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Spatial Distribution of Productivity and Technical Efficiency of Smallholder Rubber Lands in the Kalutara District

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ABSTRACT

This study was focused on the smallholder rubber sector of Kalutara district. The objective of this study was to estimate the major indicators of sustainability, *viz.* land productivity and technical efficiency (TE) of smallholder rubber lands and to employ GIS tools to develop maps for future decision making. Data collection was done through a questionnaire to gather information on smallholder farmers and their fields. Technical efficiency was obtained by the Cobb-Douglas production frontier model. Digital maps with Grama Niladhari (GN) divisions 1:50000 scale were used for spatial analysis and mapping. An attempt was also made to predict productivity and efficiency using spatial statistical methods and prediction options.

The productivity ranged from 198 to 3023 kg/ha/year. The DS divisions were ranked according to productivity and highest ranks were recorded for Bandaragama, Palindanuwara and Madurawala respectively. The TE ranged from 39% to 95% with an average value of 67% and the highest mean efficiency, 72% was observed in Madurawala. This suggests that 33% of the potential productivity is lost due to inefficiency due to various reasons. The DS divisions were ranked according to TE and highest ranks were recorded for Ingiriya, Palindanuwara and Madurawala. There is a reasonable agreement between the levels of productivity and TE (Spearman's r = 0.944, P<0.001). The maps developed employing GIS tools in this study will be valuable outputs for planning efficient extension programs to uplift the smallholder rubber sector. Furthermore they can be used to explore various applications of GIS in the smallholder rubber sector of Kalutara district and the methodology can be successfully employed in other districts.

KEYWORDS: GIS, Productivity, Rubber, Smallholder sector, Technical efficiency

INTRODUCTION

Rubber *(Hevea brassiliensis)* plays a vital role in Sri Lankan economy, in terms of export earnings and employment generation (Anon, 2011). Sri Lankan rubber sector comprises of smallholders and large estates. The large estates are managed by Regional Plantation Companies (RPCs). This demarcation is mainly based on the extent. Lands below 20.2 ha in extent are classified as private sector which is dominated by the smallholdings (<4 ha) and a few small estates (4 to 20.2 ha). In Sri Lanka more than 62 % of rubber lands belong to the smallholders (Anon, 2012a).

The average land productivity of rubber plantations is 1552 kg/ha/year (Anon, 2011). However, this is far below the potential productivity which is about 2500 kg/ha/year (Anon, 2007). Productivity gaps exist between experimental figures and what farmers produced. This is very often attributed to farmers' inability to adopt agronomic practices. Therefore, improving productivity is correlated with the use of proper cultivation practices. The performance of a production unit can be defined in many ways and there are different performance measures. Among these measures, production efficiency is an important measurement of the producer performance (Mangika *et al.*, 2009). TE is the maximum attainable level of output for a given level of production input, given the best technologies available to the farmer (Sampath and Edirisinghe, 2009).

Land productivity and TE are among the key indicators which drives the sustainability of the rubber sector. Identifying these indicators in the spatial domain is important in extension planning. Nowadays, it is increasingly being realized that easy access to spatial information by policy makers and administrators. This is reflected in the growing interest in the concept of Spatial Data Infrastructure (SDI) at the national and global levels. Since the SDI helps to provide geographic information to decision makers, it offers the prospect of better decision-making in the management and development of resources and, hence, improved socio-economic growth.

The Geographic Information System (GIS) which is embedded in SDI is a computer based information system which integrates, hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information. GIS helps to answer questions and solve problems by looking at available data in a way that is quickly understood and easily shared (Anon, 2012b). Great potential exist for application of

GIS in plantation resources monitoring and management, in crop growth and yield estimation, in production forecasting, in land suitability assessment and in prioritization of resources in estates (Anon, 2008).

This study is focused on the smallholder rubber sector taking Kalutara district as a pilot study with the objective to estimate land productivity and technical efficiency and develop maps employing GIS tools for the purpose of efficient decision making especially for extension activities.

METHODOLOGY

Description of the Study Area

The study covered the Kalutara district which belongs to agro ecological zones WL1 and WL 4. Rubber is found in all 14 Divisional Secretariat (DS) divisions in the Kalutara district.

Questionnaire Survey

A questionnaire was designed to gather information from rubber farmers. For this study, data were collected from 232 farmers covering all 14 DS divisions. Numbers of farmers were selected for each DS division using proportional sampling techniques. The questionnaire format contained questions on socio-economics status of smallholders and information on their rubber lands.

Data Analysis

Data collection, construction of GIS database, analysis of data and preparation of out-puts were organized as depicted in the Figure 1. Frontier 4.1 and ArcGIS version 10.0 were used for technical efficiency and GIS analyses respectively. Minitab 15.0 was used for descriptive statistical analyses.

Analysis of Technical Efficiency

The efficiency values and determinants of efficiency were jointly estimated as described by Coelli (1996). The following variables were used to develop the production frontier with latex production (kg/ha/year) as the dependent variable.

TAPTREES- No. of trappable trees per ha
FERTAMT- Fertilizer applied (kg/year)
AGEPLANT- Age of plantation (years)

Rest of the variables; *viz.* farm and farmer specific factors used in the analysis which may affect efficiency are listed below.

EXT- Extent of land (ha); *TAPINT*- Dummy for tapping intensity (1-recommended method, 0-otherwise); *PANEL*- Tapping panel (1-virgin bark, 0-otherwise); *HIREDLAB*- Labour for other activities (1-hired, 0-family only); *TAPLAB*- Labour for tapping (1-family, 0-hired); *DIST*- Distance from home (km); *AGE*- Age of smallholder (years); *DAL*- Dummy for education (1- If A/L and higher, 0-otherwise); *DOL*- Dummy for education (1- If O/L and higher, 0-otherwise); *EXP*- Experience of farmer (years); *DCLREC*- Dummy for recommended clone (1-recommended clone, 0-otherwise)

These variables were regressed with the inefficiency term to identify the values of productivity and efficiency and then averaged for each DS divisions.

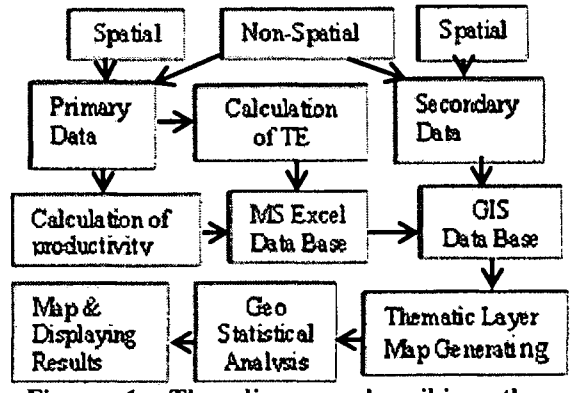

Figure 1. The diagram describing the organization of the research methodology

Spatial Analysis

Geo-database was used for surface mapping, and the prepared maps were used to analyze the spatial distribution of land productivity and (TE). Data collected at spatial support of polygons at DS divisions were converted to point support data considering the centroid of the respective DS divisions. Using those points support data semivariogram model was developed to model the spatial auto correlation using exponential model. Developed spatial model together with Kriging algorithm was used to developed surface continuous maps to predict the productivity and efficiency in Kalutara district.

RESULTS AND DISCUSSION

Summary statistics for productivity and TE are given in Table 1. The productivity ranged from 198 kg/ha/year to 3023 kg/ha/year in Kalutara District. The highest Standard Deviation (SD) was recorded in Bandaragama DS and its productivity ranged from 371 to 2964 kg/ha/year. The highest average productivity was also recorded in Bandaragama DS as 1667 kg/ha/year. The efficiency ranged from 38.5 % to 95.7 % and the highest mean efficiency (75.2 %) was observed in Madurawala DS division.

Efficiency Levels of Mature Farming Units

The frontier estimated in this study is justifiable over the estimation by Ordinary Least Squares (OLS) method. The estimate γ of this study was 0.883 which suggests that

Table 1. Summary Statistics of productivity and technical efficiency of different DS divisions in Kalutara district

DS Divisions	Productivity (kg/ha/year)				Efficiency (%)			
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
Horana	367	3023	1242	719	47.5	94.3	69.1	13.5
Bulathsinhala	198	2306	1031	528	38.8	93.5	65.7	13.5
Agalawaththa	371	1938	987	507	46.5	84.8	63.7	12.0
Mathugama	395	2816	1034	704	49.3	95.7	66.6	14.0
Dodangoda	309	1482	807	448	42.2	83.9	62.6	15.8
Walallawita	259	2371	1036	516	38.5	95.0	67.0	14.0
Palindanuwara	494	2371	1395	529	53.3	91.8	74.0	11.0
Madurawala	534	2729	1516	602	51.7	92.0	75.2	12.0
Millaniya	395	2371	763	526	45.8	90.7	55.9	12.0
Ingiriya	445	2964	1374	676	48.2	91.0	72.3	13.2
Bandaragama	371	2964	1664	961	43.9	93.7	70.1	22.5
Beruwala	346	1667	885	507	44.0	79.5	64.3	13.3
Kalutara	593	2329	1176	626	48.5	85.2	62.1	12.5
Panadura	296	1556	819	454	41.6	75.4	58.2	11.7

Min= Minimum, Max=Maximum, S.D.=Standard Deviation

88% of the error variation is due to the inefficiency effect (Table 2). The production efficiency levels estimated using the Cobb-Douglas production frontier ranged from 39 % to 96 %, with an average value of 67%. This suggests that 33 % of the potential maximum productivity is lost due to inefficiency of farmers in the Kalutara district. Nearly 51 % of the sample is observed above the average value of 67 %. The distribution of technical efficiency of smallholder unit is depicted in Figure 2. About 4 % of the farmers were above the 90 % efficiency level.

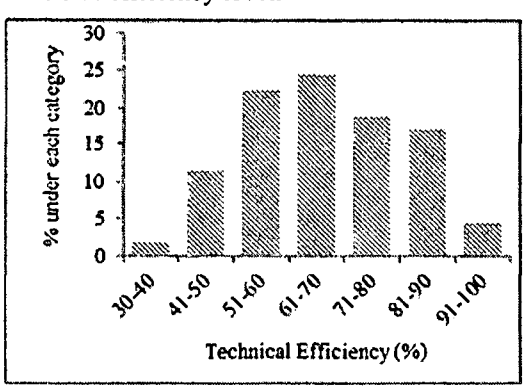

Figure 2. Distribution of technical efficiency of smallholder units in Kalutara district

Among the variables used in the analysis, labour for tapping (TAPLAB) and dummy for education (DOL) were significant at the level of 0.05 while extent of land (EXT) was significant at 0.001 level (Table 2). The extent of land (EXT) had a significant estimate with a negative sign, which suggested that higher the efficiency with higher the extent. Hiring of labour had no effect on the efficiency. However the dummy for labour for tapping (TAPLAB), was found to be significant with a negative sign, suggesting that those who tap their own land have higher efficiencies with respect to production. The average efficiency in the lands tapped by owners themselves was 71 % while when tappers were hired it was only 64 % distance and age of farmers did not have any significant effect on the efficiency. Further family labour involvement and the dummy for the recommended clones were found to be non-significant but returned the expected sign (Table 2).

Table 2. Maximum Likelihood Estimates for parameters of the stochastic frontier and inefficiency model

Variables	Co-efficient		t-ratio
Constant	2.486	***	8.49
TAPTREES	0.319	***	3.34
FERTAMT	0.065		0.63
AGEPLANT	0.024		1.49
Constant	0.731	***	5.52
TAPINT	0.023		0.35
PANEL	-0.020		-0.28
HIREDLAB	0.049		0.94
TAPLAB	-0.116	*	-2.04
DIST	-0.029		-1.56
AGE	-0.003		-1.90
DOL	-0.114	*	-2.07
DAL	-0.007		-1.06
DCLREC	-0.007		-0.14
EXP	-0.002		-1.19
EXT	-0.046	***	4.25
γ	0.883		9.17
σ^2	-0.051		6.71
Log likelihood Function	369		

,, and *** indicates 0.05,0.01 and 0.001 levels of significance respectively*

For achieving production efficiency, reallocation of resources with changing economic conditions is vital. Education provides this by enabling the farmers to (a) perceive that a change has occurred (b) collect, retrieve and analyze useful information (c) drawing valid conclusions from available information and (d) act quickly and decisively (Abdulai and Huffman, 2000). This also is in line with other similar studies such as Basnayake and Guneratne (2001) in tea smallholding sector of Sri Lanka, Ali and Flinn (1989) for rice production in Pakistan and

Edirisinghe and Wijesuriya (2010) for rubber in Sri Lanka.

Spatial Analysis

Figure 3 depicts the spatial distribution of productivity and Figure 4 depicts the technical efficiency (TE) of smallholder farmers in Kalutara district.

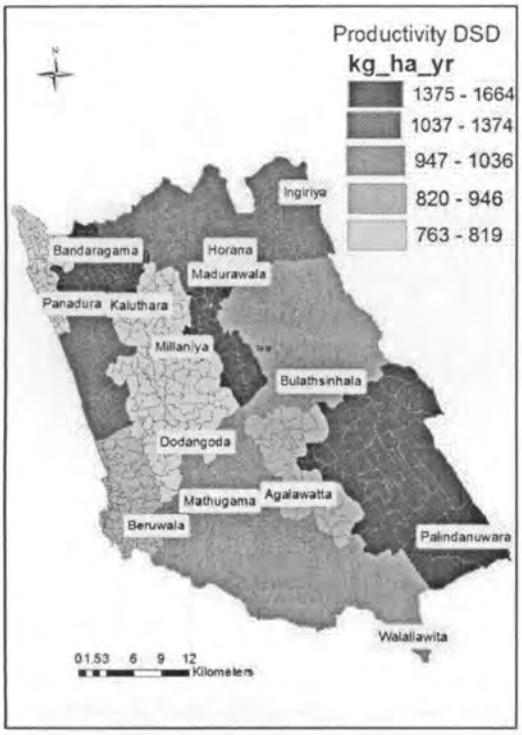

Figure 3. The spatial distribution of productivity in Kalutara district

Five levels of productivity and TE were derived using GIS. Table 3 summarizes the levels obtained by each DS division with respect to productivity and TE.

Table 3. Levels of productivity and TE obtained by each DS division

DS Division	Level of productivity obtained	Level of Technical Efficiency obtained
Panadura	5	5
Horana	2	2
Ingiriya	2	1
Bandaragama	1	2
Kalutara	5	4
Millaniya	5	5
Madurawala	1	1
Bulathsinhala	3	3
Dodangoda	5	4
Agalawatta	4	4
Palindanuwara	1	1
Beruwala	4	4
Matugama	3	3
Walallawita	3	3

Note: Rank 1 is given for the highest levels of Productivity and Technical Efficiency

There is a reasonable agreement between productivity and TE confirmed by the value of Spearman's rank correlation ($r=0.944$, $P<0.001$).

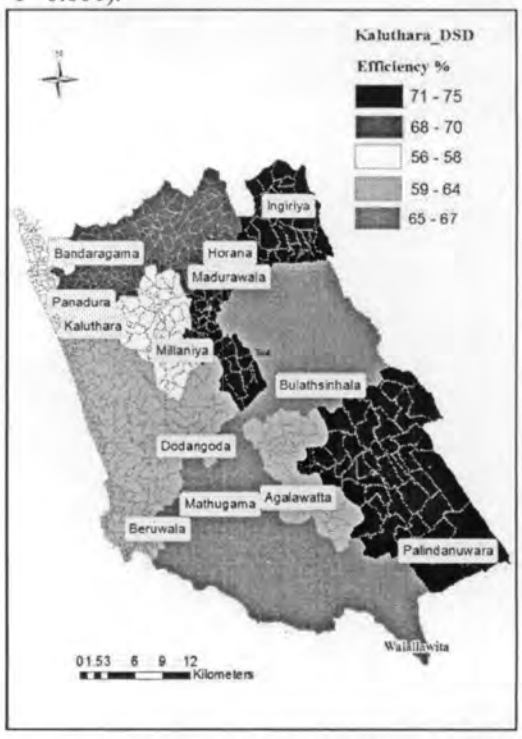

Figure 4. The spatial distribution of TE in Kalutara district

Figure 5 and 6 illustrates the spatial distribution of predicted productivity and TE of the smallholder farmers in Kalutara district.

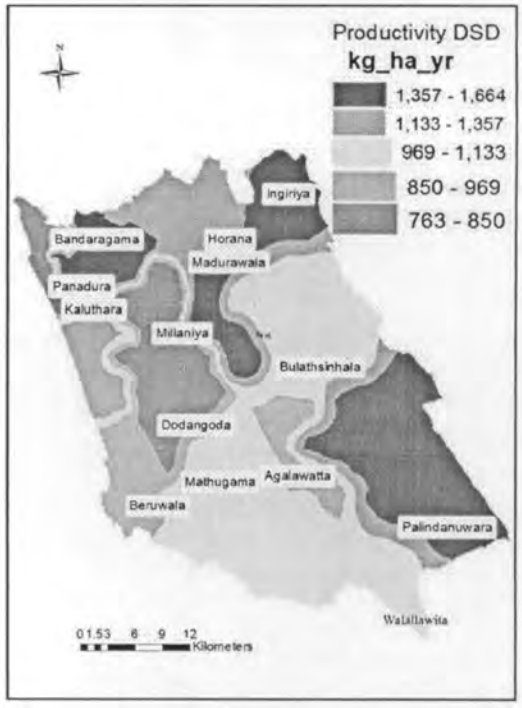

Figure 5. The spatial distribution of predicted productivity in Kalutara district

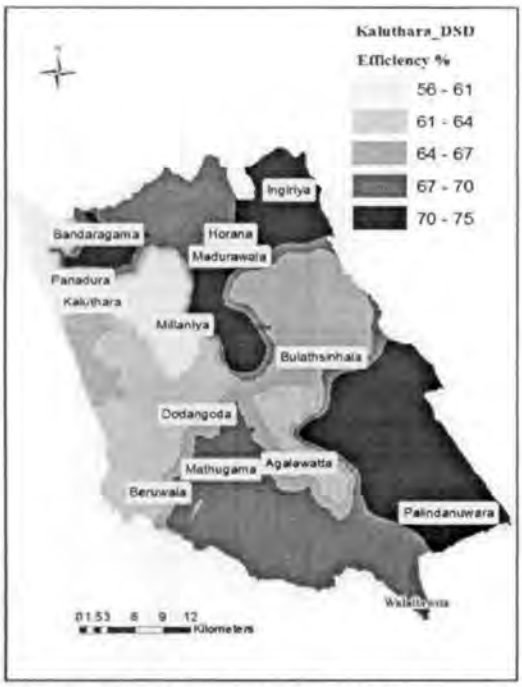

Figure 6. The spatial distribution of predicted TE in Kalutara district

These predicted maps were produced by integrating the five levels of productivity and TE in GIS. According to these predicted maps, encompass spatial modeling of neighbouring effect through Kriging method, the highest productivity is predicted for Bandaragama and Madurawala, while lowest is predicted for Dodangoda, Panadura and Millaniya. For TE, the highest was predicted for Palindanuwara and Madurawala and lowest levels were predicted for coastal areas such as, Panadura, Kalutara, Beruwala, and Dodangoda, Millaniya and Agalawatta DS divisions.

CONCLUSIONS

The study reveals that the TE is positively related to the educational level and negatively related to land size. Also, TE was found to be high when land owner was involved in the harvesting process. DS divisions like Ingiriya, Palindanuwara, Madurawala and Bandaragama which were ranked 1 on TE showed highest productivity levels and demonstrate the agreement between productivity and TE.

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