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RESEARCH ARTICLE

Edapho-climatic influence on the growth of farm-grown casuarina under different agroclimatic zones of Tamil Nadu, India

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Abstract

Casuarina plantations are increasingly established in Tamil Nadu because of quick economic returns from its multi-utility uses. However, casuarina growth depends on site conditions and relationships have been established between various climatic and edaphic parameters and growth attributes. The present study evaluated the influence of climatic factors, such as rainfall, temperature and relative humidity, as well as soil physicochemical properties on teak growth in two agroclimatic zones of Tamil Nadu, namely North eastern zone (NEZ) and the Western zone (WZ) in two years old casuarina trees respectively. From each zone, climatic factors were analyzed and soil samples were collected at 0-15 cm and 15-30 cm in the soil profile for physicochemical analysis. The results show that the growth biometrics of block plantations of casuarina trees were positively correlated with climatic and edaphic factors. Maximum and minimum temperature, pH, electrical conductivity, organic carbon and available nitrogen showed significant positive correlations with the tree volume index. This studys' key finding is that the casuarinas' growth varies among agroclimatic zones, which can be monitored by means of edapho-climatic factors that influence casuarina plantations.

Keywords: agroclimatic zones; casuarina; correlation; farmland; volume index

Introduction

Casuarina species, commonly known as Australian pines, are fast -growing trees widely cultivated for timber, fuelwood and soil conservation (1). In India, casuarina plantations play a crucial role in meeting the increasing demand for wood-based industries and agroforestry systems (2). The growth and productivity of casuarina clones are significantly influenced by edapho-climatic factors, which include soil characteristics, moisture availability, temperature and rainfall patterns (3). Understanding the relationship between these environmental parameters and tree growth is essential for optimizing site selection and management practices. With its diverse agroclimatic zones, Tamil Nadu provides an ideal setting to assess how different environmental conditions impact casuarina growth (4).

Edapho-climatic factors vary across regions, leading to the differential growth performance of casuarina clones. Soil properties such as texture, pH, organic matter content and nutrient availability directly affect root development and nutrient uptake (5). Similarly, climatic factors like temperature fluctuations, precipitation levels and humidity influence physiological processes such as photosynthesis and transpiration. The interaction of these factors determines overall tree vigour, biomass accumulation and wood yield (6). By studying these variations, researchers can identify site-specific casuarina clones best suited for sustainable cultivation under different agroclimatic conditions (7).

Tamil Nadu encompasses multiple agroclimatic zones, including coastal, semi-arid and humid regions with distinct soil and climatic attributes (8). Assessing the influence of these zones on casuarina growth provides valuable insights into genotype-environment interactions (9). The findings from such studies can aid in developing site-specific silvicultural practices, improving productivity and enhancing economic returns for farmers. Furthermore, understanding the adaptability of different clones to varying environmental stresses can contribute to climate-resilient forestry. This study aims to analyze the growth performance of farm-grown casuarina clones across different agroclimatic regions of Tamil Nadu, providing critical information for sustainable plantation management and genetic improvement programs.

Materials and Methods

Study Area

Farm-grown casuarina plantations are surveyed in two agroclimatic zones of Tamil Nadu: North Eastern Zone (NEZ) and Western Zone (WZ).

Age class

In two selected agroclimatic zones, two-year-old plantations were selected for study and subjected to biometric analysis.

Type of plantation

The study was undertaken in block plantations in both agroclimatic zones. In these types of plantations, biometric estimation was carried out for two years of age casuarina.

Sampling

A preliminary field survey was conducted to identify plantation sites and casuarina clones were planted on farmlands in two agroclimatic zones considered for the study. The biometric attributes, viz., collar diameter, plant height and volume index, were estimated using a tree telescope. The estimation was done using a simple random sampling method with a sampling intensity of 5 %.

Estimation of volume index

The climatic and edaphic response of casuarina clones was measured in terms of growth biometry by estimating height (cm) using a Laser distance meter (Leica DISTO ™ S910), basal diameter (cm) by vernier calliper and the volume index (cm^3) was worked out as per the standard prescribed Equation 1 formula (10). The form factor was ignored while measuring laser distance meter as the diameter is taken at every 2 m height interval, so the trees' destructive sampling was ignored.

$$V.I = Height\ (cm) \times Collar\ diameter^2\ (cm^3) \quad (Eqn.1)$$

Correlation of edaphic and climatic influence on growth of farm-grown teak

The prevailing climate in the study area was collected from the scientific sources as described below.

Climatic parameters

The climatic parameters for one year (2024) were collected from the scientific institutes' database. The climatic data for Maduranthakam, Chengalpattu and Mettupalayam, Coimbatore districts were collected from the Agroclimate Research Centre (ARC), Tamilnadu Agricultural University Coimbatore (Fig. 1 & 2). The climatic parameters collected are rainfall (mm), maximum temperature (°C), minimum temperature (°C) and relative humidity (%).

Edaphic parameters

The representative soil samples were collected from two agro -climatic zones of Tamil Nadu for analyzing the soil physicochemical (Table 1) and soil chemical properties (Table 2) under two different depths *viz.,* 0-15 cm (Surface) and 15-30 cm (Sub-surface). During the collection of samples, the old manures, wet spots, dead plants, furrows and compost pits were excluded to minimize the differences that may arise due to the dilution of soil organic matter. The collected soil samples were air-dried, mixed well and passed through 2 mm sieve for the soil physio-chemical and soil chemical properties analysis.

Statistical analysis

Karl Pearsons' correlation coefficient was worked out using IBM SPSS (Statistical Package of the Social Science) and Agricolae under R environment to correlate the growth of farm-grown casuarina clones with the climatic and edaphic factors (11).

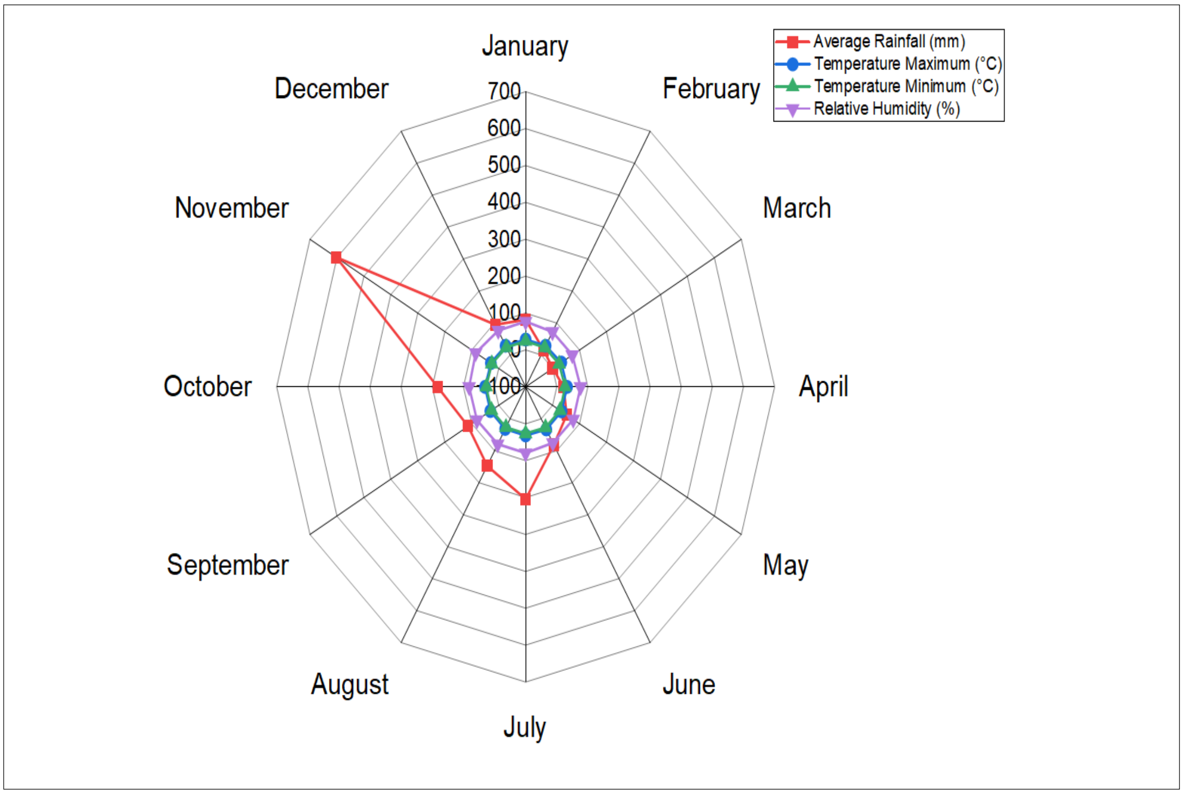

Fig. 1. Average weather data of NEZ (2024) (Source: Agro Climate Research Centre, Tamil Nadu Agricultural University).

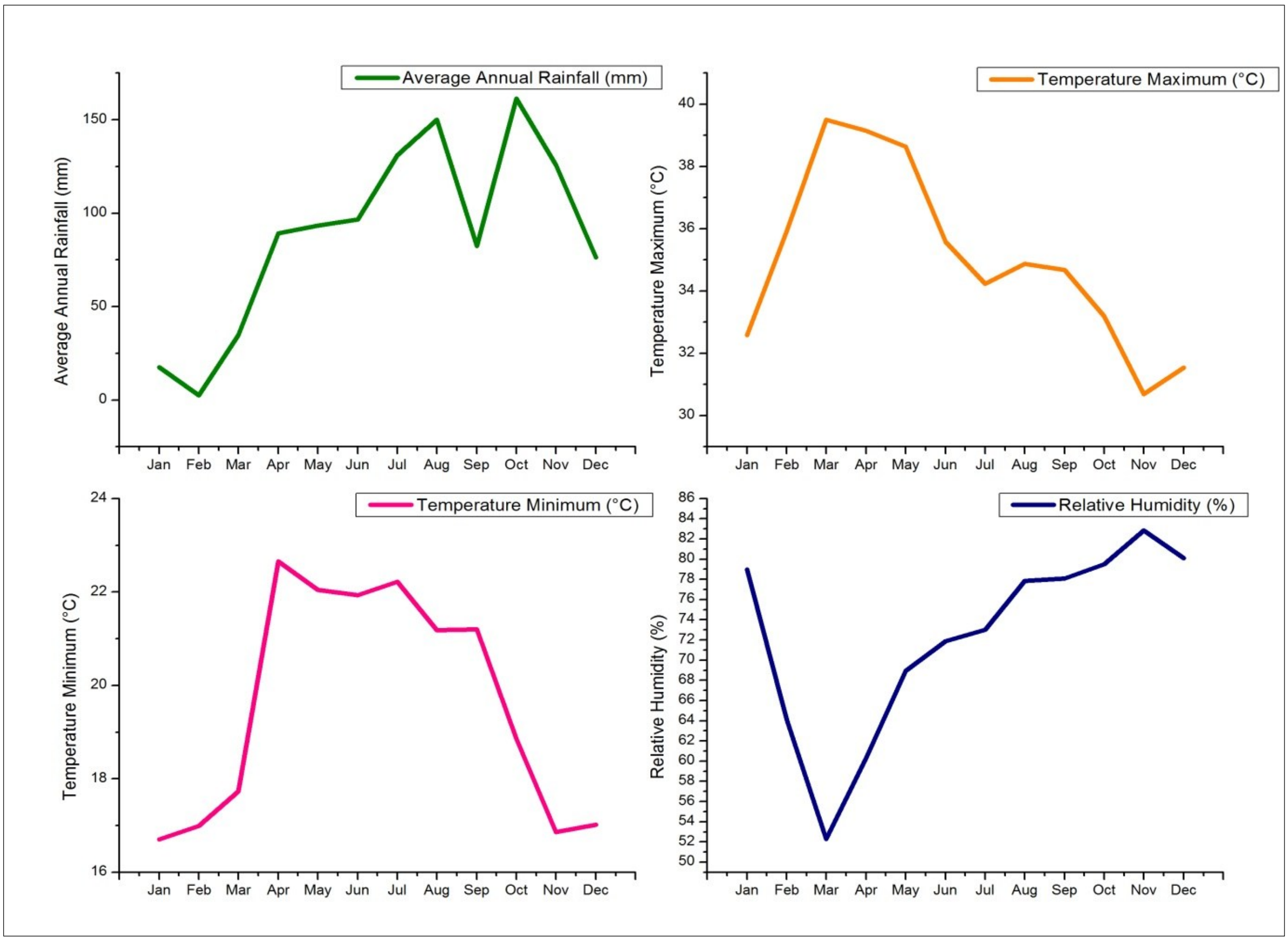

Fig. 2. Average weather data of WZ (2024) (Source: Agro Climate Research Centre, Tamil Nadu Agricultural University).

Table 1. Methods used for analyzing soil physicochemical properties

S.no	Soil Parameter	Methodology	References
1	Soil pH	Elico model pH meter	26
2	Soil EC	Conductometry	26

Table 2. Methods used for analyzing soil chemical properties

S.no	Soil Parameter	Methodology	References
1	Available nitrogen	Alkaline permanganate method	27
2	Available phosphorus	Olsens' method	28
3	Available potassium	Neutral Normal NH_4OAc, Flame photometry	29
4	Soil organic carbon	Wet chromic acid digestion	30

Results and Discussion

Climatic parameters in the study site (Agro-climatic zones)

The climatic data were received from the Agriculture Extension Centre (AEC) under Tamil Nadu Agricultural University in the districts of Chengalpattu and Coimbatore. From January to December, the average annual rainfall for 2024 was recorded as 955.5 mm in the Northeastern agro-climatic zone, followed by 872.4 mm in the Western agro-climatic zone. The maximum temperature range was recorded as 31.1 °C to 43.8 °C in NEZ and 36.1 °Cto 40.3 °C in WZ. Similarly, the minimum temperature ranges from 12.3 °C to 21.0 °C in NEZ and 11.0 °C to 13.2 °C in WZ of Tamil Nadu. In NEZ, the average relative humidity for the past year was recorded as 68.92 % and WZ as 72.23 %.

Correlation analysis

Karl Pearsons' correlation coefficient was worked out between climatic parameters, namely rainfall (mm), maximum temperature (°C), minimum temperature (°C) and relative humidity (%), with biometric values, namely collar diameter, total height and volume index for different age gradation of two years for farm grown casuarina clones in block plantations of selected agroclimatic zones.

Karl Pearson correlation for tree biometrics vs. climate in Northeastern zone (NEZ)

The biometric attribute of volume index Vs collar diameter (r = 0.996) and total height Vs collar diameter (r = 0.987) were positively correlated ($p<0.01$). Meanwhile, total height was also positively correlated with volume index with the correlation coefficient value of r = 0.991 (Table 3). Concerning Karl Pearsons' correlation coefficient, the climatic factors viz., maximum temperature were positively correlated with total height, collar diameter and volume index with the correlation coefficient of r = 0.781, r = 0.742 and r = 0.733, respectively. Similarly, minimum temperature positively correlates with total height, collar diameter and volume index, with the correlation coefficients of r = 0.418, r = 0.394 and r = 0.380. At the same time, mean average rainfall was negatively correlated with total height, collar diameter and volume index with the correlation coefficient of r = -0.453, r = -0.450 and r = -0.438, respectively. It is also interesting to note that the relative humidity was also inversely correlated with total height, collar diameter and volume index with r = -0.364, r = -0.340 and r = -0.357 recorded in the study zones. Among the growth biometrics, a strong correlation of r = 0.996 was

Table 3. Karl Pearson Correlation for tree biometrics vs. climate in Northeastern zone (NEZ)

Pearsons' Correlation	Total height (cm)	Collar diameter (cm)	Volume index (cm³)	Average rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Total height (cm)	1						
Collar diameter (cm)	0.987**	1					
Volume index (cm³)	0.991**	0.996**	1				
Average rainfall (mm)	-0.453	-0.450	-0.438	1			
Maximum temperature (°C)	0.781*	0.742*	0.733*	-0.304	1		
Minimum temperature (°C)	0.418	0.394	0.380	0.173	0.764	1	
Relative humidity (%)	-0.364	-0.340	-0.357	0.845**	-0.159	0.430	1

*significant at the 0.01 level (2-tailed)

**significant at the 0.05 level (2-tailed)

recorded between volume index and collar diameter. On comparing the growth attributes Vs climatic parameters, a strong positive correlation of r = 0.781 was registered between total height and maximum temperature (Fig. 3).

Trees on farmlands improve micro-climates that contribute to climate change. Integrating trees on farms benefits farmers, especially those struggling to cope with the impacts of climate change (12). The climatic parameters, *viz*., rainfall, relative humidity, maximum and minimum temperature were correlated with the volume index obtained in casuarina under two years old in selected Tamil Nadu agro-climatic zones. The study found that climatic factors were positively associated with volume index under the maximum temperature (r = 0.733) and minimum temperature (r = 0.380). Research indicates that the highest increase in mean annual increment (MAI) of 2-year-old casuarina plantation was registered in 2017 at Navsari, Gujarat, where the average yearly rainfall was more than the previous years, about 950 mm (13). Another research finding related to temperature in casuarina plantation observed that the mean growth rate of casuarina ranged from 4.5 mm/year/tree (Initial years) to 5.2 mm/year/tree (2 years onwards); however, a slow growth rate was observed when the rainfall was less than 800 mm (14). Research evidence explained that casuarina grows well in areas with 800-1500 mm rainfall annually with an altitude of about 1100 m (15).

Karl Pearson correlation for tree biometrics vs. climate in the Western zone (WZ)

Karl Pearsons' correlation coefficient for growth attributes of casuarina plantations was analyzed in the western zone. The result infers that the volume index positively correlated with collar diameter and total height with the correlation coefficient of r = 0.992 and r = 0.946 respectively at 1 % significance level (Table 4).

On comparing the correlation coefficient with growth and climatic parameters, a positive correlation was observed between average annual rainfall Vs collar diameter, average yearly rainfall vs total height and average annual rainfall Vs volume index with the correlation coefficient of r = 0.090, r = 0.105 and r = 0.051 at p<0.01 respectively. Similarly, maximum and minimum temperature were positively correlated with collar diameter, total height and volume index with the correlation coefficient of r = 0.698, r = 0.428 and r = 0.654 for maximum temperature, whereas r = 0.338, r = 0.168 and r = 0.289 for minimum temperature,

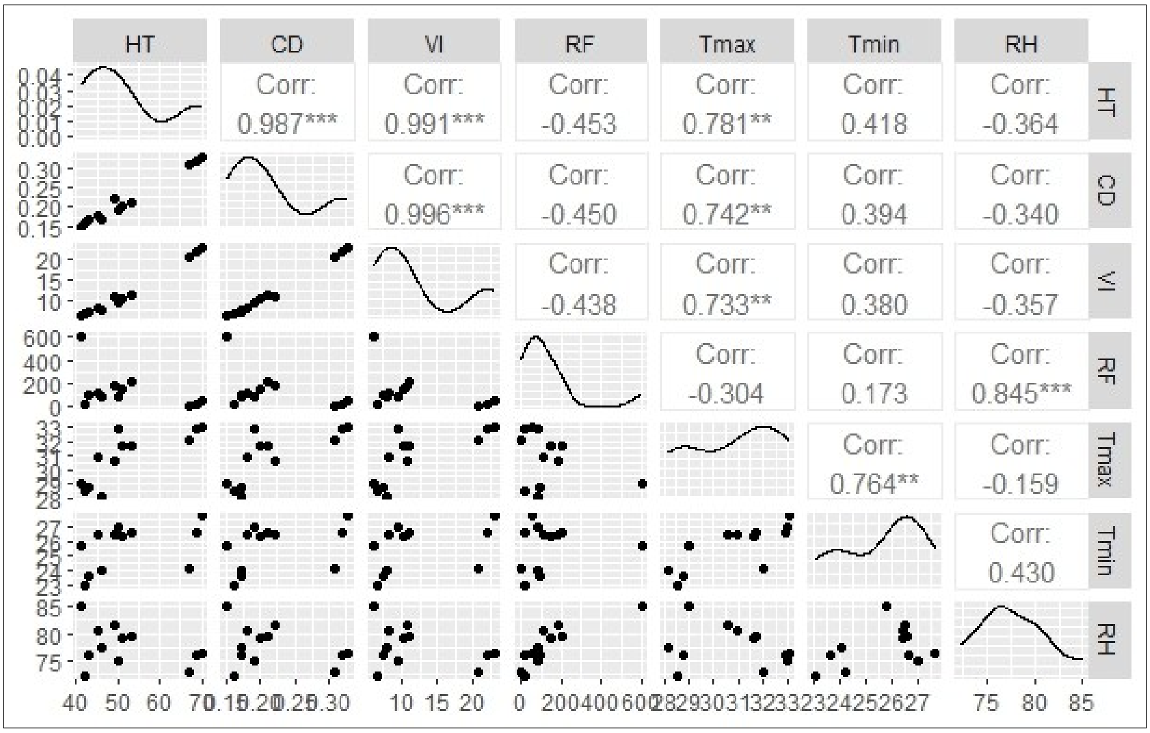

Fig. 3. Growth vs. climate correlation in plantations of Northeastern zone.

Table 4. Karl Pearson Correlation for tree biometrics Vs climate in Western zone (WZ)

Pearsons' Correlation	Total height (cm)	Collar diameter (cm)	Volume index (cm^3)	Average rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
Total height (cm)	1						
Collar diameter (cm)	0.904**	1					
Volume index (cm^3)	0.946**	0.992**	1				
Average rainfall (mm)	0.105	0.090	0.051	1			
Maximum temperature (°C)	0.428	0.698*	0.654*	-0.259	1		
Minimum temperature (°C)	0.168	0.338	0.289	0.470	0.492	1	
Relative humidity (%)	-0.400	-0.596	-0.571	0.472	-0.891	-0.163	1

*significant at the 0.01 level (2-tailed) ; **significant at the 0.05 level (2-tailed)

respectively. The relative humidity was negatively correlated with all the growth biometrics, respectively. On comparing the growth Vs climate, a strong positive correlation of r = 0.698 was recorded between collar diameter and maximum temperature (Fig. 4).

The growth of the trees depends on the edapho-climatic and locality factors. The development of trees is strongly influenced by climatic factors like rainfall, temperature (maximum and minimum) and relative humidity. In the current study, the volume index of casuarina trees was found to have a strong positive correlation with average rainfall (r = 0.051), maximum temperature (r = 0.654) and minimum temperature (r = 0.289), respectively. The results align with the earlier findings in 2-year-old *Populus deltoids* in which a positive correlation between total volume and mean annual rainfall (16).

In the present study, it is interesting to note that the relative humidity was negatively correlated with the volume index with the correlation coefficient of r = -0.571. Similar results on the negative correlation between relative humidity and volume index were recorded in *Hevea brasilliensis* plantations (17). The correlation study result infers that climatic parameters such as mean annual rainfall, temperature and relative humidity influenced casuarina trees' tree growth and volume index.

Correlation analysis on soil physio-chemical properties in selected agro-climatic zones of Tamil Nadu

Karl Pearsons' correlation coefficient was carried out between edaphic factors, namely pH, Electrical Conductivity (dSm^{-1}), organic carbon (%), available nitrogen (kg ha^{-1}), available phosphorus (kg ha^{-1}) and available potassium (kg ha^{-1}) with all biometric values in two years age-gradation of selected agroclimatic zones respectively (Table 5).

Karl Pearson correlation for tree biometrics Vs edaphic factors in the Northeastern zone (NEZ)

Among the biometric attributes, collar diameter and total height were positively correlated with the volume index with a correlation coefficient of r = 0.996 and r = 0.992, respectively. Similarly, the collar diameter was positively correlated with the total height, with a correlation coefficient of r = 0.985 (Fig. 5).

On comparing Karl Pearsons' correlation coefficient with the edaphic factors, available nitrogen (N), available phosphorus (P) and available potassium (K) showed negative correlation with all the growth attributes viz., collar diameter (r = -0.505, r = -0.569 and r = -0.475), total height (r = -0.468,

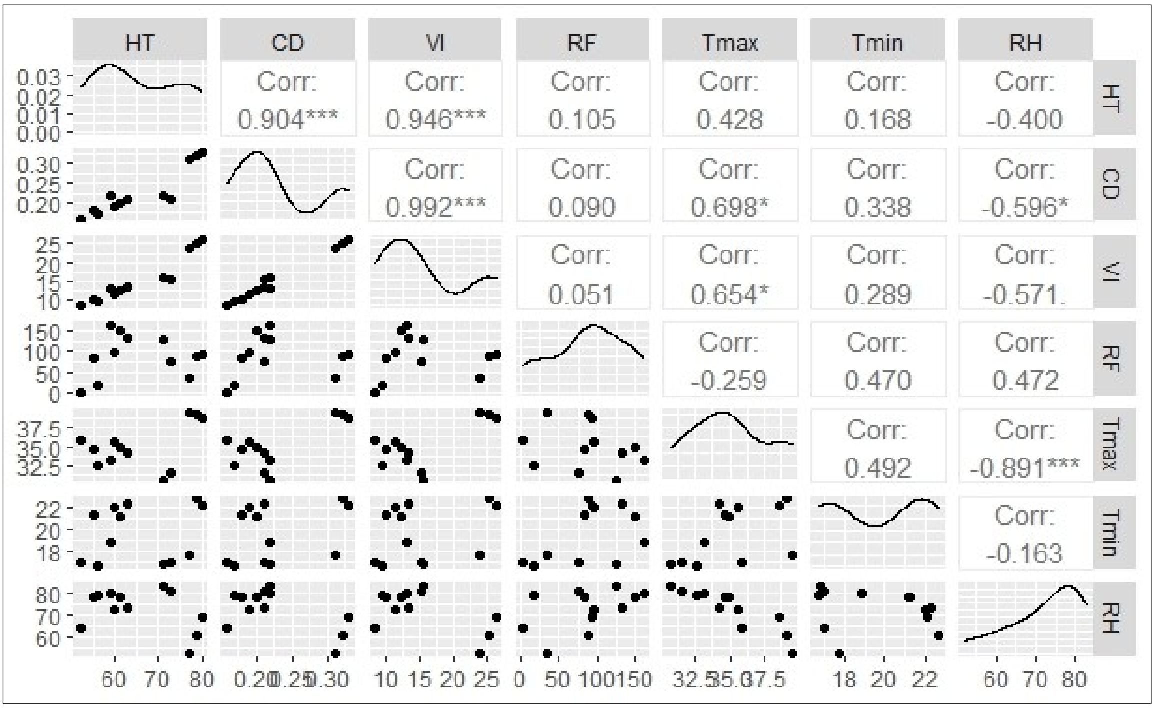

Fig. 4. Growth vs. climate correlation in plantations of the Western zone.

Table 5. Soil physico-chemical properties of two agroclimatic zones

Sl. No.	Location	Age (Years)	Soil pH	EC (dS/m)	Organic carbon (%)	Available nitrogen (Kg/ha)	Available phosphorus (Kg/ha)	Available potassium (kg/ha)
Surface Soil (0-15 cm)								
1.	Maduranthakam (NEZ)	Two	8.13	0.12	0.60	177	16.0	268.0
2.	Vellaputhur (NEZ)	Two	7.17	0.16	0.56	173	20.0	295.0
3.	Odanthurai (WZ)	Two	8.10	0.12	0.60	165	11.0	235.0
4.	Jaganari slope (WZ)	Two	8.43	0.18	0.48	153	17.0	275.0
Subsurface soil (15-30 cm)								
1.	Maduranthakam (NEZ)	Two	8.70	0.18	0.62	185	18.3	358.0
2.	Vellaputhur (NEZ)	Two	7.01	0.17	0.59	180	25.0	312.0
3.	Odanthurai (WZ)	Two	8.44	0.22	0.84	173	15.0	257.0
4.	Jaganari slope (WZ)	Two	8.47	0.21	0.52	161	20.0	290.0

(NEZ - North Eastern Zone; WZ - Western Zone)

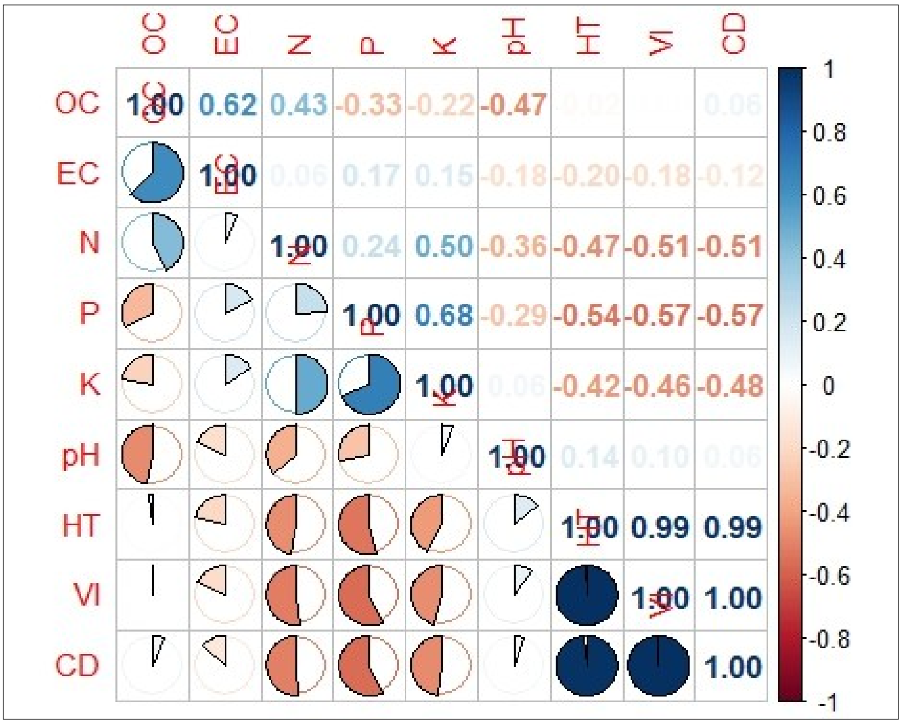

Fig. 5. Growth vs. soil correlation in plantations of Northeastern zone

r = -0.540 and r = -0.422) and volume index (r = -0.514, r = -0.566 and r = -0.463). Similarly, electrical conductivity was negatively correlated with all the biometric attributes, viz., collar diameter (r = -0.125), total height (r = -0.204) and volume index (r = -0.182). A positive correlation was also observed between pH with all growth attributes with the correlation coefficient of r = 0.144 (total height), r = 0.057 (collar diameter) and r = 0.097 (volume index), respectively, in 2 years of casuarina block plantations (Table 6).

In selected agro-climatic zones of Tamil Nadu, farm-grown casuarina was studied for its edaphic influence on the volume index. The research evidence also concluded that casuarina grows well in coastal areas and sandy loam soils but poorly on clayey, black cotton and waterlogged soils. It tolerates dry localities subject to great heat and drought in the hot season and soil pH 6.5 to 7.0 (18).

Edaphic parameters, namely soil pH (r = 0.097) and soil organic carbon (r = 0.001), were positively correlated with the volume index of casuarina. Similarly, soil-available nitrogen (r = -0.514), soil-available phosphorus (r = -0.566) and soil-available potassium (r = -0.463) were negatively correlated with the volume index of casuarina. The research evaluated the correlation between casuarina growth and soil physicochemical properties, where a negative correlation of soil parameters (Available nitrogen, phosphorus and potassium) influences a positive correlation effect of other parameters (Soil pH and organic carbon) on casuarina growth (19). Another study on casuarina showed that the fact that poor soil depth is an essential factor limiting tree growth. In contrast, the most profound soil depth leads to positive tree growth (20).

Karl Pearson correlation for tree biometrics vs edaphic factors in the Western zone (WZ)

Concerning Karl Pearsons' correlation coefficient with the edaphic factors of block plantations of western zone showed that pH and available nitrogen were positively correlated with all the growth attributes viz., collar diameter (r = 0.050 and r = 0.415), total height (r = 0.257 and r = 0.433) and volume index (r = 0.074 and r = 0.414) (Table 7). Whereas electrical conductivity (EC) and soil organic carbon (SOC) were negatively correlated with the growth parameters of collar diameter, total height and volume index with the correlation coefficient of r = -0.664, r = -0.362, r = -0.622 for EC and

Table 6. Karl Pearson correlation for tree biometrics Vs edaphic factors in North eastern zone (NEZ)

Pearsons' Correlation	Total height (cm)	Collar diameter (cm)	Volume index (cm^3)	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Total height (cm)	1								
Collar diameter (cm)	0.985**	1							
Volume index (cm^3)	0.992**	0.996**	1						
pH	0.144	0.057	0.097	1					
Electrical conductivity (dSm^{-1})	-0.204	-0.125	-0.182	-0.180	1				
Organic carbon (%)	-0.022	0.060	0.001	-0.474	0.624*	1			
Nitrogen (kg ha^{-1})	-0.468	-0.505	-0.514	-0.357	0.061	0.431	1		
Phosphorus (kg ha^{-1})	-0.540	-0.569	-0.566	-0.285	0.171	-0.326	0.239	1	
Potassium (kg ha^{-1})	-0.422	-0.475	-0.463	0.056	0.155	-0.221	0.502*	0.681*	1

*significant at the 0.01 level (2-tailed); **significant at the 0.05 level (2-tailed)

Table 7. Karl Pearson correlation for tree biometrics Vs edaphic factors in Western zone (WZ)

Pearsons' Correlation	Total height (cm)	Collar diameter (cm)	Volume index (cm^3)	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Total height (cm)	1								
Collar diameter (cm)	0.915**	1							
Volume index (cm^3)	0.946**	0.995**	1						
pH	0.257	0.050	0.074	1					
Electrical conductivity (dSm^{-1})	-0.362	-0.664	-0.622	0.536	1				
Organic carbon (%)	-0.658	-0.837	-0.825	0.185	0.808**	1			
Nitrogen (kg ha^{-1})	0.433	0.415	0.414	0.536*	-0.146	-0.255	1		
Phosphorus (kg ha^{-1})	-0.203	-0.103	-0.127	-0.562	-0.047	0.021	-0.375	1	
Potassium (kg ha^{-1})	-0.434	-0.636	-0.614	0.567*	0.724*	0.791*	0.204	-0.361	1

*significant at the 0.01 level (2-tailed); **significant at the 0.05 level (2-tailed)

r = -0.837, r = -0.658, r = -0.825 for SOC respectively. The negative correlations were obtained for available phosphorus and potassium correlated with all growth attributes *viz*., collar diameter (r = -0.103 and r = -0.636), total height (r = -0.203 and r = -0.434) and volume index (r = -0.127 and r = -0.614) respectively (Fig. 6).

The edaphic factors, viz., soil physico-chemical and soil chemical properties, strongly influence the growth parameters in the block plantations. The soil macronutrients such as available nitrogen, phosphorus and potassium significantly influenced the growth biometrics of farm-grown casuarina trees.

When soil physicochemical properties were compared, soil EC was negatively correlated with all biometric attributes, whereas pH exhibited a significant positive correlation. Soil pH and EC influence trees' growth and distribution; a significant relationship was witnessed between the volume increment of casuarina and soil physicochemical properties. The soil organic carbon negatively correlated with the *Casuarina equisetifolia* volume index (21).

The available nitrogen in the soil positively interacted with the volume index, whereas available phosphorus and potassium exhibited a negative interaction effect. The findings of positive interaction between available nitrogen and volume index were established in different trees at different localities (22, 23). The positive influence of soil factors on the growth and productivity of tropical tree species was also reported in *Tectona grandis* and *Ailanthus excelsa* (24, 25).

Conclusion

Farm-grown casuarina holds a significant place in sustainable farm forestry and agroforestry systems. Cultivating casuarina on farmlands has gained considerable prominence as an environmentally beneficial approach to meeting economic and ecological needs. The study result concerning correlation analysis has strongly suggested that edaphic factors and climatic variables play a crucial role in the growth and development of casuarina raised in farmlands. Climatic conditions, viz., temperature, which includes both maximum and minimum, average rainfall and relative humidity, play a crucial role in determining the

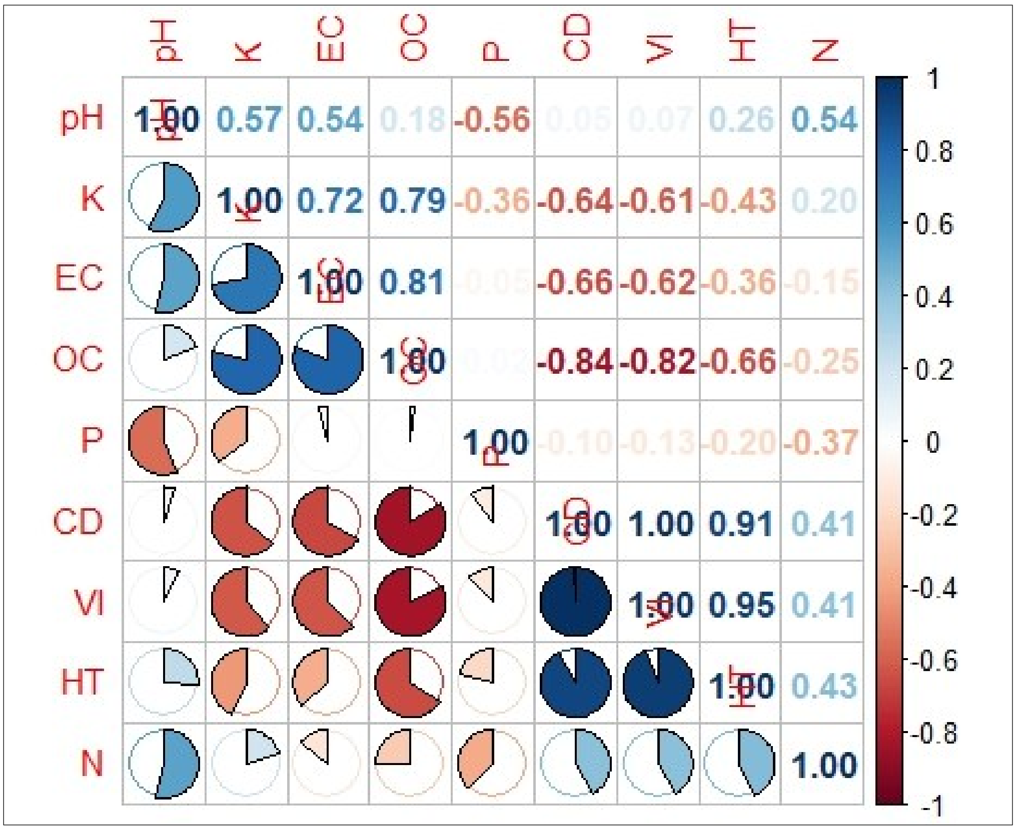

Fig. 6. Growth vs Soil correlation in plantations of the Western zone.

growth rate, wood quality and overall growth of farm-grown casuarina. Similarly, the edaphic factors, soil type, pH, nutrient availability and soil moisture significantly impact the casuarinas' ability to thrive. Therefore, for optimal growth of casuarina in farm conditions, a comprehensive understanding and management of these climatic and edaphic factors are essential. This will enhance the productivity of the casuarina raised on farms and contribute to sustainable forestry practices. Understanding these influences can help optimize cultivation practices and improve productivity in different environmental conditions.

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Authors' contributions

SN contributed to the conceptualization of the research work and provided the initial framework for the study. AB was involved in formulating the research concept and refining the study objectives. SR participated in developing the research idea and contributed to shaping the overall direction of the work. IS designed the experimental layout and guided the selection of appropriate methods. TC contributed to planning the experimental setup and determining technical procedures. SV assisted in designing the experiments and helped ensure their scientific validity.MS executed the field and laboratory experiments and was responsible for data collection. BS participated in the implementation of experiments and assisted in gathering research data. CN conducted the data analysis and contributed to interpreting the results. GS supported data interpretation and participated in compiling results for the manuscript. AE was involved in analyzing the data and preparing the draft of the manuscript. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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