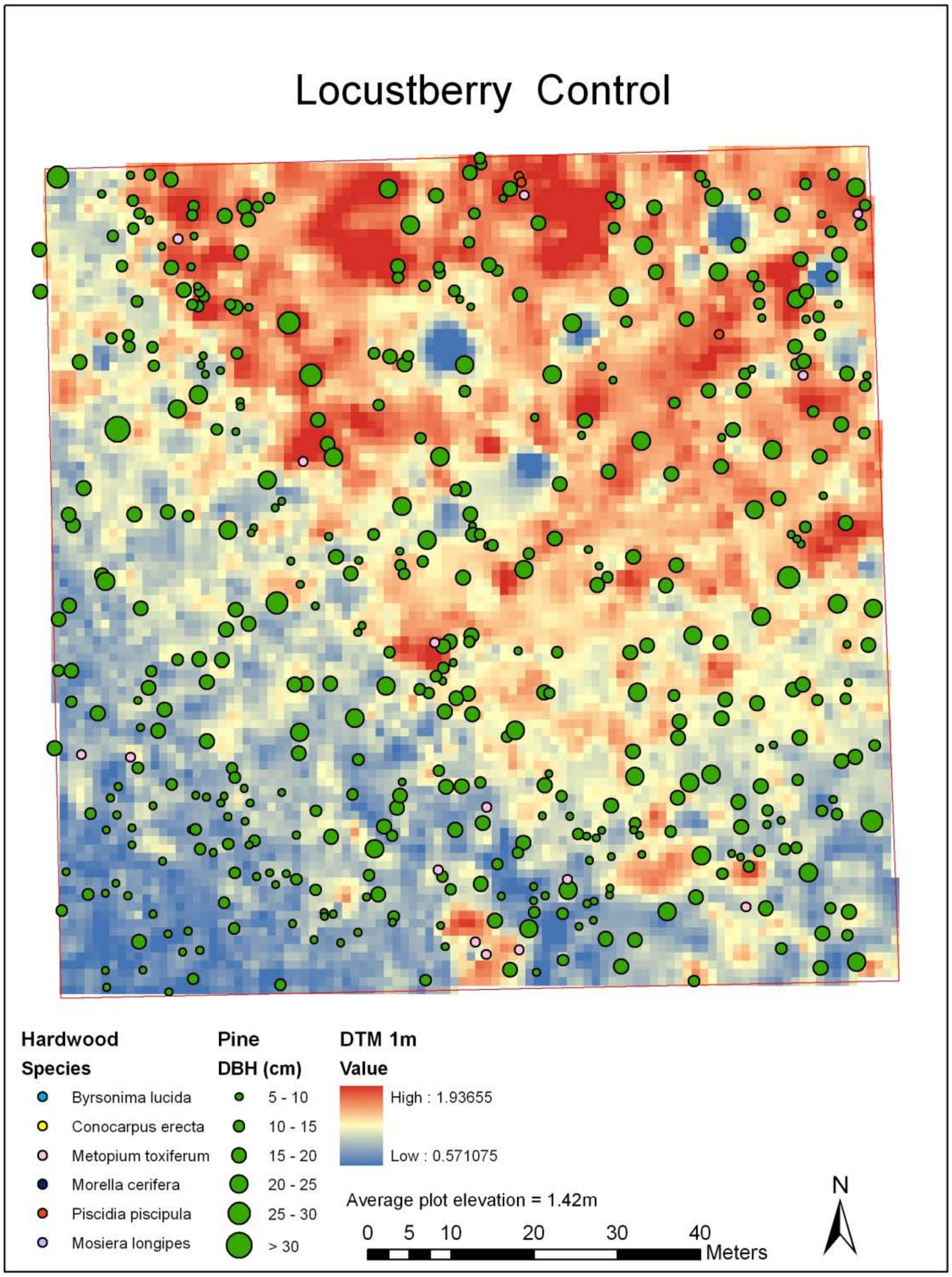


Figure 17: Map showing the locations of live trees of different size classes overlaid on ground elevation in Locustberry Control (LC) plot in 2008.

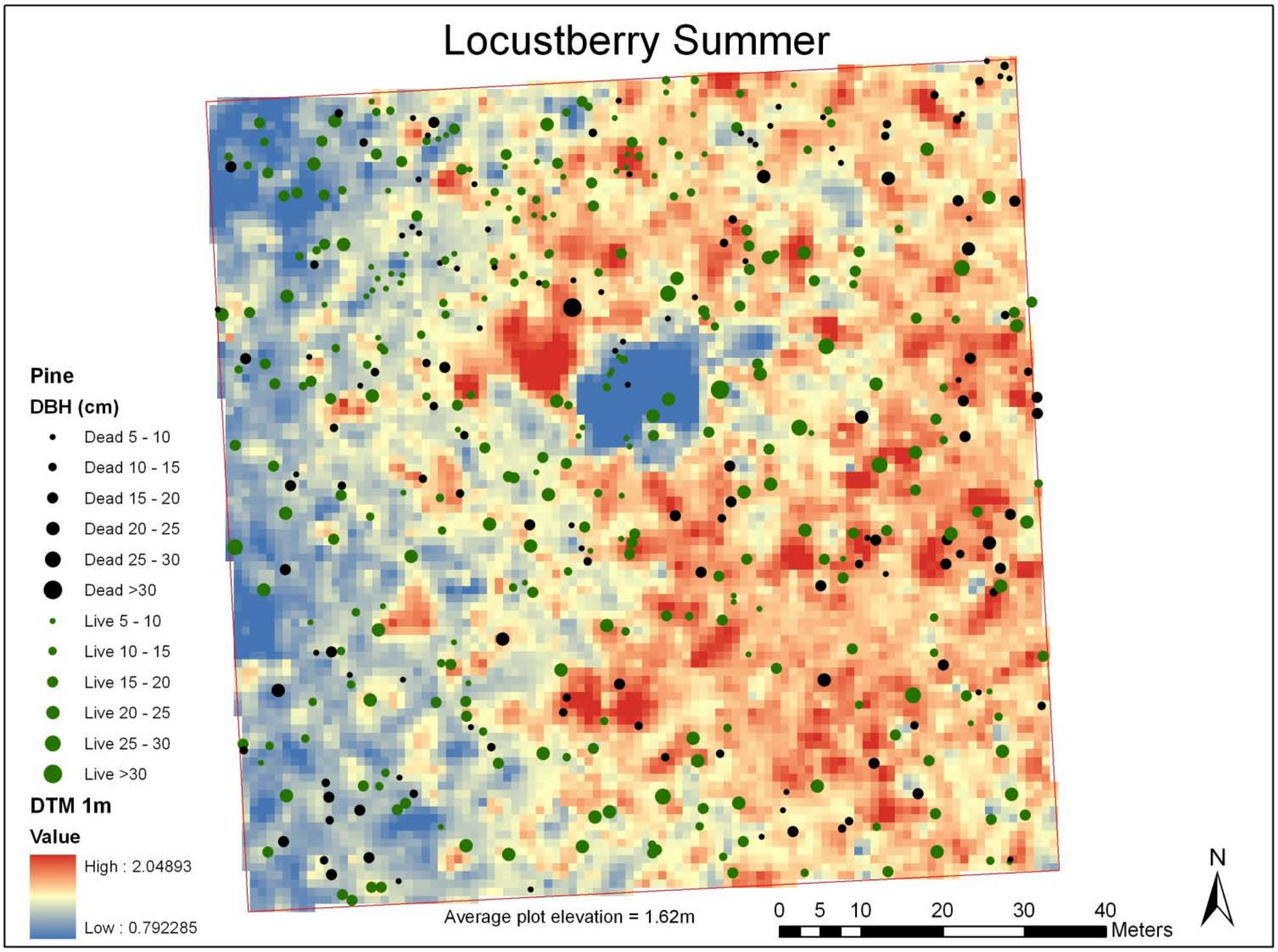


Figure 18: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Locustberry Summer (LS) plot in 2008.

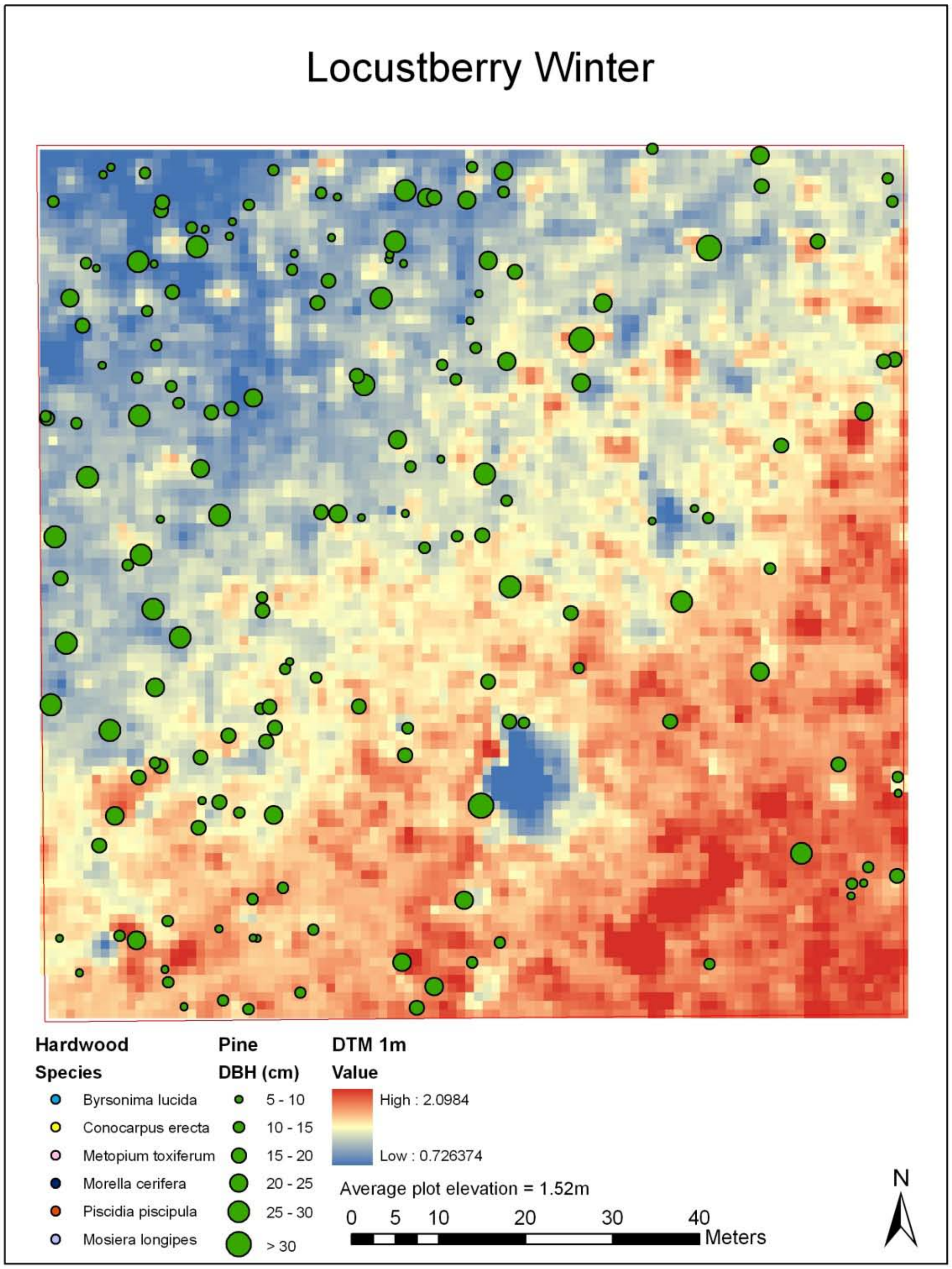


Figure 19: Map showing the locations of live trees of different size classes overlaid on ground elevation in Locustberry Winter (LW) plot in 2008.

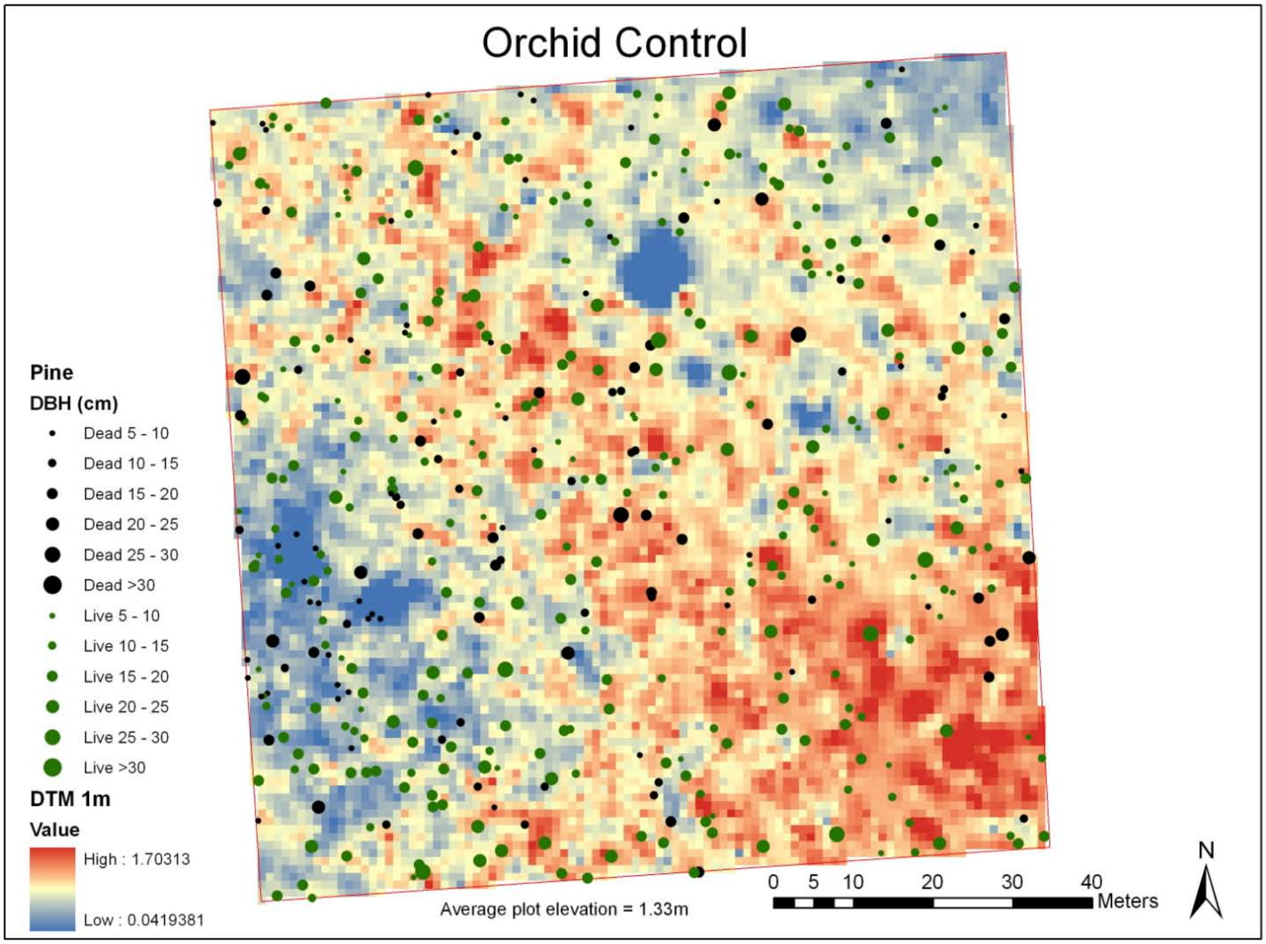


Figure 20: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Orchid Control (OC) plot in 2008.

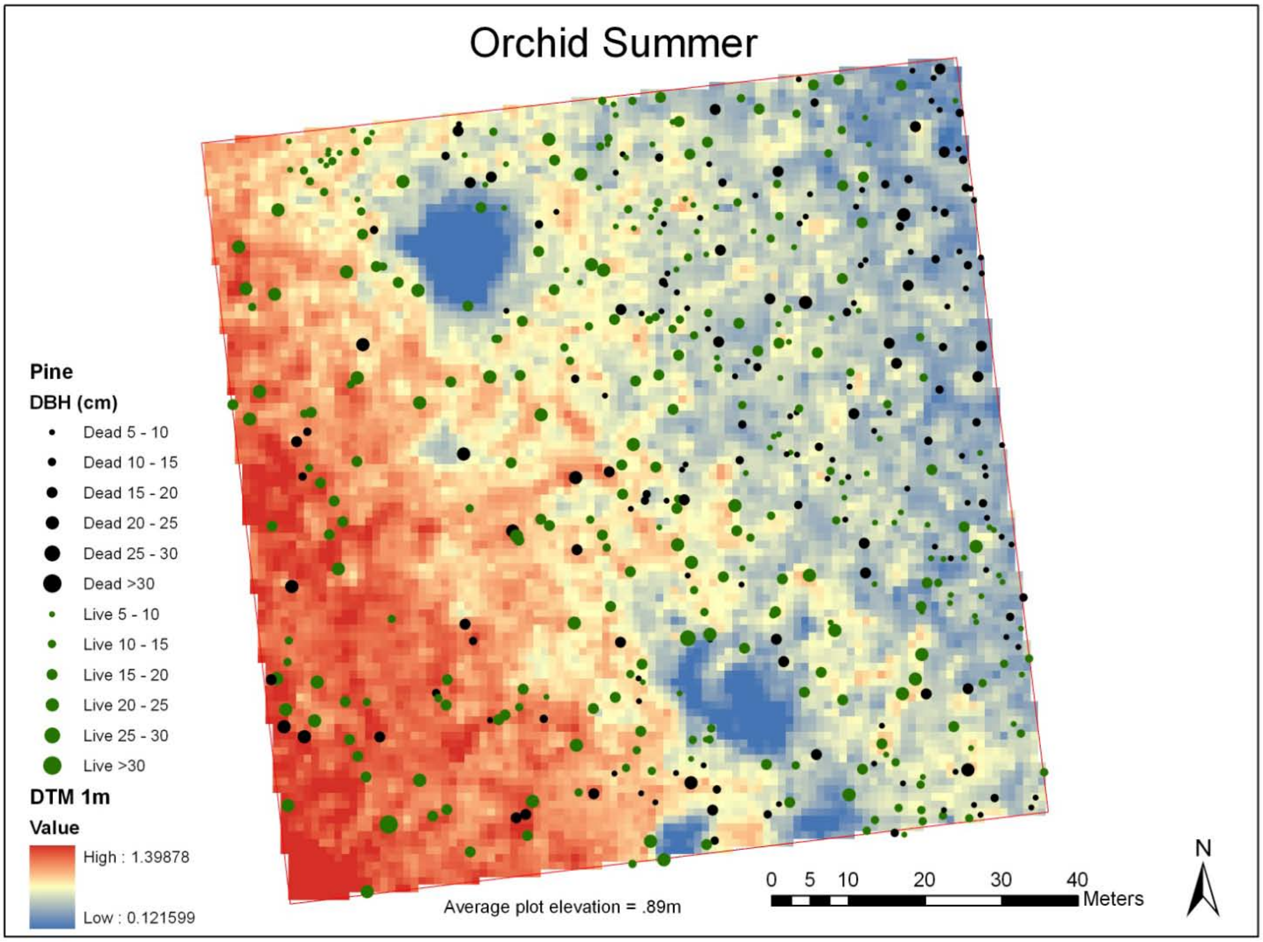


Figure 21: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Orchid Summer (OS) plot in 2008.

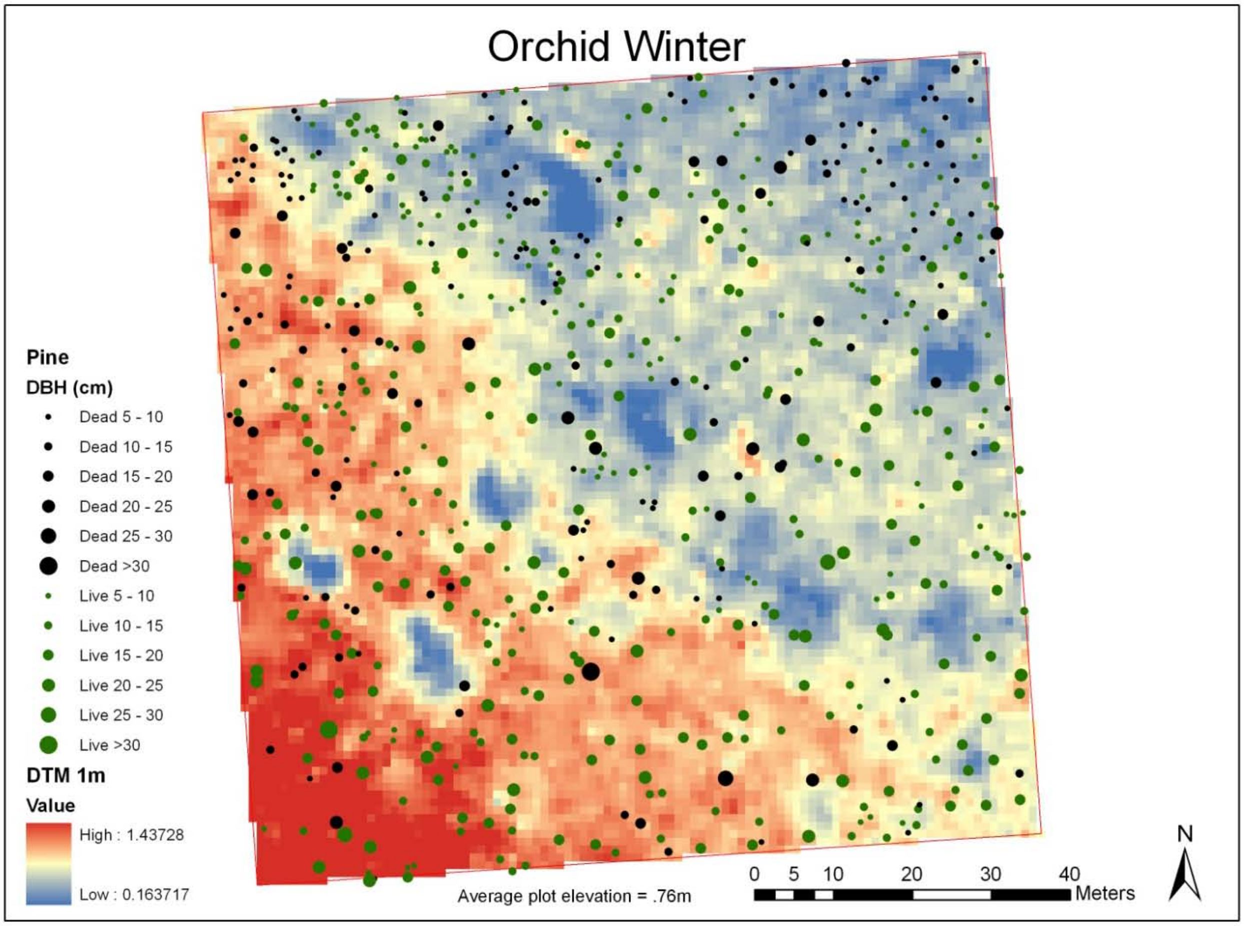


Figure 22: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Orchid Winter (OW) plot in 2008.

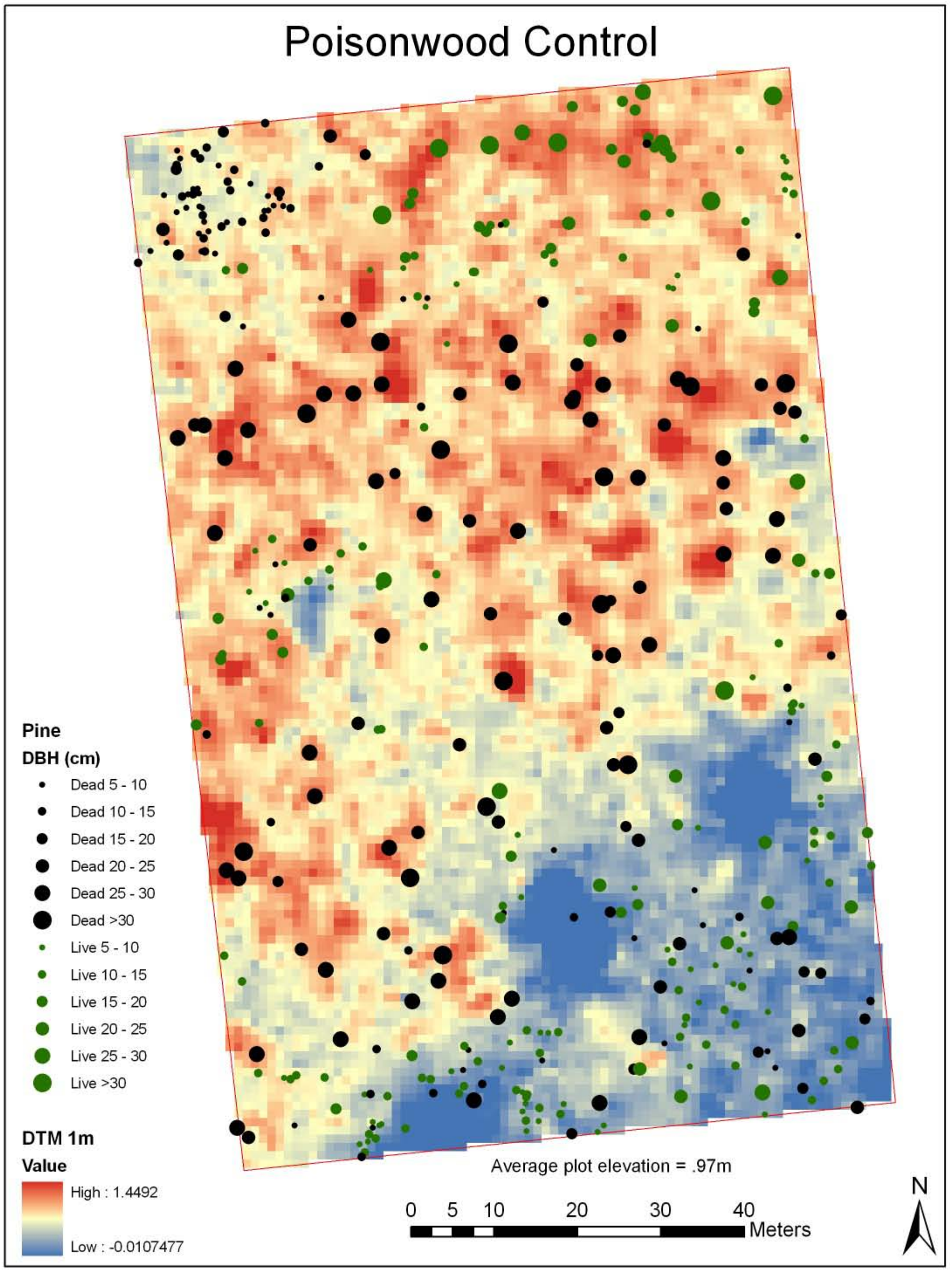


Figure 23: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Poisonwood Control (PC) plot in 2008.

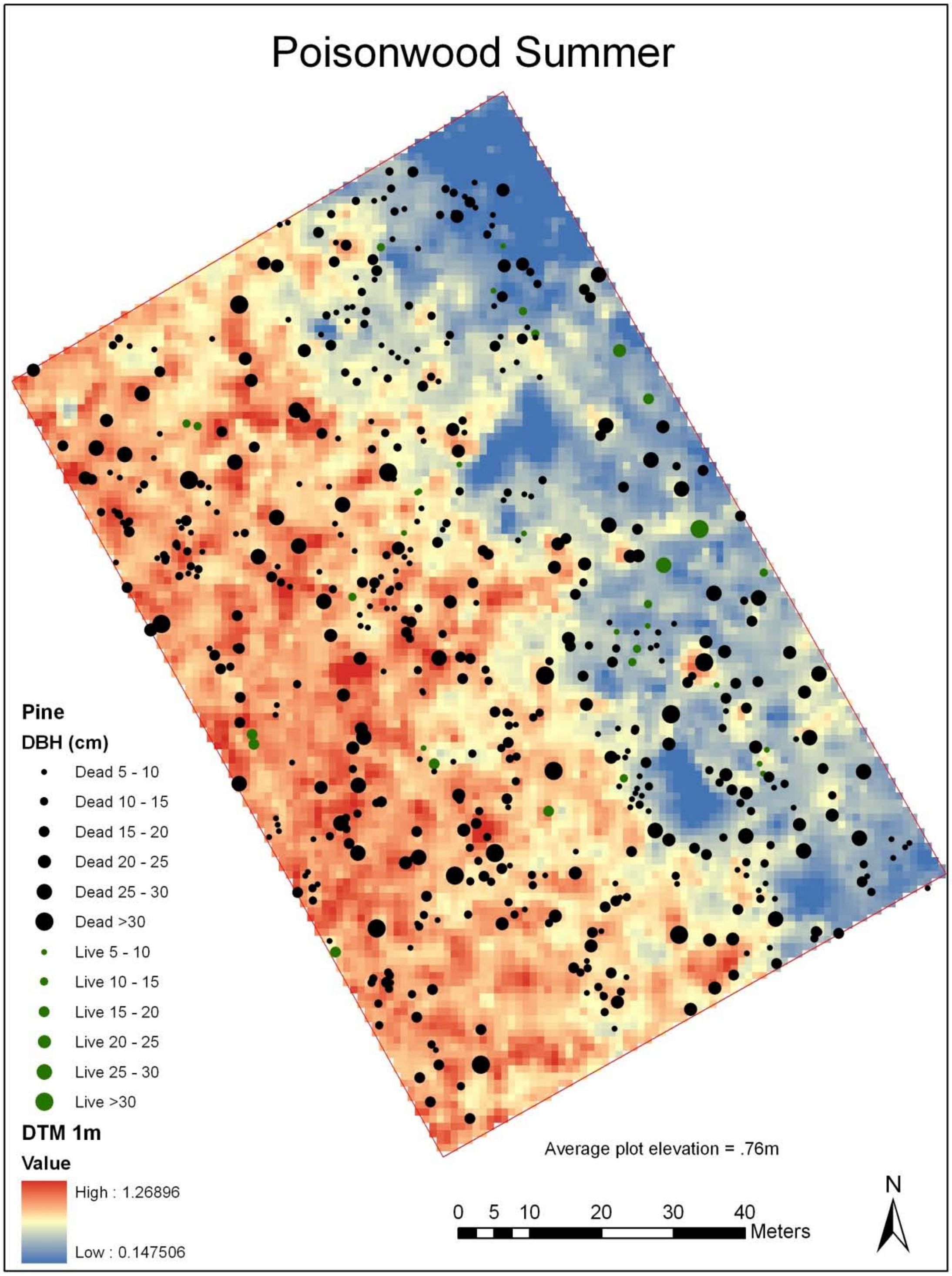


Figure 24: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Poisonwood Summer (PS) plot in 2008.

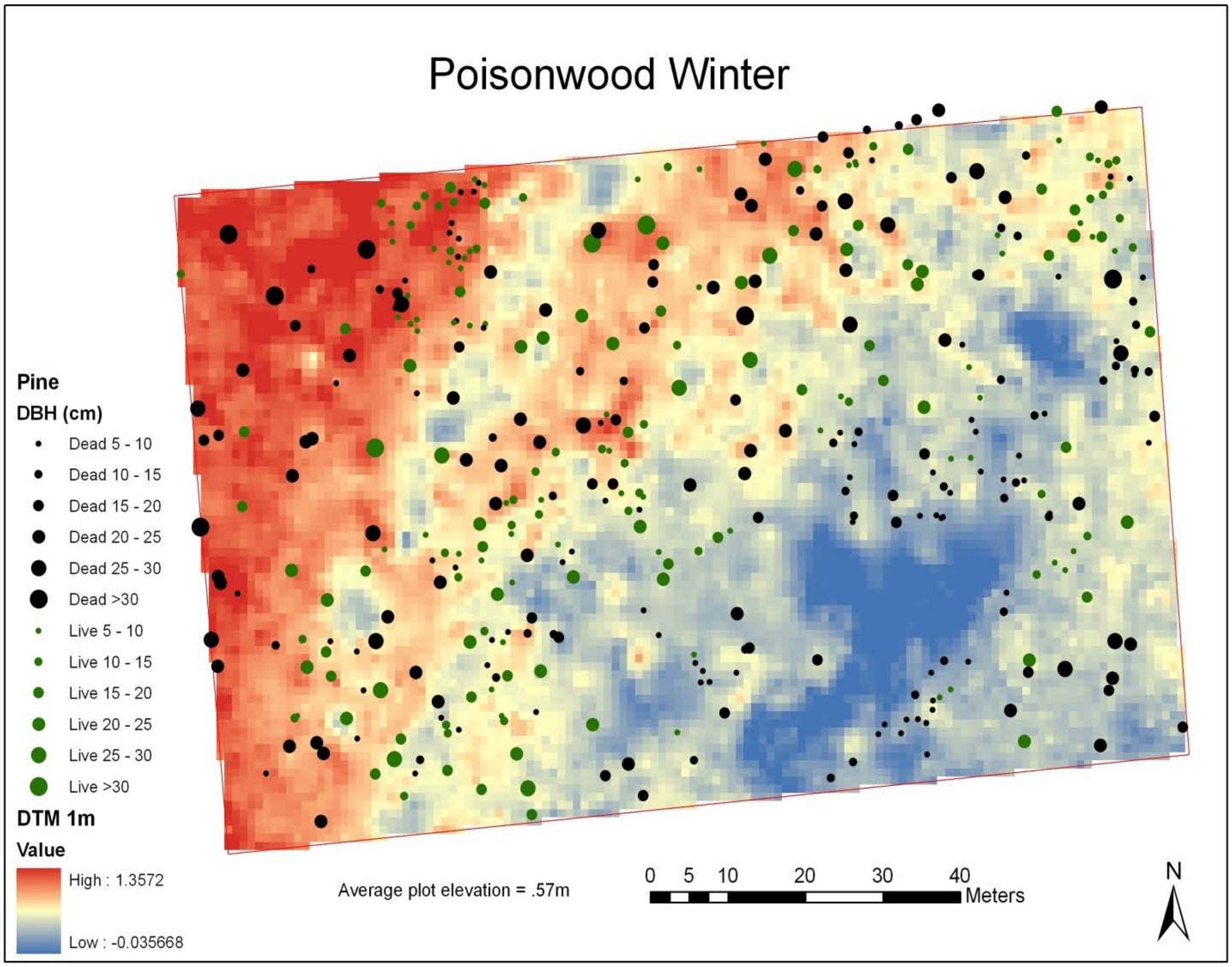


Figure 25: Map showing the locations of live and dead trees of different size classes overlaid on ground elevation in Poisonwood Winter (PW) plot in 2008.

Appendix I
Corrections to tree locations for plots mapped using interpoint method 1998-2000

Danielle Ogurcak

Plots OW, PW, IW, and LS were all mapped during the original study in 1998-2000 using the interpoint method (Boose et al. 1998). Since the original benchmark locations were not recorded in UTM coordinates, but were instead recorded in meters along the meter tape from the plot corner with the assumption that the plot was oriented in a due north-south direction, 2 benchmarks had to be re-created for each plot. Knowing that the field crew used the southwest corner as one benchmark (SE corner for PW) and that the other two benchmarks were located 6 and 8 m away from the corner to create a 6-8-10 right triangle, I calculated likely coordinates for the other two benchmarks for each plot in ArcGIS 9.2. Rebars marking plot corners were located in 2000 using a Trimble GPS unit. Plot rebars were not relocated in 2008 using the Promark system since a sample of rebars relocated using the Promark (rover only) gave approximately the same results.

Interpoint benchmarks were originally created by adding 6 m and 8 m in the N and E direction from the SW plot corner (SE for PW, 8 m to the west) to derive the two other benchmark locations for each plot. However, the results obtained for tree locations upon running the interpoint program with these paramenters placed trees outside the actual plot boundaries to the south and to the east. This meant that, despite best efforts by field crew, the plots were not exactly oriented in a due north-south direction.

I compensated for actual plot orientation in the second and third benchmarks by rotating the 6-8-10 triangle on the plot corner axis. Since the interpoint method results in all tree locations within a plot being linked to each other, changing the orientation of the triangle, and thus changing the x,y values for the second and third benchmarks, would correct all tree locations in each plot. In ArcGIS, using the create polygon tool, I calculated the degrees offset from the cardinal direction from the SW to SE plot corner to derive the direction of the second benchmark and from the SW to the NW plot corner to derive the direction of the third benchmark. The assumption is that the benchmarks would be located along a line between adjacent corners of a plot. However, re-running the interpoint program with the new benchmarks resulted in tree locations now being "overcorrected" in the other direction - moved slightly too far and falling outside the plots to the west and north.

To more accurately recreate the benchmarks, we obtained GPS locations of a sample of trees within each plot using the rover of the Promark system. Since the base station of the Promark was not used, the ground-truthed tree locations likely have an error comparable to that of the Trimble GPS unit (approximately a meter). Approximately a dozen trees were selected in each plot and their GPS locations recorded.

Interpoint results (x,y locations for each mapped tree) were converted to shapefiles in ArcGIS for each plot. Ground-truthed tree locations were compared in each plot to the interpoint-generated locations of those same trees. A distance function in ArcGIS was used to calculate the difference between observed and interpoint-generated locations for each ground-truthed tree. An inspection of the results, showed that the actual (observed) tree locations lay somewhere in between the results of the first and second interpoint runs. Since plot LW did not have ground-truthed tree locations, the above process was not completed for that plot. Instead, benchmarks were corrected to result in the best fit of tree locations inside the plot boundary.

To recalculate benchmarks, I manipulated the angle off due east and north for each plot by decreasing this angle by a third in most cases. I used the same angle for both the east baseline to the second benchmark and the north baseline to the third benchmark. (In the initial attempt to correct the interpoint locations I used different angles, specifically, whatever value I got by drawing a line from SW to SE corner and SW to NW corner).

Through trial and error I found the second and third benchmark locations that resulted in the smallest difference between ground-truthed tree locations and the interpoint-generated location of the same trees..I selected final benchmark locations when the distance (error) between calculated tree locations and ground-truthed locations was minimized (1m or less for most trees)

<u>Directions from plot corner and distance used for the benchmarks of each plot:</u>
(With degrees 0 to 359 beginning with 0 at due E and moving counterclockwise)

<u>OW</u>:
Benchmark 1 (1001) SW plot corner
Benchmark 2 (1002) 8m at a direction of 92.5 degrees (N)
Benchmark 3 (1003) 6m at a direction of 2.5 degrees (E)

<u>PW:</u>
Benchmark 1 (1001) SE plot corner
Benchmark 2 (1002) 8m at a direction of 184.8 degrees (W)
Benchmark 3 (1003) 6m at a direction of 94.8 degrees (N)

<u>LS:</u>
Benchmark 1 (1001) 6m at a direction of 2.0 degrees (E)
Benchmark 2 (1002) SW plot corner
Benchmark 3 (1003) 8m at a direction of 92.0 degrees (N)

<u>IW:</u>
Benchmark 1 (1001) 6m at a direction of 1.5 degrees (E)
Benchmark 2 (1002) SW plot corner
Benchmark 3 (1003) 8m at a direction of 91.5 degrees (N)

In the summer of 2008, any live ingrowth trees (previously unmapped trees) that were larger than 5cm dbh were mapped in these plots using the interpoint method, and as such, were corrected along with the previously mapped locations. There were no ingrowth trees for IW.

Appendix II
Corrections to tree locations for plots mapped using the right-angle prism method in 1998

Danielle Ogurcak

The plots in OC, OS, PC, and PS were mapped with the right-angle prism method (Reed et al. 1989) during the original study in 1998. In ArcGIS 9.2, I found the deviation from the cardinal direction for each baseline used to do the mapping. . I used the BPK permanent plot corner shapefile with locations that were acquired in 2000 using the Trimble GPS to locate the 0 and 100 m baselines (just the 0 m baseline for PC and PS). For the 50 m baselines (OC and OS) and 100 m baselines (PC and PS), I found the boundary rebars in the plots in 2008 and acquired location information using the rover of the Promark system.

For the 100 m x 100 m plots - OS and OC:

NW to NE corner = 100 m baseline
West 50 m to East 50 m = 50 m baseline
SW to SE corner = 0 m baseline

For the 80m x 125m plots - PC and PS:

NW to NE corner = 0 m baseline
West 50 m to East 50 m = 50 m baseline
West 100 m to East 100 m = 100 m baseline

Jay Sah had previously found the mean angle "degrees off 0" that the plots were rotated by comparing the plot corner location coordinates and taking an average. An equation in the excel database he created uses this information to move each tree location the appropriate amount based on the mean angle correction.

Using the create polygon tool in ArcGIS 9.2, I determined the angle off due north-south for each baseline. I then used the same equation in excel but substituted the angle that I found using the method in ArcGIS. I ran this separately for each baseline for each plot using the appropriate mean angle.

Ground-truthed tree locations as previously described in Appendix I were compared in each plot to the interpoint-generated locations of those same trees. A distance function in ArcGIS was used to calculate the difference between observed and interpoint-generated locations for each ground-truthed tree. Comparisons were made between 1) the corrected tree locations (using mean angles off baselines) and groundtruthed trees and 2) tree locations using the average mean angle for the entire plot (which Jay had calculated) and groundtruthed trees. Differences between groundtruthed and corrected locations using baselines were decreased for both PC and PS, indicating an improvement in locations of trees in those plots. For OS and OC, better results were obtained using the average mean angle method than using the mean angle for each baseline. In general, error was less than 1m between corrected and groundtruthed locations.

XY locations (NAD83 UTM17) for trees in plots OC and OS were obtained using the mean angle correction.

XY locations (NAD83 UTM17) for trees in plots PC and PS were obtained using the angle correction for each baseline.

In the summer of 2008, any live ingrowth trees (previously unmapped trees) that were larger than 5 cm dbh were mapped in these plots using the interpoint method, and as such, were corrected along with the previously mapped locations.

Appendix III

GPS coordinates for corners of 18 experimental plots. Datum=NAD83_UTM17. Note that these coordinates incorporate corrections from those listed in Snyder et al. (2005).

BLOCK	PLOT	CORNER	LONG_DD	LAT_DD	EASTING	NORTHING
Buttonwood	BC	SW	-81.37428	24.68840	462137.1	2730497.1
Buttonwood	BC	SE	-81.37377	24.68839	462187.8	2730495.9
Buttonwood	BC	NW	-81.37417	24.69022	462148.3	2730698.5
Buttonwood	BC	NE	-81.37367	24.69020	462198.5	2730696.5
Buttonwood	BS	SW	-81.37331	24.68832	462234.3	2730488.3
Buttonwood	BS	SE	-81.37281	24.68834	462285.4	2730489.5
Buttonwood	BS	NW	-81.37332	24.69014	462234.1	2730689.8
Buttonwood	BS	NE	-81.37283	24.69014	462284.4	2730689.4
Buttonwood	BW	SW	-81.37241	24.68873	462325.7	2730533.1
Buttonwood	BW	SE	-81.37193	24.68879	462374.1	2730539.4
Buttonwood	BW	NW	-81.37264	24.69054	462303.4	2730733.8
Buttonwood	BW	NE	-81.37215	24.69058	462353.2	2730738.2
Dogwood	DC	SW	-81.37625	24.70297	461942.0	2732110.4
Dogwood	DC	SE	-81.37527	24.70305	462041.2	2732118.9
Dogwood	DC	NW	-81.37634	24.70387	461933.2	2732210.4
Dogwood	DC	NE	-81.37537	24.70394	462031.3	2732218.5
Dogwood	DS	SW	-81.37641	24.70421	461925.9	2732248.3
Dogwood	DS	SE	-81.37543	24.70431	462024.7	2732258.5
Dogwood	DS	NW	-81.37653	24.70512	461914.1	2732348.6
Dogwood	DS	NE	-81.37553	24.70520	462015.2	2732357.1
Dogwood	DW	SW	-81.37787	24.70424	461777.9	2732252.1
Dogwood	DW	SE	-81.37690	24.70433	461876.8	2732261.4
Dogwood	DW	NW	-81.37794	24.70513	461771.7	2732351.0
Dogwood	DW	NE	-81.37698	24.70521	461868.7	2732359.1
Iris	IC	SW	-81.38626	24.71301	460932.4	2733225.9
Iris	IC	SE	-81.38529	24.71309	461030.6	2733233.7
Iris	IC	NW	-81.38634	24.71391	460924.8	2733324.9
Iris	IC	NE	-81.38535	24.71398	461025.1	2733332.3
Iris	IS	SW	-81.38769	24.71297	460787.4	2733221.8
Iris	IS	SE	-81.38669	24.71307	460889.3	2733232.4
Iris	IS	NW	-81.38774	24.71388	460782.6	2733321.7
Iris	IS	NE	-81.38675	24.71392	460883.2	2733326.4
Iris	IW	SW	-81.39095	24.71185	460457.5	2733098.8
Iris	IW	SE	-81.38996	24.71192	460558.2	2733106.0
Iris	IW	NW	-81.39103	24.71274	460450.1	2733197.3
Iris	IW	NE	-81.39004	24.71282	460550.4	2733205.5

BLOCK	PLOT	CORNER	LONG_DD	LAT_DD	EASTING	NORTHING
Locustberry	LC	SW	-81.37969	24.69930	461592.7	2731705.7
Locustberry	LC	SE	-81.37869	24.69933	461693.4	2731708.1
Locustberry	LC	NW	-81.37971	24.70021	461590.7	2731805.7
Locustberry	LC	NE	-81.37873	24.70023	461689.8	2731808.6
Locustberry	LS	SW	-81.37970	24.70057	461592.3	2731846.6
Locustberry	LS	SE	-81.37872	24.70062	461691.6	2731851.6
Locustberry	LS	NW	-81.37975	24.70147	461587.1	2731945.9
Locustberry	LS	NE	-81.37877	24.70152	461686.2	2731951.2
Locustberry	LW	SW	-81.37951	24.70175	461612.0	2731977.1
Locustberry	LW	SE	-81.37852	24.70177	461712.1	2731978.3
Locustberry	LW	NW	-81.37952	24.70266	461611.1	2732077.1
Locustberry	LW	NE	-81.37854	24.70267	461710.5	2732078.2
Orchid	OC	SW	-81.38028	24.70757	461535.9	2732620.9
Orchid	OC	SE	-81.37929	24.70763	461635.9	2732627.7
Orchid	OC	NW	-81.38034	24.70846	461529.4	2732720.4
Orchid	OC	NE	-81.37935	24.70853	461629.5	2732727.6
Orchid	OS	SW	-81.38244	24.71098	461317.7	2732999.5
Orchid	OS	SE	-81.38147	24.71110	461416.8	2733012.0
Orchid	OS	NW	-81.38256	24.71188	461306.2	2733099.5
Orchid	OS	NE	-81.38159	24.71199	461404.8	2733110.7
Orchid	OW	SW	-81.38100	24.70966	461463.6	2732853.4
Orchid	OW	SE	-81.38002	24.70973	461563.0	2732859.9
Orchid	OW	NW	-81.38107	24.71055	461456.7	2732951.7
Orchid	OW	NE	-81.38009	24.71062	461555.9	2732959.3
Poisonwood	PC	SW	-81.38858	24.70174	460694.7	2731978.2
Poisonwood	PC	SE	-81.38780	24.70182	460773.0	2731986.4
Poisonwood	PC	NW	-81.38872	24.70286	460680.4	2732102.6
Poisonwood	PC	NE	-81.38793	24.70294	460760.2	2732110.9
Poisonwood	PS	SW	-81.38835	24.69900	460716.4	2731674.7
Poisonwood	PS	SE	-81.38766	24.69936	460786.5	2731714.2
Poisonwood	PS	NW	-81.38895	24.69997	460656.3	2731782.8
Poisonwood	PS	NE	-81.38827	24.70034	460724.8	2731823.1
Poisonwood	PW	SW	-81.38902	24.70074	460649.3	2731867.8
Poisonwood	PW	SE	-81.38780	24.70085	460773.0	2731879.2
Poisonwood	PW	NW	-81.38910	24.70146	460642.0	2731947.7
Poisonwood	PW	NE	-81.38786	24.70157	460766.9	2731958.6

Recommendations for monitoring of permanent vegetation plots established on Big Pine Key by USGS and FIU

February 2010

A. Trees

1. Finish mapping unmapped 1.0 ha permanent plots: Dogwood Control and Dogwood Winter (unburned) and all three Buttonwood plots.
2. Conduct annual survey of tagged live trees to assess mortality in all 18 plots. Ingrowth can be tagged and approximate location recorded.
3. Remeasure dbh on all trees every 5-10 years and map ingrowth as necessary.
4. Resample after major disturbance as needed.

B. Shrub layer

1. Sample pine saplings and palms as in original study, in 20 circular subplots 50 m^2 in area per plot. Because of the high density of hardwood shrub stems, subsample only one quarter of each subplot for hardwoods.
2. Resample every 5-10 years.
3. Pine saplings might be sampled annually as part of annual survey of live trees.

C. Herb layer

1. Herbs should be sampled in the four 1 m^2 subplots located in each of the 20 shrub subplots for a total of 80 herb subplots per plot. Because of the difficulty of species identification, estimate cover of major life forms: graminoids, forbs, ferns, woody plants, and palms.
2. Sample cover, and in some cases density, of a limited number of individual species. These selected species should include listed or candidate species as well as typical pineland species that can be easily identified by novice field technicians (e.g. *Croton linearis*) and possibly include taxa known to be preferred by Key deer (e.g. *Morinda royoc*). Pine seedlings should be counted.
3. Sample every two years.

D. Shallow water monitoring wells

1. Establish a shallow well in each of the 18 plots.
2. Sample depth and conductivity monthly.

Big Pine Key Permanent Vegetation Plots

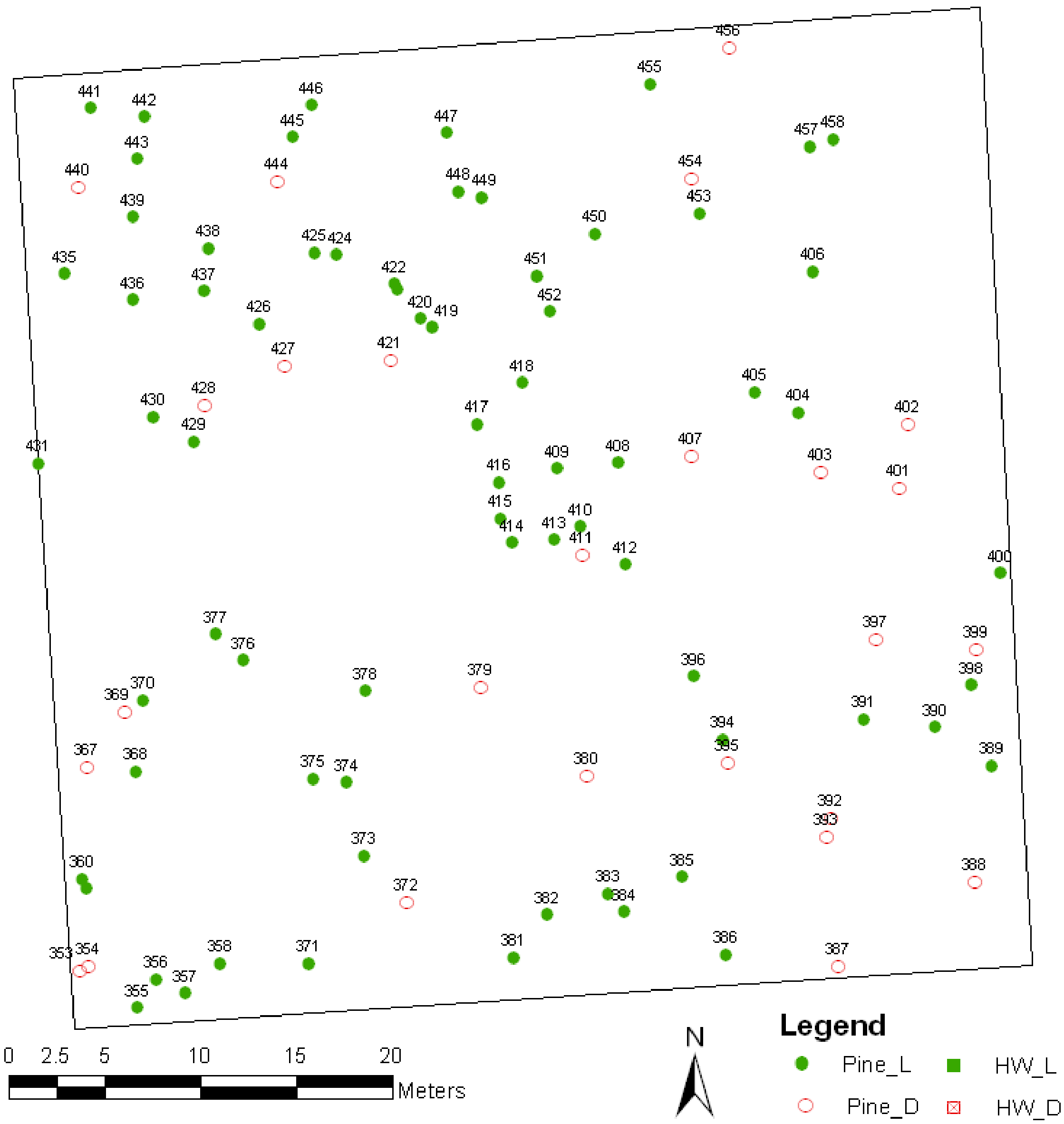
Tree Maps

To accompany report "Resampling of Permanent Pine Rockland Vegetation Plots on Big Pine Key" by Jay P. Sah, James R. Snyder, Michael S. Ross, and Danielle Ogurcak

The following maps show the location of trees (dbh ≥ 5 cm) in the 18 1.0 ha permanent plots established by FIU and USGS in 1998-2000 (Snyder et al. 2005) and resampled in 2008. The data used to create the maps are found in the Excel file "BPK all tree data 20090406."

Each plot is mapped in four quarters in order to make the map large enough to display tree tag numbers. The plot is identified by a two-letter code consisting of the first letter of the block and the first letter of the burn treatment (C = control or unburned, S = summer burn, W = winter burn). The plot quarters are arranged NE, NW, SE, and SW. Plots mapped in 2008 only show locations of live trees, whereas plots mapped earlier show both live and dead trees.

OC-NE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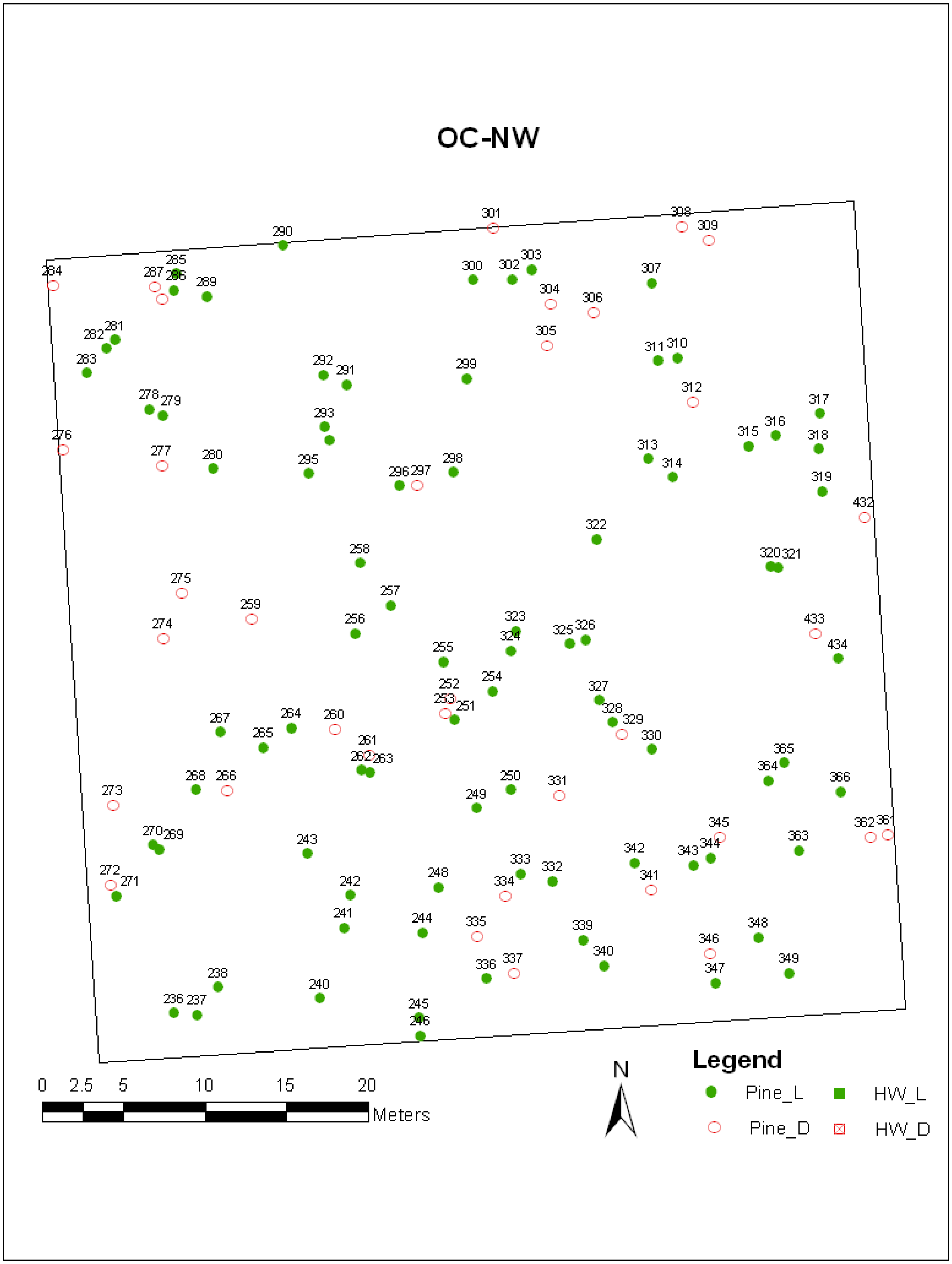
HW_L
Pine_D
HW_D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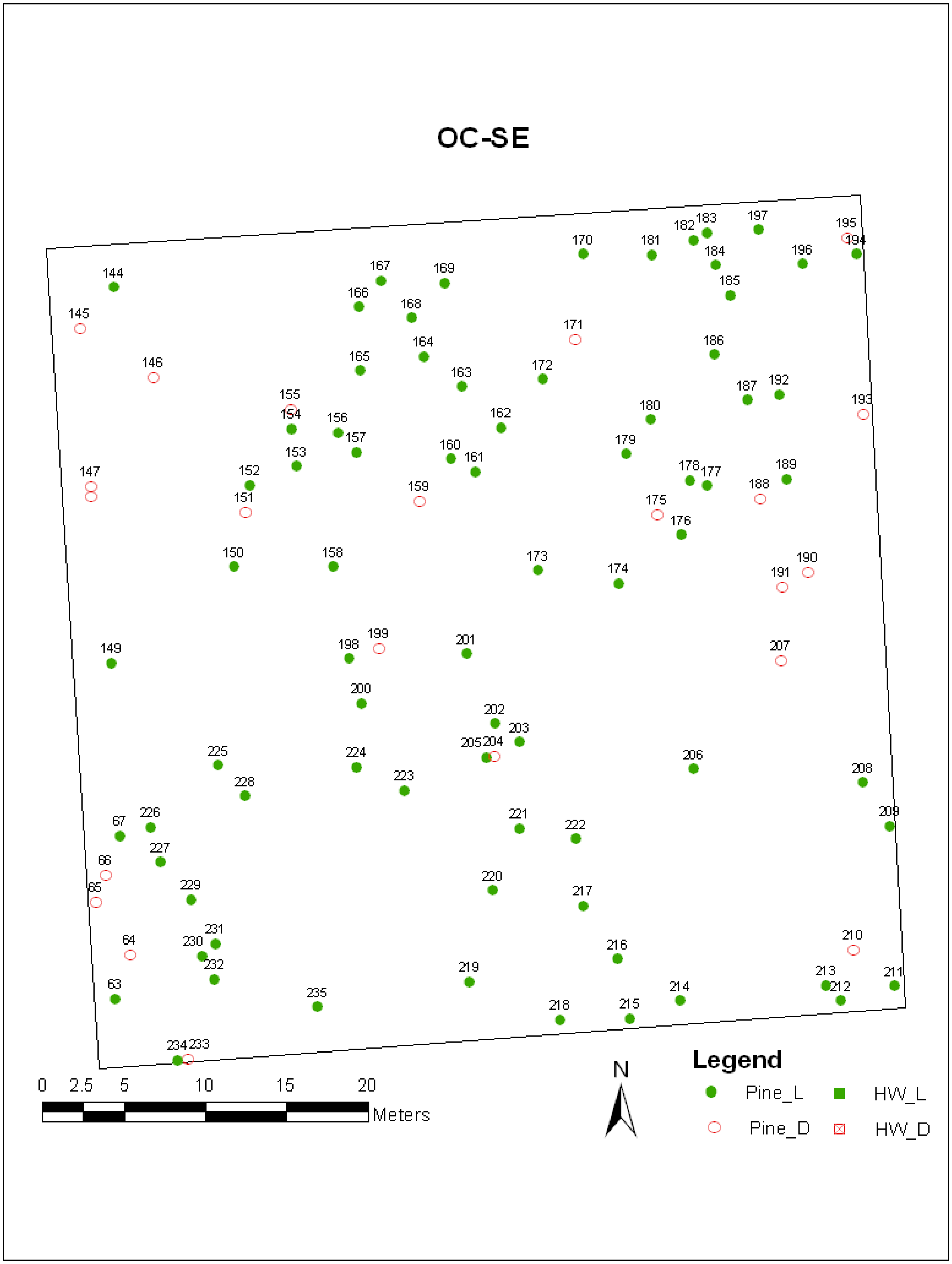
Meters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HW_L
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HW_D
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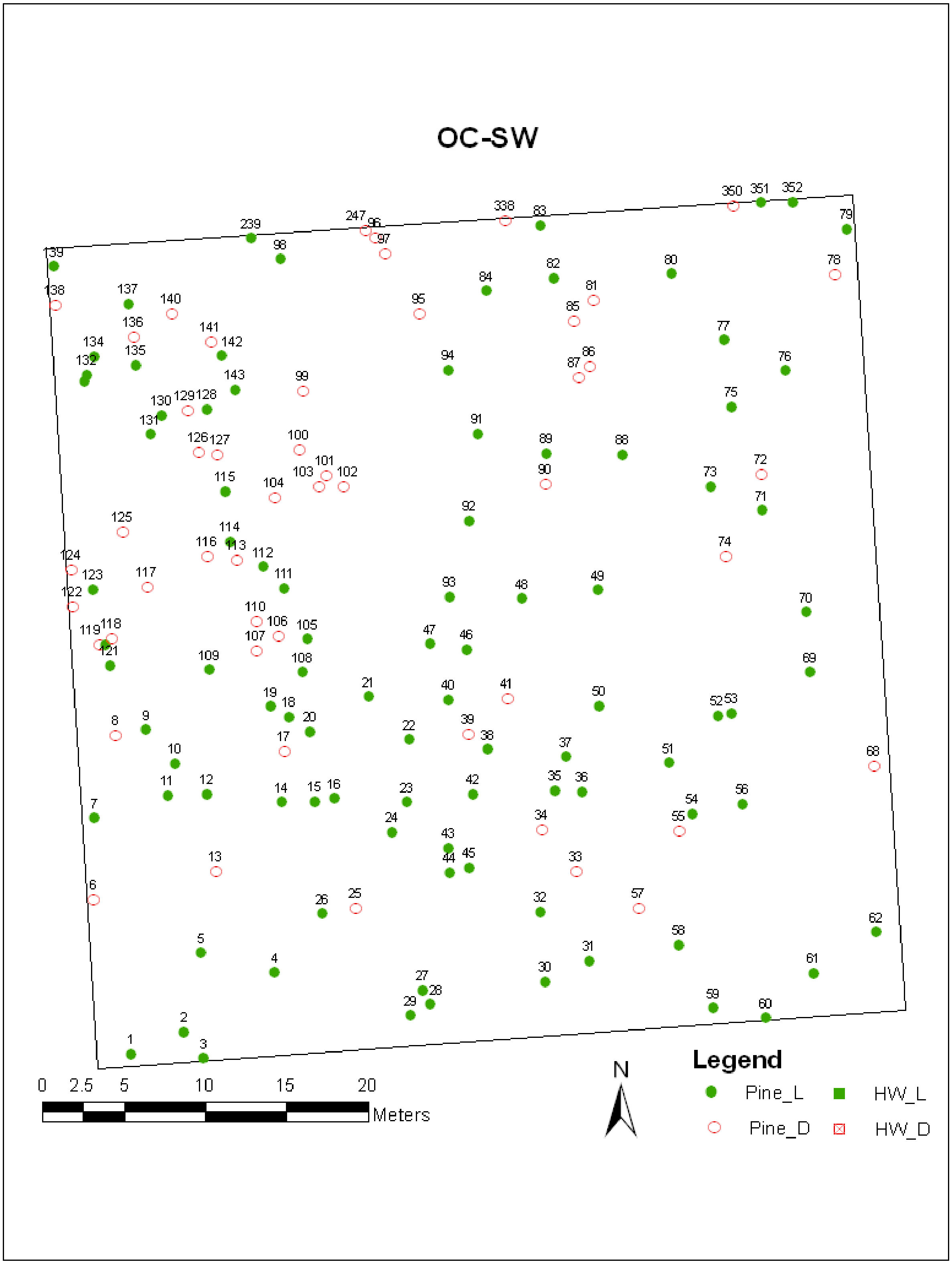
Meters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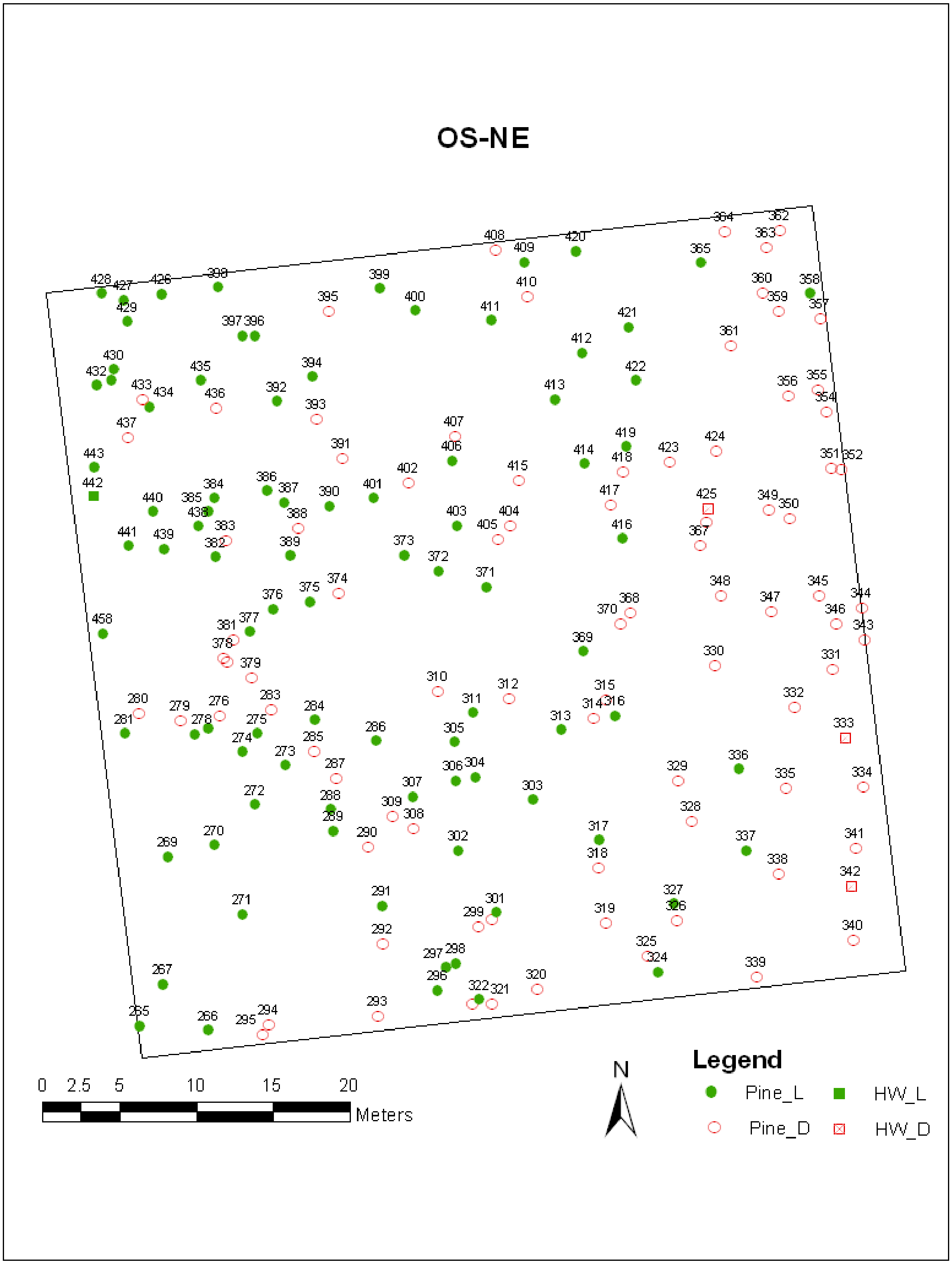
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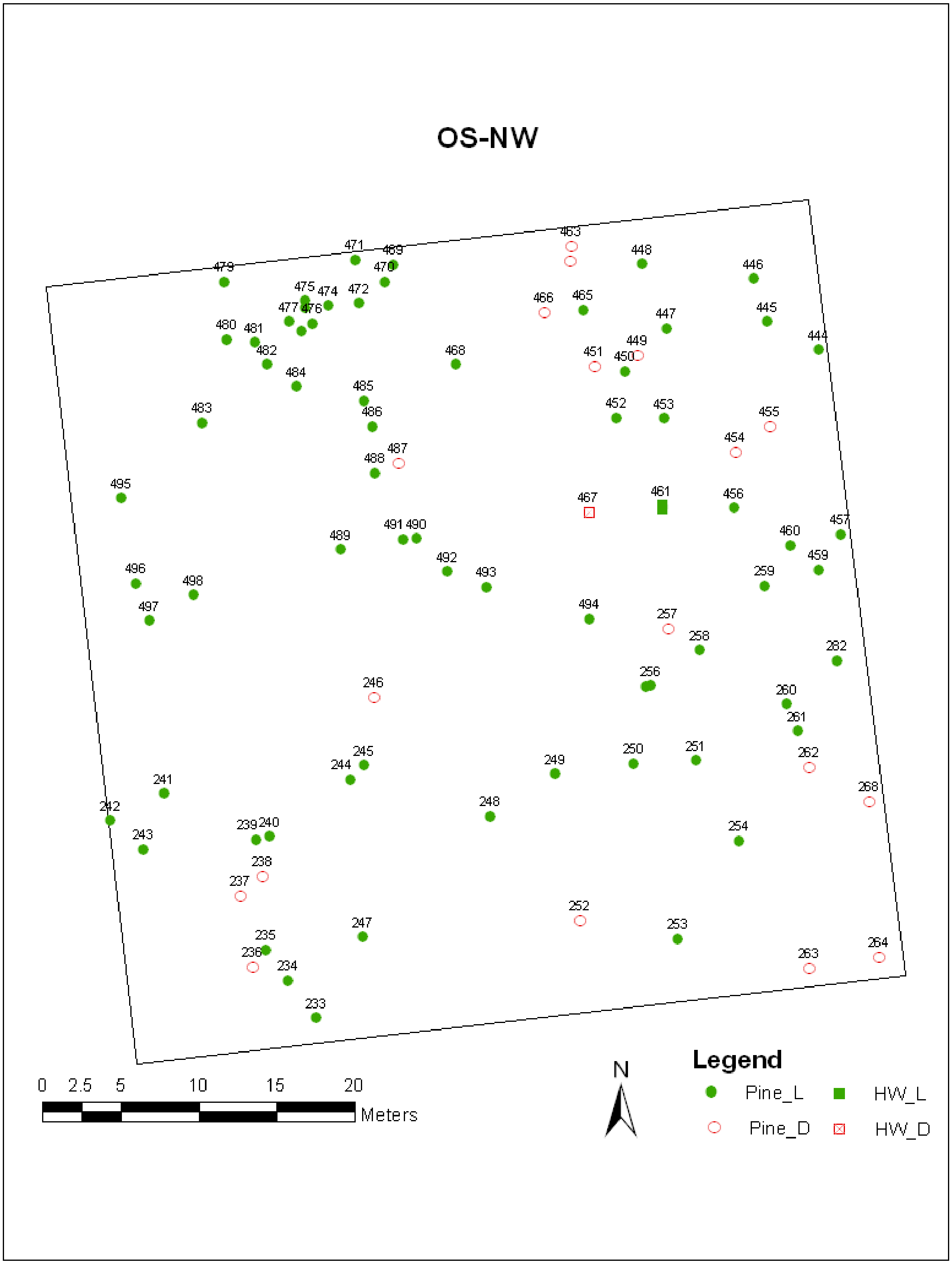
HW_D



OS-NW
Legend
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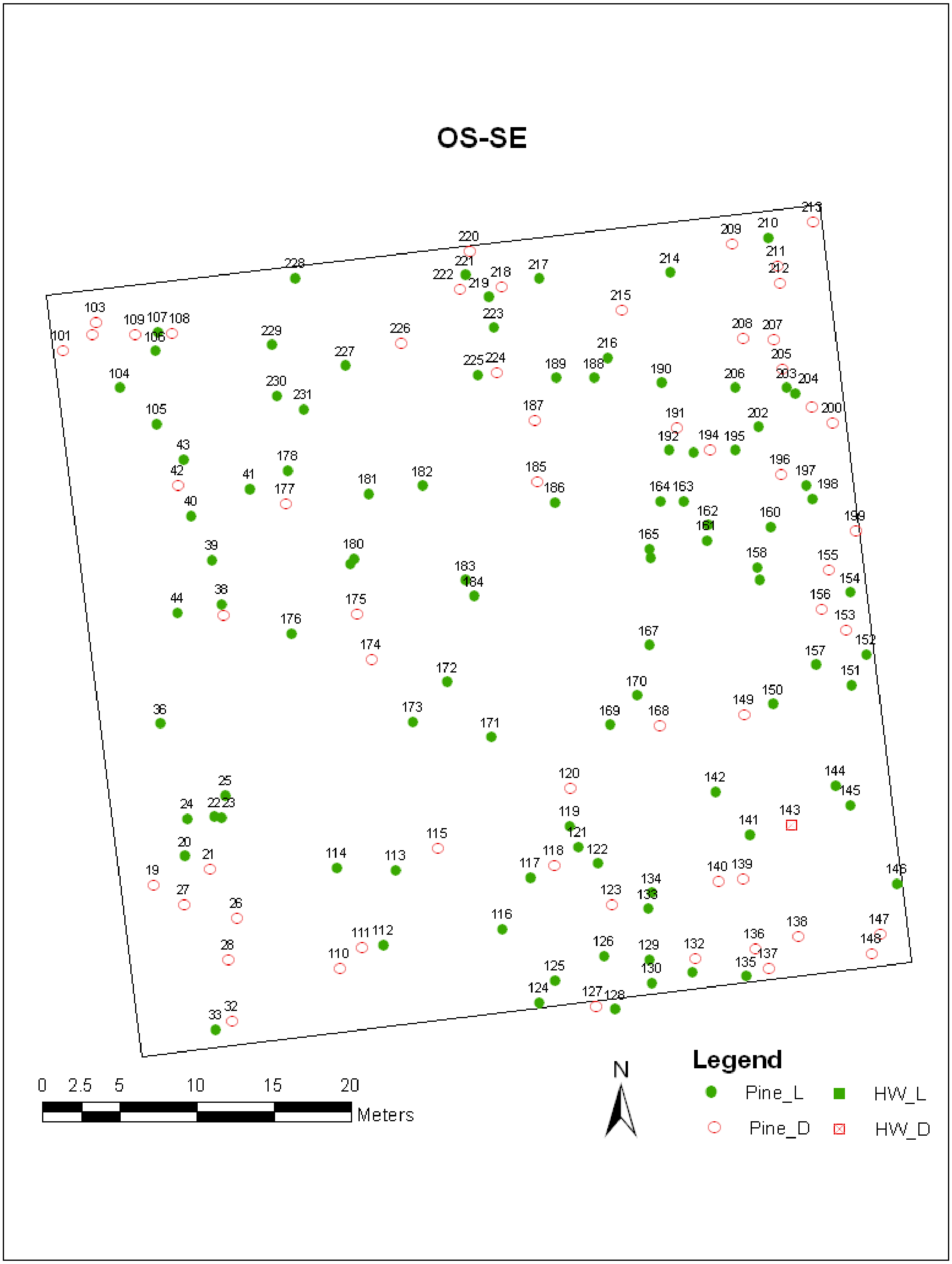
Meters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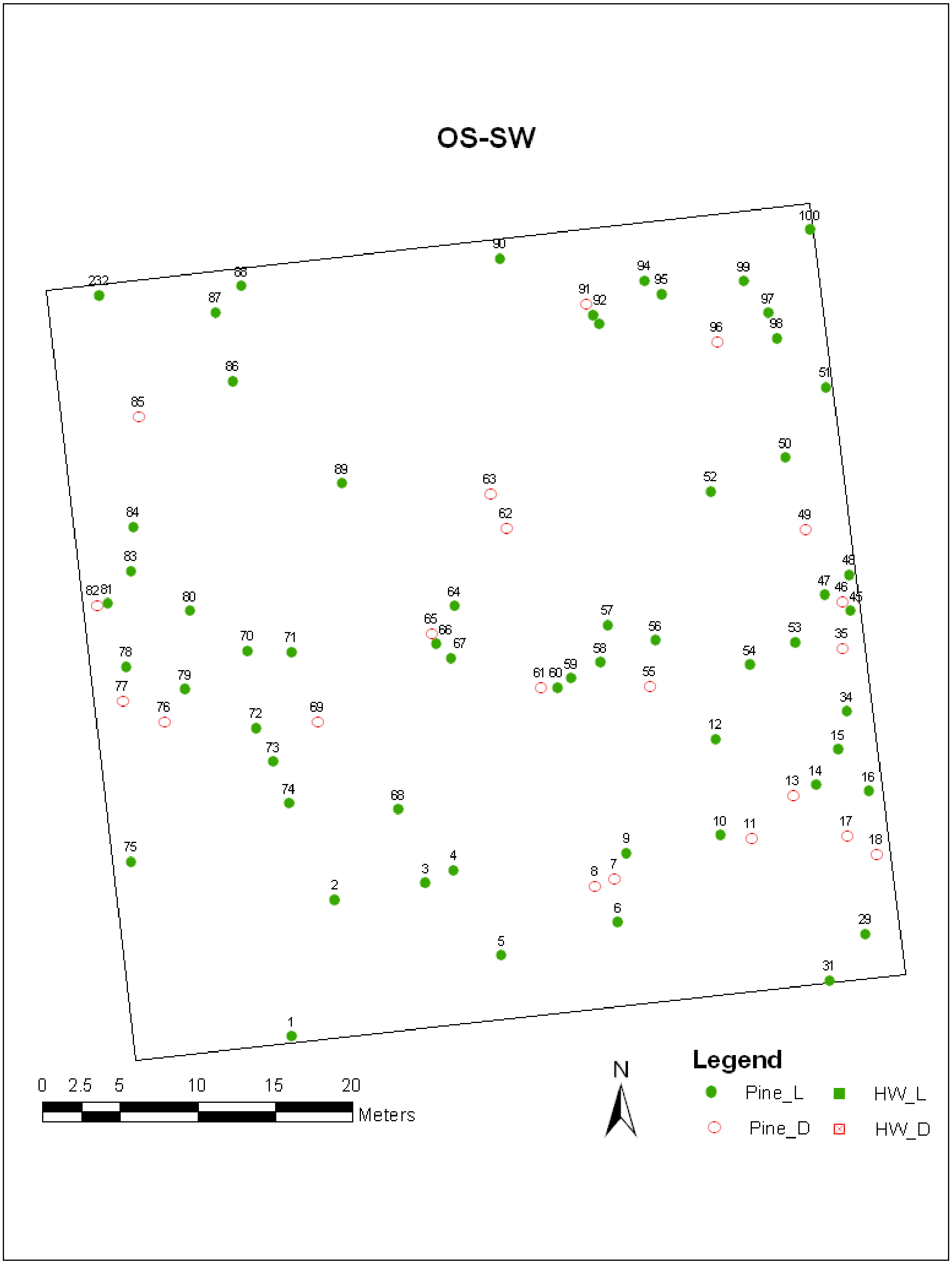
Meters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HW_D
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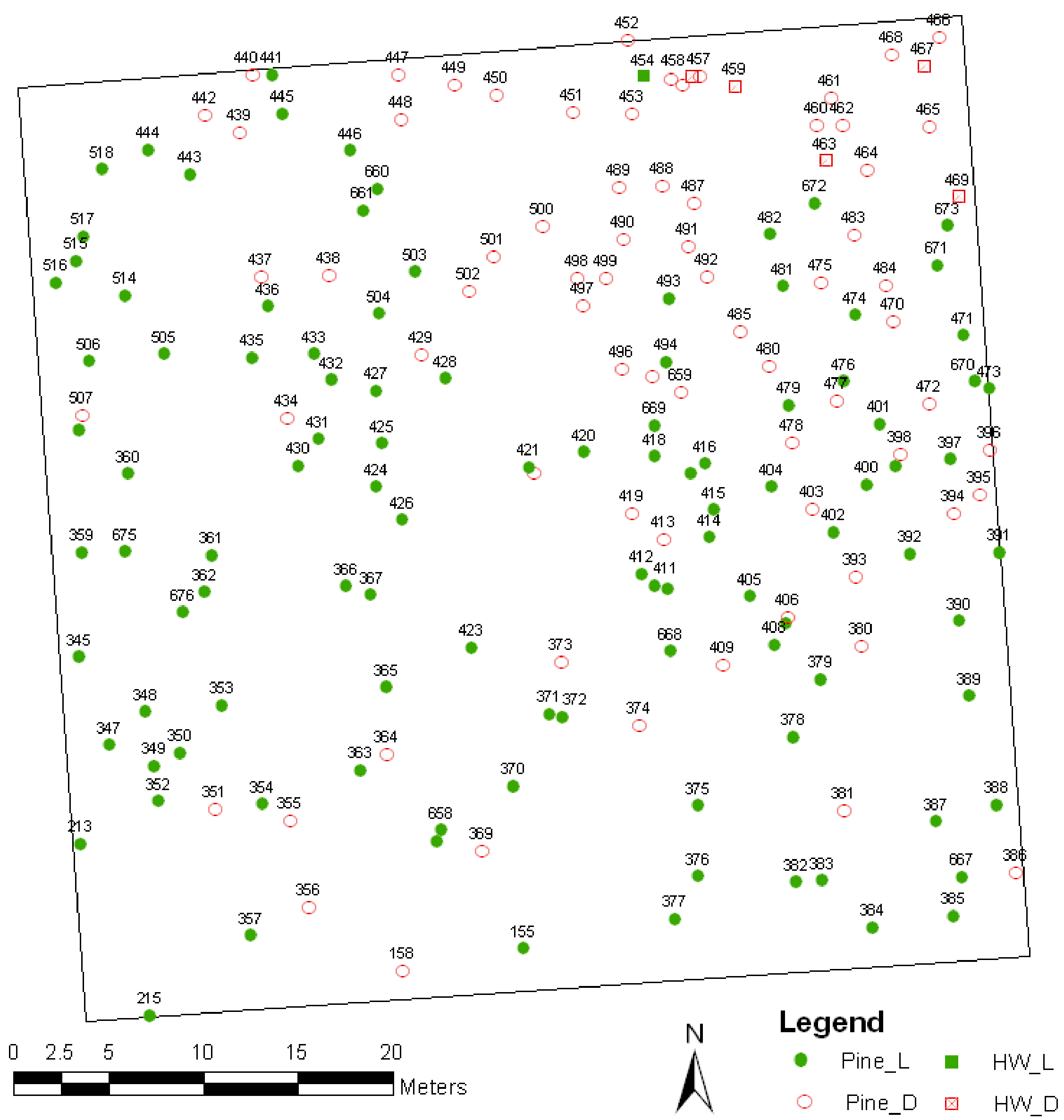
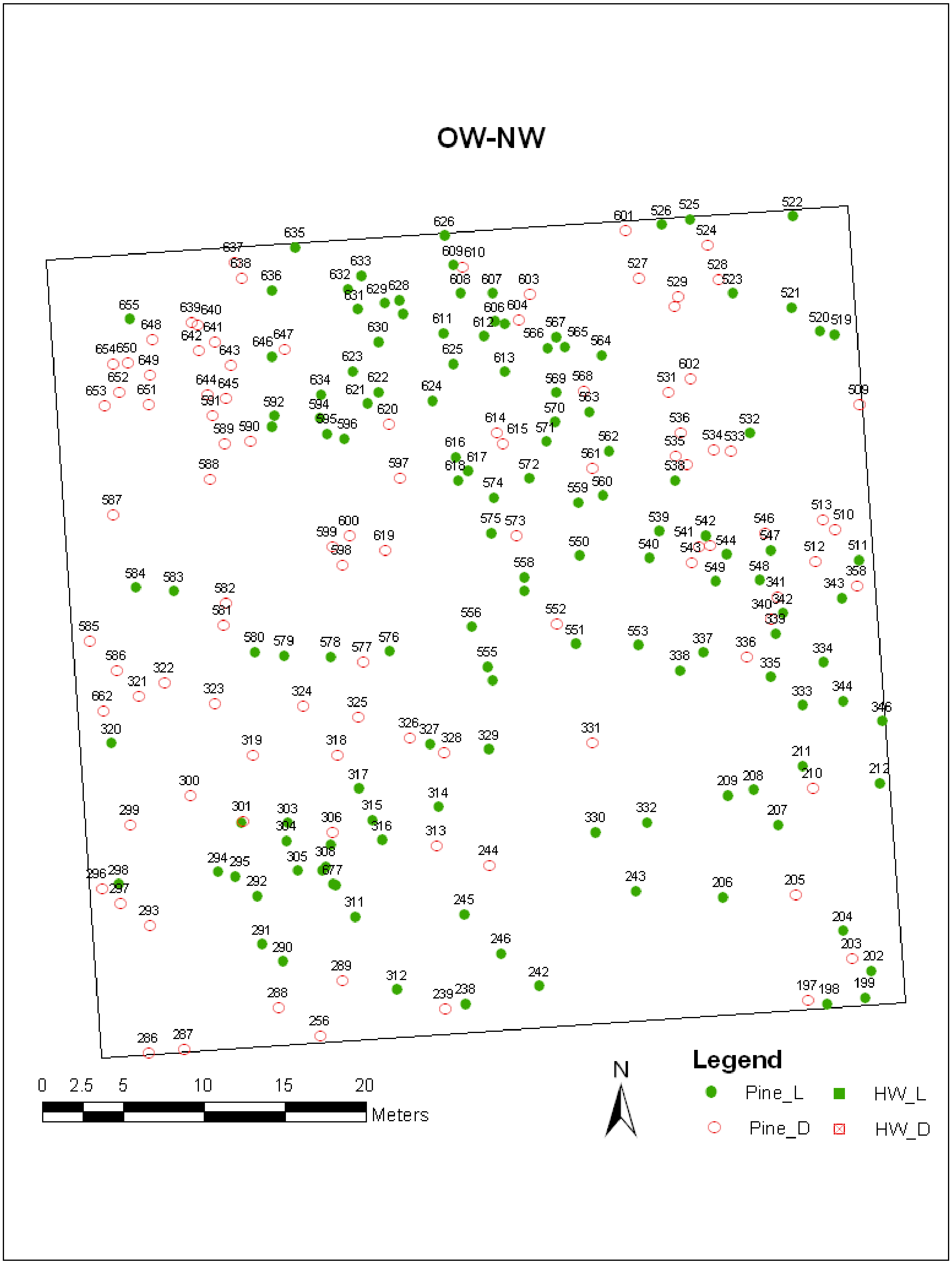
Meters

OW-NE

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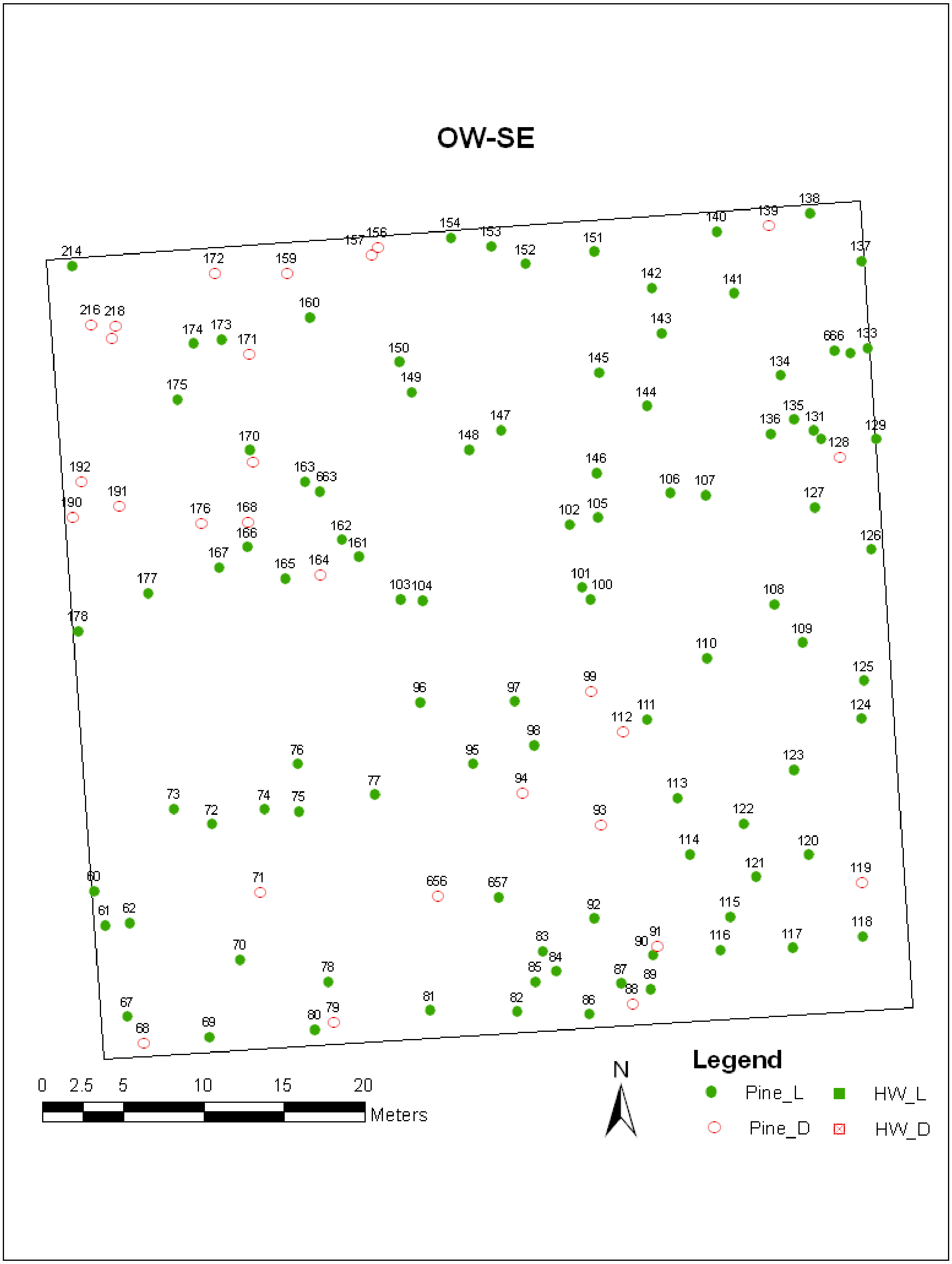
HW_D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Meters
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Legend
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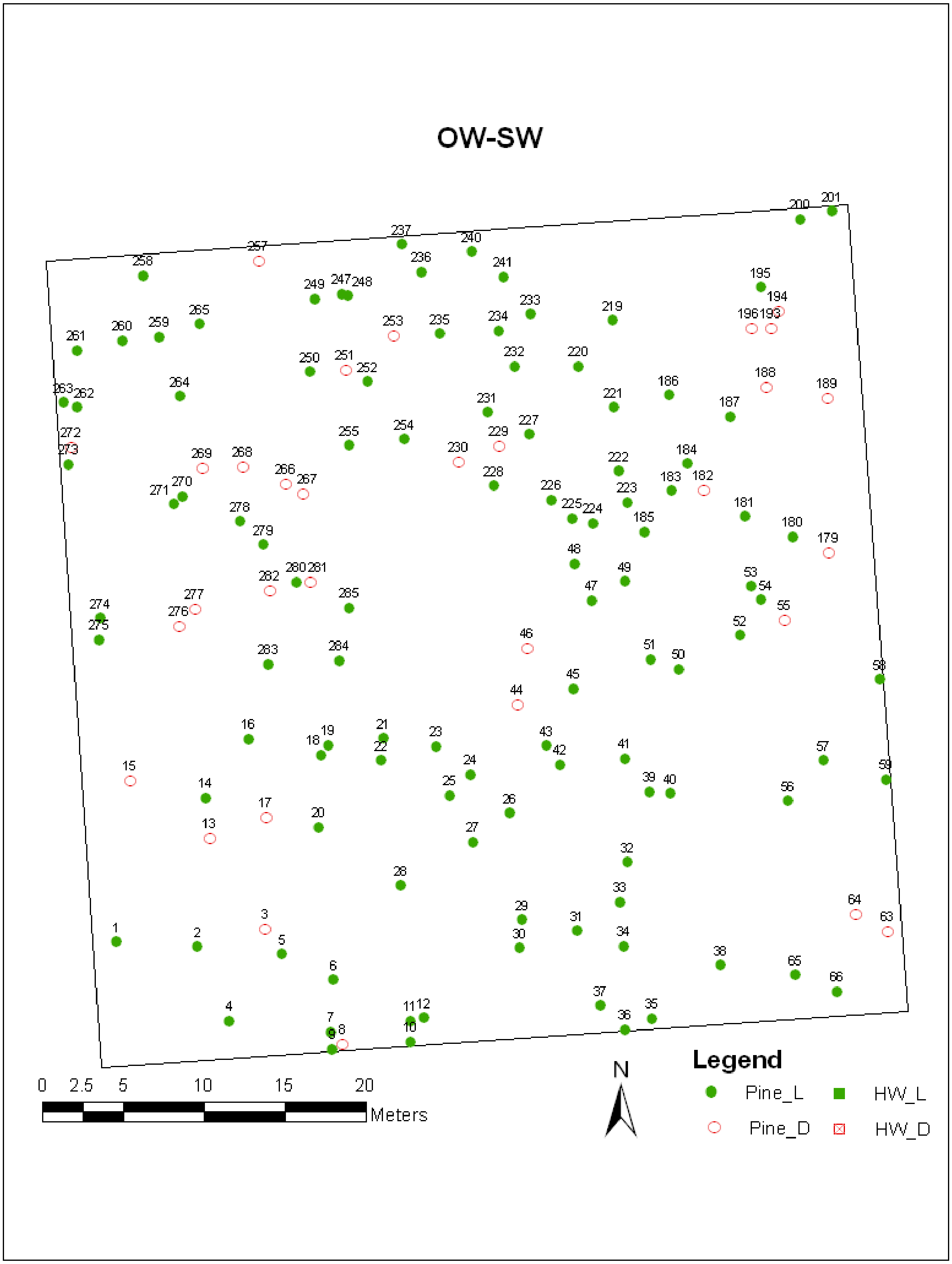
HW_L
Pine_D
HW_D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Meters
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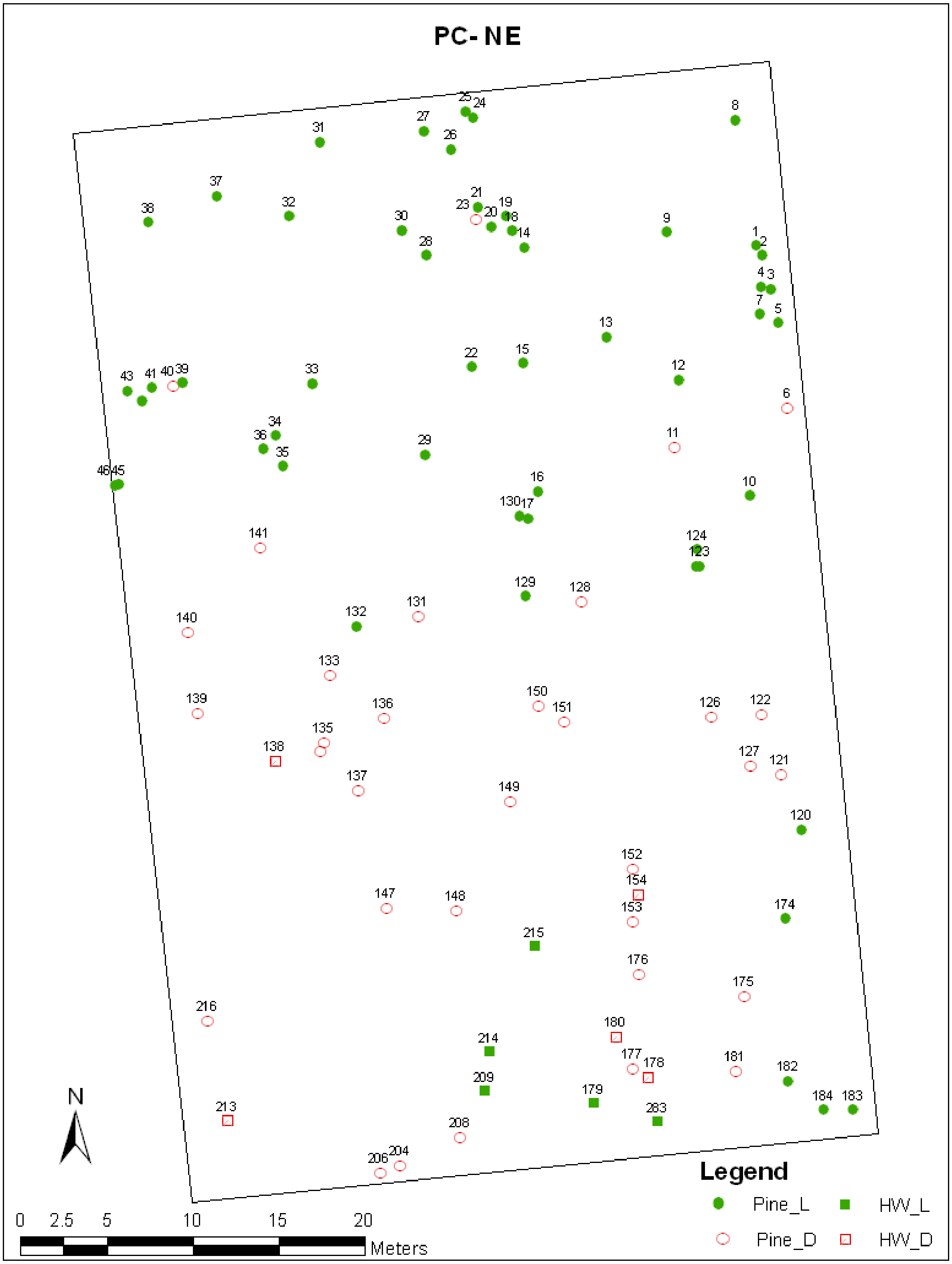
Pine_D
HW_D


PC- NE
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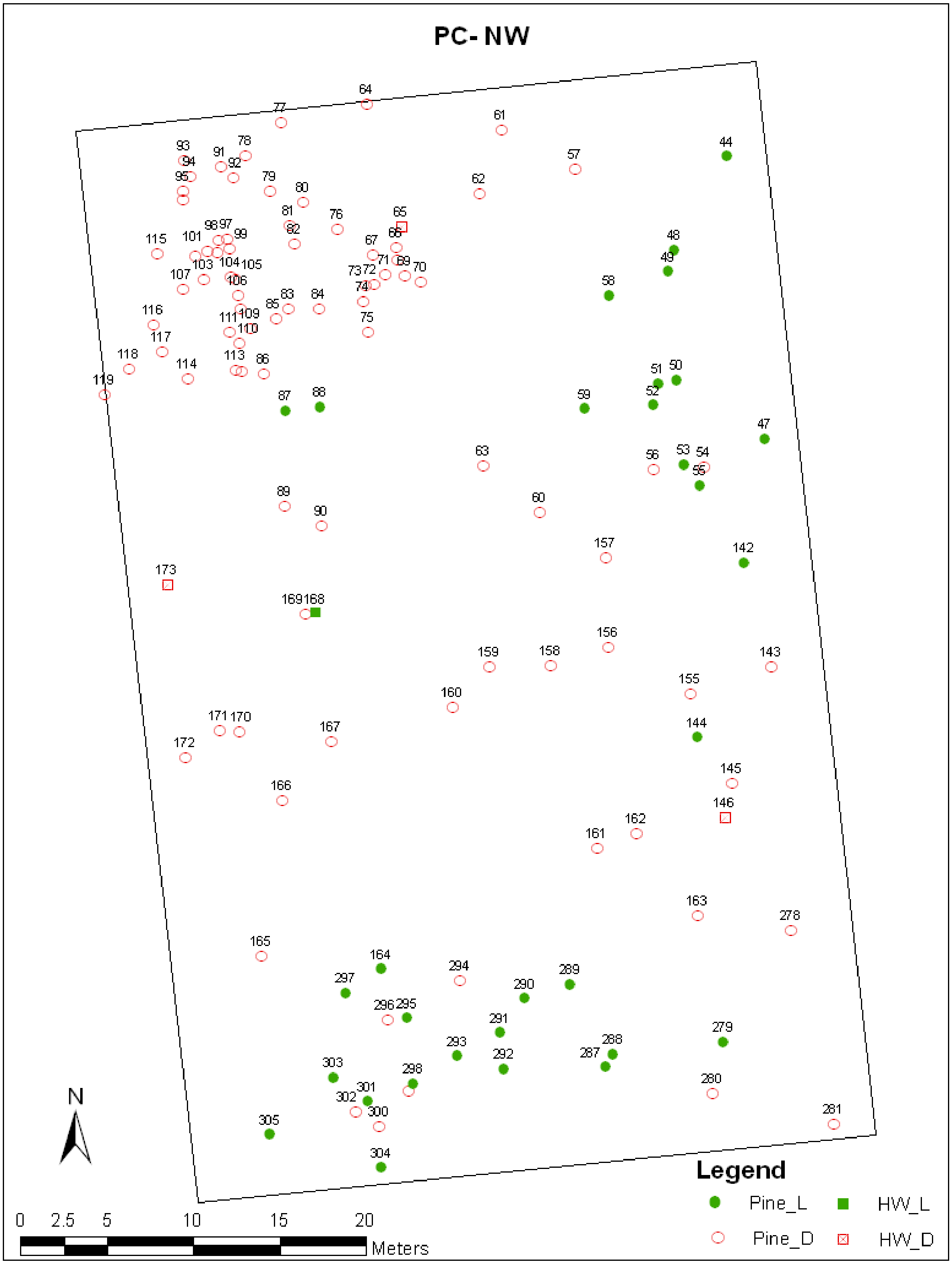
HW_L
Pine_D
HW_D



PC- NW
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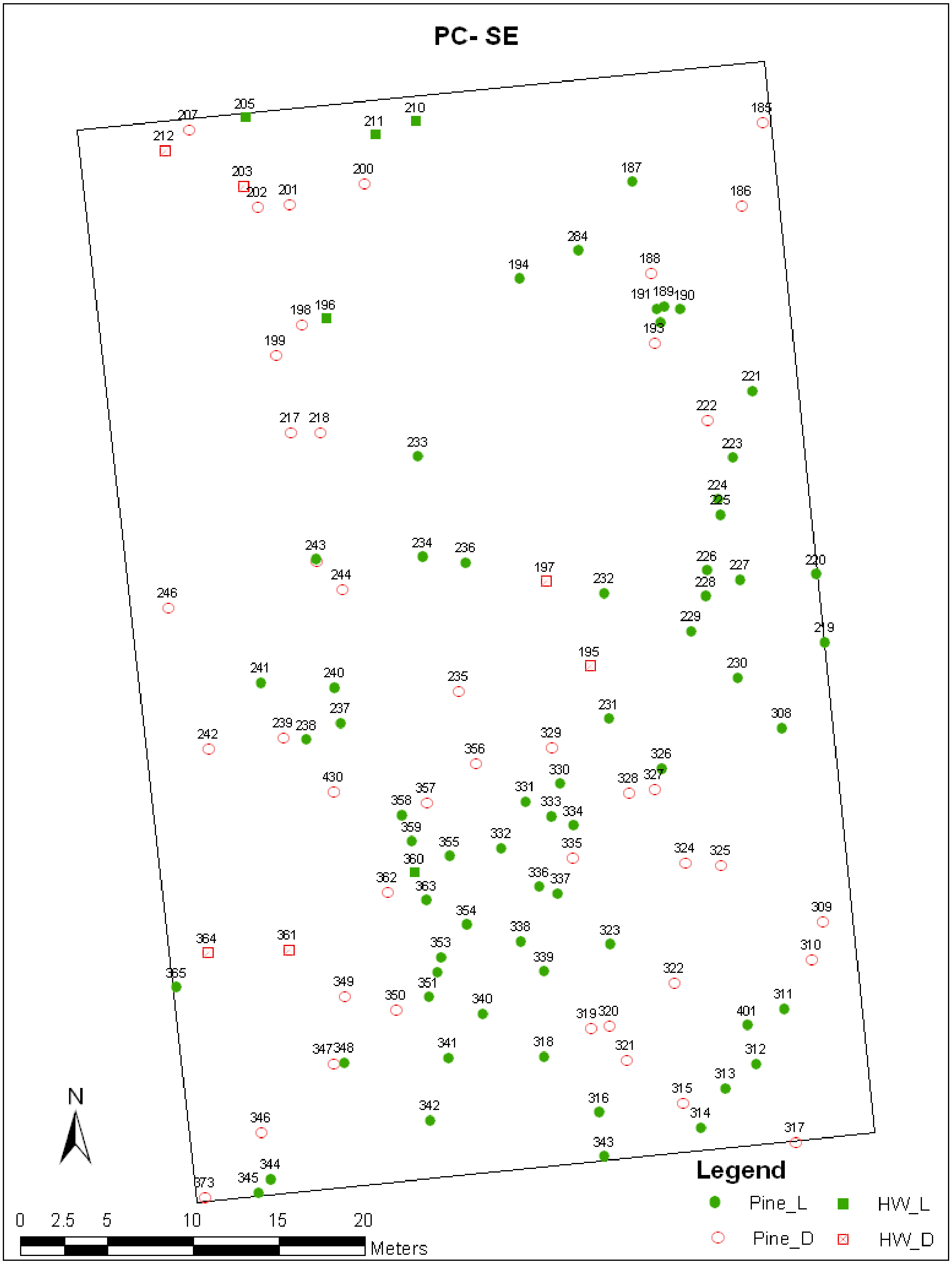
HW_D



PC- SE
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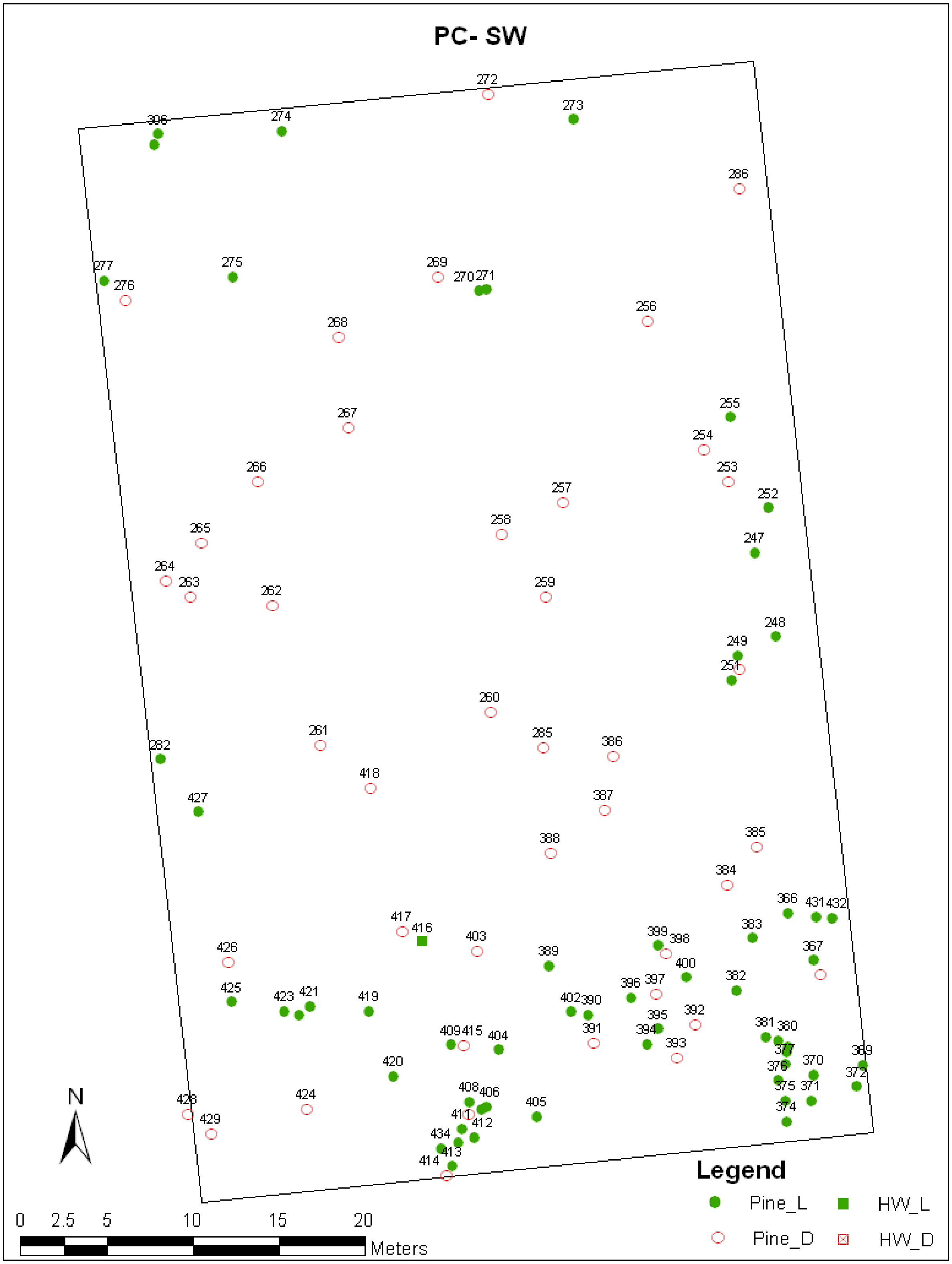
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HW_L
Pine_D
HW_D
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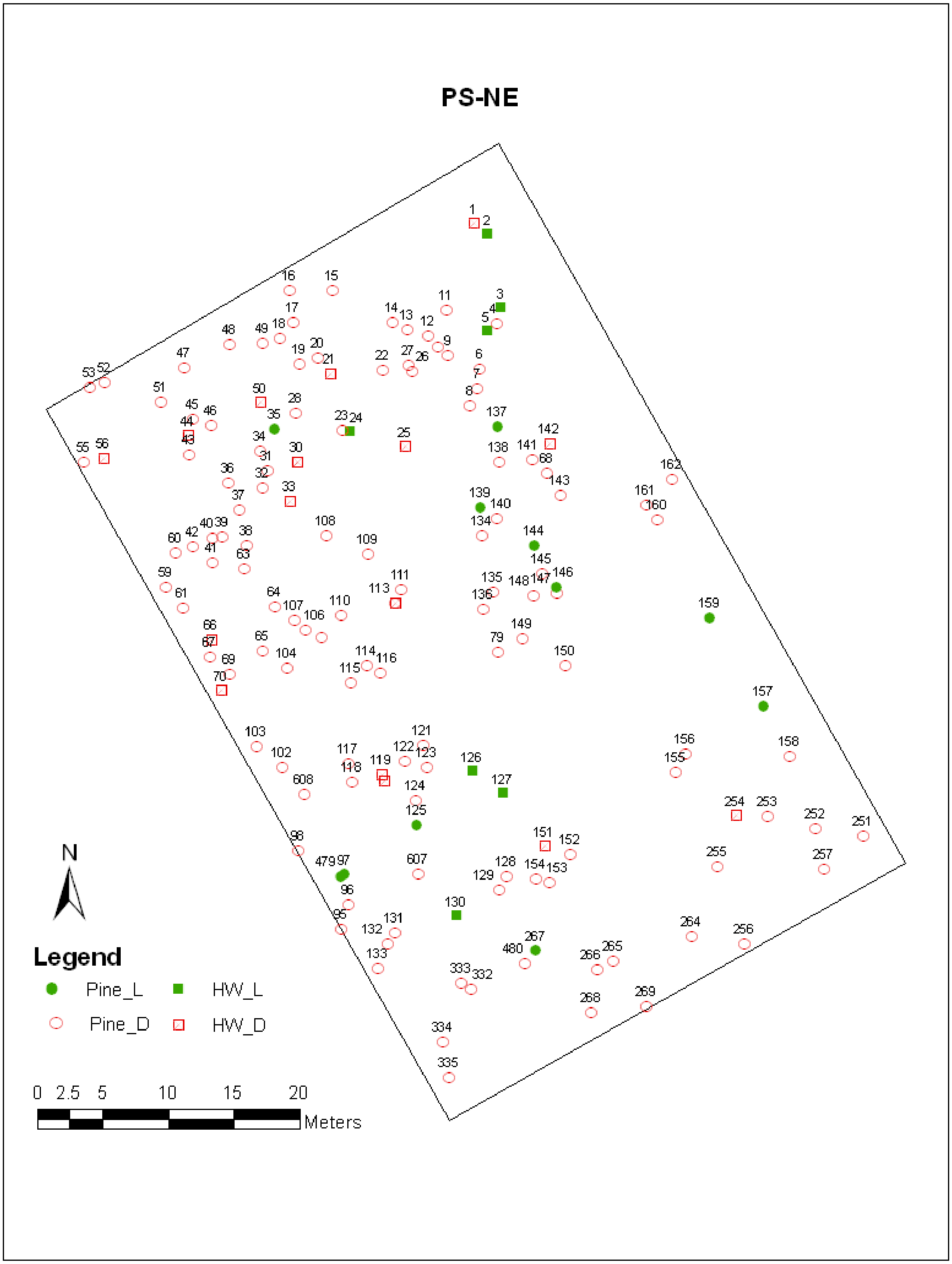
Meters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HW_L
Pine_D
HW_D
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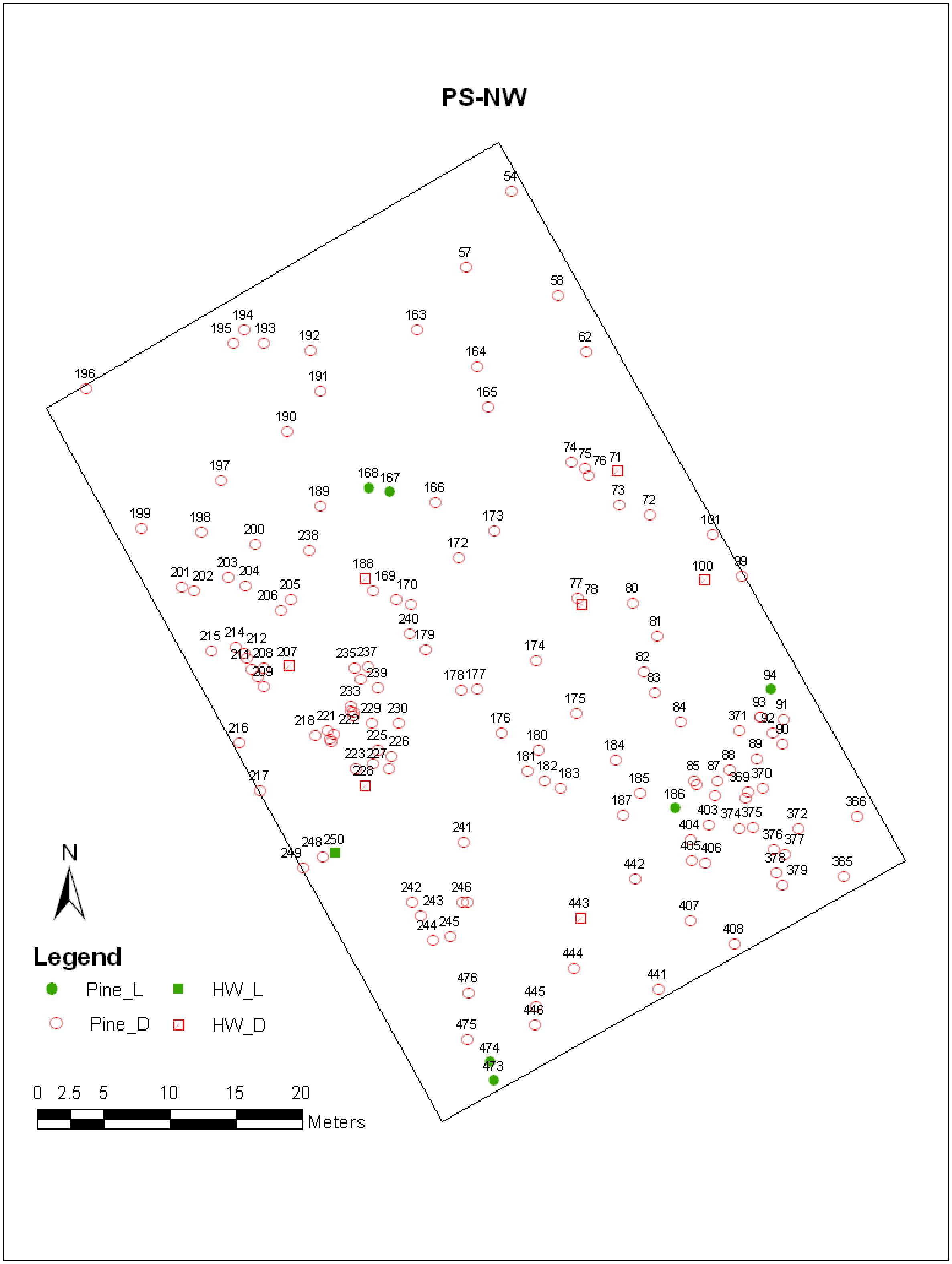
Meters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HW_D
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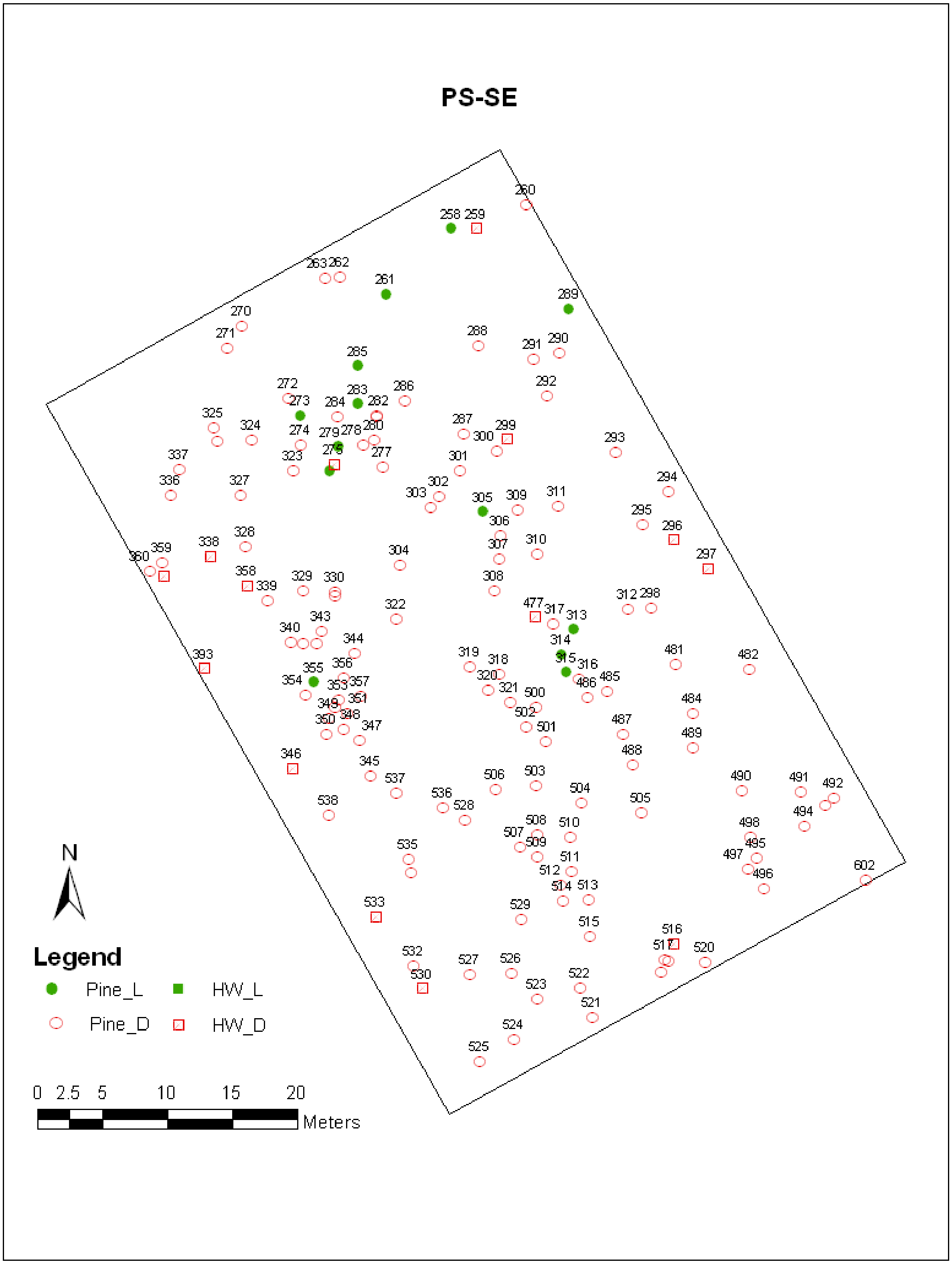
Meters



PS-SE
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HW_L
Pine_D
HW_D
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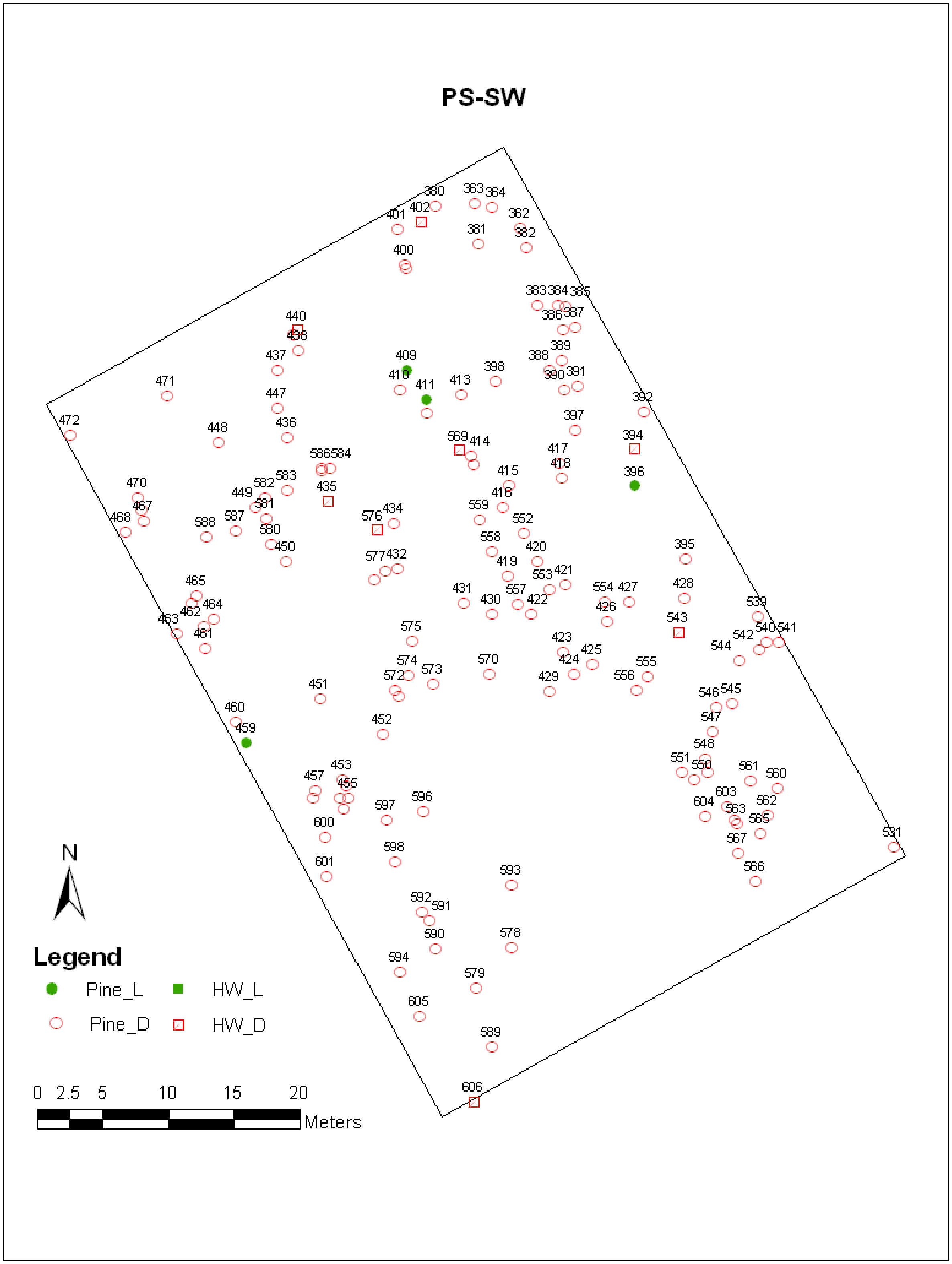
Meters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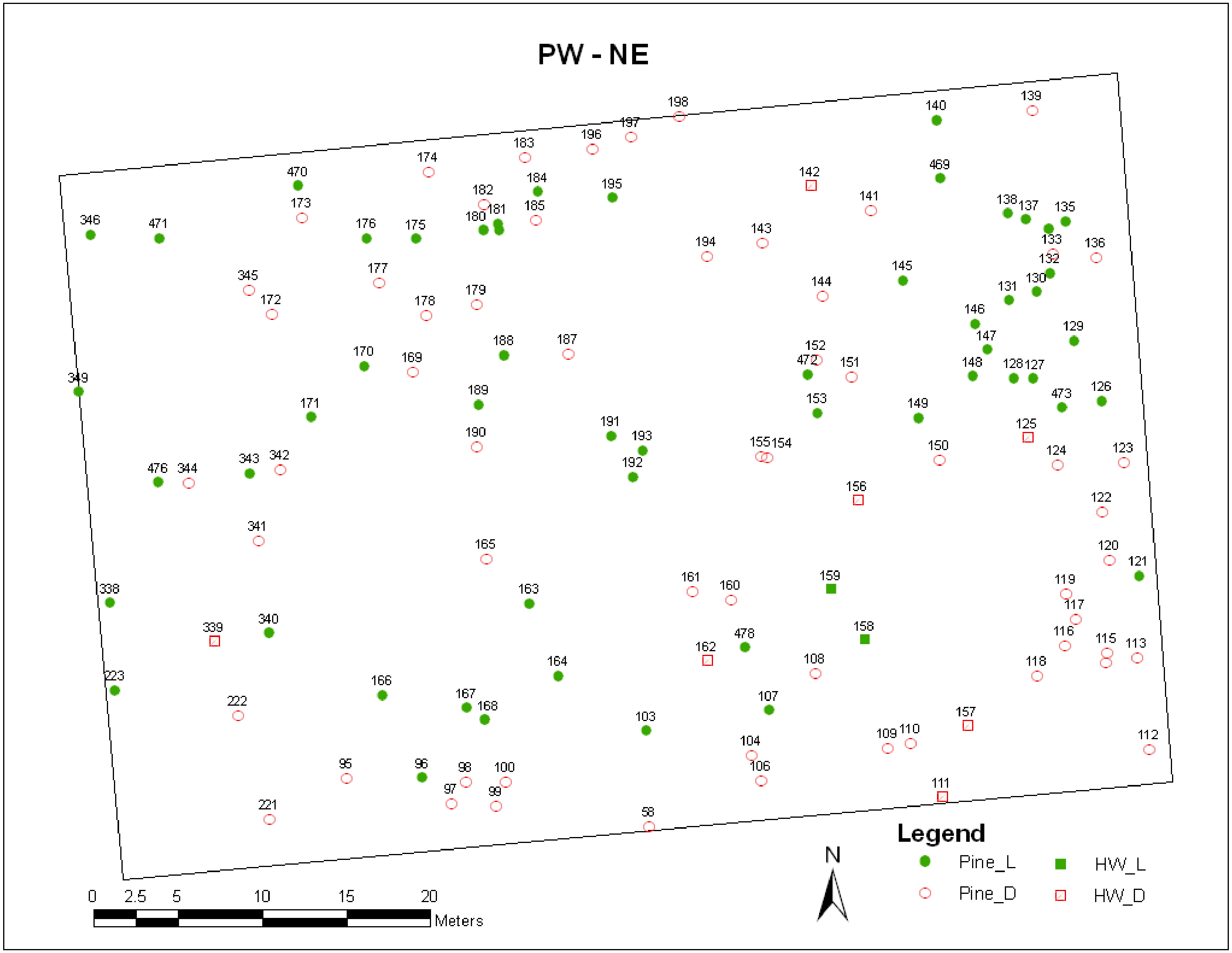
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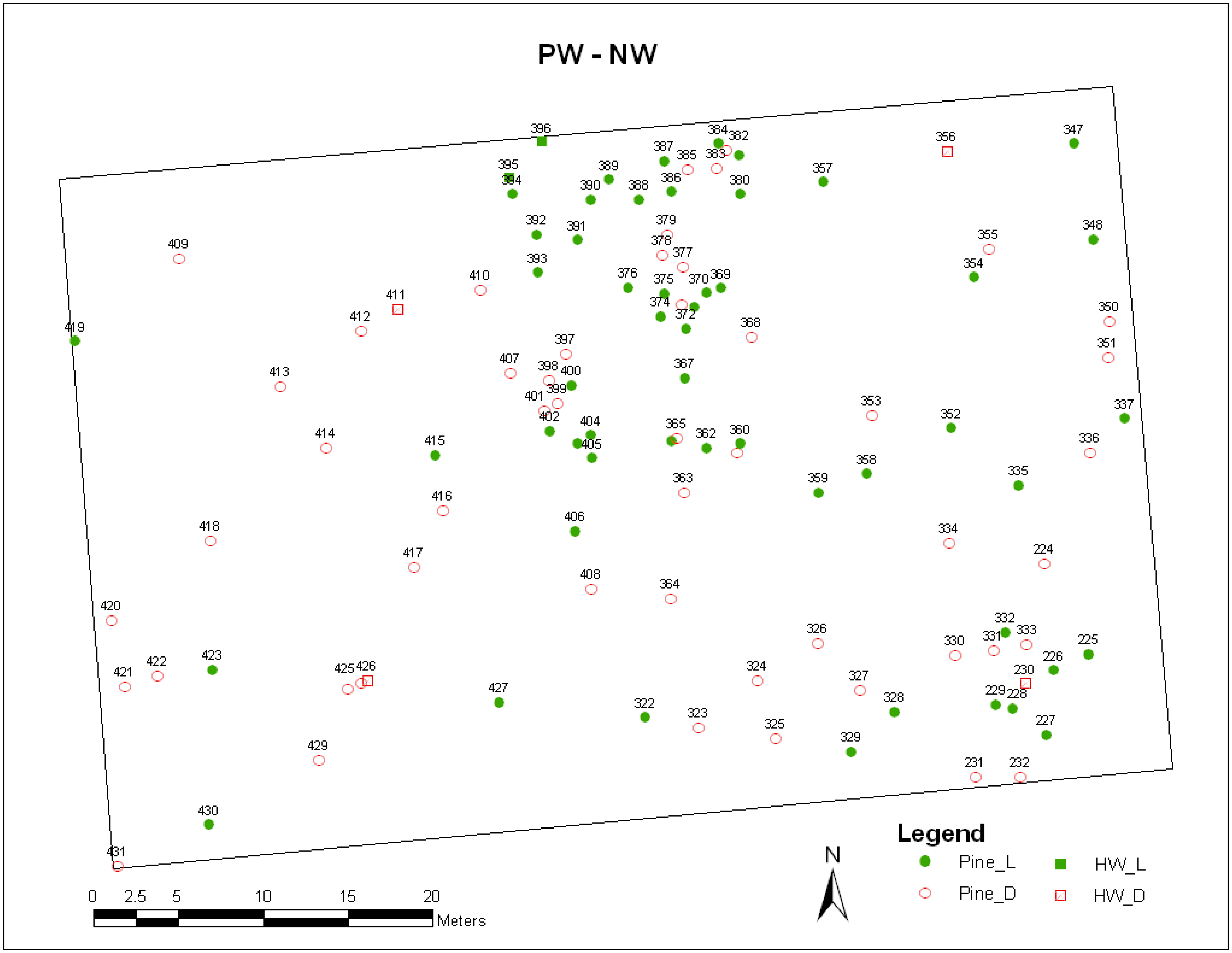
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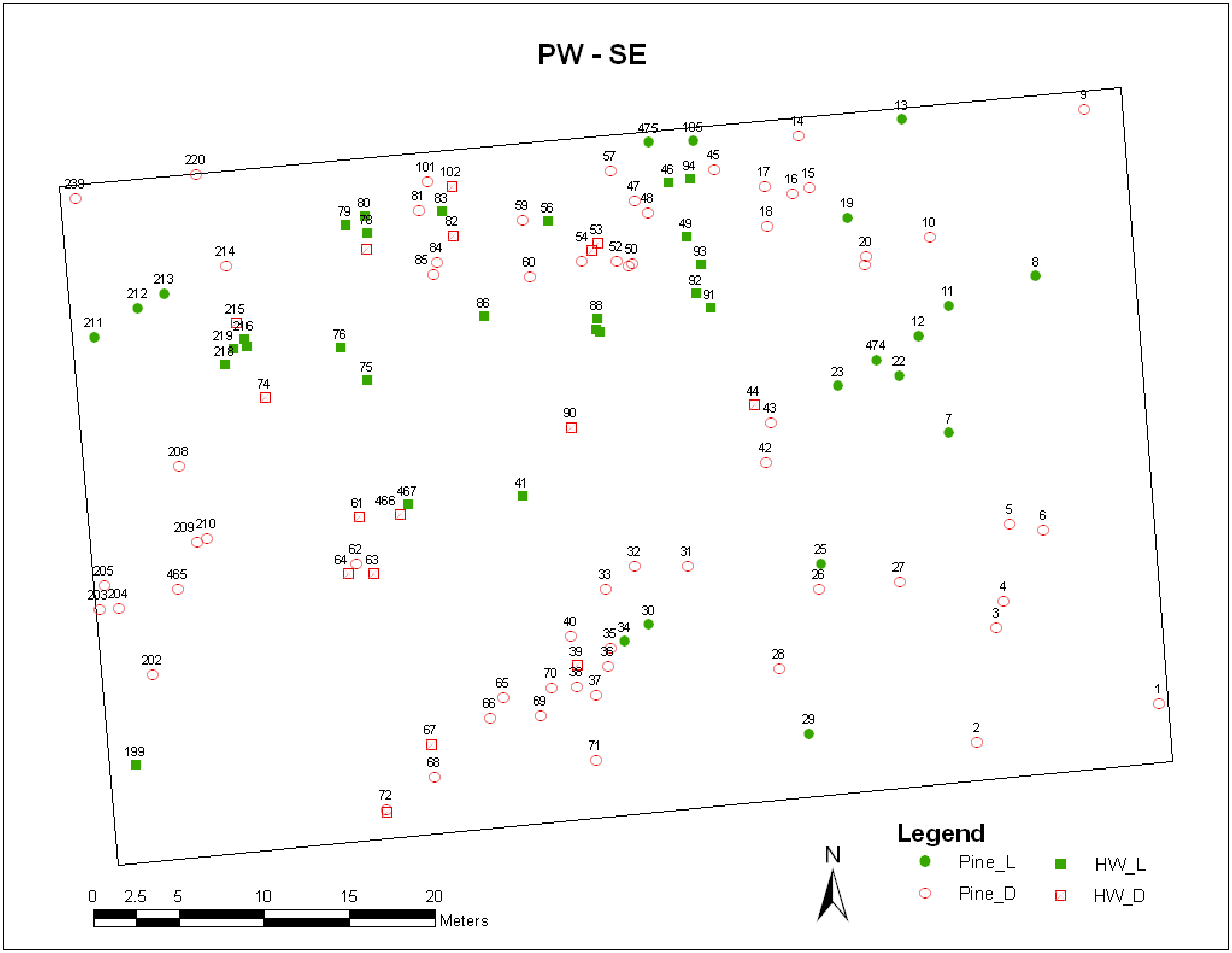
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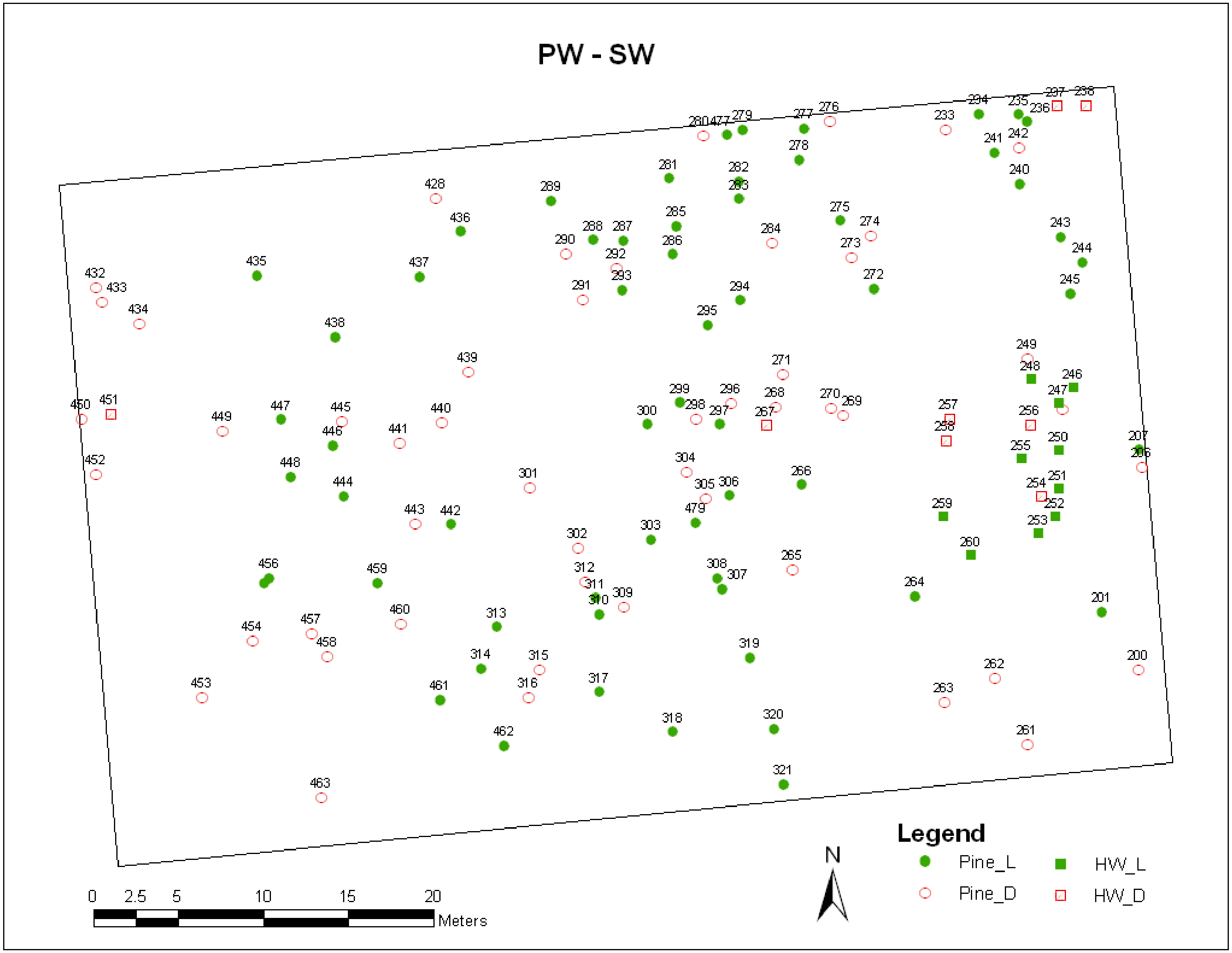
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Pine_D
HW_L
HW_D
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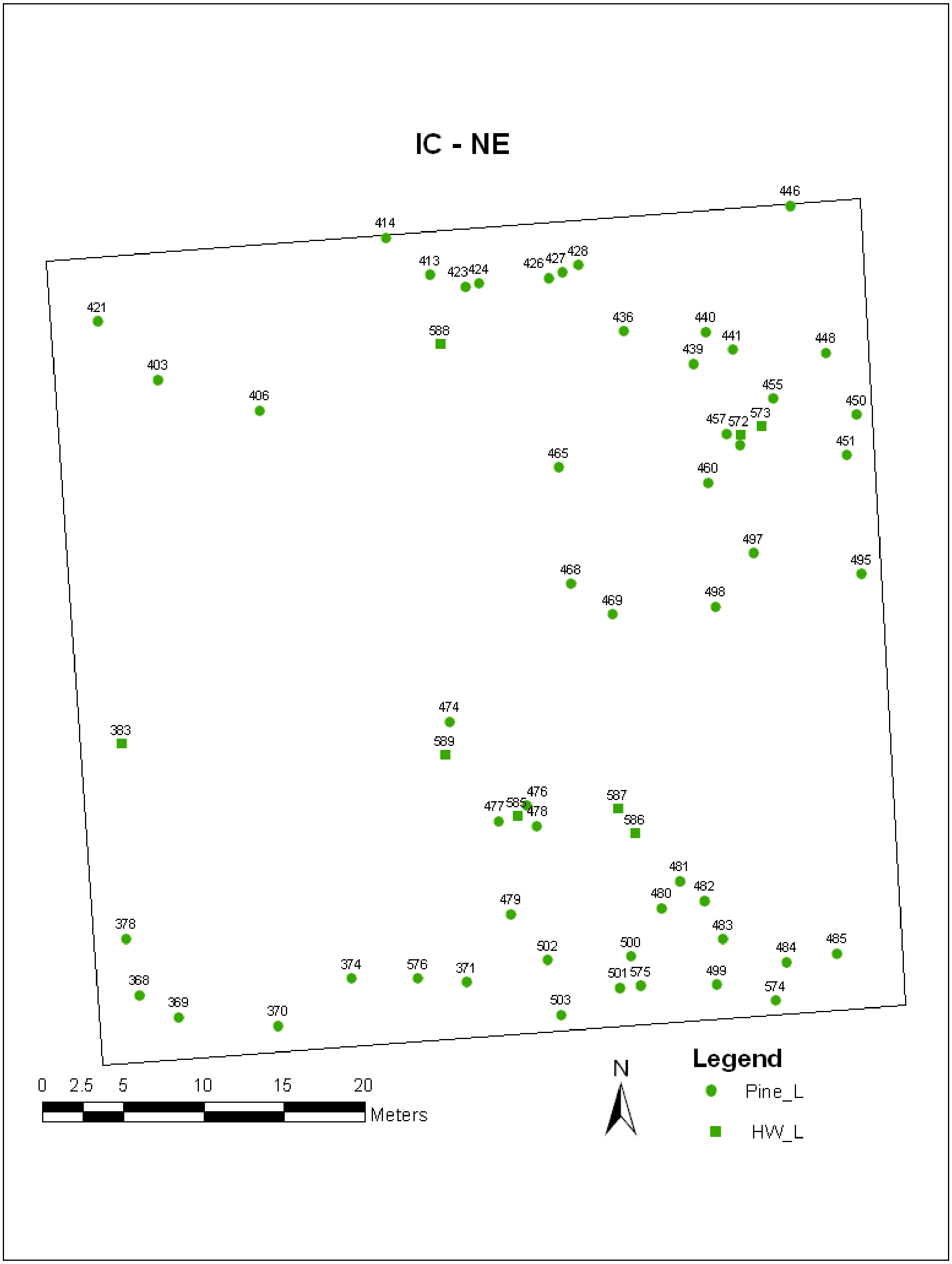
Meters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Meters
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Legend
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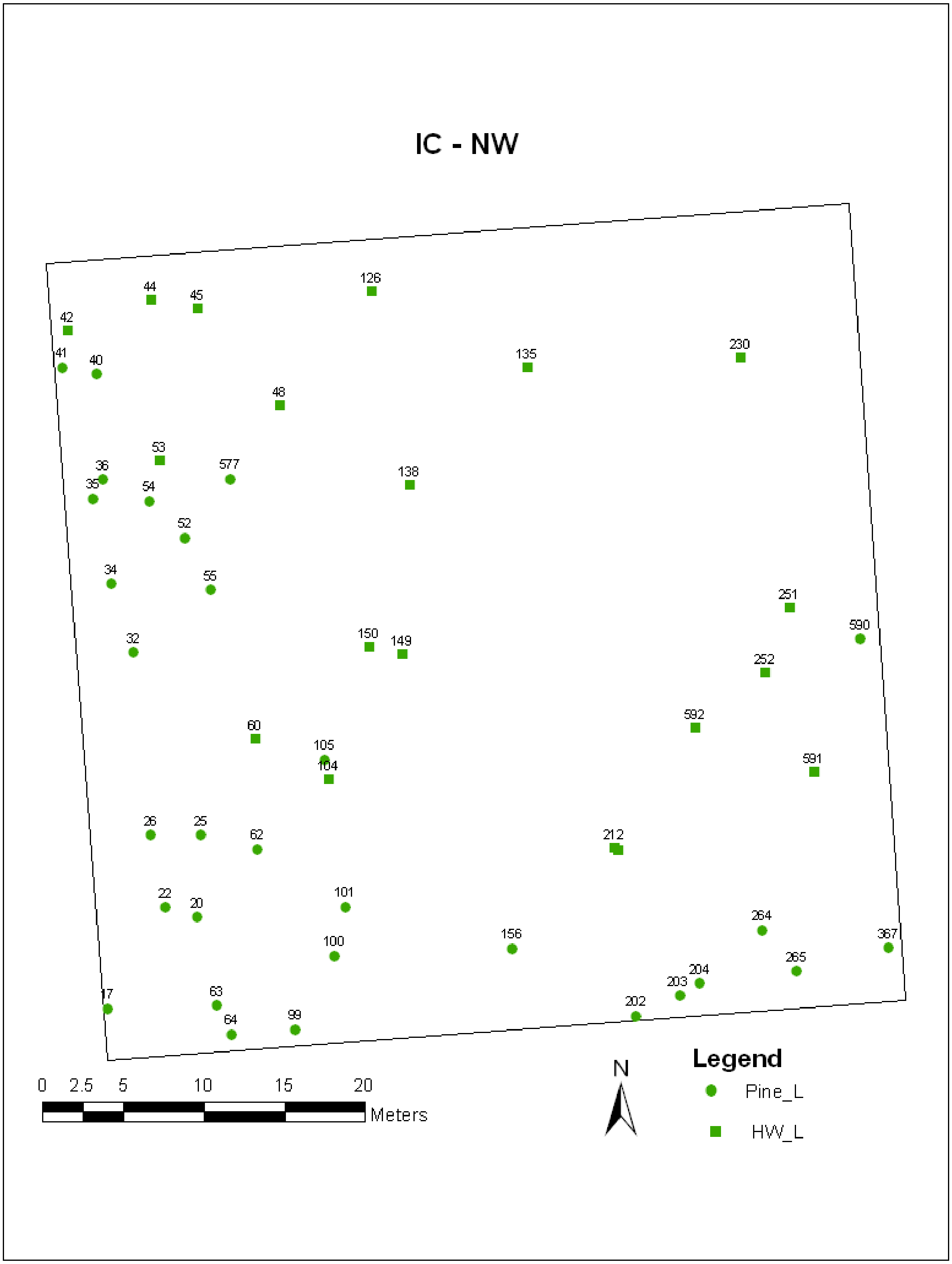
HW_L



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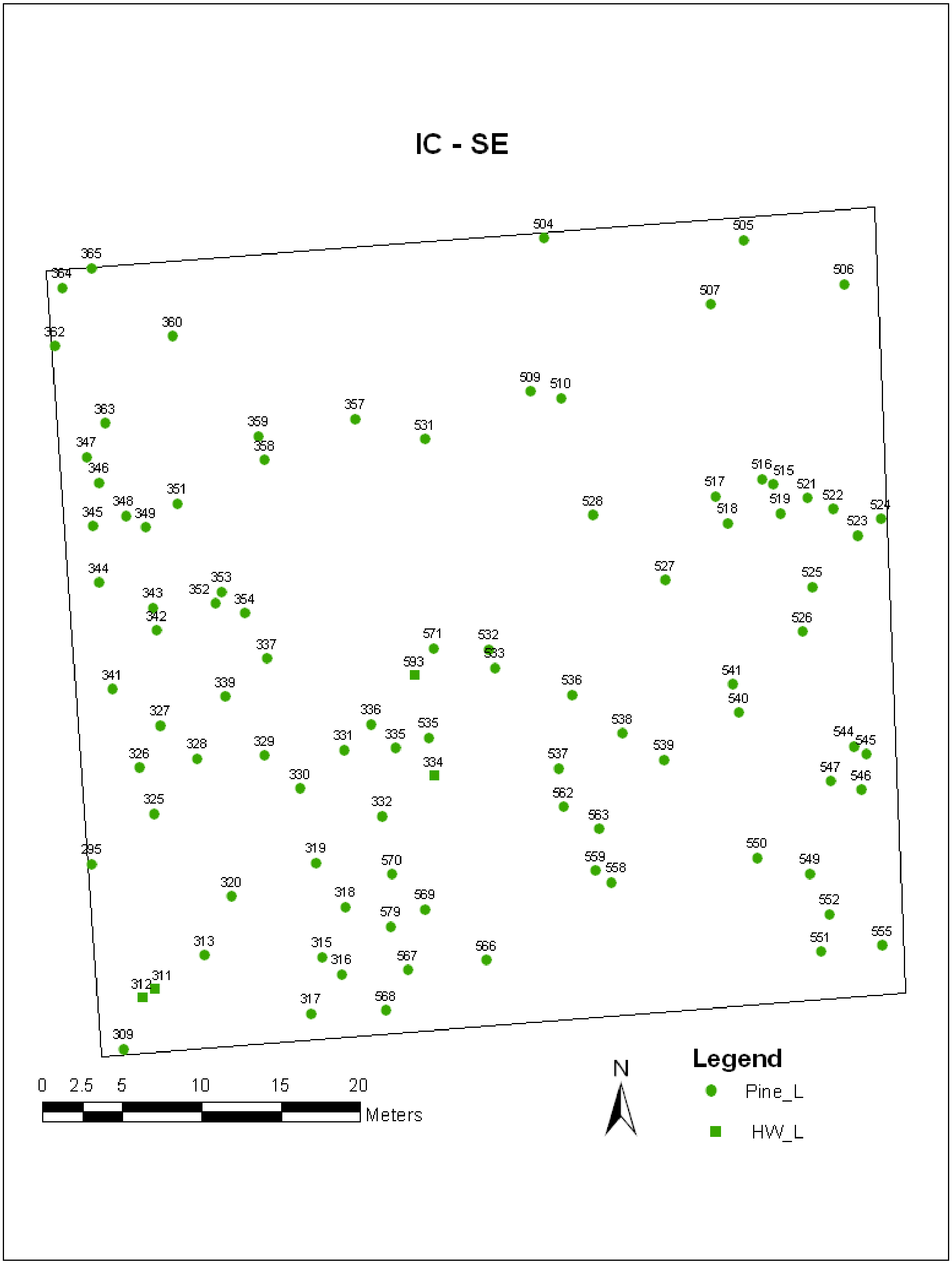
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Meters
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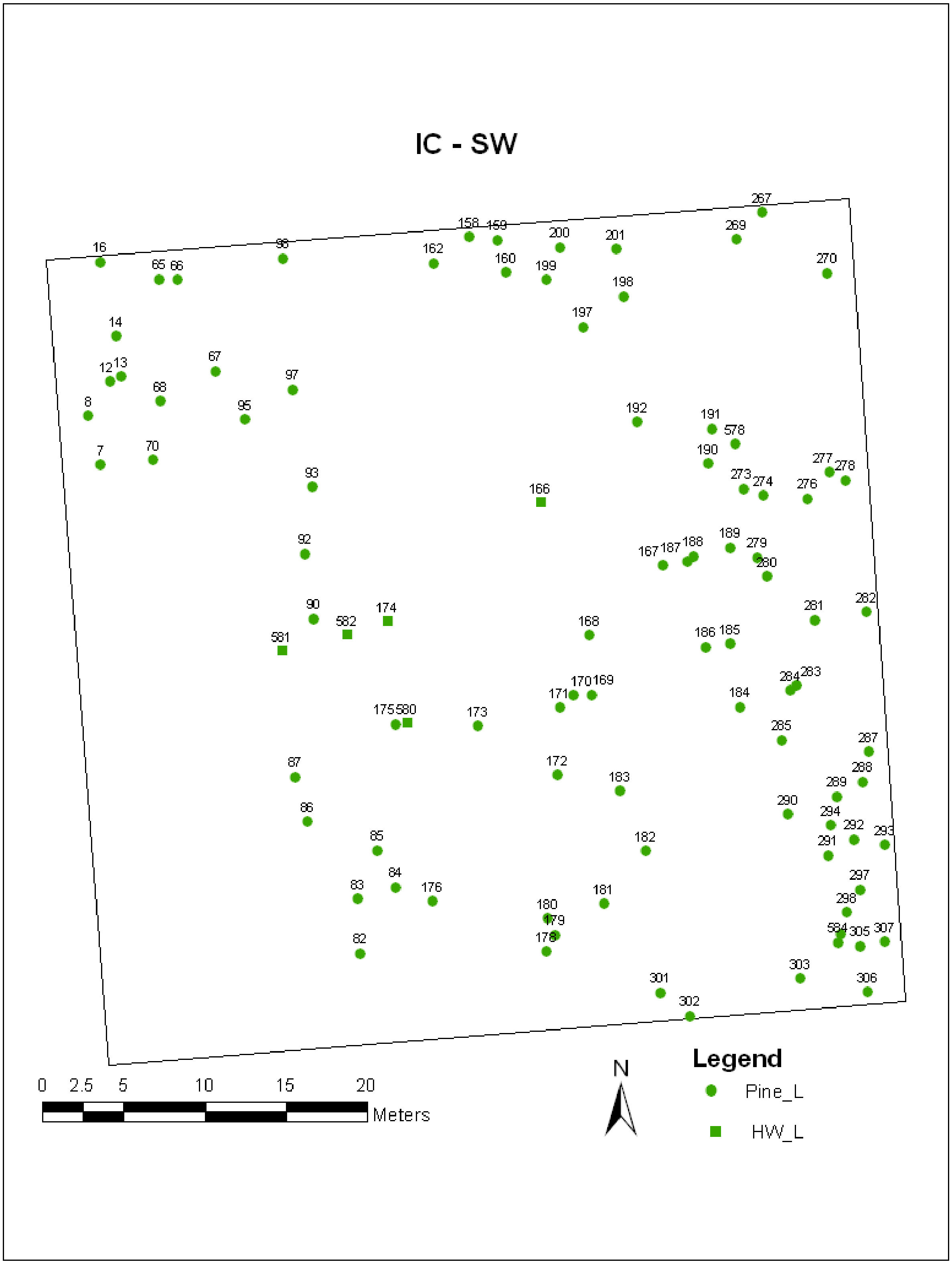
Legend
Pine_L
HW_L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284 283
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Meters
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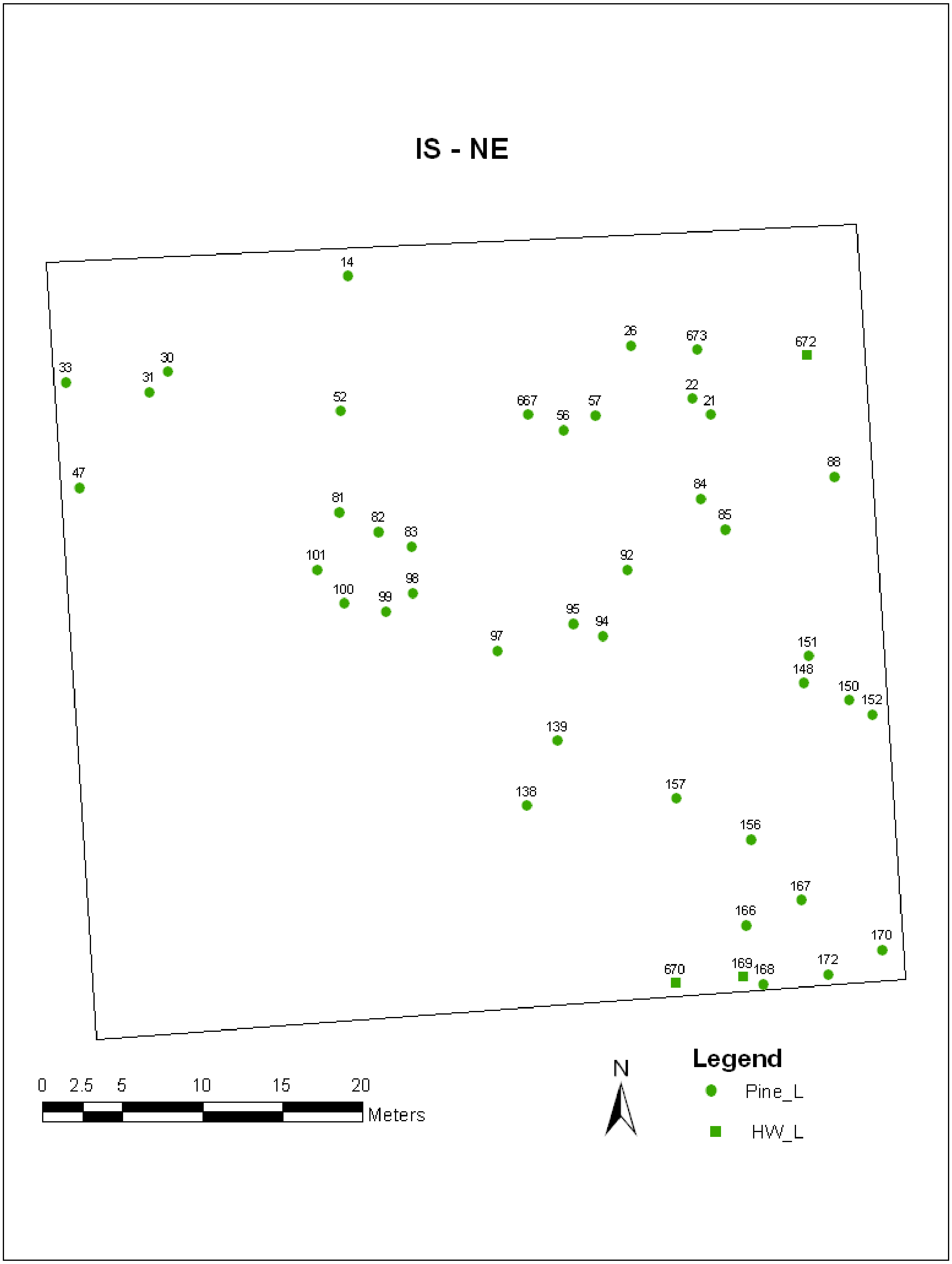
Legend
Pine_L
HW_L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670
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168
172
0 2.5 5 10 15 20
Meters
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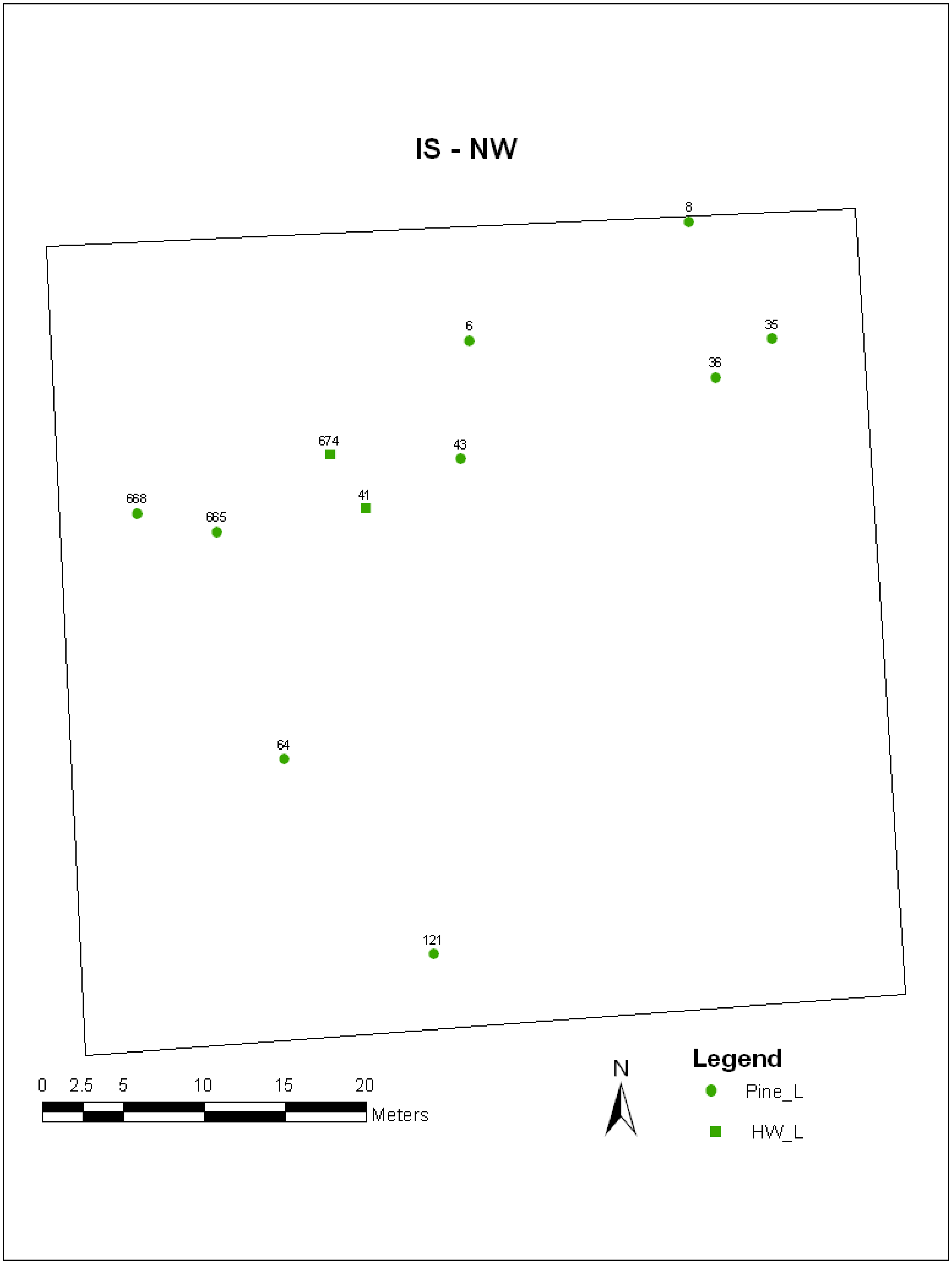
Legend
Pine_L
HW_L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Meters
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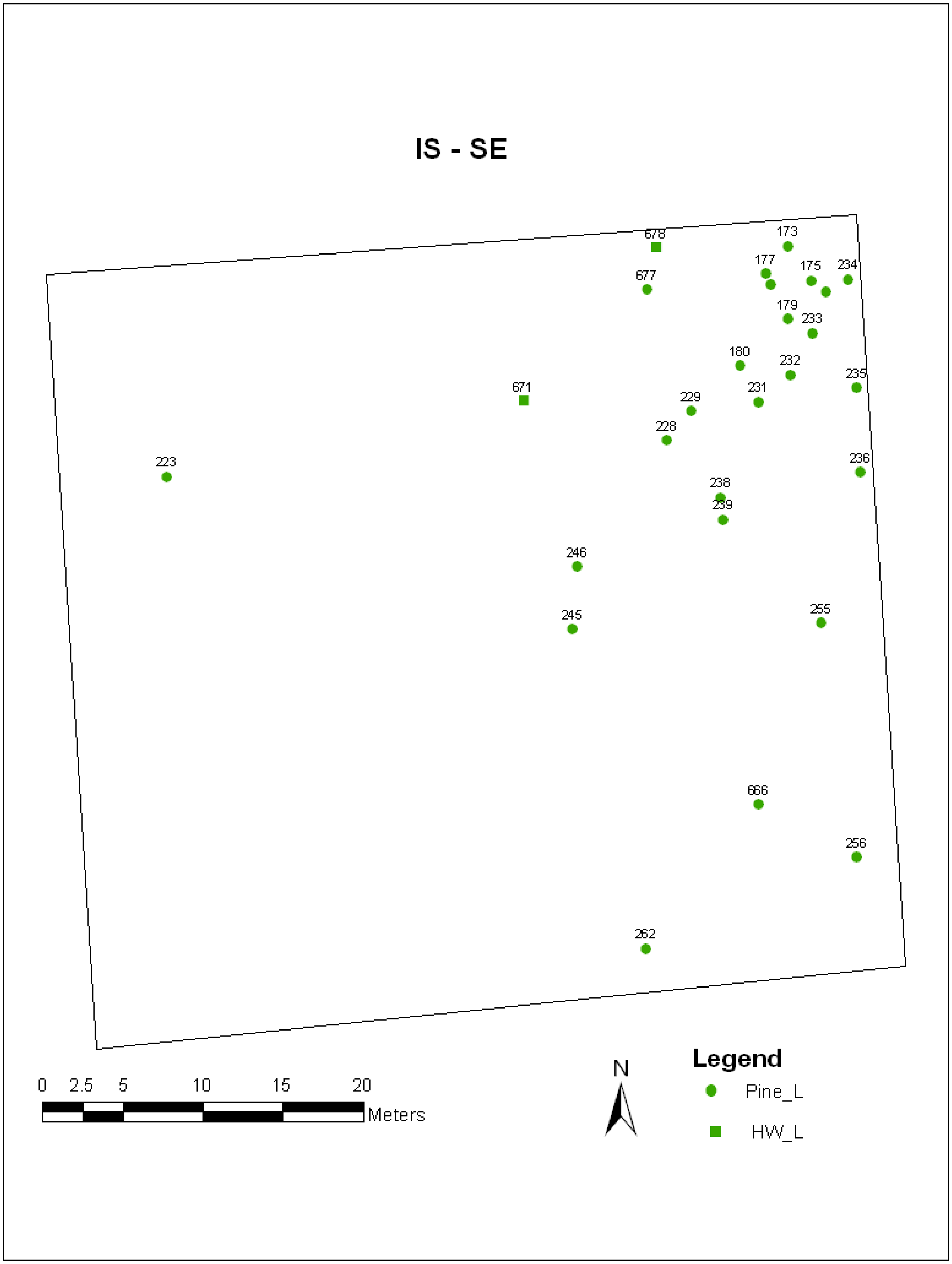
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Meters
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Legend
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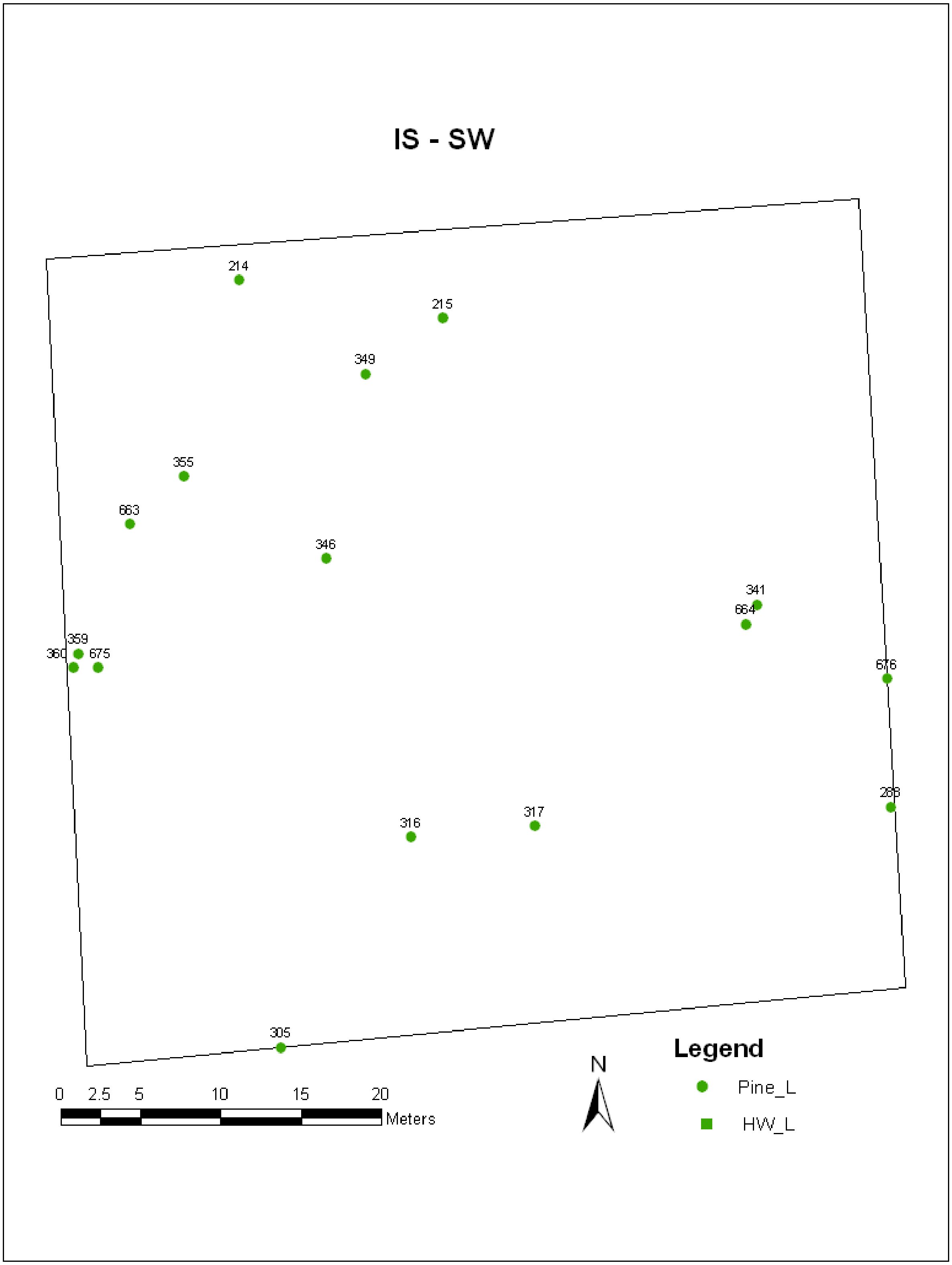
HW_L



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Meters
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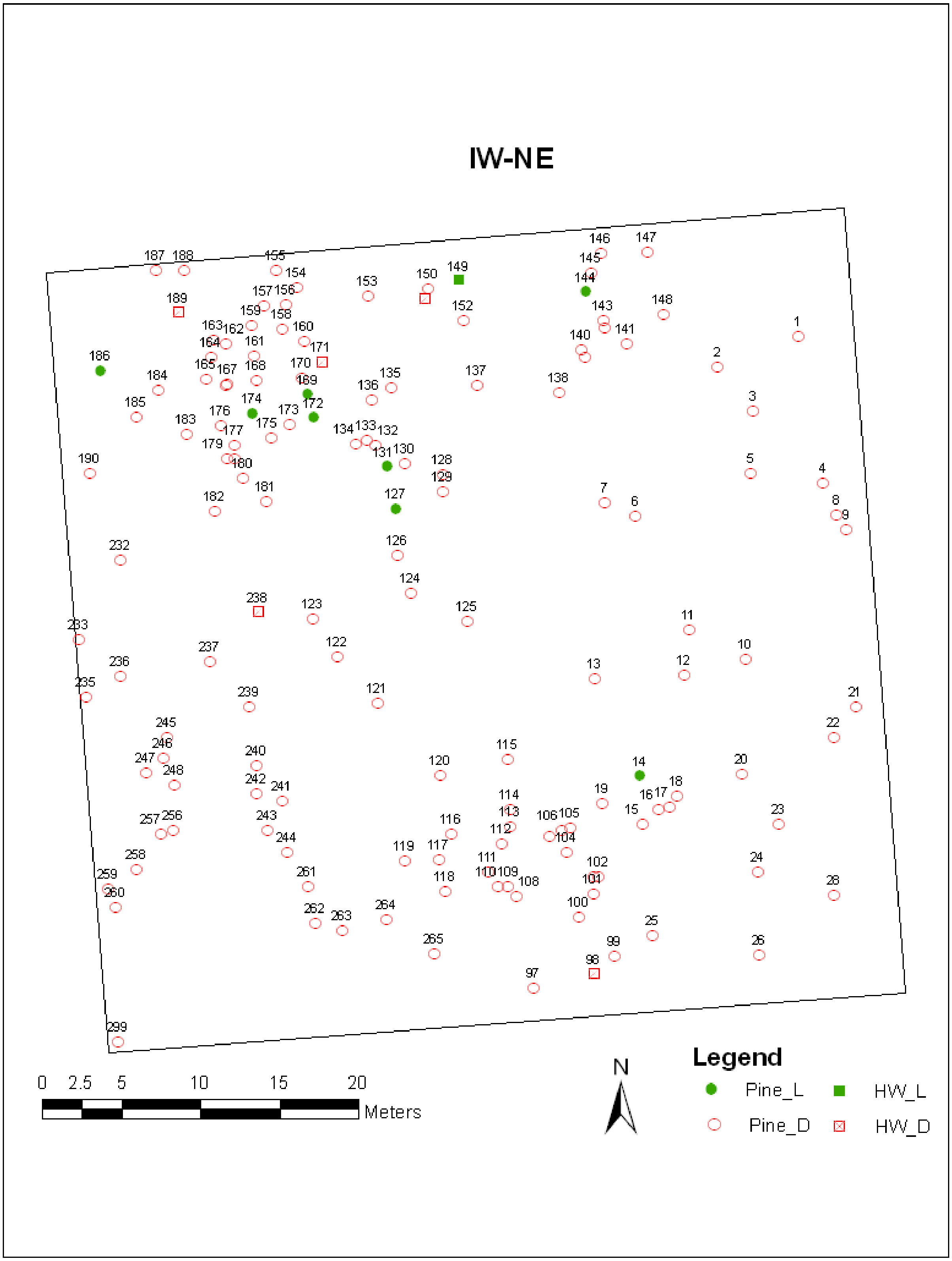
HW_L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Meters
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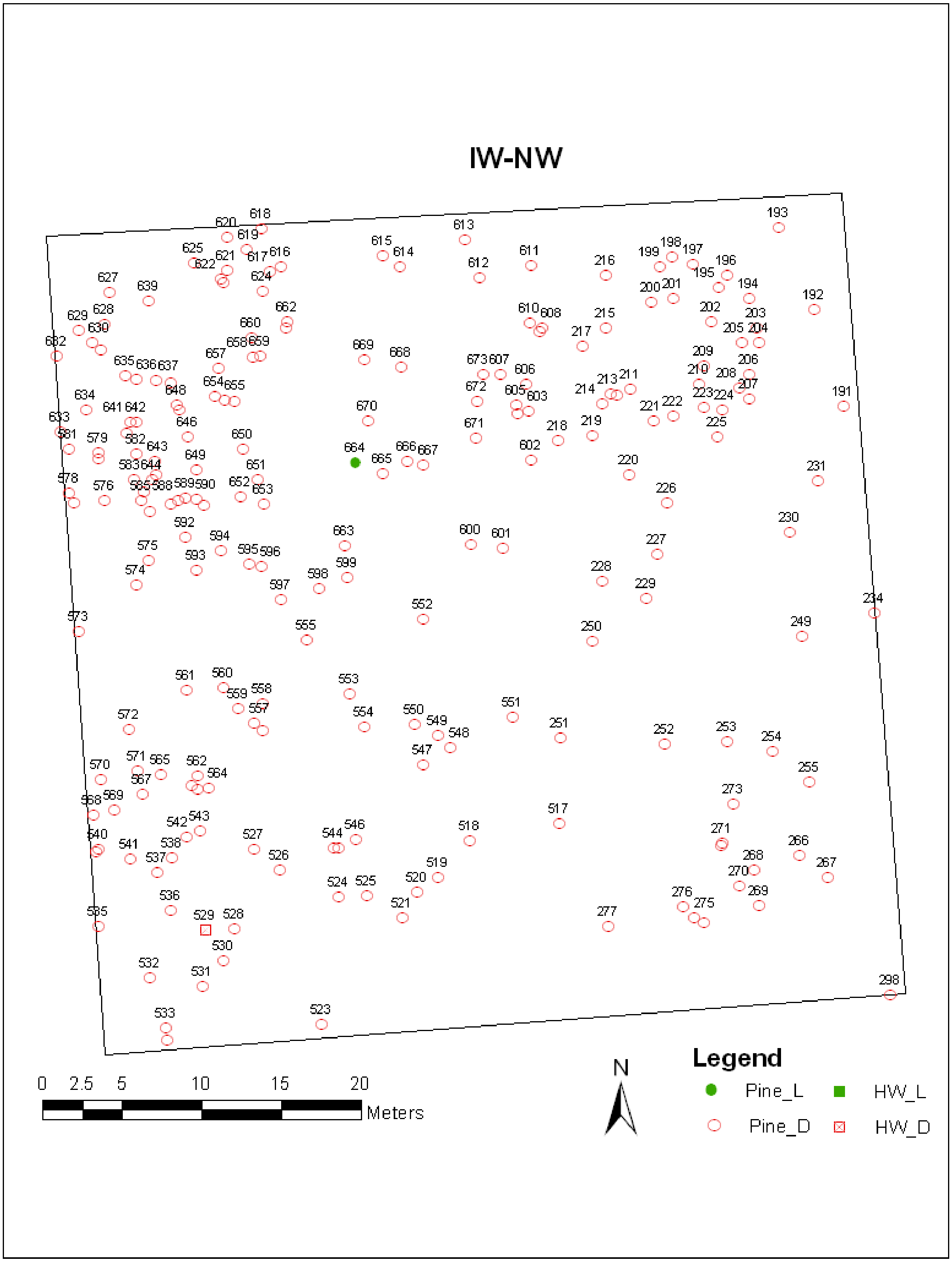
Legend
Pine_L
HW_L
Pine_D
HW_D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Meters
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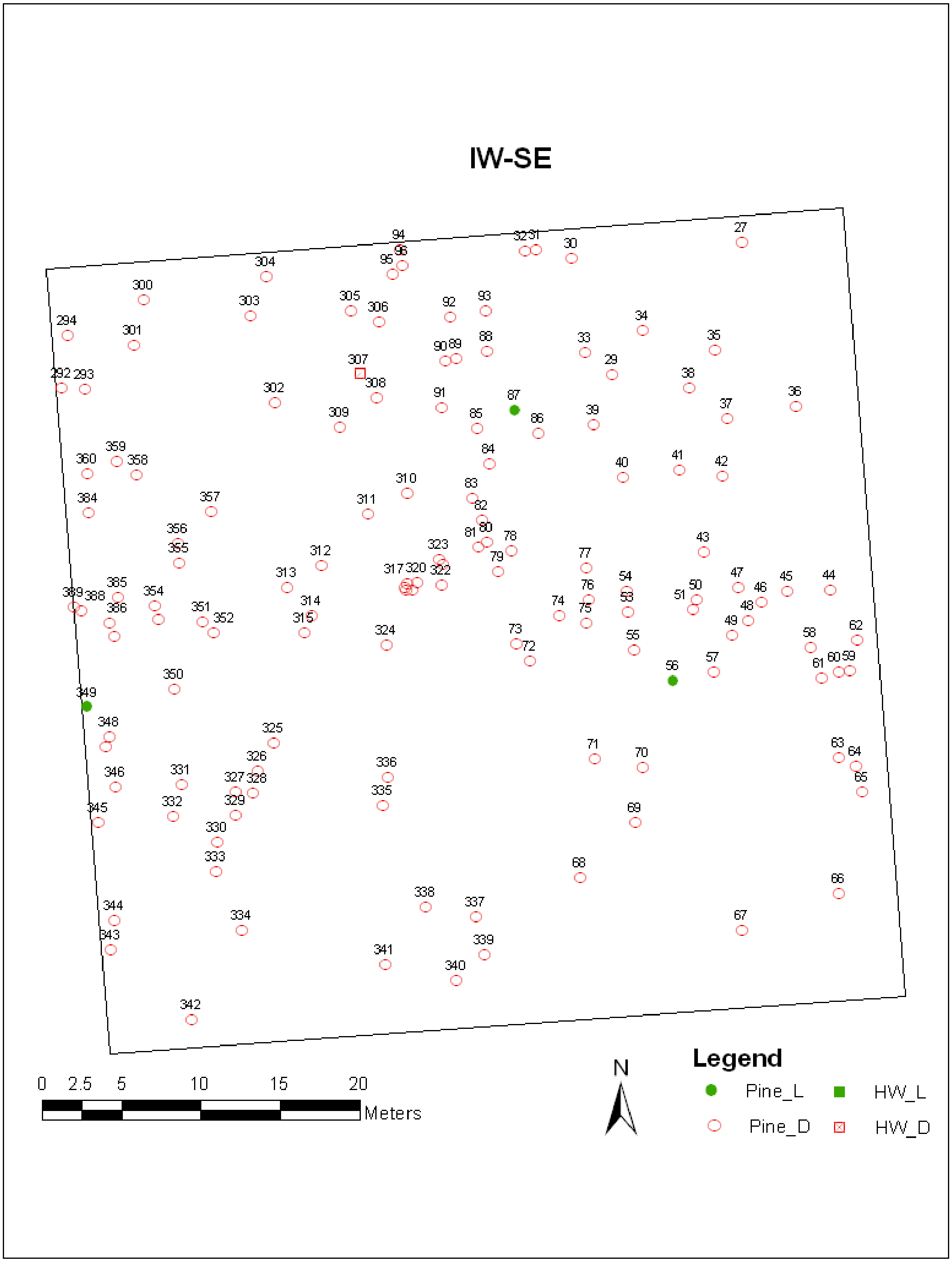
HW_L
Pine_D
HW_D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Meters
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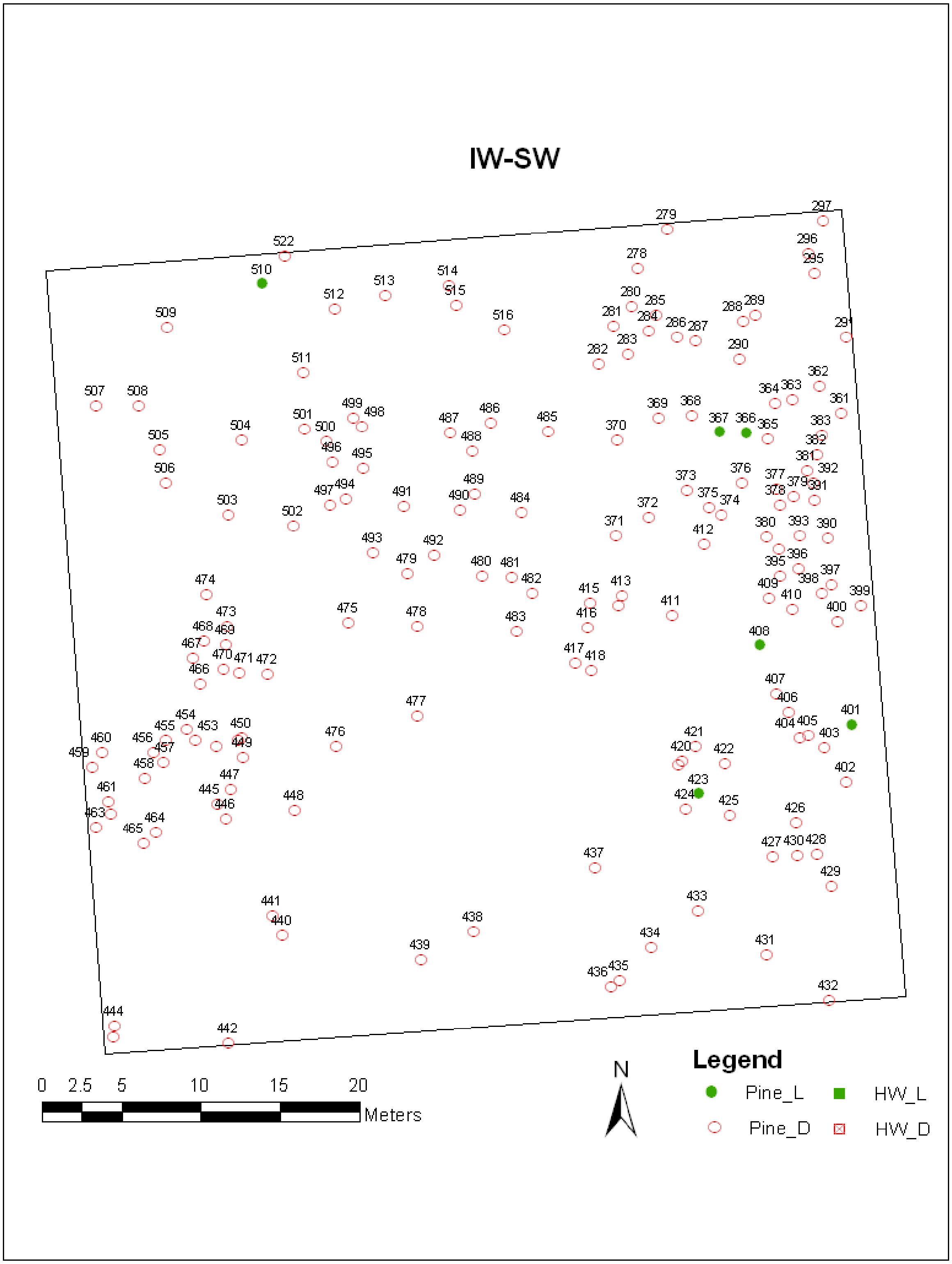
Legend
Pine_L
HW_L
Pine_D
HW_D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0 2.5 5 10 15 20
Meters
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Legend
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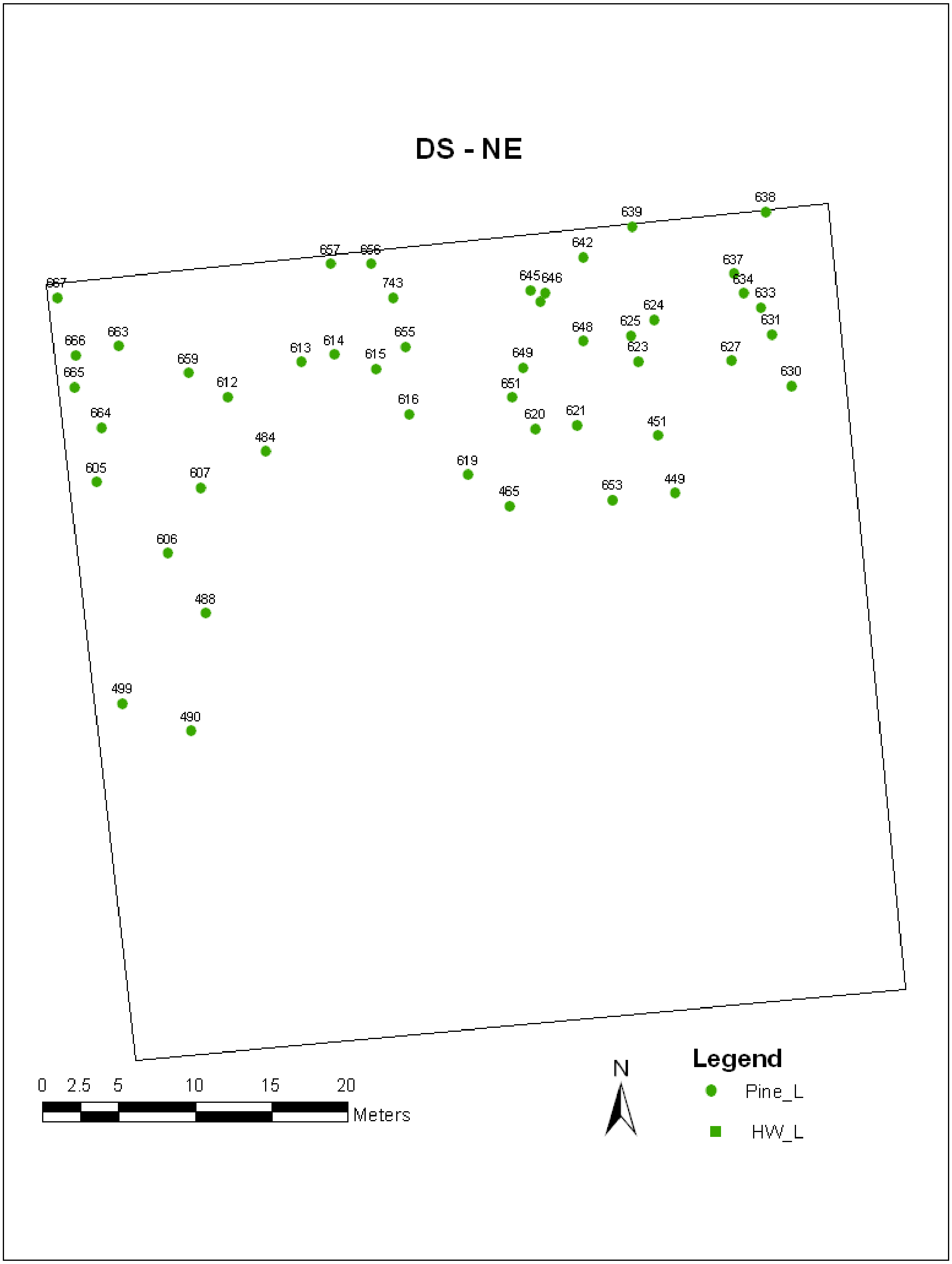
HW_L
Pine_D
HW_D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Meters
N
Legend
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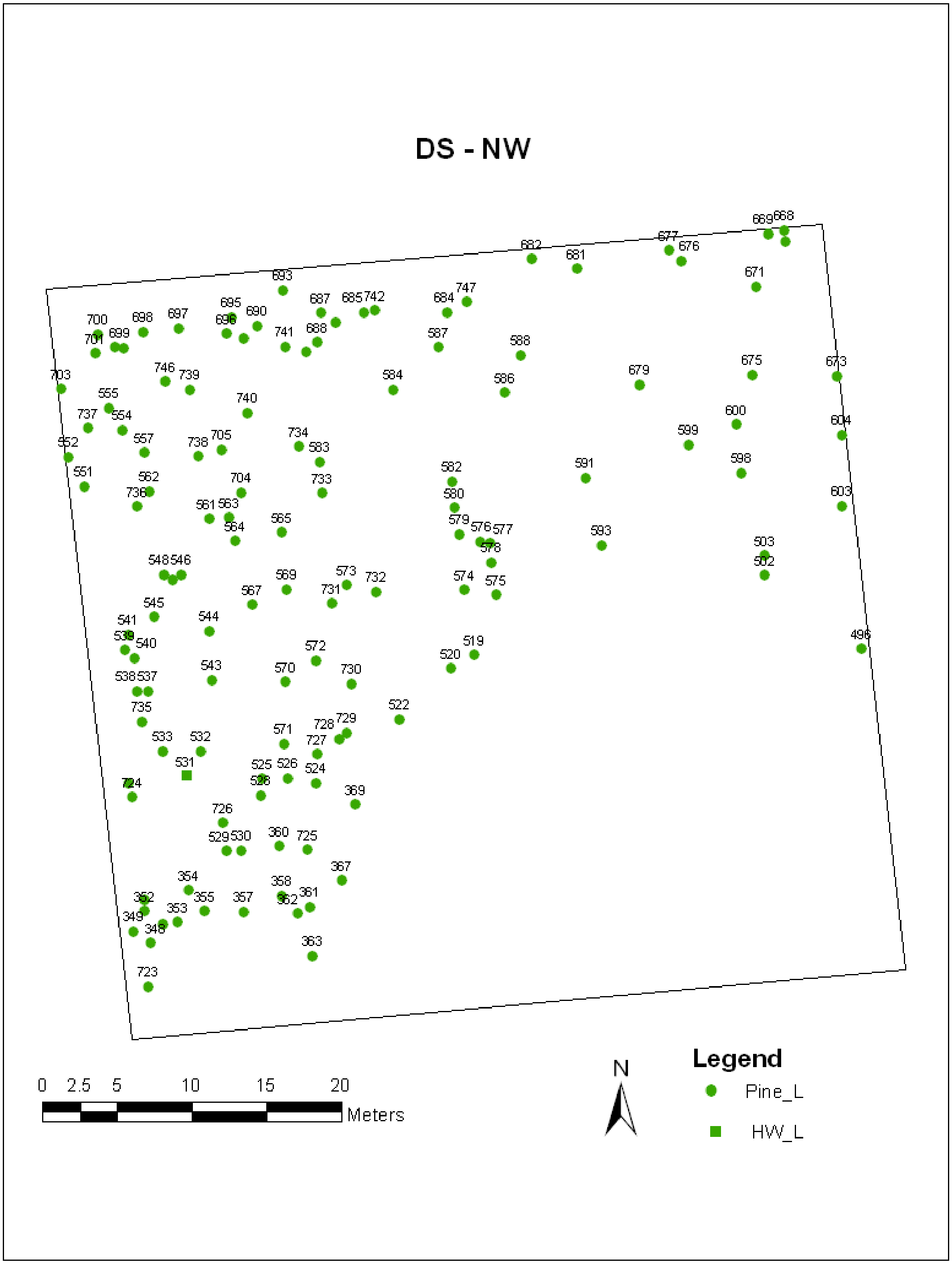
HW_L


DS - NW
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Meters
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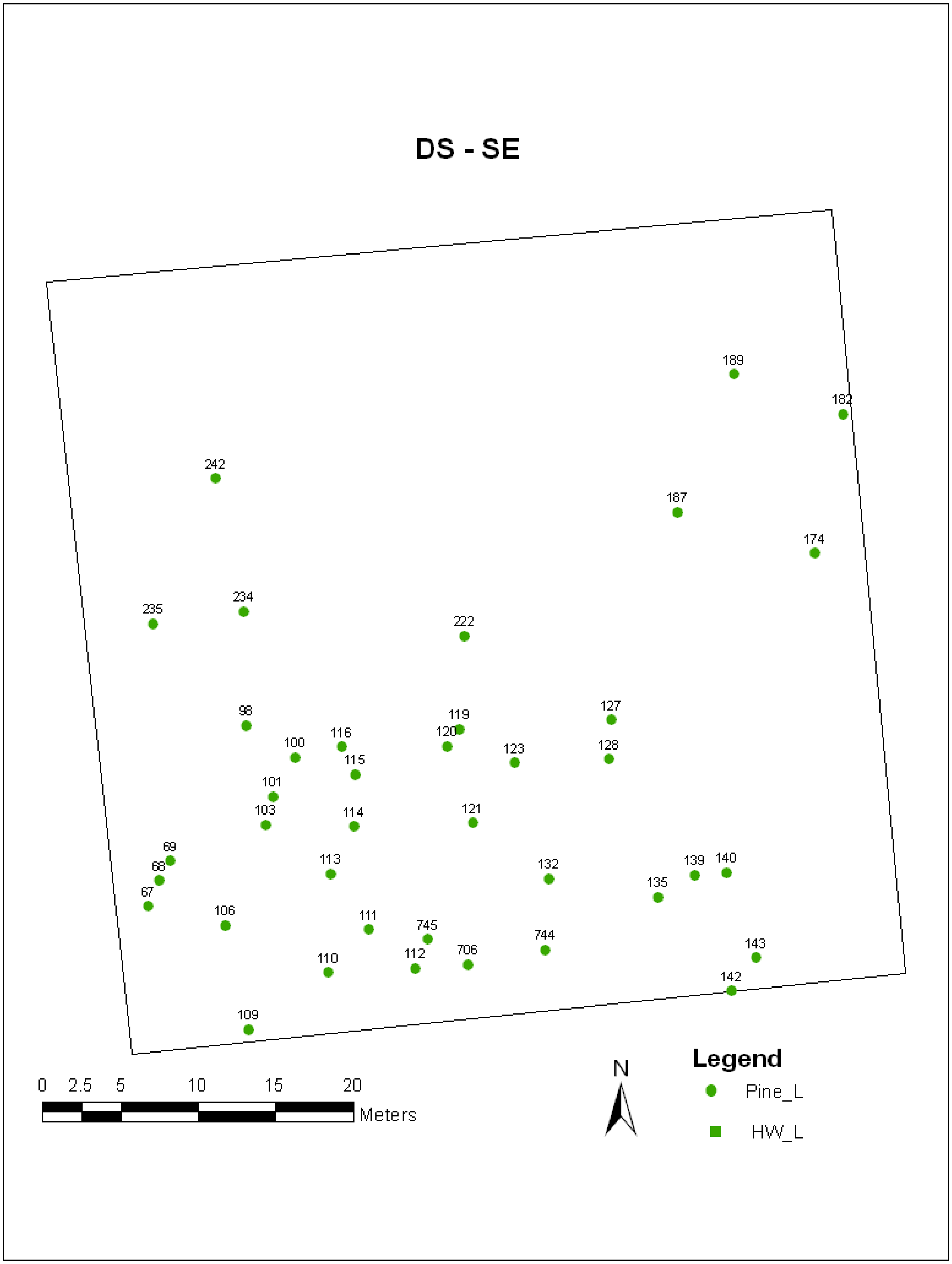
Legend
Pine_L
HW_L



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Meters
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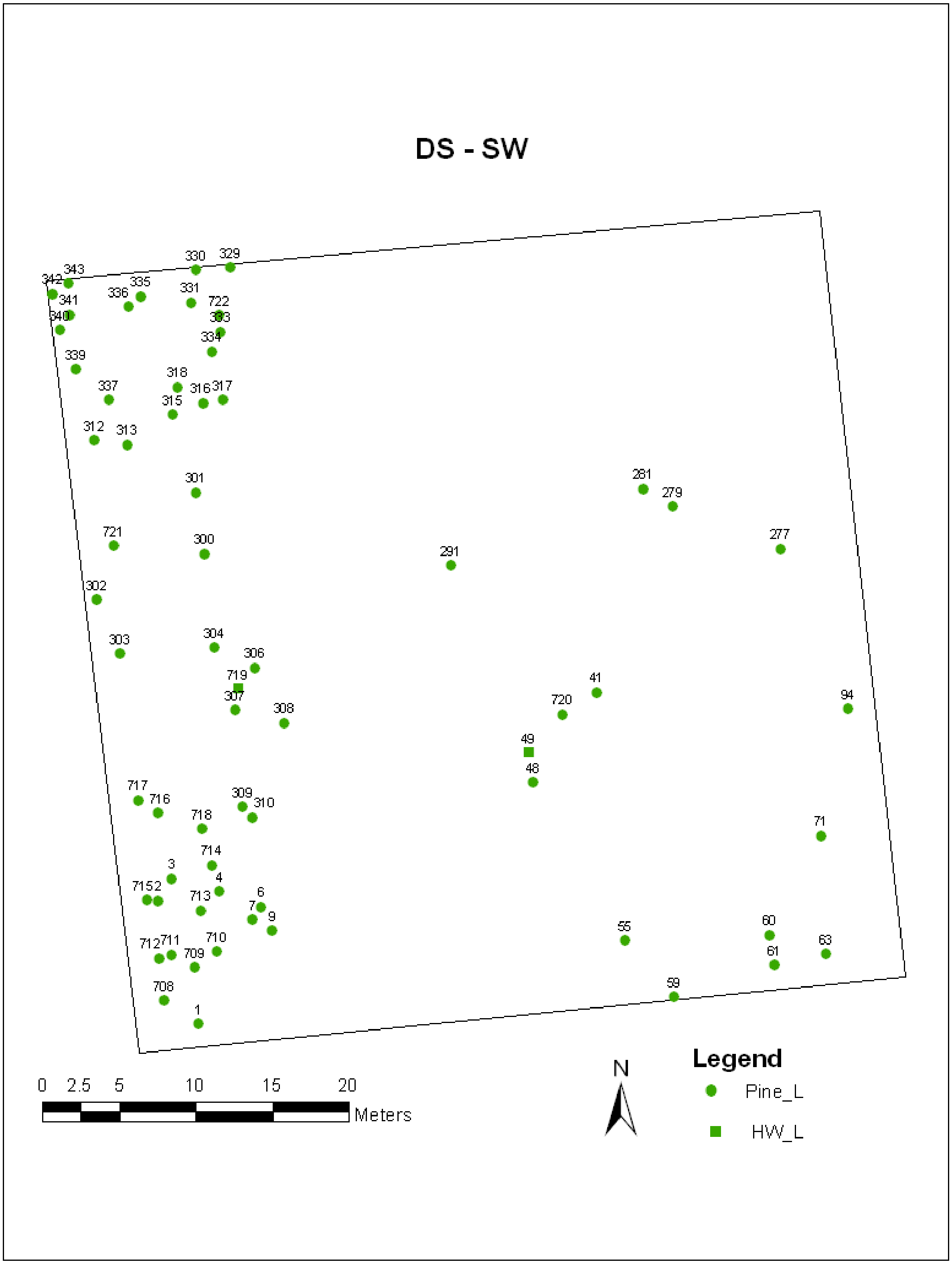
Legend
Pine_L
HW_L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Meters
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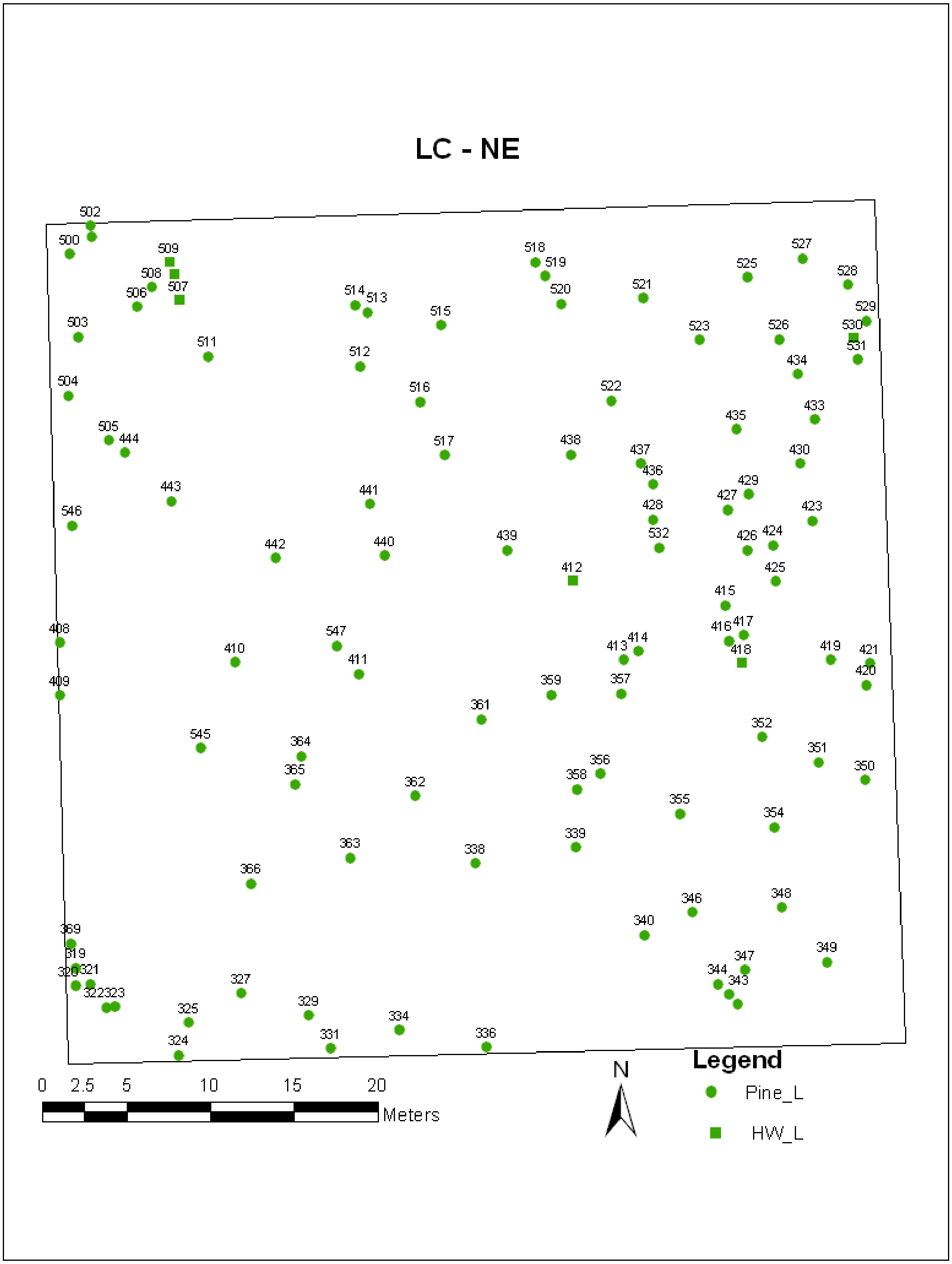
Pine_L
HW_L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Meters
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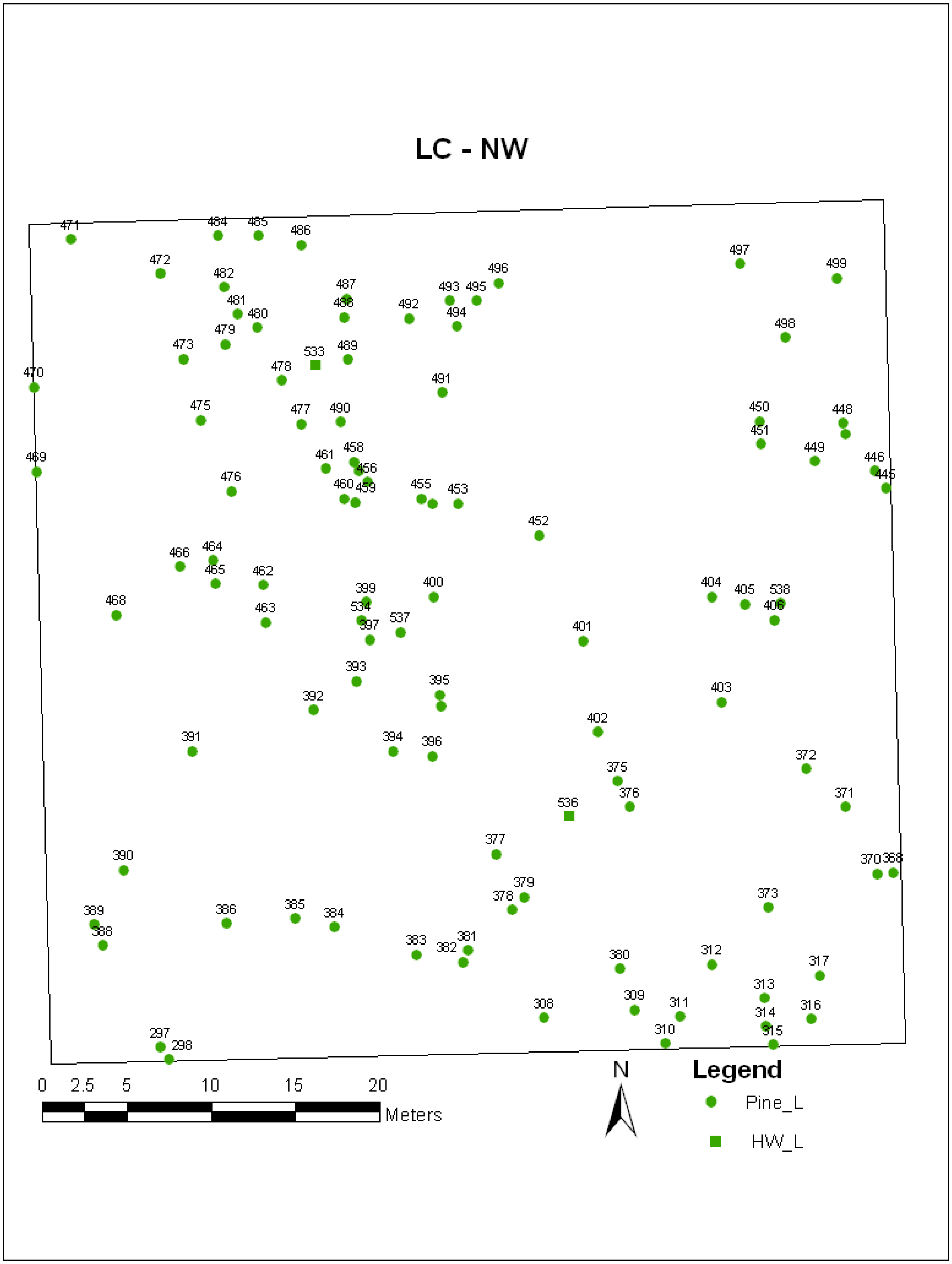
Legend
Pine_L
HW_L


LC - NW
Legend
Pine_L
HW_L
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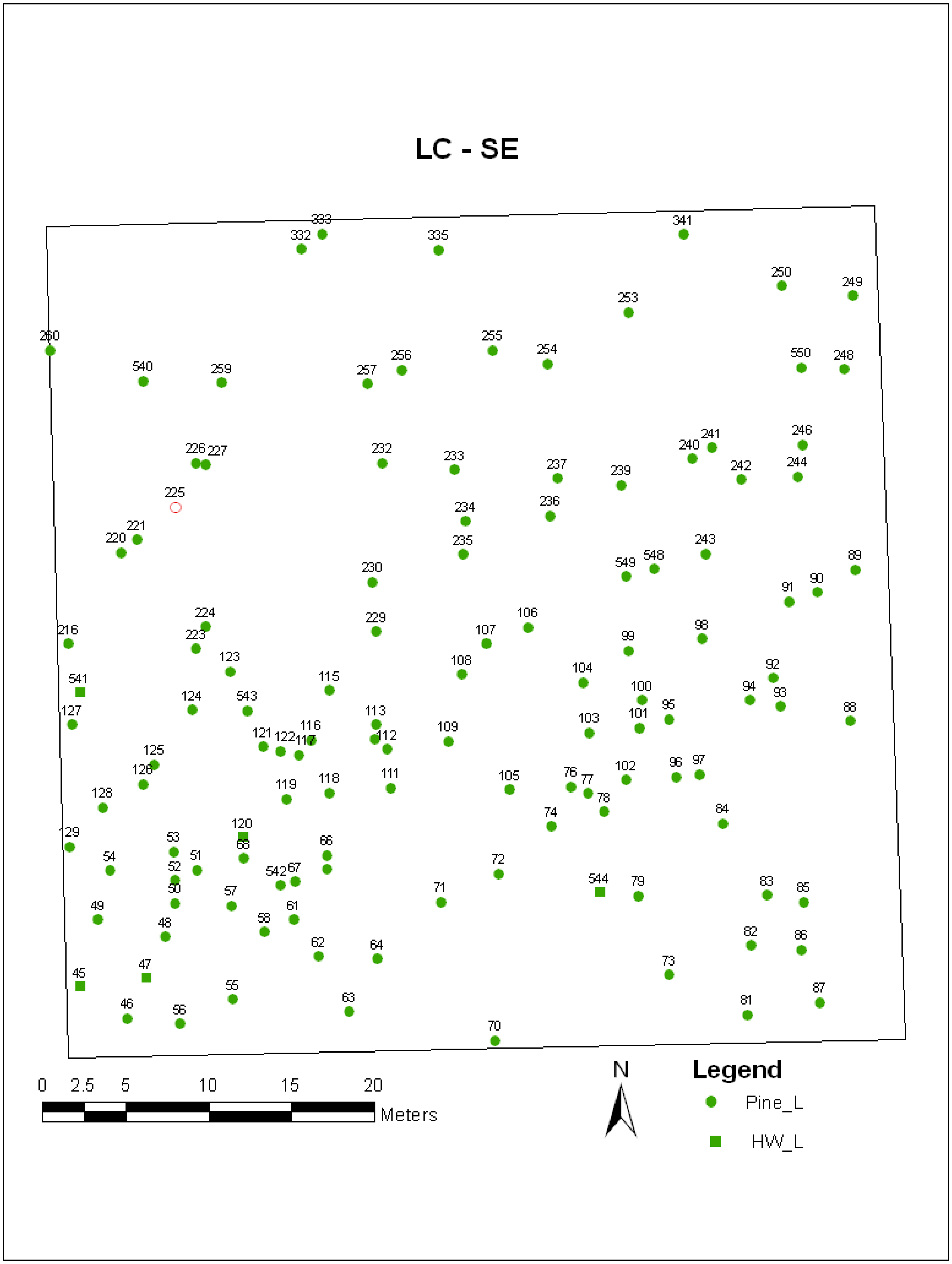
Meters



LC - SE
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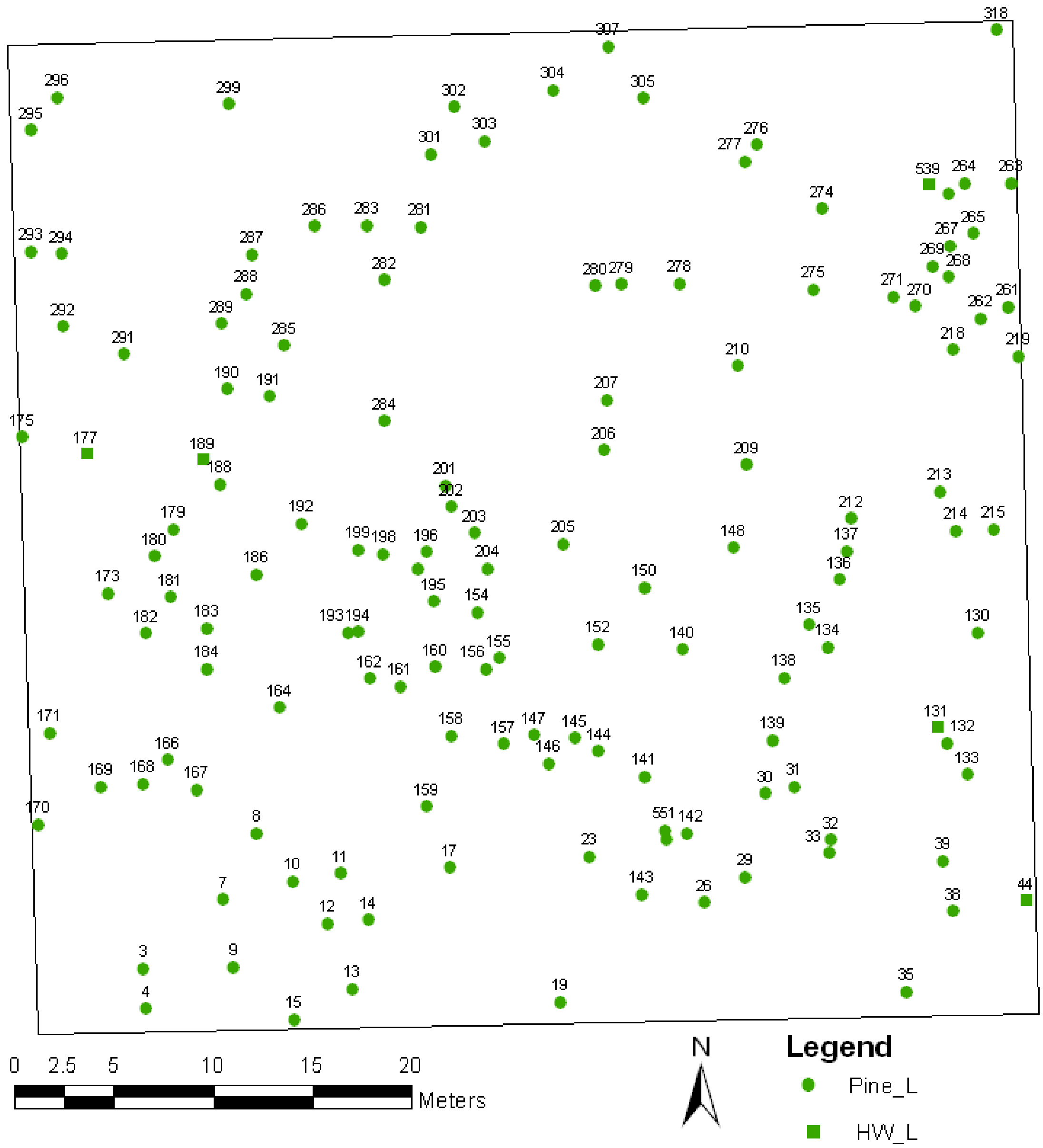
0 2.5 5 10 15 20
Meters
N
Legend
Pine_L
HW_L

LC - SW



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Meters
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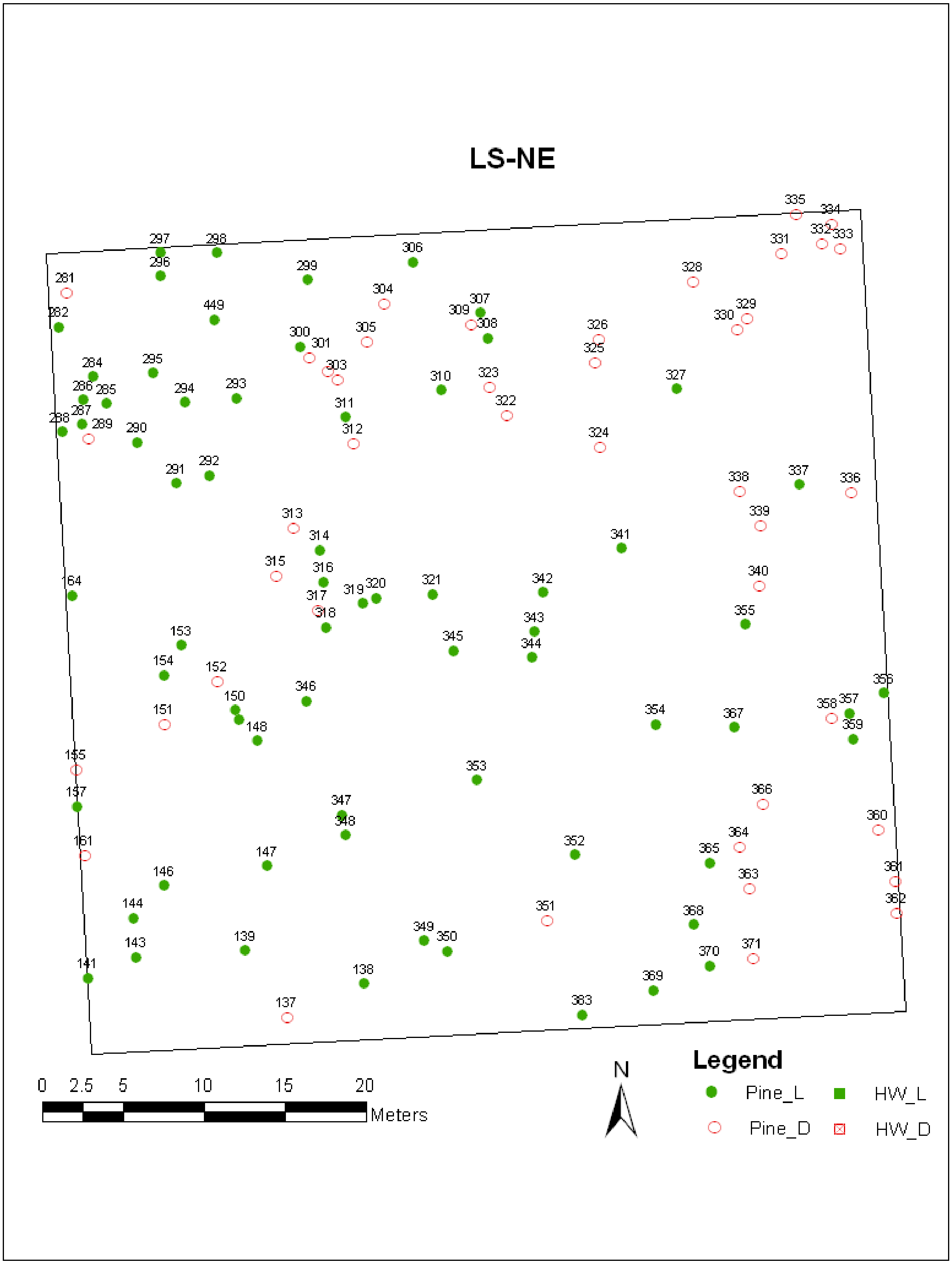
HW_L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Meters
N
Legend
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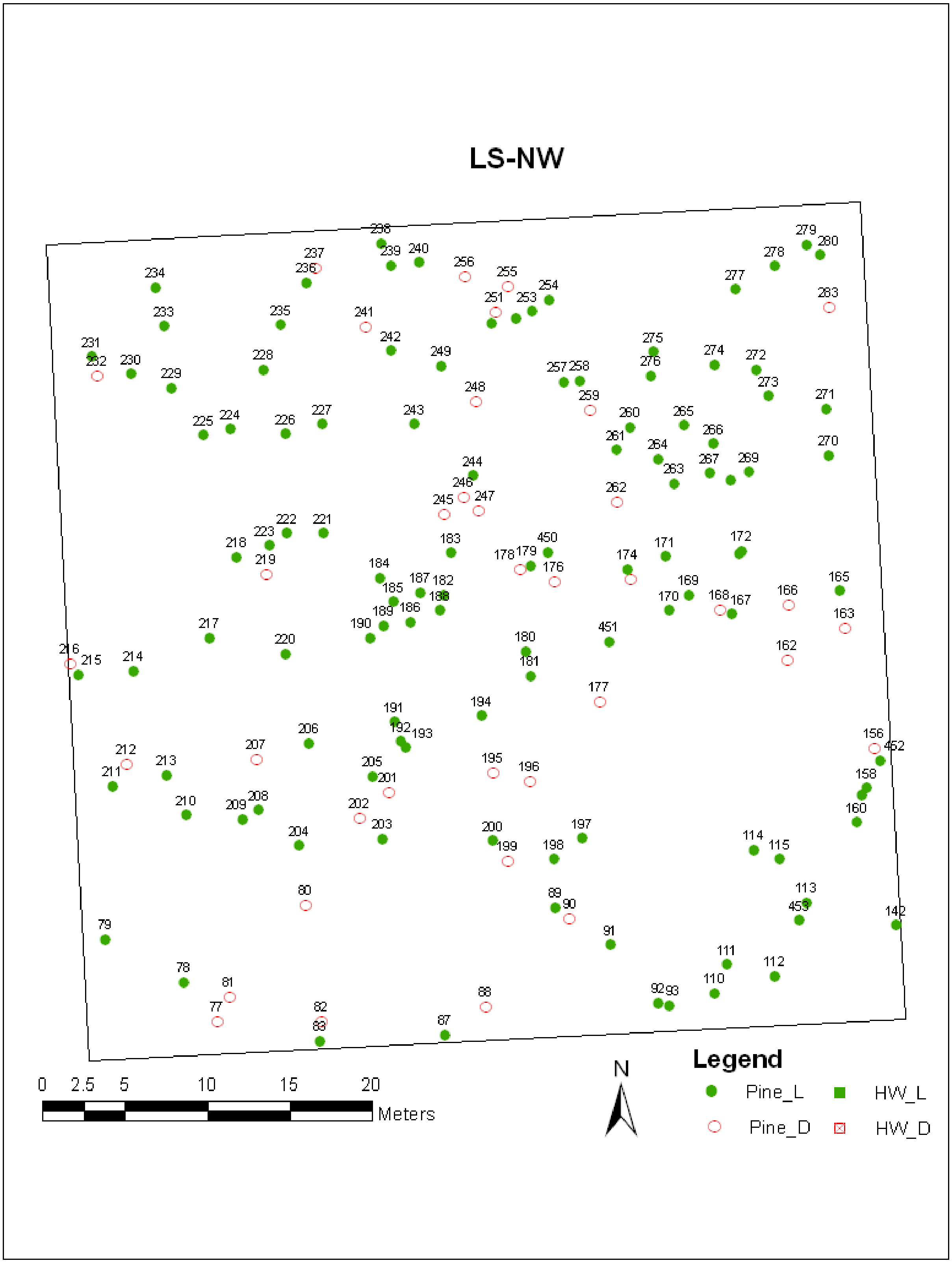
HW_L
Pine_D
HW_D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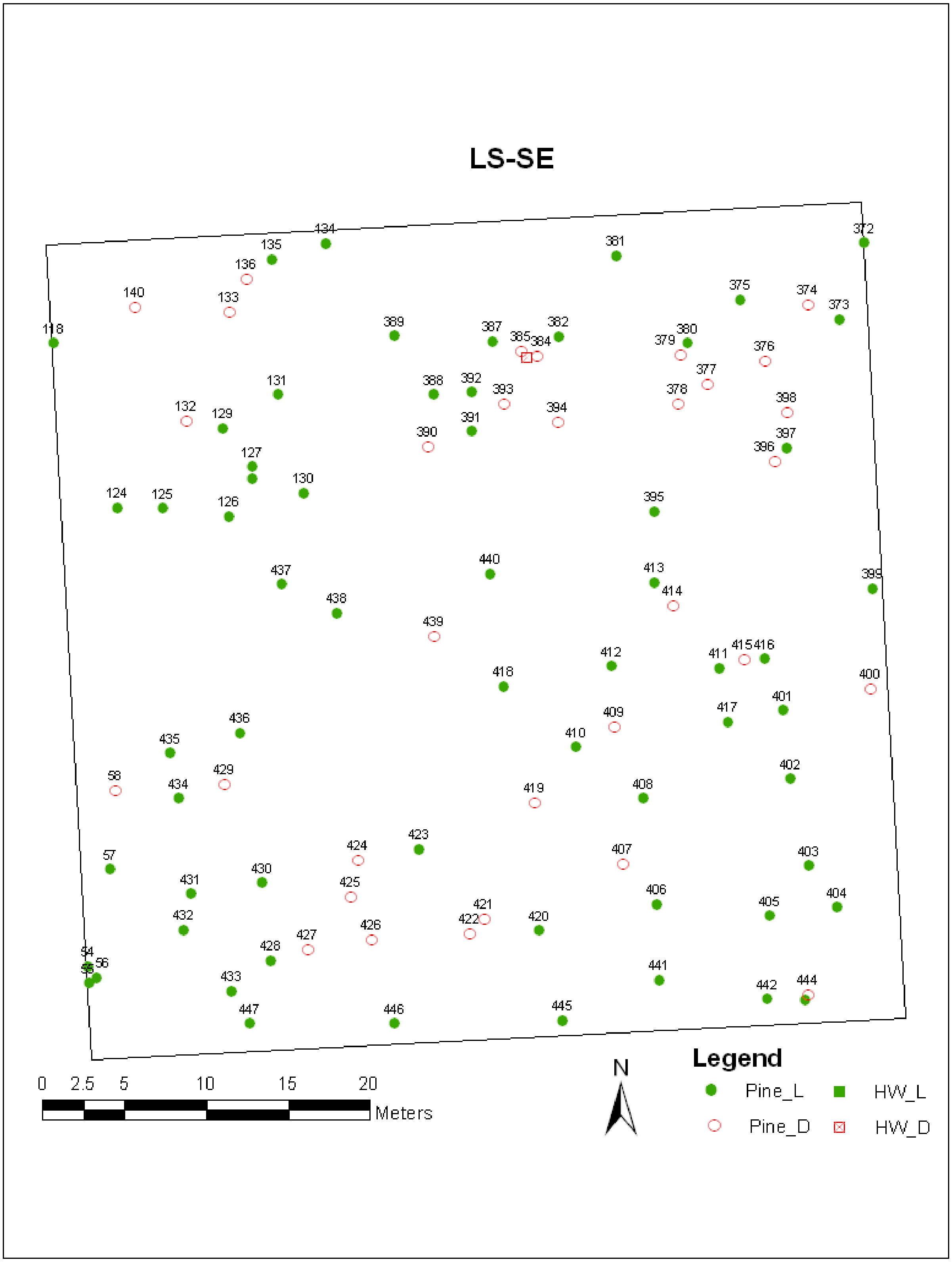
HW_L
Pine_D
HW_D



LS-SE
Legend
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HW_L
Pine_D
HW_D
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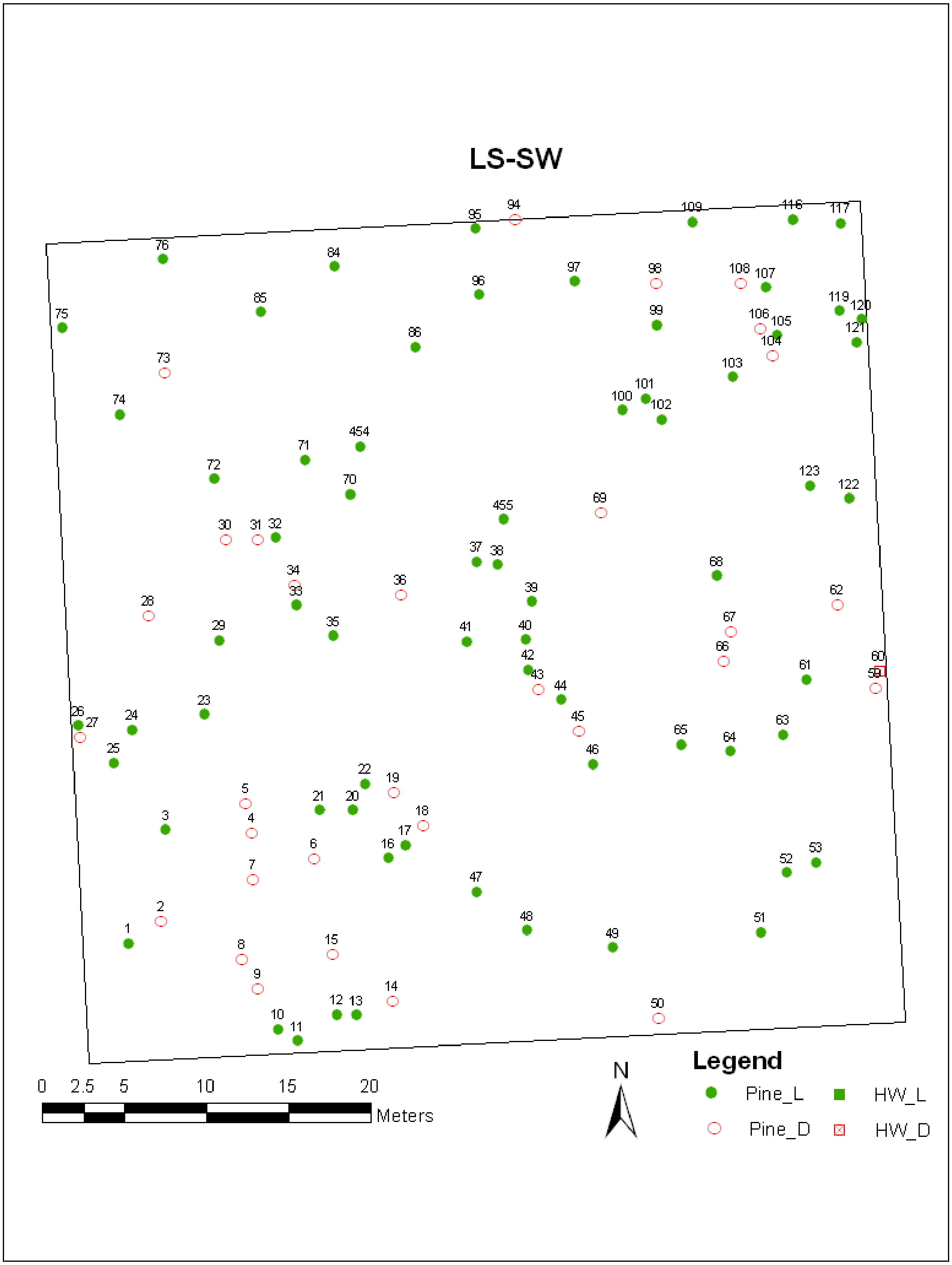
LS-SW
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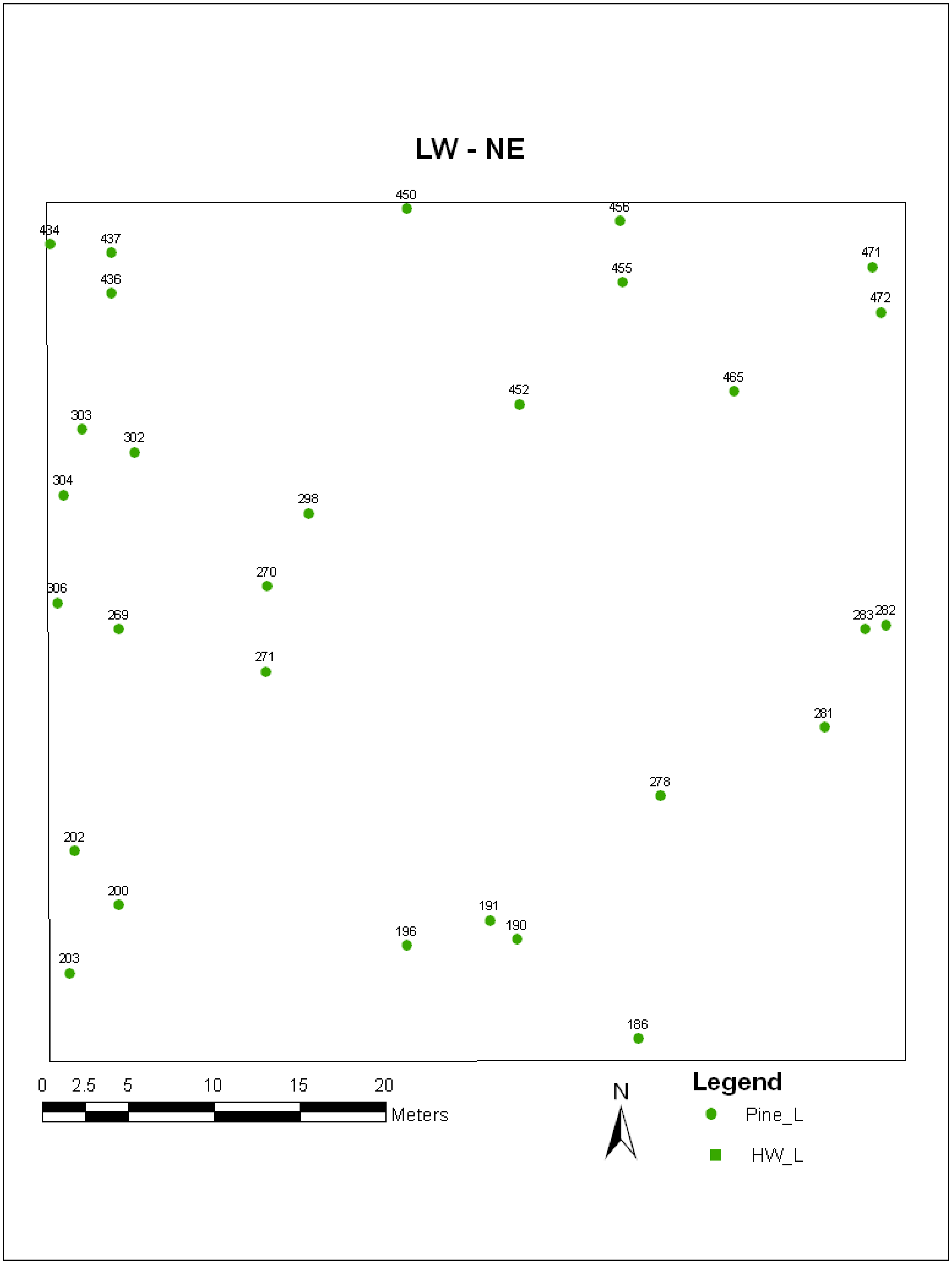
HW_L
Pine_D
HW_D



LW - NE
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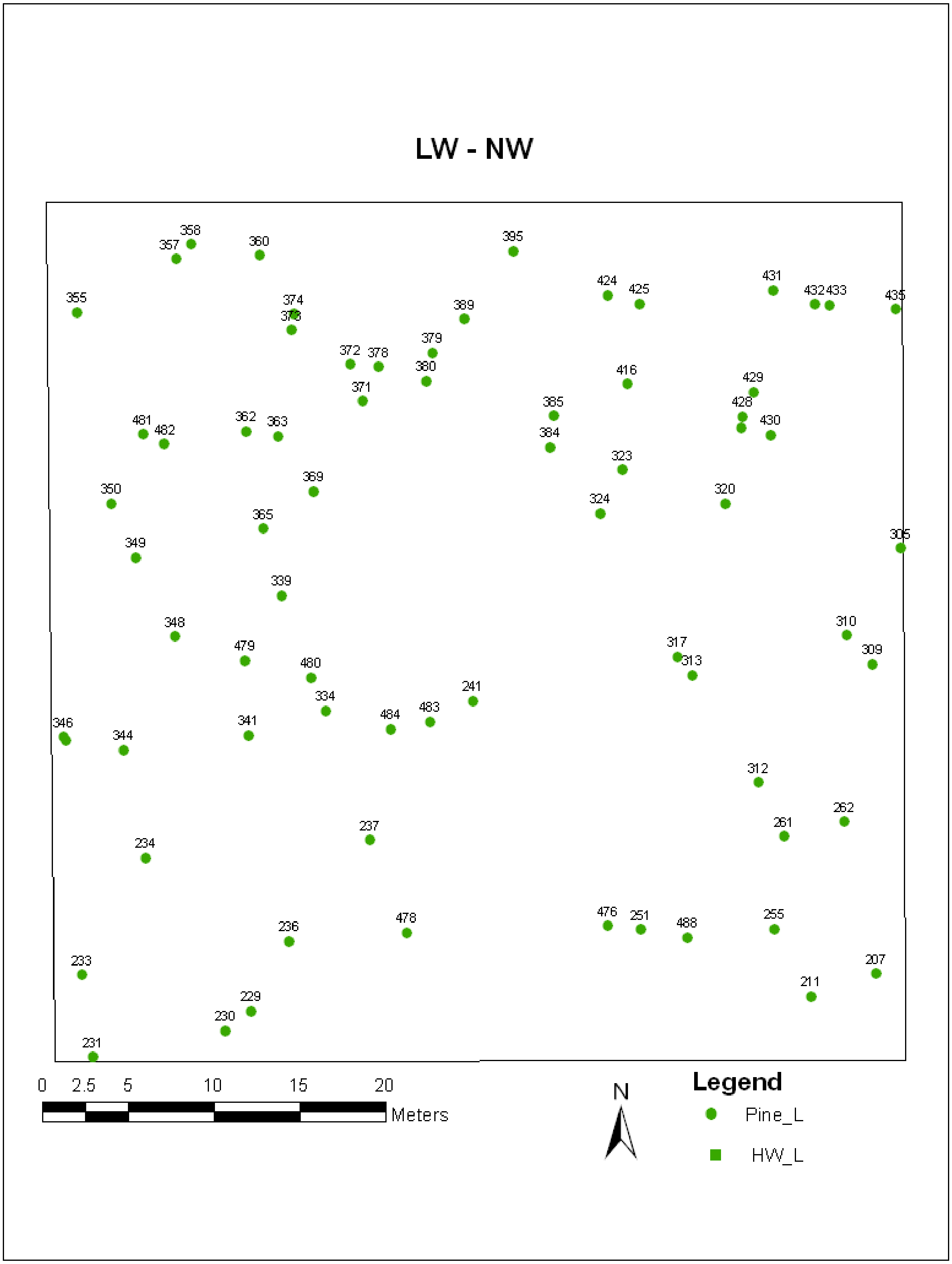
Pine_L
HW_L


LW - NW
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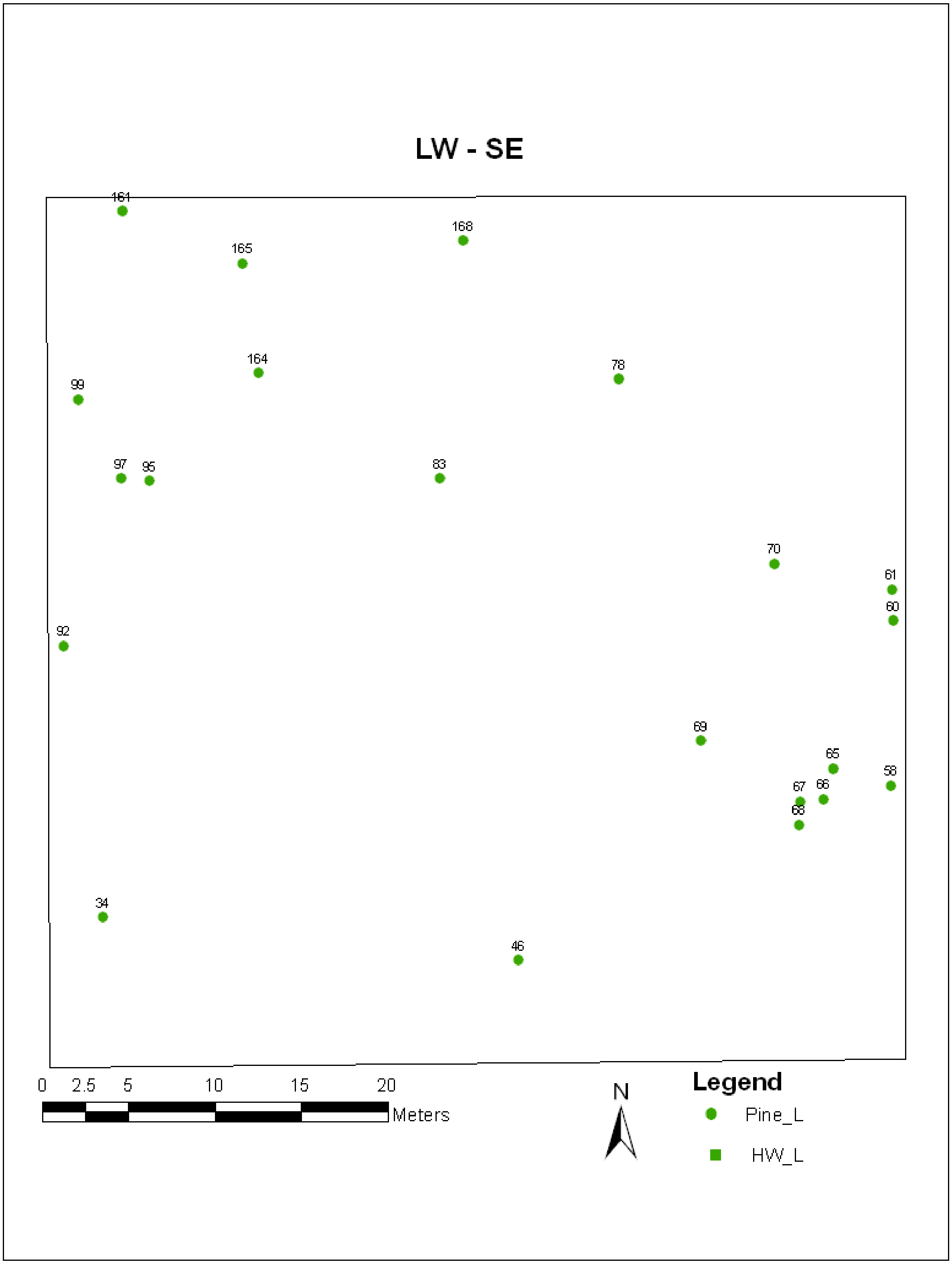
HW_L


LW - SE
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Meters
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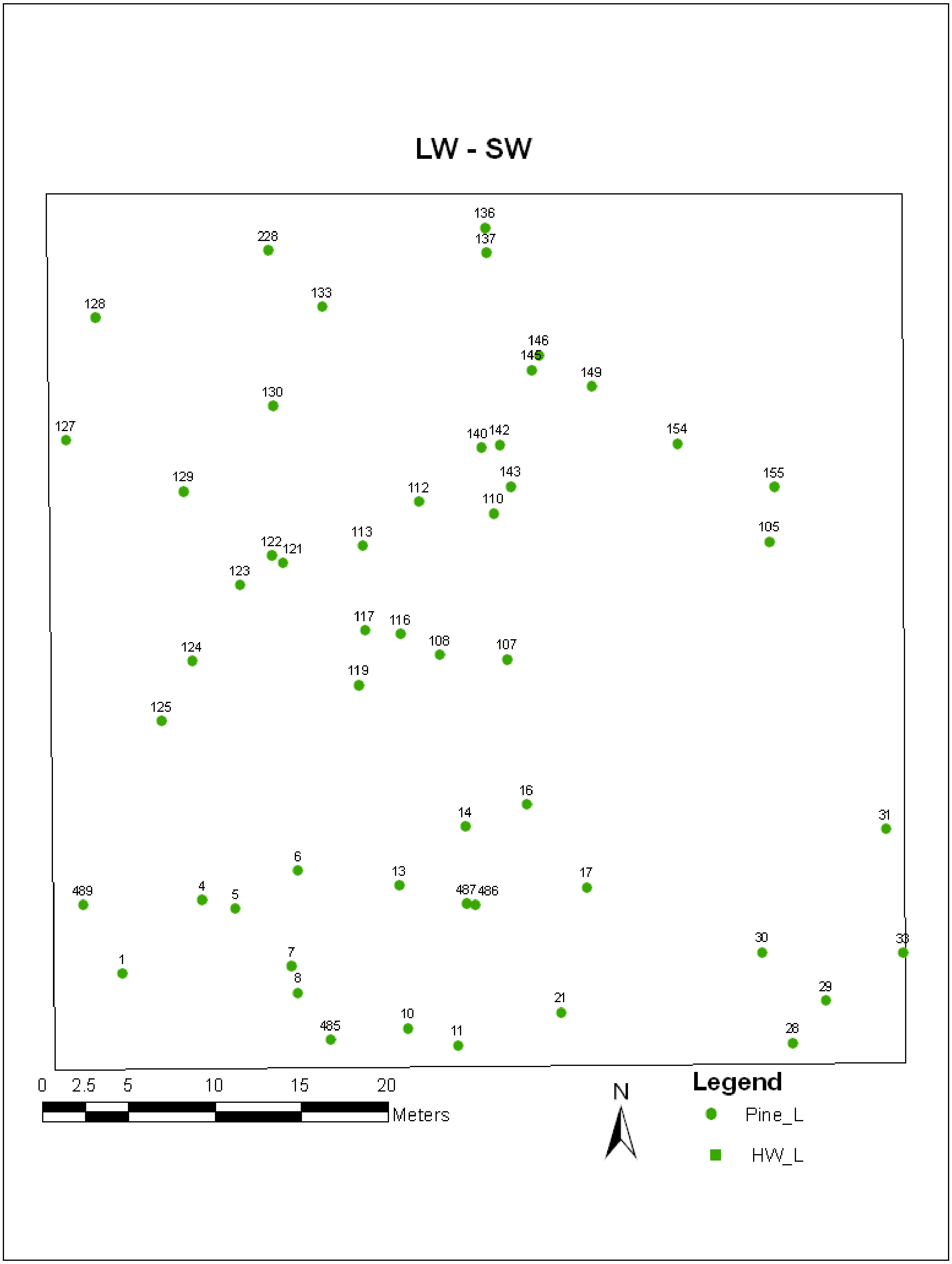
Legend
Pine_L
HW_L


LW - SW
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Meters
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Legend
Pine_L
HW_L