CAPACITIVE STUDY OF COMBINE FOR HARVESTING RICE IN CHIROMAWA VILLAGE, NIGERIA

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ABSTRACT

The capacitive performance of a combine for harvesting paddy rice was investigated in Chiromawa village, northern Nigeria. It was found that the forward speed of the combine during her operation has low value of 0.36 km/h as a result of the roughness of the surface of the rice field caused by the bunks used in making the basins. It was observed that the time for field primary operations of 50% of total field time is low due to the age of the combine. However, the field efficiency of the combine is within the acceptable limit of above 70%. The man-machine productivity and the man-machine performance of the combine in the said location for the investigated harvest season were found to range from 0.15 to 0.38 ha/hr and 0.09 to 0.27 ha/hr respectively. It was also found that there exist a correlation between the forward speed and each of theoretical capacity, actual capacity and field efficiency.

KEYWORD: Combine harvester, theoretical filed capacity, actual field capacity, man-machine productivity, man-machine performance and filed machine-index.

1. INTRODUCTION

Rice (*Oryza Sativa* L) is widely cultivated and consumed as a stable food in many parts of the world. In 1978, the total world rice production was 363 million metric tonnes (De Datta, 1981). While in 2007, world production of rice was 422 million metric tonnes (Kibar *et al*, 2010). This shows 16% increase in the production of rice in the interval of about thirty years. Rice is the second most important cereal after wheat (Kibar *et al*, 2010) and has the immediate lower yield of 2.4 tonnes per hectare after maize which has the highest world average yield of 2.8 tonnes per hectare (De Datta, 1981). Rice is the basic food of two-third of the world population (Kibar *et al*, 2010). Nigeria, with the population of about 170 million, is among the major world consumers of rice. The annum production of rice in Nigeria is 3 million tonnes (Biyi, 2005), this domestic production is augmented by the importation of another 3 million metric tonnes.

The current agricultural transformation agenda of the Federal Government of Nigeria aims at attaining self-sustenance in rice production. For this goal to be achieved there is the need for the mechanization of every stage in the processes of rice production. At the moment in Nigeria, there is a low level of mechanization in the production of rice- from its land preparation to the harvesting stage and even the post harvest stages of threshing and milling of rice (Adu *et al,* 2012). This low level of mechanization has negative effect on the quality and quantity of local rice production in the country. Thus the price of the locally produced rice cannot compete favourably with the imported ones in Nigerian markets.

Almost every process in the production of rice in Nigeria is carried out manually (Adu *et al,* 2012). It must be noted that the harvest of rice in most part of Nigeria is carried out with the aid of handheld sickle, while the threshing is done by flailing handfuls of pinnacles of rice against the body of stationary barrel. Thus the traditional processes of harvesting rice and its threshing are laborious and time-consuming. As a result of drying the harvested crop on farm floors after harvesting and before the threshing, the crop is exposed to contamination from dust, pecking from birds and pilferage (De Datta, 1981).

The traditional methods of harvesting and threshing of rice does not enhance timeliness of the process. Timeliness is an essential factor in the agricultural industry since no other industry is so dependent on season and environmental conditions as agriculture (Hunts, 1983). Hence, there is the need for timeliness in rice production in order to reduce scatter losses on the field. Timeliness would also allow harvesting to be done at the optimum moisture content and as soon as it is deemed fit. For this to be achieved, the manual methods of harvesting and threshing of rice must be replaced with mechanization. The use of combine harvester would allow for the harvesting, threshing, cleaning and even bagging of the product to be carried out at once, which would eliminate the multiple handling of the crop if the processes are to be done separately. These simultaneous operations of harvesting, threshing, cleaning and bagging in one go would also reduce the cost of handling the crop if the operations were to be done differently and lower the losses likely to be incurred in the course of the separate carrying out of the operations. It would also improve on the wholesomeness of the produce for human consumption as the product would be less exposed to contamination from exposure to duct, insects, rodents etc if handled with combine harvester instead of the traditional/manual method.

The objective of this study is to determine the capacitive performance of combine for harvesting rice in Nigeria. It would also determine the man-machine activity and productivity on the use of the combine in Chiromawa village of Chiromawa Local government area of Kano State, Nigeria. It is not in the context of this research to design any experiment for the use of the combine but to rather investigate the capacitive performance of the combine in the way and manner in which the local farmers use the machine on their farms.

2. MATERIALS AND METHOD

The data for this research is gotten by investigating the conventional way the farmers use the combine on their farms. The time used for the primary operation and other support functions were measured and recorded in the 2013 harvest season. There was no modification or any technical advice that was given to the farmers before this study. The farmer were allow to carry out the normal harvesting and threshing of the paddy rice on the field while using the combine in the convectional manner in which they have always done it. The soil type was determined. The moisture content of the harvested crop was also measured. The moisture content was determined using moisture meter. Distances were measured using a tape meter rule. Quartz stopwatch was used to measure the times spent in carrying out each activity. Speed of travelling of the combine was gotten by dividing the distance covered by the time taken to cover the distance.

A special sheet was used to record the time to carry out each activity. The turning time starts when the cutting unit of the combine is lifted to initiate the turning and ends the moment the cutting unit of the combine is lowered again to resume work. Maintenance which took less than 10 minutes was considered as minor repairs and therefore used in this study. But maintenance which took above 10 minutes to carry it out was termed as major and was not used in the study according to Barnes (1960). There were three operators on the combine during its operation. The main operator, the driver, was a man of 43 years of age with about 15 years experience on the job. He also directed the adjustment of all settings and the carried out minor repairs on the combine. The combine was acquired by the farmer 20 years ago and since then it is being used for the harvesting and threshing of rice annually. The field was sectioned into basins and the crop was planted in the traditional way and given the usual agronomic practices commonly used for the planting of rice in the region.

The field was harvested by going round it and not by making a u-turn at the end of the length of the field (Hunts, 1983). Different fields were studied within the same vicinity in the stated harvest reason. The fields have the same weather conditions and have similar soil type and were all owned by the same farmer who also owns the combine and pays for the operations. However, the yields of the fields were slightly different. The fields visited had an average yield of 1.7 tonnes per hectare.

The activity time of the combine on the field was measured using the stopwatch and recorded on the special record sheet. The distance covered by the combine was also measured and recorded. These time and distances were used to determine the speed of the combine while performing its functions on the field. The activities of interest include the performing of the primary function of harvesting and threshing of the crop by the combine which are done simultaneously, the time for other support activities viz; the time for turning, offloading of the paddy, combine maintenance and the private time of the operators. The private time of the operators were the time the combine was stationary for the operators to ease themselves, drink water etc. However, all stoppages which were in excess of ten minutes were not used for the analysis of the capacity performance of the combine. This is according to the recommendation of Barnes (1960). The data were analyzed to determine the theoretical and actual field capacities of the combine, its efficiency, man-machine performance and the field machine index (FMI). Two different methods were used for the determination of the field efficiency of the combine. The first method is the ratio of the actual to theoretical field capacities expressed as a percentage. The second method is the ratio of the time the combine was performing its primary function of harvesting and threshing to total time when the machine engine was actually running.

3. RESULTS AND DISCUSSION

The soil type was tested and found to be sandy loam. The moisture content of the harvested crop was measured using Ohaus MB25 Moisture Meter and it was found to range from 18 to 23% for this study. Table 1 below shows that the speed of operation of the combine is from 0.23 to 0.54 kilometres per hour. The values of the speed of operation of the combine may be said to be low when compared with the results of Alabi (2008) and that of Afolabi *et al* (2012) in their separate capacities study of tractors for tillage operations. While Alabi (2008) got a speed range of 5 to 7 km/h, Afolabi *et al* (2012) had a range of 4.2 to 5.8 km/h. Moreover, the speed is also lower than those of Gwarzo (1975) and Gwarzo (1991) in his field capacitive evaluations of different mobile agricultural machineries. Gwarzo (1975) and Gwarzo (1991) had speed of magnitudes 2.6 to 4.7 km/h and 3 to 12 km/h in his studies respectively. However, this speed range of the combine in this study agrees with those used by Qamar-uz-Zaman *et al* (1992) in their study on a combine for harvesting wheat. The low value of the operational speed of the rice combine harvester may be due to very rough nature of the surface of the field caused by the bunks used in making of basins for the crop.

Table 1: Obtained and Computed Indices for Capacitive Study of Combine

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
0.54	57.83	1.89	11.03	11.06	1.29	69.59	0.51	0.39	77.66	0.38	71.87	0.27	96.84	81.74
0.36	39.38	1.66	8.25	8.58	20.08	50.52	0.34	0.26	74.84	0.25	70.92	0.18	95.95	79.89
0.32	30.07	0.28	7.72	4.46	32.84	39.90	0.30	0.22	73.40	0.23	71.36	0.17	99.08	78.99
0.23	30.25	2.82	5.99	10.23	7.31	53.45	0.22	0.15	70.88	0.15	58.43	0.09	91.47	77.44

A= forward speed (km/h), B= activity time (min), C= turning time (min), D= personal time of operators (min), E= offloading time (min), F=maintenance time (min), G= percentage time used for primary operation (%), H=Theoretical capacity (ha/hr), I= Actual capacity (ha/hr), J= Capacitive Efficiency I (%), K=Man-machine Productivity (ha/hr), L= Man-machine Activity (%), M=Man-machine Performance (ha/hr), Field-machine Index (%), O= Capacitive Efficiency II (%)

The swath width of 2.6 m was used in this study, which is slightly above the 1.2 to 2.4 m used by Alizadeh and Allameh (2013). Table 1 also shows the times spent for turning, offloading, maintenance and other activities on the field. It is noted that the bulk of the activity time were used for the primary function of harvesting and threshing of the crop (column G of table 1). This shows that an average of fifty percent of the time of the field was spent on the primary function activity. On the third experiment, there was a large amount of time spent on the maintenance of the combine: this singularly affected the average of the percentage of the time used for the primary functions. The turning time of the combine ranged from 0.30 minutes to 1.89 minutes depending on the available space for manoeuvring at the ends of the field. This turning time range agrees with those obtain by Gwarzo (1975) who got a range of 0.34 to 1.25 minutes for cotton pickers. The other times recorded and shown on the table 1 are the personal time of the operators, offloading and maintenance times.

The offloading time ranged from 6 to 11 minutes depending on the distance of the combine from the point of offloading at the time the combine was to be offloaded and on the volume of threshed material in the tank of the combine at that time. The offloading of the combine was done at the operators' discretion depending on the operator decision and other logistic reasons for offloading. Sometimes, the operators go to offload when the combine's tank is yet to be full just for the operators to have some personal time. Gwarzo (1975) got the ranges of time for dumping and time for travelling to and fro dumping point as 0.18 to 6.91 minutes and 0.75 to 5.60 minutes per acre respectively.

The theoretical and actual capacities of the combine are shown on Table 1, columns H and I respectively. The theoretical capacity of the combine was determined from the speed and swath width of the combine. It ranged from 0.22 to 0.51 hectare per hour. While the actual field capacity of range from 0.15 to 0.39 hectare per hour. When converted into hectare per hour, Gwarzo (1975) got 0.4 to 0.7 ha/hr range for the actual field capacity of a cotton picker in Arizona. The low values of the field capacities in this study when compared with Gwarzo (1975) were due to the low forward speed of the combine in this experiment and the difference in the crops. The theoretical and the actual capacity of the combine are plotted against forwards speed in the Figures 1 and 2 respectively. The equations and the coefficients of determination of each curve are indicated on the graphs accordingly. The graphs shown linear relationships between each of the theoretical and actual capacities and the forward speed of the combine, the R^2 values are indicative of the co-relationship between the theoretical capacity and the forward speed and between the actual capacity and the operation speed of the combine harvester.

From the actual and theoretical capacities of the combine the field efficiency (column J, Table 1) of the machine was determined. It was found that the field efficiency of the combine harvester is in the range of 73 to 77%. This field efficiency of the combine was found to agree with those of literature (Gwarzo, 1991, Afolabi, *et al,* 2012 and Alabi, 2008). However, the field efficiency of the combine which was found solely from the ratio of activity duration of the combine ranged from 77 to 82%. The results obtained by the two methods are within the range gotten by Gwarzo (1975), who got a range of 54 % to 87.5 % for his study. While Alabi (2008) had 57 to 80% field efficiency and Afolabi *et al,* (2013) had 70.8 to 83.4% for tillage implements mounted on tractors.

The man-machine productivity of the studied combine is also shown in table 1. The range of the value of the man-machine productivity is 0.15 to 0.38 hectare per hour. This result is low when compared with those obtain by Afolabi *et al,* (2012), Alabi (2008), and Gwarzo (1991) for the same parameter. The low value of the man-machine productivity is due to the low value of the forward speed of the combine during the operation. In their studies, Afolabi *et al,* (2012), Alabi (2008), and Gwarzo (1991) got averages of 0.78, 0.90 and 1.23 ha/hr respectively for their man-machine productivities respectively.

The man-machine activity was also computed and tabulated in Table 1. The man-machine activity, in percentage, was found to be about 70%, while higher values have been obtained by other researchers. The low value of the man-machine activity when compared with literature can be put on the age of the studied combine. As a result of the advancement in age of the combine, its components reliabilities have reduced from what they used to be when the combine was first obtained. Therefore, a lot of time has to be spent on the maintenance of the combine as a result of frequent break down. Also, the largeness of the time spent on going to offload and at offloading is another reason for the low value of the man-machine activity value. The man-machine performance, also on Table 1, is low as a result of the low values of the man-machine productivity and activity of the combine.

Figure 1 shows the graph of the theoretical efficiency to the forward speed for the rice combine. The R^2 value is 0.9713, the equation of the relationship is given on the graph. It shows that a correlation exist between the theoretical capacity and forward speed of the combine. Figure 2 is the graph of effective/actual capacity to the forward speed of the combine during its operation. The graph is a linear graph with the R^2 value of 0.9998. The trend also shows that there is high correlation between the effective capacity and the forward speed of the combine. The equation of the relationship is also given on its graph. Figure 3 show the graph of field efficiency against forward speed. This efficiency was calculated as a ratio of actual to the theoretical capacities. The value of the coefficient of determination R^2 is indicative of the correlation between the speed and the field efficiency. Gwarzo (1991) obtained similar graphs in his work where he used a tractor combined with a harrow for harrowing operation. Gwarzo (1975) also had similar trends in his study of cotton picking machines in Arizona, while Alabi (2008) also expressed the same trend.

Figure 4 shows the correlation of two methods used for the determination of field efficiencies of the combine. The first method used the ratio of the actual capacity to effectual capacity express as a percentage. And the second method used the time ration of performing primary activity and total operation time spent working in field. Figure 5 shows the bar chart of the two methods used to determine field efficiency. At all times, the second method gave higher value than the first method. It was found the there existed correction between the two methods and the coefficient of determination (R^2) value was found to be 0.9997. But when the student t-test was used to test if there were significant differences between two methods, the t-test show that there is high significant difference between the two methods used to compute the efficiency.

The field machine index (FMI) on Table 1 is large, ranging from 91.5 to 99%. It indicates that the use of the combine harvester for the harvesting of rice on the field should be encouraged. Figure 6 is the graph of FMI verses turning time: the coefficient of determination and equation of the curve is given on the graph.

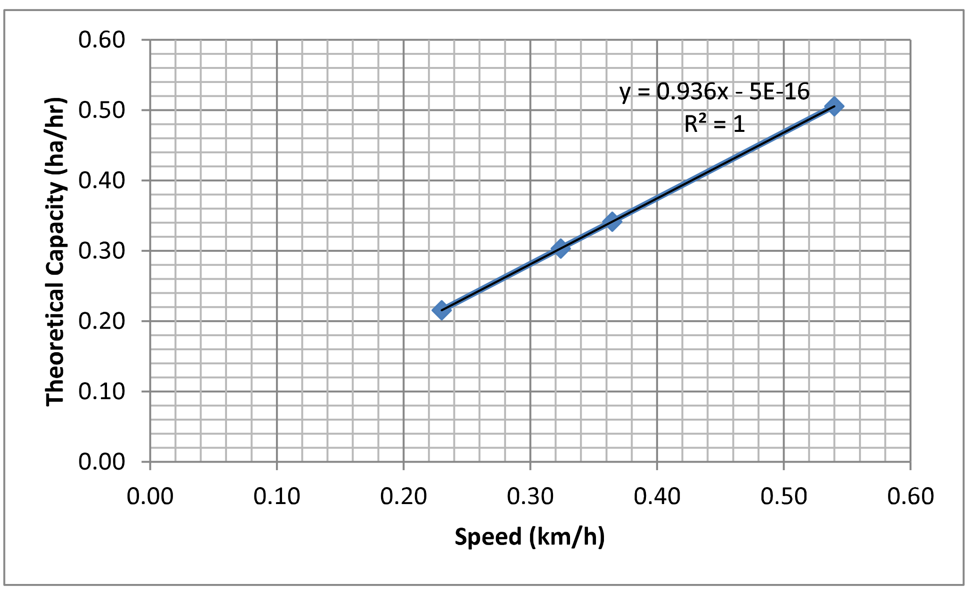

Figure 1: Theoretical Capacity (ha/hr) against speed (km/h)

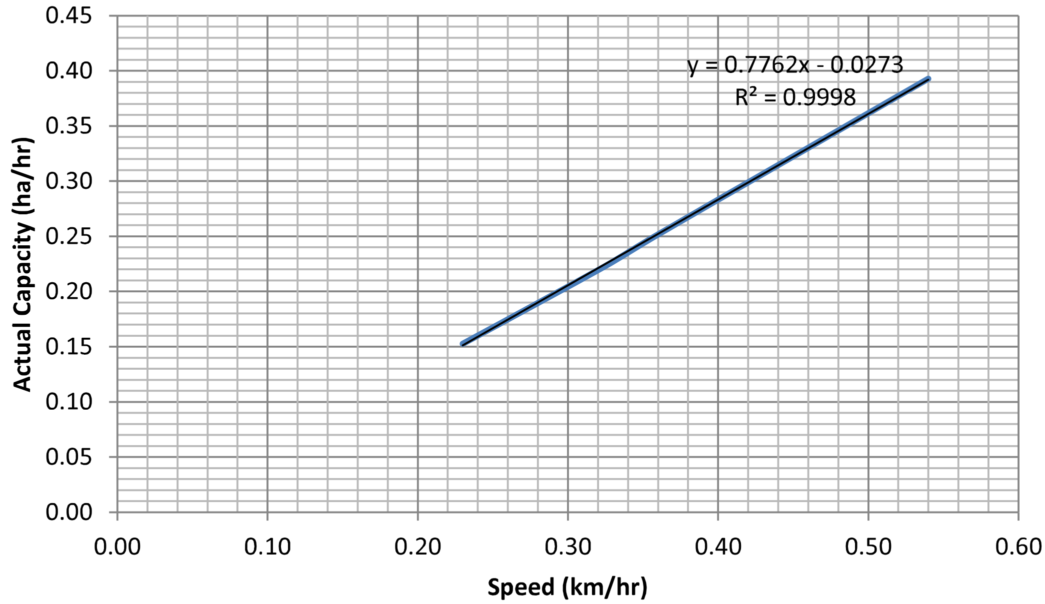

Figure 2: Actual Capacity against Speed

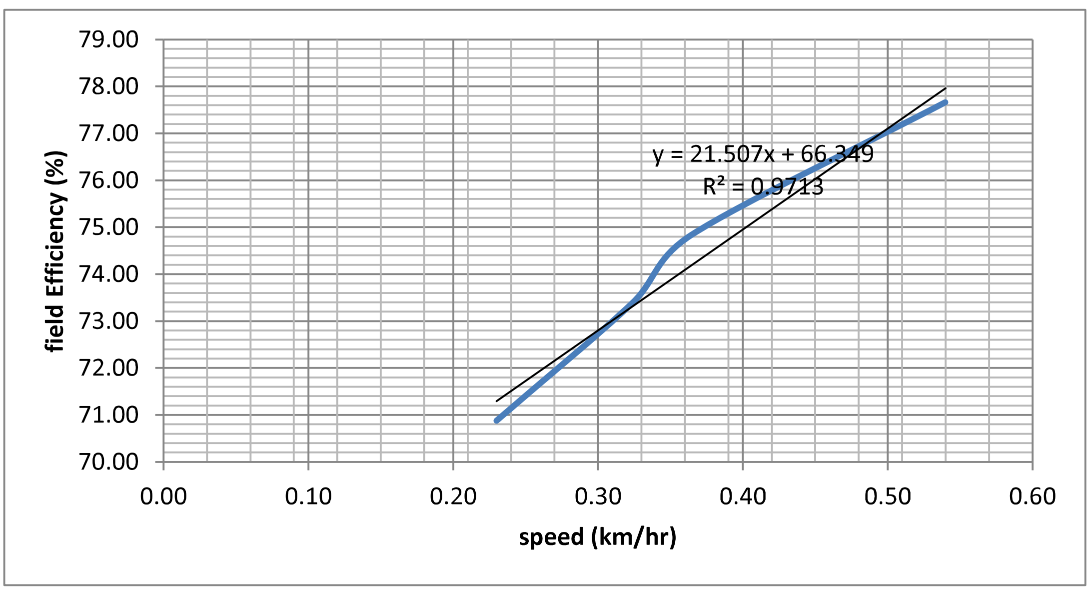

Figure 3: Field Efficiency against Speed of travel

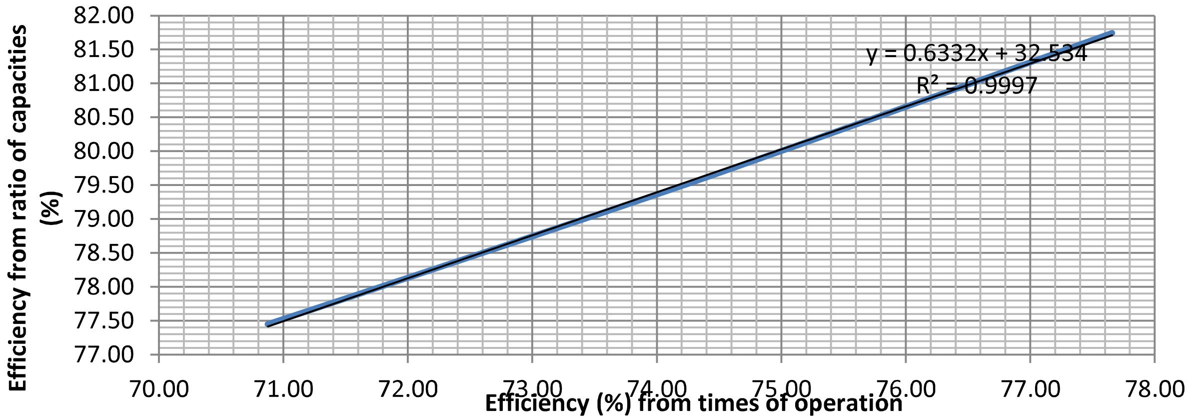

Figure 4: Comparison of two efficiencies

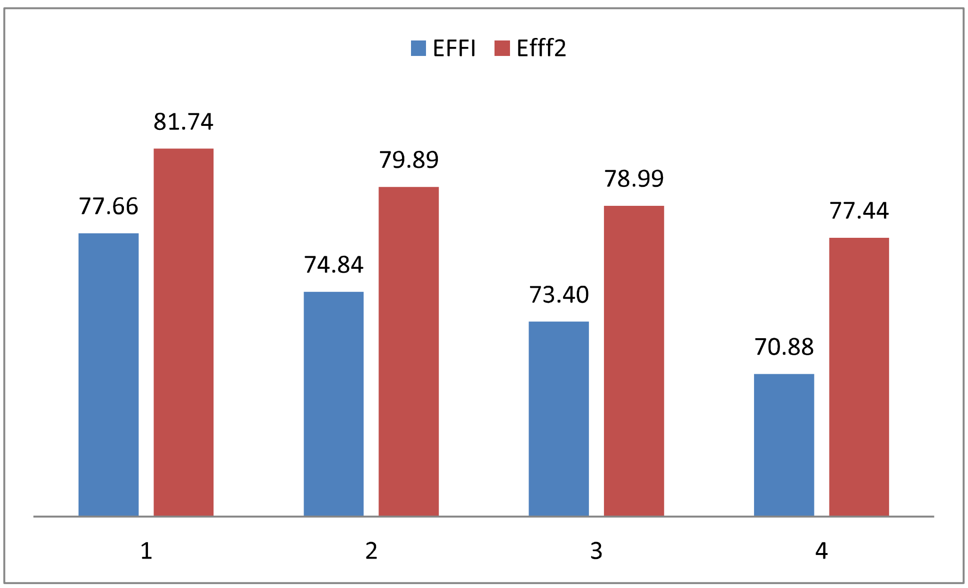

Figure 5: Bar Chart for the comparison of efficiencies

Table 2 t-test results of the methods of calculating efficiencies

SSE	T cal	T tab
1.069	10.29	10.13

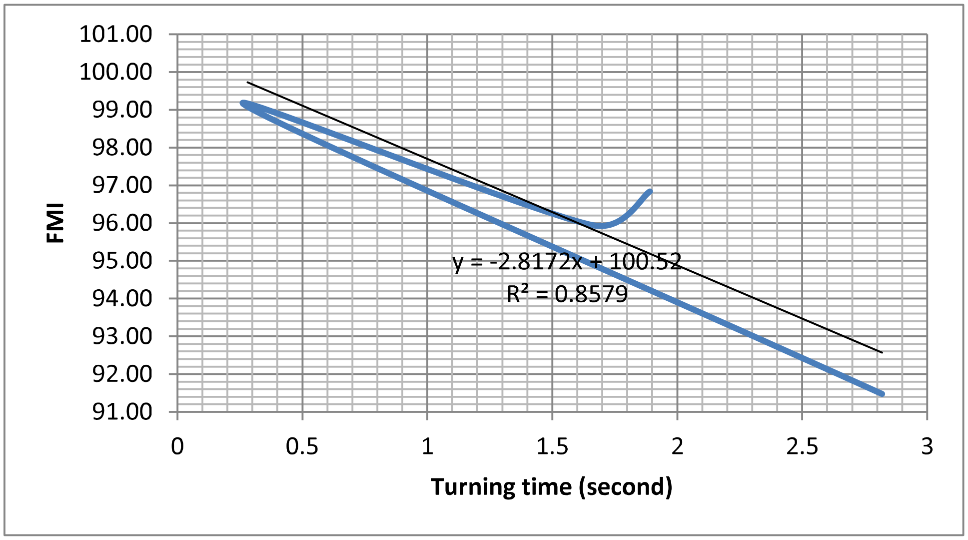

Figure 6: FMI verses Turning time

4. CONCLUSION

The capacitive performance of combine for harvesting rice was investigated in northern Nigeria. It was found that the field capacity of the combine was low due to the nature of the surface of the rice field. The low forward speed of 0.36 km/hr is responsible for the low field capacity of 0.26 ha/hr. Thus it can be concluded that field capacity is dependent on field capacity. The field efficiency of the combine harvest for harvesting rice was found to be above 70%. There exist a correlation between the forward speed of a mobile machine and the field efficiency of the machine. There is significant difference between the methods of determination of field efficiency as a ratio of activities time and as a ratio of actual to theoretical field capacities. Field efficiency from ratio of actual to theoretical field capacities is lower when compared with the field efficiency gotten from ratio of time of primary activity and total field time.

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