Agriculture Association of Textile Chemical and Critical Reviews Journal (2022) 86-91

AATCC Review

15 July 2022: Received
17 August 2022: Revised
30 September 2022: Accepted
05 October 2022: Available Online

http://aatcc.peerjournals.net/

Research Article Open Access

# Spatio Temporal Analysis of Teak Plantations in the Cauvery Delta Zone of Tamil Nadu, India

M. Vijayabhama*, K. Baranidharan, R Ravi and Hemalatha

Tamil Nadu Agricultural University, Mettupalayam-641301, India

## Abstract

*This paper explains the spatial and temporal variations of Teak (Techtonagrandis), panel data of eight districts viz, Cuddalore, Pudhukottai, Tanjavore, Trichy Tiruvarur, Nagapattinam, Ariyalur and Karur were used for the period of 24 years from 1996-97 to 2019-20. It was found that Teak area as a dependent variable and twelve independent variables like Barren unculturable, Other fallow, Culturable waste, Current fallow, Cropping Intensity, Total Food crops, Total Nonfood crops, Gross Area Irrigated, Total Rainfall, Price of Teak, Net Area Sown, Gross Area Sown are used for the analysis. The results showed that the coefficient of determination (R2) value was 46 percent within the model, 64.95 percent between the model and 54.89 percent for the overall model. The values of the model define that 46 percent of the variation in the area of teak is influenced by the explanatory variables within the model. In main effect, the area of teak is spatially and temporally significant, positively simulated for the price of teak with a 1 percent level of significance. Total rainfall is negative with 1 percent level of significance. In the spatial-panel lag model, the estimate of the parameter ρ was significant at one percent. The theta value is significant at a one percent level of significance. In direct effect, total rainfall shows a negative effect at a significance of one percent and the price of teak also shows that a positive effect at the five percent level of significance. In indirect effect rainfall shows positively significant at 5%, price of teak contributes negatively at 5% significance. The total effect of the model showed the negative effect of the total rainfall at one percent level of significance and the price of teak showed that a positive effect at five percent.The area of Teak expansion was influenced by two major factors like total rainfall and the price of teak. Among these, Rainfallis negatively related and the price of Teak was positively related with the area of Teak.*

**Keywords:** *Spatio-Temporal Variation, Spatio Autoregressive Model, OLS regression, Panel data regression, Teak*

## Introduction

Indian forests have undergone a tremendous change in the last few decades and are presently under a greater threat. The consumption of wood other than fuelwood takes place in many sectors, namely, housing, construction, and furniture. The total annual consumption was 48.00 m3 FSI. In India, 105 million hectares of land are in unutilized condition. Recently, there has been a shift in the emphasis from the utilization of the often complex natural forests to plantation species which are relatively easy to manage and capable of producing large quantities of wood per unit area. The gap between demand and supply has become still wider at the middle of this century. Teak is the farmer's favorite as they fit well in the agrarian ecosystem. Timber value, periodic

**Corresponding Author: : M.Vijayabhama*
*E-mail Address: vijayabhamam@gmail.com*
*DOI:https://doi.org/10.58321/AATCCReview.2022.10.01.91*

returns in the form of pruned branches right from the second year, ability to improve soil fertility, and ready marketability are the major factors to attract this species. In recent years, Teak cultivation is being encouraged by the Tamil Nadu Forest Department through schemes such as Tree Cultivation in Private Lands and Tamil Nadu Green Mission. The study was taken up to assess the spatial and temporal distribution of Teak plantations in 8 districts of the Cauvery delta zone of Tamil Nadu, India. To bridge the gap between the demand and supply of Timber in Tamil Nadu, the spatial autoregressive model (SAR) is used

## Materials and Methods

### 2.1 Material

#### 2.1.1 Species under study

*Tectonagrandis* was first formally described by Carl Linnaeus the Younger in his 1782 work SupplementumPlantarum. Teak is a tropical hardwood tree species in the family ***Lamiaceae.*** It is a large, deciduous tree that occurs in mixed hardwood forests it has small, fragrant white flowers arranged in dense clusters (panicles) at the end of the branches. These flowers contain both types of reproductive organs (perfect flowers). In India teak occurs naturally below 24° N latitude in the States of Kerala, Andhra Pradesh, Karnataka, Orissa, Madhya Pradesh, Maharashtra, Gujrat, Rajasthan, Uttar Pradesh, and Manipur. The first teak plantation in India was established in Nilambur, Kerala in 1846, and parts of it have been still preserved. Teak is propagated mainly from seeds. Germination of the seeds involves pretreatment to remove dormancy arising from the thick pericarp. Pretreatment involves alternate wetting and drying of the seed. The seeds are soaked in water for 12 hours and then spread to dry in the sun for 12 hours. This is repeated for 10–14 days and then the seeds are sown in shallow germination beds of coarse peat covered by sand. The seeds then germinate after 15 to 30 days.

*Tectonagrandis* occurs naturally in various types of tropical deciduous forests. In seasonal climates, T. grandis is deciduous, while trees grown in non-seasonal climates are semi-deciduous. It is often a dominant member of a mixed deciduous forest, where its main associates are Xylia spp., Afzeliaxylocarpa, Terminalia spp., and Lagerstroemia spp. The forest floor is often covered with bamboo. T. grandis generally occurs scattered but can form almost pure stands under favorable conditions. Young plants show a remarkable capability to recover after a fire. Their most suitable soil is deep, well-drained, fertile alluvial-colluvial soil with a pH of 6.5-8 and a relatively high calcium and phosphorous content. The quality of growth, however, depends on the depth, drainage, moisture status, and fertility of the soil. Teak does not tolerate waterlogging or infertile lateritic soils.

#### 2.1.2 Location

The study was conducted at the Cauvery delta agro-climatic zone of Tamil Nadu where Teak grows well, namely, which includes eight districts, namely Cuddalore, Pudhukottai, Tanjavore, Trichy Tiruvarur, Nagapattinam, Ariyalur, and Karur (Figure 1).

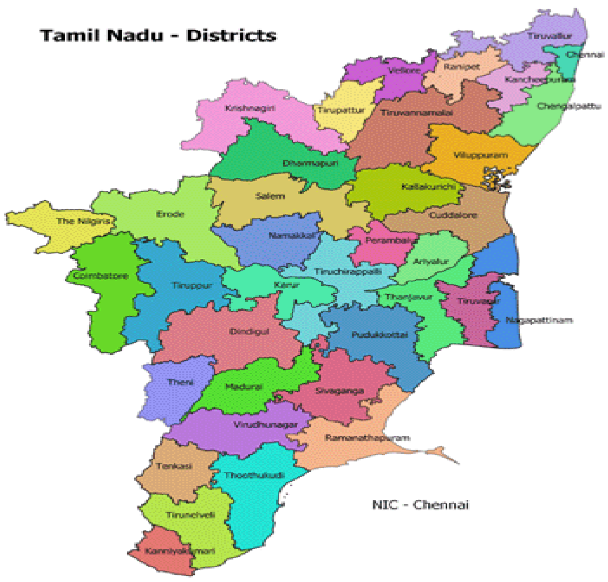


**Figure 1.** Tamil Nadu Map: showing Contiguity-based neighborhood

## Methodology

#### 2.2.1 Collection of Secondary data

The land-holding data of Teak plantations in the Cauvery delta zone in different districts were collected from the Crop Season Report published by the Directorate of Economics and Statistics, Government of Tamil Nadu. The majority of the plantations were established by Tamil Nadu Forest Department as canal plantations. The data on Teak land holding was collected from 1996 to 2020. The following details were also collected from the districts with respective year, the total area of Barren &unculturalable land, Other Fallow, Cultivable Waste, Pasture Land, Current Fallow, Net Area Sown, Gross Area Sown, Total Cereal Area, Total Pulses Area, Total Fruits and Vegetables Area, Total Paddy Area, Total Food Crops, Total Non-Food Crops, Gross Area Irrigated, Total Food Grains Productivity, Paddy Yield, Rain Fall, Tree Crops and Price of Teak. These factors are identified as influential for the area of Teak plantation in eight districts.

### 2.2.2 Spatial Econometric Analysis

Spatial econometrics deals with spatial dependence between the observations at each point in time. [10], [1], [3],[2],[6] [7] [8]. It is also testing of spatial dependence in a panel model; these spatial panel data models have a wide range of applications in agriculture and forestry.

When a value observed in one location depends on the values observed at neighboring locations, there is a spatial dependence. The spatial data may show spatial dependence in the error terms and variables. The observations associated with spatial units may reflect measurement errors. This happens when the boundaries for which information is collected do not accurately reflect the nature of the underlying process generating the sample data. The spatial dimension of a social or economic characteristic may be an important aspect of the phenomenon. Spatial Auto-Regressive (SAR) Model and Spatial Error Model (SEM) are two basic spatial econometric models.

### 2.2.3 Spatial Auto-Regressive Model (SAR)

This model is also called as Spatial Lag Model. It says that levels of the dependent variable 'Y'depend on the levels of 'Y' in neighboring regions. It is thus a formulation of the idea of a spatial spillover.
The Spatial Auto-Regressive Model (SAR) (Cliff and Ord, 1973; Ord, 1975; Bivand, 1984; Anselin, 1988; LeSage and Pace, 2009) is

$$Y = \rho WY + X\boldsymbol{\beta} + \mathbf{u} \qquad \ldots\ldots\ldots\ldots. (1)$$

Where, Y = $R$ x1 vector of observations on the dependent variable, $R$ = No. of districts,

W =$R$ x $R$ spatial weights matrix (with 0 diagonal elements),

$\rho$ = spatial autoregressive coefficient or the spatial lag parameter,

WY = spatially lagged dependent variable representing an average of spatially neighboring Y values,

X = $R$ x $k$ matrix of observations on the exogenous variables, with associated $k$ x 1 regression coefficient vector $\boldsymbol{\beta}$, and

u= vector of the error term.

Note that '$\rho$WY' makes sense since the diagonal elements of 'W'are zero, which implies that there is no circular specification such that '$Y_j$'on the left is influenced by the same '$Y_j$' on the right. Since the presence of 'Y'on both the left and right sides means that there would be a correlation-between-errors-and-regressors problem and the resulting estimates will be biased and inconsistent. But, one can easily obtain the reduced form as:

$$Y = \rho WY + X\boldsymbol{\beta} + \mathbf{u}$$
$$(I - \rho W)Y = X\boldsymbol{\beta} + \mathbf{u}$$
$$Y = (I - \rho W)^{-1}X\boldsymbol{\beta} + (I - \rho W)^{-1}u$$
$Y = (I - \rho W)^{-1}X\boldsymbol{\beta} + u^*$ (assuming that the inverse exists)

However, a couple of potential problems exists here. First, the new error term $u^* = (I - \rho W)^{-1}u$ is no longer homoskedastic. Second and probably more fundamentally, the model is no longer linear-in parameters because of the new unknown parameter '$\rho$'. The estimation and properties of this model have been studied in detail [1].

Testing of panel unit roots/stationarity by Levin-Lin-Chu (2002) test, multicollinearity by condition number test, normality of errors by Jarque-Bera test, heteroskedasticity by Breusch-Pagan test, Hausman's specification test, Moran's Test

### 2.2.4 Empirical analysis

The individual panel regression model, subject to the assumptions as discussed earlier, was estimated with and without spatial effect using a district-wise panel with balanced panels for eight districts for 24 years (from 1996-2020 [1] [2] The models were analyzed using STATA 12 software. The MLE method was applied to estimate the spatial panel models and finally, the comparison
was made with and without spatial effects. Table 1. Shows the variables used in the analysis of the land use share model.

 

In this study, the factors influencing the decision to change the land use from agricultural usestoTeakare related to two kinds of spatial effects: spatial heterogeneity and spatial dependence (Anselin, 1988). Spatial heterogeneity can be most simply understood as variables (or functional relationships between variables) that differ in space, whereas, spatial dependency is best explained as a 'functional relationship of what happens at one point in space and what happens elsewhere [1]. Based on this conceptual approach, the variables were identified and the hypotheses were constructed.

**Table 1:** Variables used in the agricultural land use share model

| Variable | Definition | Expected sign |
|---|---|---|
| **Dependent variables** | | |
| *Teak* | Teak area (ha) | |
| **Independent variables** | | |
| *BU* | Barren and unculturable land (ha) | (–) |
| *OF* | Other fallow land (ha) | (+/–) |
| *CW* | Culturable waste (ha) | |
| *CF* | Currentfallow (ha) | |
| *CI* | Cropping Intensity (CI) | |
| *TFC* | Total Food crops (ha) | |
| *TNFC* | Total Non Food crops(ha) | |
| *GAI* | Gross area irrigated (ha) | |
| *TF* | Total rainfall (ha) | |
| *NAS* | Net Area Sown(ha) | |
| *GAS* | Gross Area Sown(ha) | |
| *PC* | Price for Teak (ha) | |

The detailed description of various terms used in the Table is explained as follows.

**2.2.5 Econometric equations for Teak area model Panel data regression without spatial effect**

$$Teak = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + b_{11} X_{11} + b_{12} X_{12}$$

**Panel data regression with spatial effect**

**a) SAR Model**

$$Teak = a + \rho\, W_Y Teak + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10} + b_{11} X_{11} + b_{12} X_{12}$$

Where

ρ = spatial lag or spatial auto-regressive parameter,

*W* = Contiguity-based row-standardized spatial weight matrix and

$W_Y Teak$= spatially lagged dependent variable

$X_1$-Barren and unculturable land (ha)

$X_2$-Other fallow land (ha)

$X_3$-Culturable waste (ha)

$X_4$-Current fallow land (ha)

$X_5$- Cropping Intensity(ha)

$X_6$ -Total Food crops (ha)

$X_7$ - Total Non Food crops(ha)

$X_8$ - Gross area irrigated (ha)

$X_9$ -Total rain fall (ha)

$X_{10}$ -Net Area Sown(ha)

$X_{11}$ -Gross Area Sown(ha)

$X_{12}$-Price for Teak (ha)

**3. RESULT AND DISSUSSION**

The study results revealed that the area of Teak expansion was influenced by twelve factors($X_1$ to $X_{12}$). With regards to these factors, Total rainfall ($X_9$),Price for Teak ($X_{12}$)had more influence on area of Teak expansion. The coefficient of determination ($R^2$) value was 46 percent within the model, 64.95 percent between the model and 54.89 percent for the overall model. The values of the model define that 46 percent of the variation in area of teak is influenced by the explanatory variables within the model. The coefficient of determination results shows that the values of within, between and overall model effects are not same. In main effect, the area of teak is spatially and temporally significant, positively simulated for the price of teak with a 1 percent level of significance. Total rainfall is negative with a 1 percent level of significance. In the spatial-panel lag model, the estimate of the parameter ρ was significant at one percent. The theta value is significant at a one percent level of significance. In direct effect, total rainfall shows a negative effect at a significance of one percent and the price of teak also shows that a positive effect at the one percent level of significance. In indirect effect also showed the same result with the five present levels of significance. The total effect of the model showed the negative effect of the total rainfall at a one percent level of significance and the price of the teak showed a positive effect at five percent. (Table. 2)

**SAR Analysis**

Number of observation = 192

Group variable: id
Number of groups = 8
Time variable: Year
Panel length = 24
R-sq: within = 0.4606
between = 0.6495
overall = 0.5489
Log-pseudolikelihood = -1093.816

**Table 2** Spatio Temporal Analysis of Teak Spread in Cauvery Delta zone

| Area of Teak | Coefficient | Standard Error |
|---|---|---|
| **MainEffect** | | |
| Barren and uncultured Lands | -0.0022 | 0.0032 |
| Other fallow lands | 0.0005 | 0.0004 |
| Culturable waste | -0.0004 | 0.0004 |
| Current fallow land | 0.0006 | 0.0005 |
| Cropping Intensity | 2.5006 | 5.5226 |
| Total Food crops | 0.0016 | 0.0019 |
| Total Non food crops | 0.0018 | 0.0012 |
| Gross Area Irrigated | -0.0003 | 0.0006 |
| Net Area Sown | -0.0019 | 0.0023 |
| Gross Area Sown | 0.0013 | 0.0027 |
| Total rainfall | -0.0698** | 0.0144 |
| Price of Teak | 0.0106** | 0.0026 |
| Cons | -471.392 | 467.429 |
| Spatial rho | -0.1034** | 0.0301 |
| lgt_theta | -1.5013** | 0.2616 |
| sigma_e | 4492.075** | 1217.898 |
| **Direct Effect** | | |
| Barren and uncultured Lands | -.0011 | 0.0316 |
| Other fallow lands | 0.0005 | 0.0005 |
| Culturable waste | 0.0000 | 0.0023 |
| Current fallow land | 0.0006 | 0.0024 |
| Cropping Intensity | 2.4961 | 5.1699 |
| Total Food crops | 0.0021 | 0.0169 |
| Total Non-food crops | 0.0015 | 0.0054 |
| Gross Area Irrigated | -.0005 | 0.0167 |
| Net Area Sown | -0.0019 | 0.0023 |
| Gross Area Sown | 0.0013 | 0.0027 |
| Total rainfall | -.0684** | 0.0159 |
| Price of Teak | 0.0107* | 0.0042 |
| **Indirect Effect** | | |
| Barren and uncultured Lands | .0001 | 0.0031 |
| Other fallow lands | .00005 | 0.00005 |
| Culturable waste | -6.28e-06 | 0.0002 |
| Current fallow land | -.00006 | 0.0002 |
| Cropping Intensity | -.2109 | 0.4965 |
| Total Food crops | -.0001 | 0.0016 |
| Total Non food crops | -.0001 | 0.0005 |
| Gross Area Irrigated | .00006 | 0.0016 |
| Net Area Sown | 0.0001 | 0.0012 |
| Gross Area Sown | -.00004 | 0.0015 |
| Total rainfall | 0.0066* | 0.0026 |
| Price of Teak | -.0010* | 0.0004 |
| **TotalEffect** | | |
| Barren and uncultured Lands | -.0009 | 0.0287 |
| Other fallow lands | 0.0004 | 0.0005 |
| Culturable waste | 0.00006 | 0.0021 |
| Current fallow land | 0.0005 | 0.0022 |
| Cropping Intensity | 2.2852 | 4.7054 |
| Total Food crops | 0.0019 | 0.0153 |
| Total Non food crops | 0.0014 | 0.0049 |
| Gross Area Irrigated | -.0005 | 0.0151 |
| Net Area Sown | -.0011 | 0.0114 |
| Gross Area Sown | 0.0006 | 0.0139 |
| Total rainfall | -.0618** | 0.0140 |
| Price of Teak | 0.0097* | 0.0038 |

** = 1 %, * = 5 %,

The result indicated that the $R^2$values in within and overall models were not similar; this is the evidence for individual effects being so important in the SAR model.In the main effect, the area of teak is spatially and temporally significant, positively simulated for the price of teak with 1 percent level of significance. Total rainfall is negatively with 1 percent level of significance.In the spatial-panel lag model, the estimate of the parameter ρ was significant at one percent. The theta value is significant at a one percent level of significance. In direct effect, total rainfall shows the a negative effect at a significance of one percent and the price of teak also shows that thea positive effect at the one percent level of significance. In indirect effect also showed the same result with the five present levels of significance. The total effect of the model showed that the negative effect of the total rainfall at a one percent level of significance and the price of the teak showed that a positive effect at five percent. The theta value of the estimation was significant at one percent level. It indicated the rate at which the Teak area would decrease every year by 1.50 ha, holding all other variables constant. The explanatory variables in the model would influence the spread of Teak in the selected sample area. The price of Teak was positively significant at the 0.05 level. The higher price of Teak would increase the Teak area in both own and neighboring districts, Similar findings were also recorded by [9] in Casuarina spread.

## Conclusion

The study concludes that the area of Teak expansion was influenced by two major factors total rainfall and the price of teak. Among these, Rainfallis negatively related, and price of Teak was positively related to area of Teak, when the price of the Teak increases area of the Teak will also increase. Even though less rainfall but more irrigation facilities and the high price of Teak leads the farmers to go for more areas of Teak plantation.

## References


[1.] L. Anselin, Spatial Econometrics: Methods and Models, Kluwer Academic, Dordrecht, the Netherlands, 1988.

[2.] B. Baltagi and L. Liu, Instrumental variable estimation of a spatial autoregressive panel model with Random effects, CPR WP no. 127, 2011.

[3.] J.P. Elhorst, Dynamic models in space and time, Geogr. Anal. 33 (2001), pp. 119–140.

[4.] Forest Survey of India (FSI) (2011) India State Forest Report 2011 Published by FSI (MoEF), Dehradun, India.

[5.] B. Huang, L. Zhang, and B. Wu, Spatiotemporal analysis of rural−-urban land conversion, Int. J. Geogr. Inf. Sci. 23 (2009), pp. 379–398.

[6.] M. Kapoor, H. Kelejian, and I. Prucha, Panel data models with spatially correlated error components, J. Econom. 140 (2007), pp. 99–121.

[7.] L.F. Lee, J. Yu, Estimation of spatial autoregressive panel data models with fixed effects, J. Econom. 154 (2010), pp. 165–185.

[8.] J. Mutl and M. Pfaffermayr, The Hausman test in a Cliff and Ord panel model, Econom. J. 10 (2010), pp. 48–76.

[9.] Vijayabhama., R.Jaisankar, S.Varatharaj and K.Baranidharan 2016. "Spatial temporal variation of Casuarina spread in Cauvery delta and northeastern zone of Tamil Nadu, India: a spatial autoregressive model. Science Citation Index (SCI)" Journal of Applied Statistics, Taylor and Francis Group, United Kingdom. November 2016 ISSN 0266-4763

[10.] X. Zheng, F. Li, S. Song, and Y. Yu, Central government's infrastructure investment across Chinese regions: a dynamic spatial panel data approach, China Econ. Rev. 27 (2012), pp. 264–276