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Tree survival in forest plantations established under plantation establishment and livelihood improvement scheme (PELIS) in Kericho County, Kenya

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Abstract

Plantation Establishment and Livelihood Improvement Scheme (PELIS) in Kenya is an efficient and cost effective method of seedling establishment in plantation programs. However, in Kenya the method has produced inconsistent/conflicting results in tree seedling survival rates, posing challenges to the forest sector as they lead to uncertainty in decision making and policy formulation. The purpose of this study was to establish tree survival in plantations established under PELIS in Kericho County. The study determined tree seedling survival under different tree-crop combinations in Masaita block, Masaita Forest Station, Kericho County, Kenya. The Masaita forest was stratified based on tree species planted in 2014 namely: Cypress (Cupressus lusitanica), Pine (Pinus patula) and Eucalyptus (Eucalyptus saligna). Farmers Plots in each sub-compartment were stratified based on the crops grown by the farmers; maize (Zea mays), potato (Solanum tuberosum) and beans (Phaseolus vulgaris). In each stratum (tree crop combinations), 5 plots were picked based on simple random sampling, and in each plot two lines were selected randomly excluding the outer lines to avoid boundary effects. Data was collected using a data collection sheet and analysed using One-Way ANOVA. Eucalyptus-potato, Cypress-beans and Eucalyptus-Beans showed significantly higher (P <0.05) survival rate (64.3%), (63.1%) and (62.0%) than other seedling respectively while Pine-maize recorded the lowest survival (56.4%). The study concluded that for better seedling survival, Eucalyptus and Cypress are the best trees for PELIS while Potato and beans are the best PELIS food crops. The study recommends the planting of Eucalyptus and Cypress under PELIS but not Pines and intercropping with Potatoes and Beans but not Maize especially in the first year of tree planting under PELIS.

Keywords: Taungya, PELIS, tree survival, plantations.

Introduction

Globally, forests cover about 3.4 billion hectares, of which 123.7 million hectares; approximately 4% are plantation forests[1-3]. These forests are vital in the world for a multiplicity of reasons among them air purification, temperature and rainfall moderation, conservation of water catchments, support of biodiversity and provision of wood materials such as wood fuel, timber, paper, food, and medicine[2,4,5]. With increasing population, the demand for forest products and services increase simultaneously casting doubt on the ability of forests to sustain the consumptive global demand[1].

In Africa, forests accounts for only 21.4% of land surface, corresponding to about 674 million hectares[4]. As a result of increasing population growth resulting to increased pressure on the existing natural and plantation forests, Africa has been losing about 3.4 million hectares of forest lands annually since 2000[4,5]. To cope up with this demand, plantations are established world over using different methods of site preparation such as total cultivation, slashing, slashing and spot hoeing, ploughing, bush planting, coppice management and Taungya[6].

Though these methods have increased plantation forests cover by about 7% from early 2000 in East Africa[7,8], each of them is faced with different short comings mainly very high costs or very low initial survival or both[8,9]. However, Plantation Establishment Livelihood Scheme (PELIS), Taungya or Shamba system is very popular in the region due to its low costs emanating from free labor offered by participating farmers and high survival and growth achieved as a result of the total and frequent cultivation[10]. In PELIS adjacent communities are given the opportunity to cultivate agricultural crops during early stages of plantation forest establishment[11].

In Kenya, the Shamba system was introduced in 1910 where resident workmen were allocated freshly cleared areas to plant food crops for 2-3 years while tree seedlings established[12]. The system was initially used to convert natural forests to plantations until 1979 when the conversion was stopped but the system continued to re-establish harvested plantations. By this time 160,000ha of plantations had been established[5]. The system was reorganized and re-introduced in 1994 as Non-Residential Cultivation (NRC) but it was banned again by Ministry of Environment and Natural Resources (MENR) in 2004[12]. However, this programme's pilot study in 2004 produced a

seedling survival rate of about 75%[13]. Based on this result, the system was allowed in areas experiencing large planting backlogs under PELIS with rules as stipulated in the Kenyan forest act 2005-47(ii)[14].

Although improved Shamba system now termed ”PELIS’’ has proved efficient and cost effective as compared to others seedling establishment methods in industrial plantation programs, it has produced inconsistent results in seedling survival rates[6,13]. A survival of as high as 79% in Nyandarua County, 51% in Trans-Nzoia County and a National mean of 67% were recorded according to Kenya Forest Service (KFS) data on the 2012/2013 planting season and no research has been done to account for the heterogeneous performances[13,12].

In Kenya, a forest plantation is considered established, requires beating up (replacements the same year), or failed (requires replanting the following year) if it attains an initial survival of at least 75%, 35% to 74% or below 35%, respectively[15]. These inconsistent results are posing a big challenge to the forest sector as they lead to forest plantation failures, uncertainty in decision making and policy formulation[6,16]. Uncertain decisions and policies leads to poor governance of the sector[16].

The study therefore provided necessary information accounting for the variations in tree seedling survival under PELIS. The objective of the study was to determine tree seedling survival of Eucalypts, Cypress and Pines planted in combination with potato, beans and maize under different PELIS systems (tree-crop combinations) in Masaita Forest Station, Kericho County.

Materials and methods

The study was conducted in Masaita forest station, Kericho, County, Kenya. Masaita Forest Station lies West of Mount Londiani between $35^0$30 and $35^0$40 East longitude and latitude $0^0$06 and $0^0$09 South. The altitude of Masaita Forest Station ranges between 2320 m above sea level in the Western part and 2500m above sea level in the Eastern part. The annual rainfall ranges between 1000mm to 1500mm per annum with an average rainfall of 1267mm. Masaita Forest Station is divided into 13 compartments and several sub-compartments for administrative and management purposes[17]. The Station has a total area of 4152ha. Stocked area comprises of mainly Cypress, Pines and eucalyptus as major commercial plantation tree species that constitute 82%. The unstocked area comprises of a backlog of 317.9ha.

Multistage sampling technique was used in selecting the research treatments and participants. In selecting one county where tree survival, under PELIS was determined, simple random sampling was used, and Kericho County was selected among the 47 counties in Kenya. Out of eight forest stations in Kericho County, namely: Londiani, Makutano, Kuresoi, Sorget, Malagat, Tendeno, Masaita and Kericho, Masaita forest station was randomly selected.

The plantations were stratified based on three tree species, namely: Masaita 2N of *Eucalyptus saligna*, 9C of *Cupressus lusitanica* and 4L of *Pinus patula*. The three sub-compartments (2N, 9C and 4L) were selected because they were established in 2014 and PELIS programs were going on. Each sub-compartment was again divided into farmer’s plots (measuring 0.5 hectares), which were stratified based on crops crown by Farmers, namely: beans, maize and potatoes. The Farmers plots were already divided into 0.5 hectare plots.The number of plots measuring 0.5 hectares (replicates) that were included in each crop grown were determined based on Ralph, Holleran and Ramakrishnan (Equation-1)[18].

$$n = \log\alpha/\log p \quad (1)$$

Where: n = Sample size, α = permitted error (0.05 correspond with 95% confidence level), p = the standard deviation, if unknown, Ralph *et al*.[18] recommends the use of 0.5

$$n = \log 0.05/\log 0.5$$

= 4.32 plots = 5 plots for each crop

Therefore, the total number of plots was:
(3 sub-compartments*3 types of food crops *5plot replicates) = 45 plots

Simple random sampling was used in selecting individual plots. In each plot, 2 lines were selected using simple random sampling technique. However, the outer rows were excluded from the research to avoid boundary effects. All trees in the selected lines were included in the study.

Survival was determined by counting the number of tree seedlings that were planted on the selected line, and then counting the number of seedlings that survived till the time of this research, and then getting the percentage (Equation-2). The seedlings planted were determined by looking at the spacing to determine areas that seedlings seemed to have died.

$$Sr = \left(\frac{n}{N}\right) 100 \quad (2)$$

Where: Sr = is the survival rate, n = number of seedlings that survived, N = number of seedlings planted.

Data on tree survival results were presented in tables and bar graphs. They were then analyzed using Anova to determine if there are any significant differences ($P<0.05$) in survival between different tree-crop combinations in PELIS in Kericho County. Mean separation was done using Duncan Multiple Range (DMRT).

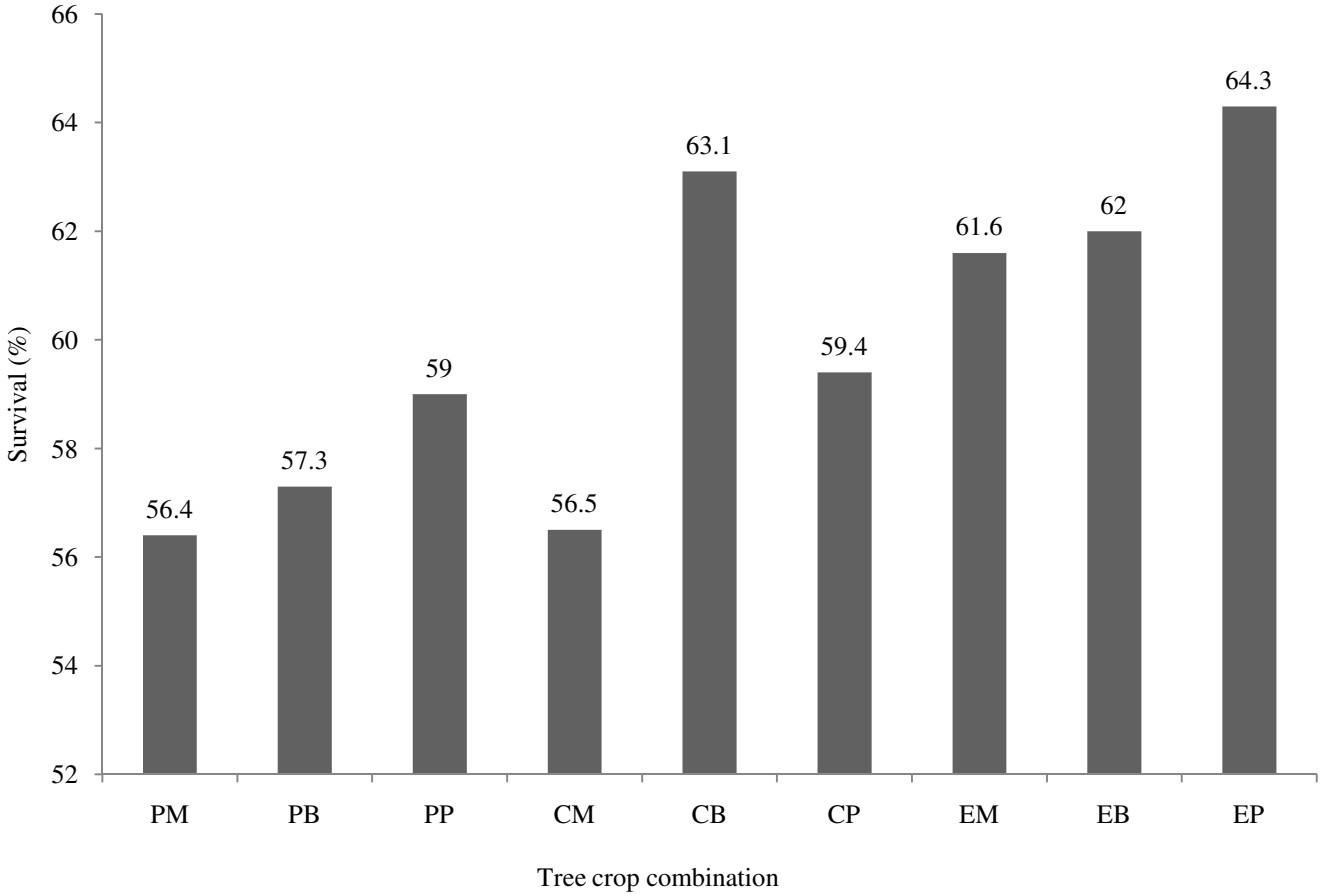
Results and discussion

Tree survival in PELIS were in the following order: Eucalyptus-Potatoes (EP)>Cypress - Beans (CB)>Eucalyptus - Beans (EB)>

Eucalyptus - Maize (CB)>Cypress - Potatoes (CP)>Pines - Potatoes (PP)>Pine - Beans (PB)>Cypress - Maize (CM)>Pine - Maize (PM) in PELIS (Figure-1).

The results of the Analysis of Variance (Anova) indicated that there was a highly significant difference (P<0.05) in survival rates of Eucalyptus, Cypress and Pine in PELIS (tree crop combinations) (Table-1).

The Duncan's Multiple Range Test (DMRT) clearly indicated that the seedling survival of Eucalyptus and Cypress was significantly higher (P<0.05) in Eucalypts-Potatoes (EP), Cypress-Beans (CB) and Eucalyptus-Beans (EB) than Pine in Pine-Maize (PM), Pines in beans (PB) and Cypress in Cypress-Maize (CM) in PELIS (Table-2).



Key: PM=Pine and Maize, PB = Pine and Beans, PP = Pines and Potatoes, EB = Eucalypts and Beans, EM = Eucalypts and Maize, EP = Eucalypt and Potatoes, CM = Cypress and Maize, CB = Cypress and Beans, CP = Cypress Potatoes.
Figure-1: Cypress, Pine and Eucalyptus Seedling Survival in different Tree crop combinations in Masaita Forest Station 2016.

Table-1: Anova for Eucalyptus, Cypress and Pine seedling survival in Masaita Forest Station in 2016.

Survival percentage					
	Sum of Squares	df	Mean square*	F	Sig.
Between Groups	7630.875	8	953.859	5.622	.001
Within Groups	167973.458	990	169.670		
Total	175604.333	998			

Table-2: Duncan's Multiple Range Test for seedling survival in Masaita Forest Station 2016.

Tree crop combination	N	Subset for alpha = 0.05				
		1	2	3	4	5
Cypress-Maize	122	56.2090a				
Pines-Maize	90	56.3711a				
Pines-Beans	98	57.3102a	57.3102b			
Cypress-Potatoes	131	58.4053a	58.4053b	58.4053c		
Pines-Potatoes	98	58.9571a	58.9571b	58.9571c		
Eucalyptus-Maize	118		60.2881b	60.2881c	60.2881d	
Eucalyptus-Beans	115			61.9722c	61.9722d	61.9722e
Cypress-Beans	117				63.1239d	63.1239e
Eucalyptus-Potatoes	110					64.2809e
Sig.		.169	.124	.064	.129	.218

Means for survival (%) with same letters are not significantly different (P > 0.05).

The results of the study therefore generally demonstrated that Eucalyptus (*Eucalyptus saligna*) seedling survived best in the Eucalyptus–potato combination system, while seedling survival of Pines (*Pinus patula*) in Pine-Maize combination survived least in PELIS.

In general, the survival range of between 56.4% and 64.3% of Eucalyptus, Cypress and Pine in PELIS is consistent with the results in literature that reported of a survival rate of 67% in PELIS in Kenya[13]. In addition, the results demonstrated generally that the Eucalyptus tree survival is highest in a potato combination in PELIS. Tree survival was apparently poor in maize combinations.

Poor survival in maize combination may be due to its fast growth that also draws many resources (nutrients and water) from the soil thereby competing the tree crop and reducing survival[19]. Maize had been considered a controversial agricultural species for use in Taungya (PELIS) and even banned in some countries[19]. The reasons given for exclusion of maize in some areas including Malawi, Mauritius and Senegal was fast growing characteristic of the crop that provide shade for trees, hence, competing and killing or retarding the development of the trees[19,20]. Beans *(Phaseolus vulgaris)* and potatoes (*Solanum tuberosum*) are cover crops that never grow to shade the tree crop. Beans are nitrogen-fixing plants and they add nutrients to the soil. However, inherent high growth rates of Eucalyptus even in maize plantations make them better competitors with maizein PELIS[19]. Pine relies on mycorrhiza for normal growth. The mycorrhizae are absent in non-pine previous plantation. They are also significantly reduced by tillage, fertilization and chemical applications in PELIS[19]. This makes pines poor performers under PELIS. Based on the results of this study the Eucalyptus-potato combination is a good option for farmers practising PELIS in optimizing tree survival.

Conclusion

On average, eucalyptus tree species in potatoes and Cypress species in Beans in Kericho County recorded the highest seedling survival rates of 64.3%, 63.1%, respectively. Pine seedlings planted with maize recorded the lowest survival rates of 56.4%.

Potato performs better than other agricultural crops in PELIS systems in favoring the tree-crop survival especially when combined with Eucalyptus. Beans on the other hand performed better compared to maize in tree seedling survival especially when planted with Eucalyptus and Cypress tree species. Therefore, the potatoes and beans produce a Win-Win situation for farmer and the Kenya Forest Service (KFS) in increasing food availability, household income and increasing forest cover.

The survival of Pinus species is the poorest amongst all agricultural crop combinations in PELIS. This therefore supports the recommendations from the (Forest Department General Orders) that require Pinus patula to be planted in

grasslands other than cultivated lands. Therefore, if problems underpinning seedling survival in PELIS systems is not identified and dealt with, the problems of low seedling survival may not be resolved.

Recommendations: KFS officials need to work closely with PELIS farmers in Kericho County to identify better strategies of improving seedling survival. Some of these strategies may include: encouraging Eucalyptus and Cypress under PELIS but planting pines in grasslands, carrying out better tree and crop site matching, disease and pest control, and capacity building capacity on better seedling management.

Since all tree species intercropped with Maize experienced low survival, maize should be discouraged in PELIS by KFS especially in the first year of tree establishment under PELIS.

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