

# LOESS Analysis Of Plowing Charges And Acreage Plowed In The Agro-Ecological Zones Of Ghana

Gerald Ahorbo, Johnson Ofori, Joseph Otoo.

**Abstract:** The plowing charges of farm tractor-hire service enterprises sometimes influence the acreage plowed. This study was to explore the relationship between farm acreage plowed and the plowing service charges of farm tractor-hire service enterprises and also assess the effect of changes in plowing charges of farm tractor-hire service providers on the acreage plowed for smallholder farmers in four agro-ecological zones (the coastal savannah, deciduous forest, transitional, and guinea savannah) of Ghana using a locally weighted regression (LOESS). A total of 120 tractor-hire service providers who plowed for smallholder farmers over the period of 2008 and 2011 were randomly sampled across the four agro-ecological zones and interviewed. The results showed that the relation between the farm acreage plowed and the plowing service charges varied from one agro-ecological zone to the other and the average maximum acreage plowed per service provider was found to be in the neighborhood of 270 acres at average rate of GH¢29 per acre in the Coastal Savannah Zone, 850 acres at average rate of GH¢28 per acre in the Deciduous Forest Zone, 650 acres at average rate of GH¢25 per acre in the Transitional Zone, and 450 acres at average rate of GH¢24 per acre in the Guinea Savannah Zone. The overall outcome of this study would assist the tractor-hire service providers, policy makers, and agricultural extension agents to know the suitable average plowing charges that a lot of the smallholder farmers could afford at the various agro-ecological zones to promote the plowing of more farm lands.

**Index Terms:** Agro-ecological Zone, Ghana, LOESS Analysis, Plowing, Smallholder Farmer.

## INTRODUCTION

Agriculture is a strategic sector of development in Ghana which is dominated by smallholder farmers with holdings less than 2 ha in size [1]. The sector provides employment for over 50% of the total workforce in the country [1] and 82.5% of the rural households who are primarily farmers [2]. About 93% of households in the rural northern savannah areas are involved in farming while the corresponding figure for the rural forest and rural coastal savannah is 81.3% and 64.7% respectively [2]. Most of the farming activities of these smallholder farmers are done manually except for some primary tillage (mostly disc plowing) that are done with tractors predominantly in the rural areas within the agro-ecological zones favorable for tractor usage. A survey conducted in 2013 in Ghana by International Food Policy Research Institute and Savanna Agricultural Research Institute indicated that almost 50% of smallholder farmers hired tractor services for plowing [3]. Another work by Ngeleza et al. [4] revealed that about 35% of maize farmers hired tractor services purposely for plowing. In general only 40% of farmers in the country use some form of mechanization [5]. With even the increased number of tractors providing mechanization services, some farmers just could not access the services because of their inability to raise money for the service fee. There were also situations where some farmers who had the money have to approach more than one tractor owner before securing services to plough their farm [3]. This circumstance was not quite different from what was experienced outside Ghana in a place such as Vhembe District in Limpopo Province of

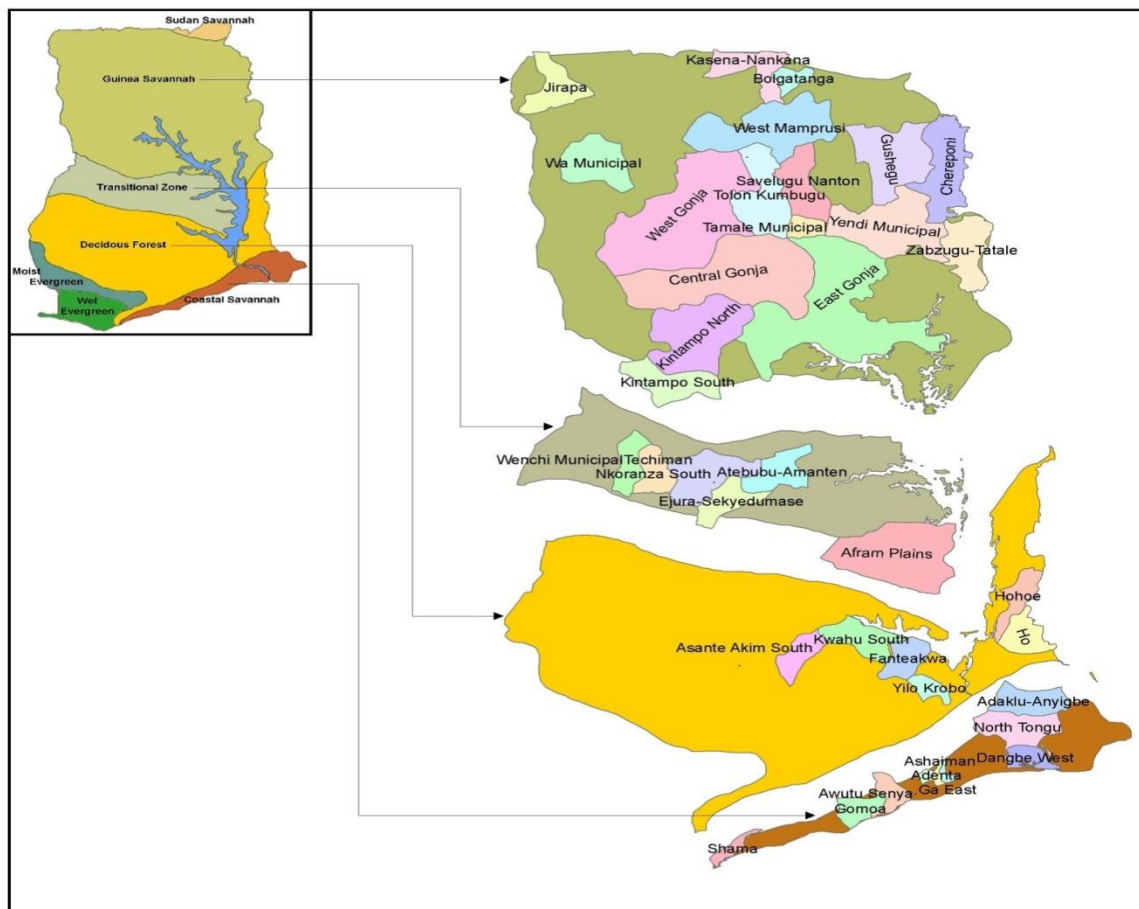
South Africa where Sikhwari [6] found that many farmers miss out on tilling their land because of cost and the availability of the plowing service. It was found that smallholder farmers usually react primarily to costs paid in cash and cash-equivalent costs involving payments in kind [7]. A study by Benin et al. [8] confirmed this situation and further revealed that tractor-hire service providers were able to service more farmers and also plowed more acreage when the plowing charges was done on flexible terms (payment in cash or credit or kind basis). This suggests a possible relation between the plowing charges and acreage plowed. In this paper an attempt was made to assess the effect of changes in plowing service charges of farm tractor-hire service enterprises on acreage plowed for smallholder farmers and also explore the relationship between the farm acreage plowed and the plowing service charges in the agro-ecological zones of Ghana.

## 1 METHODOLOGY

### 1.1 Study Area and Data Collection

The study was conducted on tractor-hire service enterprises providing plowing services to smallholder farmers in 38 districts of Ghana across four agro-ecological zones (coastal savannah, deciduous forest, transitional and guinea savannah) as shown in Fig. 1.

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Source: Authors' illustration.

Fig. 1. Map of Ghana showing districts surveyed in the four agro-ecological zones.

Purposively, all tractor-hire service provider enterprises who were established through the support of the Government's special hire purchase scheme (total of 42 service providers as at year 2010), were identified across four (4) agro-ecological zones and interviewed together with one or two randomly sampled enterprise(s) that were set up through the sole effort and finance of the owner and also servicing smallholder farmers within the same operating (or catchment) area. Finally, a total of 120 service providers (as detailed in Table 1) who plowed for smallholder farmers over the period of 2008 and 2011 were interviewed.

Table 1. Distribution of Service Providers in the Agro-ecological Zones Covered

Agro-ecological zones	Number of districts	Number of service providers	Average distribution of service providers per district
Coastal savannah.	9	22	2.4
Deciduous forest.	6	12	2.0
Guinea savannah.	16	45	2.8

Transitional.	7	41	5.9
Total	38	120	

Source: Field Survey of Service Providers.

The instrument employed was a questionnaire which was designed to include both structured and semi-structured questions to make room for uniform answers and individual opinions. The questionnaire was designed to collect a range of data that included acreage plowed, fee charged per acreage plowed, location of service provider in the community and district, and the number of farmers serviced. To help correct errors related to clearness and accurateness of the questions, a pre-test of the questionnaire was done on five tractor-hire enterprises that have not been included in the main study sample. The data collected and used in the analysis were completely primary which were got through face-to-face interview of the tractor-hire service providers using the questionnaire.

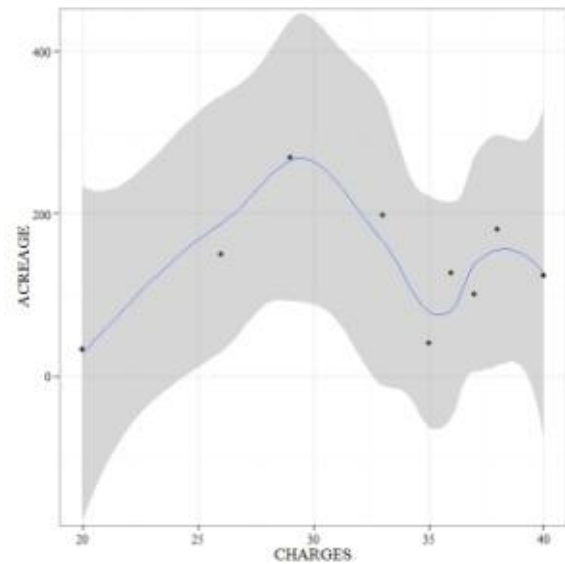
### 1.2 Data Analysis

The study employed bivariate local polynomial regression (LOESS) to determine the type of relationship that exist between acreage plowed and plowing charges and the effects of charges on acreage plowed. LOESS is nonparametric and fitting technique that does not require an a priori specification

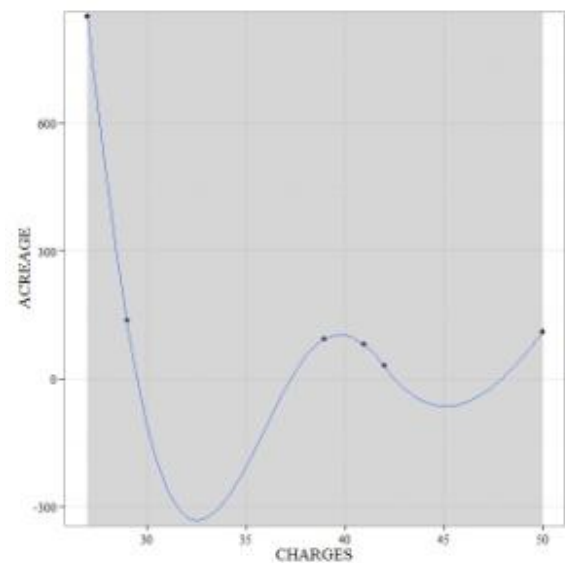
of the relationship between the dependent and independent variables [9]. It combines simple regression over small subsets of the data with nonlinear smoothing techniques similar to a least-squares method for data analysis [10]. The LOESS smoothing technique additionally allows 95% confidence intervals to be simply generated using bootstrap techniques. This is a very useful tool for discerning systematic structure within empirical data [9]. LOESS is a kernel smoothing method that essentially fits local polynomial regressions and joins (smooth) them together [11]. The regression fit at point  $x$  is made using points in the neighborhood of  $x$ , weighted by their distance from  $x$ . Half the size of the smoothing window is called the span or bandwidth, which is defined based on a nearest neighbor strategy. As the span increases the estimated curve becomes smoother. In choosing the span or bandwidth, care must be taken since small values do not provide much smoothing and large values also provides too much smoothing. A span or bandwidth that is too small in value (meaning that insufficient data fall within the window) produces a curve characterized by a lot of noise (results in large variance). A large span or bandwidth value produces an over smoothed local polynomial regression which may not fit the data adequately and may result in loss of vital information (thus fit will have large bias) [9]. In this study LOESS was employed because parametric models like the linear, logarithm and the exponential regression models could not fit the data well. Also other complex parametric models which involved interaction of variables could also not give adequate fit for the data. In this study, a span or bandwidth of 0.75 was used in the LOESS plots. For diagnostics, absolute residuals were plotted against the predictors (fitted values) to detect the dependence of the residuals on predictors. These were executed by using R Statistical Software.

## 2 RESULTS AND DISCUSSION

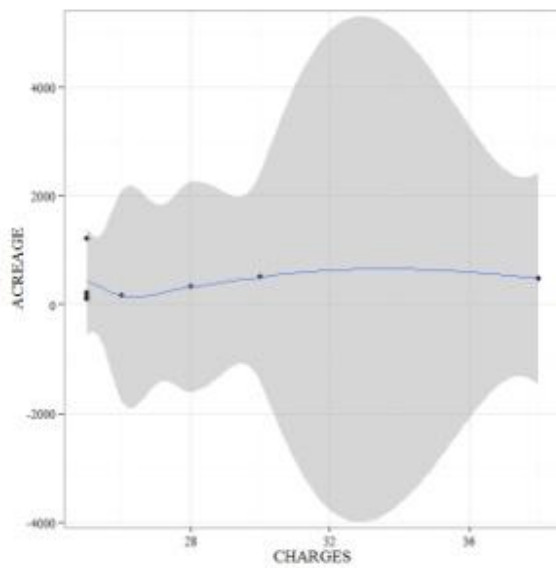
The certainty of an estimation of the curves that depicts the relation between the plowing service charges of farm tractor hiring enterprises and the acreage plowed was established by the 95% confidence bands in Fig. 2, 3, 4, and 5. Almost all the data points of plowing service charges against acreage plowed in the four agro-ecological zones fall within the upper and lower confidence bounds, hence suggesting a 95% certainty of how well the data define the best-fit curve.



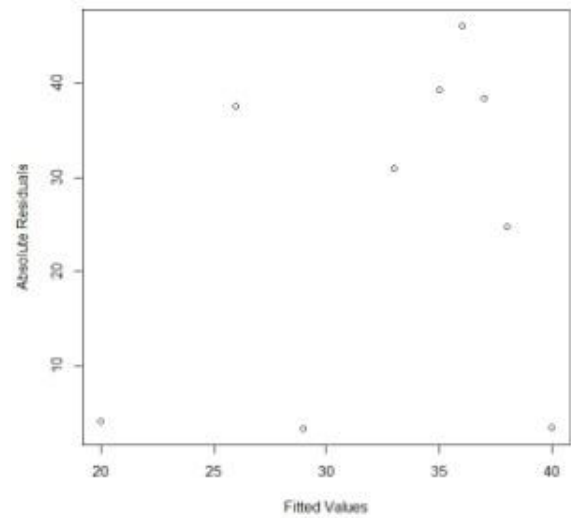
**Fig. 2.** Confidence Envelope for Charges and Acreage Plowed in the Coastal Savannah Zone



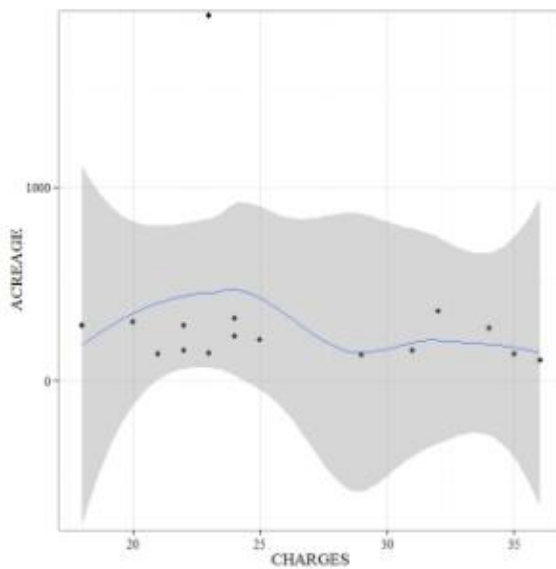
**Fig. 3.** Confidence Envelope for Charges and Acreage Plowed in the Deciduous Forest Zone



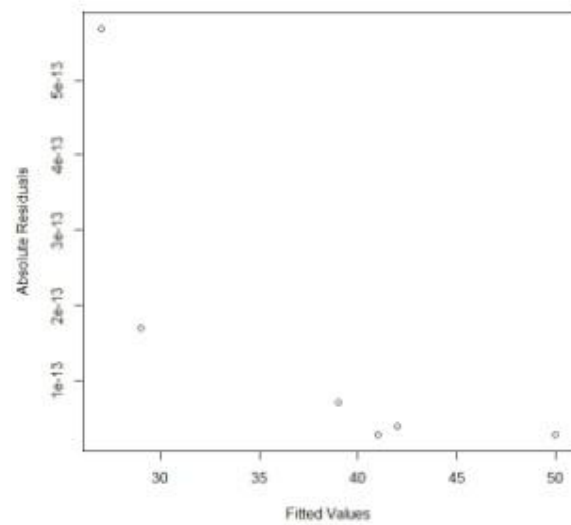
**Fig. 4.** Confidence Envelope for Charges and Acreage Plowed in the Transitional Zone



**Fig. 6.** Absolute Residuals against Fitted Values in the Coastal Savannah Zone

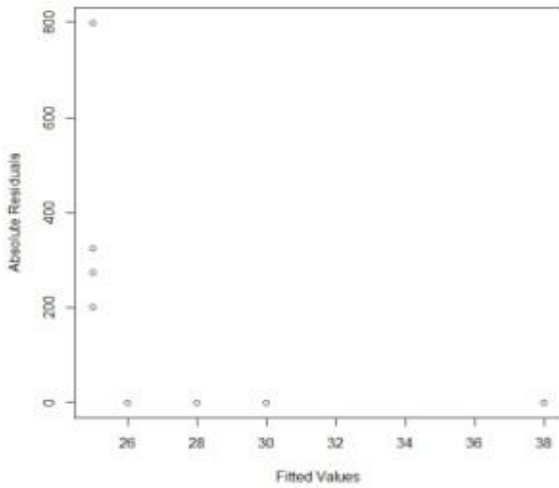


**Fig. 5.** Confidence Envelope for Charges and Acreage Plowed in the Guinea Savannah Zone

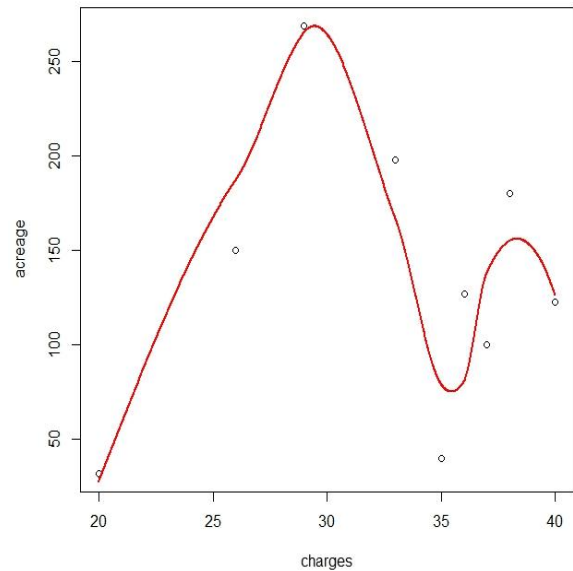


**Fig. 7.** Absolute Residuals against Fitted Values in the Deciduous Forest Zone

A further plot of absolute residuals against fitted values (Fig. 6, 7, 8, and 9) shows no discernible pattern which again indicates that the curve of plowing charges of farm tractor-hire service providers on the acreage plowed in the four selected agro-ecological zones of Ghana represents best fit of the data as illustrated in Fig. 10, 11, 12, and 13.

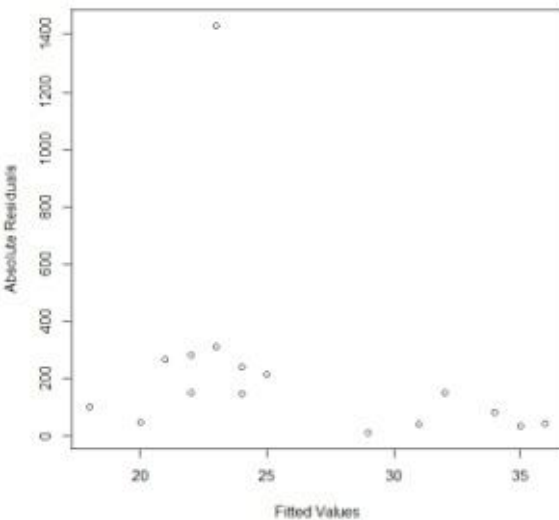


**Fig. 8.** Absolute Residuals against Fitted Values in the Transitional Zone



**Fig. 10.** LOESS Smoothing for Charges and Acreage Plowed in the Coastal Savannah Zone

A further incremental change in the charges beyond the GH¢29 per acre, witnessed a sudden rapid incremental drop in acreage plowed up to about 75 acres and then a slight rise and fall within GH¢35 and GH¢40 per acre. This suggested that the smallholder farmers in this zone began retracting fast from plowing services (or the service providers within this zone began losing clients) when the charge went beyond GH¢29 per acre. The curve probably imply that demand in plowing service rose even with incremental change in the plowing charges up to a point and began dropping with further incremental change in the plowing charge. It further suggests that tractor-hire service providers operating in the coastal savannah zone maximized profit when their plowing service charge was in the neighborhood of GH¢29 per acre.



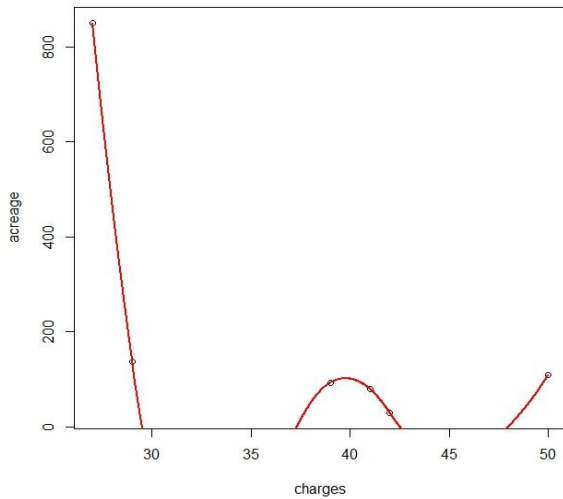
**Fig. 9.** Absolute Residuals against Fitted Values in the Guinea Savannah Zone

**2.1 Coastal Savannah Zone**

An incremental change in plowing service charge of GH¢20 to about GH¢29 per acre, was accompanied with a gentle incremental change in the acreage plowed from a low figure of about 26 acres to a maximum of about 270 acres in the Coastal Savannah Zone (Fig. 10).

**2.2 Deciduous Forest Zone**

In the Deciduous Forest Zone, (Fig. 11), incremental changes in the plowing charge resulted in rapid decrease of acreage from a high of about 850 acres at a plowing charge of about GH¢28 per acre to zero when the charge got to GH¢30 per acre.

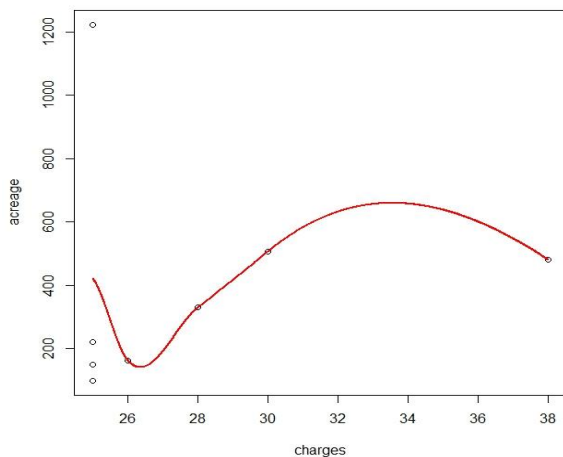


**Fig. 11.** LOESS Smoothing for Charges and Acreage Plowed in the Deciduous Forest Zone

Beyond the GH¢30 per acre, only a maximum of 100 acres were plowed within GH¢37 and GH¢42 per acre, and GH¢47 and GH¢50 per acre. This is an indication that the smallholder farmers within this zone began reducing patronage of the plowing services (or the service providers began losing clients) when the charge went beyond GH¢28 per acre. The curve suggests a decline in demand of plowing service with incremental change in the plowing charges. It further imply that tractor-hire service providers operating in the forest zone maximized profit when their plowing service charge was in the neighborhood of GH¢28 per acre.

**2.3 Transitional Zone**

The Transitional Zone experienced sharp decline in acreage plowed from 400 acres to about 100 acres for incremental change in the plowing charges from GH¢25 to GH¢26 per acre (Fig. 12).

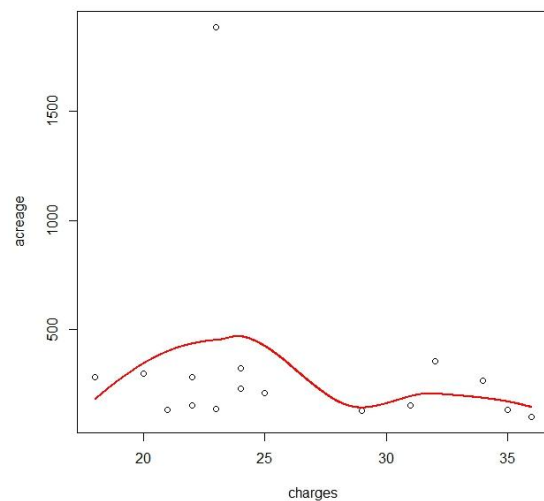


**Fig. 12.** LOESS Smoothing for Charges and Acreage Plowed in the Transitional Zone

A further incremental change in the charges caused an incremental change in the acreage plowed up to a maximum of about 650 acres in the neighborhood of GH¢33 per acre and then declined further to about 450 acres at GH¢38 per acre. In other words, the service providers in this zone always plowed 100 acres to 650 acres for incremental changes in the plowing charge. This is an indication that the smallholder farmers operating in this zone employed the tractor-hire services extensively within plowing charges of GH¢25 and GH¢38 per acre.

**2.4 Guinea Savannah Zone**

The acreage plowed in the Guinea Savannah Zone (Fig. 13) ranges from about 100 acres to 450 acres at plowing charges of about GH¢18 to GH¢36 per acre.



**Fig. 13.** LOESS Smoothing for Charges and Acreage Plowed in the Guinea Savannah Zone

An incremental change in the charges resulted in gentle rise in acreage plowed up to the maximum of 450 acres at GH¢24 per acre and a further incremental change in the charges caused a sharp decline in acreage plowed down to figures in the neighborhood of 150 acres within GH¢29 and GH¢36 per acre plowing charges. This then implies service providers operated at maximum profit when the charge is in the neighborhood of GH¢24 per acre. Again tractor-hire services were extensively employed in this zone at plowing charges between GH¢18 and GH¢36 per acre.

**3 CONCLUSION**

The relationship between farm acreage plowed and the plowing service charges varied from one agro-ecological zone to the other and does not follow any definite pattern however, the curves derived explained the effect of incremental charges on acreage plowed in each zone. The reduction in acreage plowed with respect to incremental change in plowing charges began at GH¢29 per acre in the Coastal Savannah Zone, GH¢28 per acre in the Deciduous Forest Zone, and GH¢24 per acre in the Guinea Savannah Zone. For the Transitional Zone, the reduction in acreage plowed occurred within charges of GH¢25 and GH¢26 per acre and again beyond GH¢33 per

acre. The average maximum acreage plowed per service provider was 270 acres in the Coastal Savannah Zone, 850 acres in the Deciduous Forest Zone, 650 acres in the Transitional Zone, and 450 acres in the Guinea Savannah Zone at average rates of GH¢29 per acre, GH¢28 per acre, GH¢25 per acre and GH¢24 per acre respectively. The results further point to the fact that smallholder farmers react to fees charged for plowing.

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