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Does Land Tenures Affect Productivity of Coffee? Farm Level Evidences from Western Ghats of India

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A B S T R A C T

Does land tenures affect coffee productivity? The response from farm level data is affirmative. Taking into account redeemed and unredeemed land tenure systems in Kodagu, the study investigate factors influencing productivity of coffee. The primary data was collected from 50 Arabica and 50 Robusta coffee growers in Kodagu district between March-June 2020 using snow ball sampling method. The estates were classified into four categories viz., redeemed Arabica, unredeemed Arabica, redeemed Robusta and unredeemed Robusta estates. The analysis indicated that productivity was highest in unredeemed Arabica and redeemed Robusta estates. The indigenous shade trees (number) and age of coffee trees (years) significantly influenced productivity of coffee under different land tenures. The White Stem Borer (*Xylotrechus quadripes*) significantly influenced both redeemed and unredeemed Arabica estates. The exotic silver oaks (*Grevillea robusta*) and dadap trees (*Erythrina spp*) positively influenced redeemed Robusta and unredeemed Arabica estates respectively. The elevation of estates and average annual rainfall though positively influenced redeemed Robusta estates, however indicated contrast results in unredeemed Robusta estates. The study recommends cultivation of indigenous shade trees, dadaps in unredeemed Arabica estates, limit cultivation of exotic silver oaks in unredeemed Robusta estates and cultivation of Arabica at higher elevations.

***Key words*:** Land tenure, Redeem, Unredeem, Arabica, Robusta

The land is a limited natural resource, affecting the efficiency of all agricultural systems. Land as well as land tenure structures are viewed as major issues in the national development strategy [1]. The land tenure systems are perceived as the institutions governed by a set of rules and regulations formulated by the society to synchronize human behaviour in a particular direction. This also determines the utilization of resources with respect to land [2] and allocation of property rights within the society.

There are two major types of land tenure systems in Kodagu viz., redeemed and unredeemed land tenures. As per the Coorg Land and Revenue Regulations 1899, in case of redeemed land the owner holds tree rights and permitted to cut trees in their own estates. Contrastingly, in case of unredeemed land the government holds tree rights and owner is not permitted to harvest trees in their own land though the land is legally owned by the owner. In the later case, the owners need to obtain prior permission from the Forest Department for tree felling, thereby restricting the owners to cut trees in their own land [3].

While, the land tenure system in Kodagu affects the coffee agro-forestry in Western Ghats of India [4]. But does the land tenure also affect productivity of coffee? Surprisingly, this topic is yet to be researched while there also exists vast research gap on this aspect. Earlier studies by [5] showed that land tenures affect agricultural productivity by determining efficient allocation of inputs. [6] noted that the customary land tenures in Ghana affected tree planting and decision to cultivate or leave it fallow. Interestingly, [7] had shown that land tenures had no impact on productivity of coffee. But our survey indicated that land tenures significantly influenced productivity of coffee. For instance, productivity of Arabica (691 kg/ha) was highest in unredeemed land tenure system viz., 1.61 times higher than the national average Arabica productivity (427 kg/ha). Contrastingly, Robusta coffee indicated maximum productivity (1292 kg/ha) under redeemed land tenure that was 1.31 times higher than national average Robusta productivity (983 kg/ha) (Table 1). Certainly, there could be several factors impacting the productivity of different varieties of coffee differently under different land tenure system. So, what are the major factors impacting productivity of coffee under different land tenure need to be investigated. The paper finds plausible answer to the above question by considering several environmental and genetic factors and looks into its impact on productivity of coffee under different land tenure systems.

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Table 1 Productivity of coffee (kg/ha) under different land tenures and regions of India

Land tenure system	Arabica productivity (kg/ha)	Robusta productivity (kg/ha)
Redeemed estates	625	1292
Unredeemed estates	691	1022
Kodagu	638	1197
Karnataka	609	1123
Kerala	455	791
Tamil Nadu	480	695
Andhra Pradesh	155	132
Odisha	164	-
North Eastern regions	72	232
Overall India	427	983

Source: Indian Coffee Board, 2021 and survey results

MATERIALS AND METHODS

The present study was conducted in Kodagu district of Karnataka state, Western Ghats of India. The region is considered as one of the global biodiversity hot spot, well known for its coffee cultivation. The district alone contributed for 35.96 per cent of India's total coffee production [8]. In order to understand the factors impacting productivity of coffee under different land tenure system, the study employed both qualitative (in-depth telephonic interviews and review of documents) and quantitative data. The study followed snowball sampling method. The data relevant to the study was collected during March-June, 2020 through personal interviews. The data pertains to the reference period of 2018-19 agricultural year. The study included a sample of 100 coffee growers, of whom 50 were Arabica and other 50 were Robusta growers. The growers were classified into four categories viz., redeemed Arabica, unredeemed Arabica, redeemed Robusta and unredeemed Robusta estates (Table 2). The multiple regression analysis was used to determine factors influencing productivity of coffee under redeemed and unredeemed land tenures. The secondary data pertaining to the study were collected from publications of Indian Coffee Board and earlier literature in the area.

Table 2 Distribution of sample households (number) according to land tenure system in Kodagu

Land tenure system	Arabica (N=50)	Robusta (N=50)
Redeem estates	25 (50.00)	25 (50.00)
Un-redeem estates	25 (50.00)	25 (50.00)
Total	50 (100)	50 (100)

Figures in parentheses indicate percentage to total number of households

Multiple regression analysis

The productivity of coffee (kg/ha) under redeemed Arabica, unredeemed Arabica, redeemed Robusta and unredeemed Robusta was regressed against indigenous shade trees(number), exotic silver oaks (number), dadap trees (number), White Stem Borer incidence (uprooting of trees per ha), age of coffee trees (years), elevation of estates (m.a.s.l) and average annual rainfall (mm). The functional form of the model is given as:

$$Y = \alpha_0 + \beta_1 \text{ shade trees} + \beta_2 \text{ silver oaks} + \beta_3 \text{ dadap trees} + \beta_4 \text{ WSB incidence} + \beta_5 \text{ age of coffee trees} + \beta_6 \text{ elevation of estates} + \beta_7 \text{ average annual rainfall} + e$$

Where,
Y is the productivity (kg/ha) of coffee
e is the unexplained error term
α_0 is constant or intercept

RESULTS AND DISCUSSION

Indigenous shade trees and productivity of coffee under different land tenures

The Indian coffee is mainly cultivated in the ecologically sensitive Western Ghats of India under thick canopy of shade. Several tropical and sub-tropical shade trees dominate the coffee agro-forestry system in India. The major ones being Dadaps (*Erythrina variegate*), Balanji (*Acrocarpus fraxnifolius*), Beeti (*Dalbergia latifolia*), Karadi (*Chukrasia tabularis*), Nerale (*Syzygium cumini*), Nandi (*Lagerstroemia microcarp)* (Fig 1).

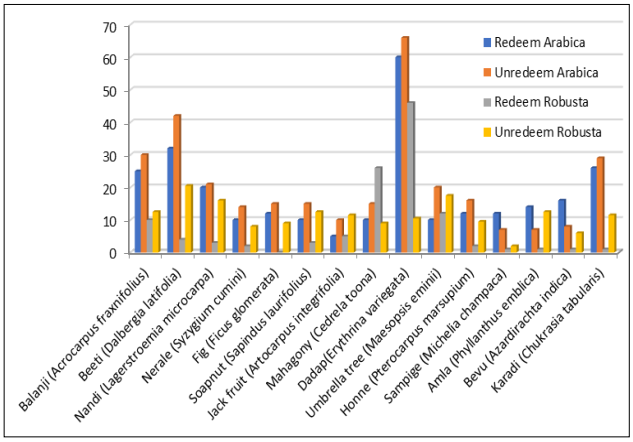

Fig 1 Major indigenous shade trees (numbers) under different land tenures

The unredeemed estates (both Arabica and Robusta) comprised of higher number of native shade trees than the redeemed estates since the tree felling restriction controlled the cutting of native shade tree species viz., 1.16 and 1.44 times higher in unredeemed Arabica and Robusta respectively.

The indigenous shade trees positively impacted productivity of redeemed Arabica (0.22), unredeemed Arabica (0.02), unredeemed Robusta (2.13), while negatively influenced redeemed Robusta estates (-2.26) (table 3 & 4). Basically, Arabica is a shade loving plant. The increased number of shade trees (>60 per cent) in Arabica estates positively influenced the productivity of coffee by reducing the temperature (< 24C) and stress in Arabica estates thereby creating congenial environment for Arabica cultivation. Henceforth, higher productivity was observed in Arabica variety in both redeemed and unredeemed land tenures.

The unredeemed Robusta estates comprised of higher number of shade trees *viz*., 85 shade trees/ha inducing about 55-60 percent of shade. The buffered temperature combined with warm weather and bright sunlight enhanced the productivity of coffee in unredeemed Robusta estates.

Contrastingly, the redeemed Robusta estates comprised of only 62 shade trees/ha that provided lower shade canopy (35 to 40 per cent) in these estates. The aggravated higher solar radiations and higher temperature (> 30 C) created unfavourable micro-climatic conditions for cultivation of Robusta in this type of land tenure. This was a major climatic limitation for redeemed Robusta estates, that adversely affected coffee physiology that was being reflected in terms of lower productivity in redeemed Robusta estates.

Table 3 Factors affecting productivity (kg/ha) of Arabica under different land tenure system

Arabica coffee

Variable	Redeemed Arabica estates			Unredeemed Arabica estates		
	Co-efficient	t value	Level of significance	Co-efficient	t value	Level of significance
Constant	528	6.63***	4.25E-06	644.26	32.48***	9.63E-17
Shade trees per ha (**No.**)	0.22	2.72***	0.01	0.02	3.26***	0.00
Silver Oaks per ha (**No.**)	0.16	0.45	0.65	0.00	0.02	0.97
Dadap trees per ha (**No.**)	-0.14	-1.35	0.19	0.17	2.29**	0.03
WSB Infestation (Number of trees uprooted per ha)	-0.23	-3.57***	0.00	-0.09	-3.60***	0.00
Age of coffee trees (**Y**ears)	0.78	2.03**	0.05	0.12	2.57***	0.01
Elevation of estates (m.a.s.l)	0.02	1.87*	0.07	0.01	2.49**	0.02
Average annual rainfall (mm)	0.01	0.72	0.47	0.00	-0.124	0.90
R Square		0.96			0.98	
F		58.95***			213.14***	
Number of observations		25			25	

*****, ** and *Significant at 0.01, 0.05 and 0.10 level respectively**

Table 4 Factors affecting productivity (kg/ha) of Robusta under different land tenure system

Robusta coffee

Variable	Redeemed Robusta estates			Unredeemed Robusta estates		
	Co-efficient	t value	Level of significance	Co-efficient	t value	Level of significance
Constant	45.57	0.17	0.86	943.48	9.36***	2.44E-08
Shade trees per ha (**No.**)	-2.26	-2.60***	0.01	2.13	13.93***	4.4E-11
Silver Oaks per ha (**No.**)	2.01	2.34**	0.03	-0.32	-1.70	0.20
Dadap trees per ha (**No.**)	-0.46	-0.50	0.62	-0.16	-0.43	0.67
Age of coffee trees (**Y**ears)	5.23	2.53**	0.02	2.29	2.36**	0.02
Elevation of estates (m.a.s.l)	0.61	3.17***	0.00	-0.16	-3.49***	0.00
Average annual rainfall (mm)	0.21	2.46**	0.02	-0.05	-2.29**	0.03
R Square		0.84			0.93	
F		16.81***			42.54***	
Number of observations		25			25	

*****, ** and *Significant at 0.01, 0.05 and 0.10 level respectively**

Silver Oaks (Grevillea robusta) and productivity of coffee under different land tenures of Kodagu

The exotic trees are non-native to the region, probably introduced from other countries. Over the recent years owing to commercialization of coffee plantations, the indigenous shade trees are being replaced by exotic Australian silver oaks (*Grevillea robusta*). The tree rights granted to redeemed owners permitted them to cut indigenous shade trees and replace them with exotic silver oaks. Henceforth, the redeemed tenured estates comprised of higher number of silver oaks viz., 1.17 and 1.43 times higher in Arabica and Robusta respectively (Fig 2). This has led to radical shift from coffee traditional poly-culture to silver oak monoculture in the coffee agro-forestry system [9]. The silver oaks were positive and significant only in case of redeemed Robusta estates (2.01 per cent), since the silver oaks in redeemed Robusta estates provided filtered sunlight, lower shade and optimum humidity that positively affected productivity of Robusta. However, even the redeemed Robusta estates could maintain maximum silver oaks upto 121 trees per ha after which it adversely impacted productivity of coffee.

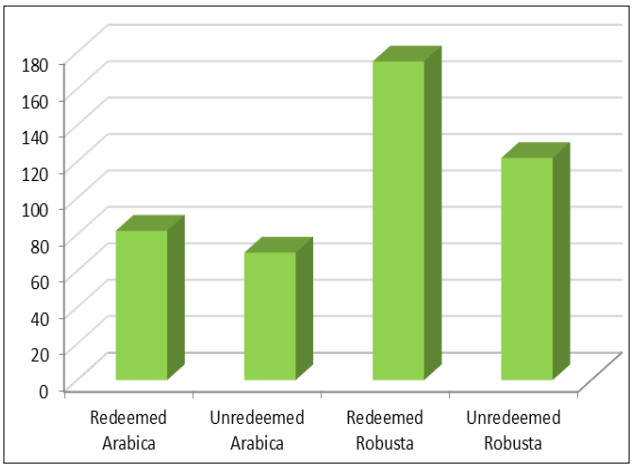

Fig 2 Number of silver oak trees per ha

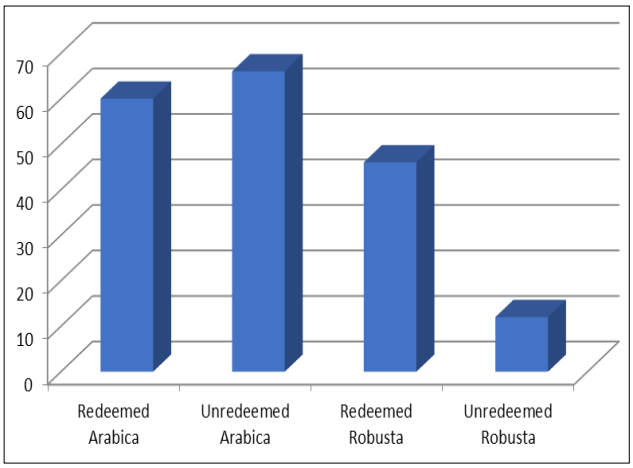

Fig 3 Number of dadap shade trees (*Erythrina spp*) per ha

Dadap shade trees ((Erythrina spp.) and productivity of coffee under different land tenures

Generally, the Arabica plantations are cultivated in two tier shade system. The upper canopy comprises of permanent shade trees and the lower canopy comprises of Dadap trees (*Erythrina spp*). Interestingly, the cultivation of dadaps as temporary shade also varied across different land tenure system. For instance, the unredeemed Arabica estates comprised of higher number of dadap trees (66 trees/ha) followed by redeemed Arabica (60 trees/ha), redeemed Robusta (46 trees/ha) and unredeemed Robusta (12 trees/ha) (Fig 3). The dadap trees positively (0.17) influenced productivity of only unredeemed Arabica estates. This was due to regular dadap shade pruning activities undertaken by the unredeemed Arabica growers that proved beneficial in terms of productivity.

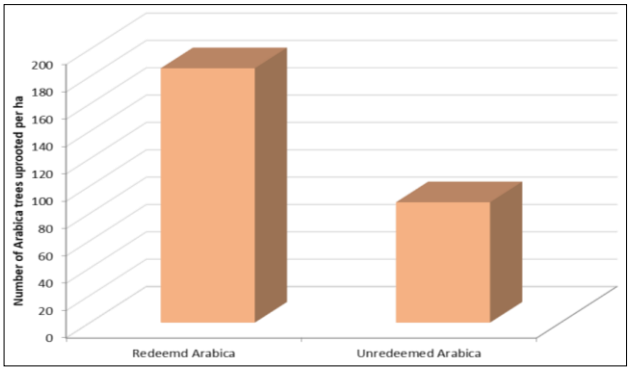

Fig 4 Incidence of WSB (number of plants uprooted/ha) under different types of land tenures

White Stem Borer (WSB) and its impact on productivity of Arabica variety of coffee

The White Stem Borer (*Xylotrechus quadripes*) is a major pest of only Arabica and does not attack Robusta coffee. The severe borer attack on Arabica has led to subsequent uprooting of Arabica plants resulting in cumulative revenue losses to the growers. Unable to bear the losses, growers are shifting from Arabica to Robusta variety of coffee [10]. The White Stem Borer (WSB) infestation in terms of number of Arabica trees uprooted per ha was 2.11 times higher in redeemed Arabica estates compared to unredeemed estates (Fig 4). Further, the regression results indicate that the productivity of Arabica coffee reduced by 0.23 per cent and 0.09 per cent respectively in redeemed and unredeemed Arabica estates respectively (Table 4). As mentioned earlier, the redeemed Arabica estates comprise of lesser number of indigenous shade trees, characterized by higher temperature together increased the stress in Arabica plantations. These environmental conditions are in fact highly congenial for borer infestation in Arabica, as seen from our redeemed Arabica estates. Contrastingly, the higher shade canopy combined and optimum shade management was observed in unredeemed that relatively controlled borer attack in unredeemed Arabica estates, as shade was one was the single natural factor that effectively controlled incidence of borer attack in Arabica.

Age of coffee trees (years) and productivity of coffee

The productivity increased with the increase in age of coffee trees in both redeemed and unredeemed land tenure system (Table 5). The least productivity was observed in younger estates below 20 years of age. The age of coffee trees had a positive and significant impact on all four classified estates viz., redeemed Arabica (0.02), unredeemed Arabica (0.01), redeemed Robusta (5.23) and unredeemed Robusta (2.29) (Table 3-4).

In case of Arabica, one reason for positive relation between age and productivity was that the incidence of White Stem Borer reduced with the increase the age of coffee trees. The older trees, were resistant to borer attacks and exhibit the signs of bore attack only under high moisture stress [11]. Secondly, [12] noted that shade had a positive influence on the age of coffee trees, that had positively impacted productivity of coffee in Arabica and unredeemed Robusta estates.

Table 5 Age of coffee trees (years) and productivity of coffee (kg/ha) under different land tenures

	Productivity of coffee (kg/ha)			
Age of coffee trees (Years)	Redeemed Arabica (kg/ha)	Unredeemed Arabica (kg/ha)	Redeemed Robusta (kg/ha)	Unredeemed Robusta (kg/ha)
< 20 Years	519	675	1194	988
20-30 Years	586	682	1282	1010
30-40 Years	639	690	1331	1031
40-50 Years	664	694	1445	1130
> 50 Years	674	700	-	

Elevation of coffee estates (m.a.s.l) and productivity of coffee under different land tenures

The classification of redeemed and unredeemed estates across the different elevation ranges are provided in the (Table 6). Our model indicated that the elevation of estates had positive impact on productivity of redeemed Arabica (0.02), unredeemed Arabica (0.01) and redeemed Robusta estates (0.61), while found negative (0.16) in unredeemed Robusta estates.

The ideal elevation for cultivation of Arabica is 1000-1500 m.a.s.l. The higher elevations are characterized by heavy rainfall and lower temperature that effectively controlled the incidence of White Stem Borer (WSB) in Arabica. This could be one of the reasons for higher productivity of Arabica estates located at higher elevations irrespective of land tenures. However, the unredeemed Robusta estates indicated lower productivity with higher elevation. As mentioned earlier the unredeemed Robusta estates comprised of higher shade canopy. These estates are characterized by higher elevation; higher shade trees and lower temperature were found to be uncongenial for Robusta cultivation. Meanwhile, the unredeemed Robusta growers at higher elevation are still struggling with cultivation of coffee.

Average annual rainfall (mm) and productivity of coffee

The average annual rainfall was found to be insignificant in both redeemed and unredeemed Arabica estates. The redeemed Robusta estates indicated a positive relation with average annual rainfall as shown in the (Table 4). Overall, the model indicated that the average annual rainfall influenced only Robusta estates in Kodagu irrespective of land tenures. The ideal rainfall for Robusta coffee is between 1000-

2000 mm. However, the unredeemed Robusta estates with higher shade canopy, heavy rains (2500-3000 mm) and lower temperature (< 20C) was uncongenial for cultivation of Robusta, thereby resulting in lower productivity.

Table 6 Elevation of estates (m.a.s.l) and productivity of coffee (kg/ha) under different land tenure system

	Productivity of coffee (kg/ha)			
Elevation of estates (m.a.s.l)	Redeemed Arabica (kg/ha)	Unredeemed Arabica (kg/ha)	Redeemed Robusta (kg/ha)	Unredeemed Robusta (kg/ha)
<800	576	-	-	
800-1000	614	-	-	1386
1000-1200	644	688	1191	1016
1200-1500	651	698	1390	963
>1500	652	-	1518	-

CONCLUSION

The study concludes that the land tenure system in Kodagu had a considerable impact on productivity of coffee in both varieties. In case of Arabica, maximum productivity was observed in unredeemed land tenure. Contrastingly Robusta exhibited maximum productivity under redeemed land tenure. The present study reveals several factors determining productivity of coffee under different land tenure systems. The indigenous shade trees and age of coffee trees had substantial impact on productivity in both redeemed and unredeemed land tenure system in both Arabica and Robusta varieties of coffee. The silver oaks proved beneficial only for redeemed Robusta estates, while dadaps positively influenced unredeemed Arabica. The White Stem Borer incidence proved detrimental for Arabica irrespective of land tenures. The elevation of estates and average annual rainfall showed contrasting results in redeemed and unredeemed Robusta estates in the model. The study recommends cultivation of more number of indigenous shade trees in both types of land tenures, encourage dadap cultivation in unredeemed Arabica estates, limit cultivation of exotic silver oaks in unredeemed Robusta estates and cultivation of Arabica at higher elevation, irrespective of land tenures.

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