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Land Fragmentation and its Implications for Productivity: Evidence from Southern India

Raghbendra Jha,
ASARC, RSPAS
ANU, Canberra

Hari K. Nagarajan,
NCAER, New Delhi

Subbarayan Prasanna
Indian Institute of
Management, Bangalore

All correspondence to:

Prof. Raghbendra Jha,
Australia South Asia Research Centre,
RSPAS, Division of Economics,
Australian National University,
Canberra, ACT 0200, Australia

Fax: + 61 2 6125 0443
Email: r.jha@anu.edu.au

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I. Introduction

In developing economies land reform, in particular land redistribution has occupied a central role in debates about poverty — particularly chronic poverty — alleviation in rural areas. Even if it were accepted that land redistribution could alleviate poverty the enthusiasm for such redistribution needs to be tempered with consideration of the potential efficiency effects of land fragmentation. The fragmentation of land holdings could rise with land fragmentation. In turn, land fragmentation could lead to sub-optimal usage of factor inputs and thus to lower overall returns to land. The factors contributing to this could be losses due to extra travel time, wasted space along borders, inadequate monitoring, and the inability to use certain types of machinery such as harvesters.

Fragmentation of land is widespread in India and it is believed that fragmented nature of land holdings may play a major role in explaining low levels of agricultural productivity. Despite substantial rise in yields India ranks 34th in yields for sugarcane, 57th for cotton, 118th for pulses, and, 51st for rice although India is a leading producer of each of these crops in aggregate terms.[1] Further, there is evidence of inefficient use of resources in agriculture and the resulting increases in costs, e.g., 25 times more water/tonne of output is being used to irrigate Cotton in India than in Egypt.

In response to the perceived adverse effects of land fragmentation the then Finance Minister allocated Rs. 5 million over a period of five years, as an incentive for land consolidation, in his 2000 budget speech. However, the Planning Commission of India has indicated a near complete failure on this front.

To date, however, there has been no systematic attempt at quantifying the effects of land fragmentation and understanding the channels through which these effects operate. The present paper attempts to fill this void.

In this paper, we undertake a detailed assessment of the consequences of land fragmentation using a unique panel data set from Southern India, with comprehensive information on all landholding households in two contiguous villages over a five-year period. In particular, we examine whether technical efficiency of farm production is significantly related to farm size, whether yield is importantly impacted by the degree of fragmentation as measured by the number of plots, average plot size, and an index of

[1] Economic Survey 1998–99.

fragmentation,[2] and whether such fragmentation impacts upon labor allocations. We then use stochastic production function methods to measure the degree of technical efficiency and relate this to the degree of land fragmentation. Our results show clearly that land fragmentation has a significant adverse effect on land productivity.

The plan of this paper is a follows. In section II we review the literature on this issue whereas section III discusses the data asset. Section IV details the methodology and estimation procedure, section V presents the results and section VI concludes.

II. A Brief Literature Review

An important consideration in an evaluation of the consequences of land fragmentation for technical yields is whether economic processes that reflect local agro-climatic conditions drive such fragmentation. However, a more immediate reason for the overall patterns of land fragmentation in rural Indian the prevalence of the Zamindari system in many of the river valleys. The Zamindari system was characterized by highly inequitable pattern of land holdings with very few landowners holding onto most of the cultivatable land. To correct this inequitable pattern of land holding, the Indian Constitution (enacted in 1949), granted powers to different states to enact land redistribution measures. These efforts were supplemented in the early 1970s by the enactment of Land Ceiling Acts, which placed upper limits on land holdings and required the surplus land to be redistributed among the landless. This process along with the fragmentation through acts of succession from one generation to the next has reduced size of land holdings and led to fragmentation of land holdings of farmers. As noted earlier various laws designed to address the issue of fragmentation have met with only limited success.[3]

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[2] The Januszewski index is defined as, $K = \frac{\sqrt{\sum a}}{\sum \sqrt{a}}$

where 'a' represents the parcel size. The index ranges between 0 and 1. 1 implies that the farmer holds all his land in the form of single plot. It has three properties: fragmentation increases (the value of the index decreases) as the number of plots increases, fragmentation increases when the range of plot sizes is small, and fragmentation decreases when the area of large plots increases and that of small plots decreases. Specifically, Januszewski's index measures the number of plots and the size distribution of the plots.

[3] The Bombay Prevention of Fragmentation and Consolidation Act 1947, provides for State intervention for consolidation of fragments irrespective of the willingness of the people. This act also provides various incentives for co-operation such as wavering of consolidation fee charged by the government and granting of Taccavi loans to agriculturists whose lands have been consolidated. The East Punjab Holdings Act 1948, empowered the Punjab Government to take up consolidation in any area either on the request of the holders of an area or, on its own initiative. The Bihar Consolidation of Holdings and Prevention of Fragmentation Act 1956, prohibits the creation of future fragments, a certain minimum area necessary for profitable cultivation to be defined as a standard minimum area and all holdings below that size to be treated as fragments.

The literature on land size and land productivity is large and has been around for decades. In recent times Binswanger et. al. (1995) have argued that there is an inverse relation between the tow whereas Banerjee and Ghatak (1996) have questioned this result. Carlyle (1983), Heston and Kumar (1983), Bentley (1987), Blarel et al. (1992), Jabarin and Epplin (1994)) have focused on the impact of fragmentation on yield and productivity. The debate has focused basically on the impact of fragmentation on the ability of farmers to minimize risk since fragmentation was perceived to have a negative impact on productivity and yield.

The impact of land size on technical efficiency has been investigated in a series of papers. The countries where this relationship has been studied include the Philippines (Herdt and Mandac 1981; Kalirajan and Flinn 1983; Dawson and Linagard 1989), Brazil (Taylor and Shonkwiler 1986), Tanzania (Shapiro 1983), Pakistan (Ali and Chaudhry 1989) and India (Huang and Bagi 1984; Kalirajan 1981; Junankar 1980; Sidhu 1974; Lau and Yotopoulos 1971; Battese, Coelli and Colby 1989; Tadesse and Krishnamoorthy 1997; Kumbhakar and Bhattacharya 1992; and, Jha and Rhodes 1999).[4] These studies make use of stochastic production function methods and conclude that the large variation in yield across farmers is due to differences in technical efficiency, which is largely influenced by farm size, size of the land holding, ecological factors and their interaction with factor inputs like land, technology and fertilizer. However, to the best of our knowledge there does not exist any study linking technical efficiency to land fragmentation. Part of the reason for this is the lack of reliable data on land fragmentation. We address this issue by studying a unique primary data set where information on such fragmentation and its evolution are collected.

III. The Data

The deltas at the ends of the river valley systems in India have traditionally been major centers of agricultural production, with farmers adopting innovative methods of cultivation in response to changing conditions and new technologies. In recent years, these regions have been increasingly prone to water stress arising from either, a) depletion of ground water resources through over-exploitation, and, b) river water disputes. The Kaveri Delta in Tamil Nadu has been historically considered as a ‘rice bowl’ of southern India. This is the region in which scientific methods of irrigation were developed as far back as the Chola period in the 8th century AD. One of these villages, in this region (Nelpathur) is also the place in which the

[4] For a good review, see Sankar (1997) and Battese and Coelli (1992)

‘grow more food’ program — a precursor of the Green Revolution — in the late 1960s was launched. This region is, however, currently seeing a general decline in rice production and farmers are resorting to crop diversification.

The data for this study were collected over a 5-year period beginning 1995 in 2 contiguous villages (Nelpathur and Thirunagari) situated in the Sirkhazi taluk of the Thanjavur district of Tamil Nadu, India. These villages are located in the Kaveri Delta. Thirunagari is a larger village as compared to Nelpathur. According to the 1991 Census the number of households in Nelpathur is 550 whereas it is 881 in Thirunagari. The population in Nelpathur is 2237 whereas in Thirunagari it is 3700. The number of children below the age of 6 is 306 in Nelpathur whereas in Thirunagari it is 410. Around 19% of the Thirunagari village population is engaged in farming (165 households). Nelpathur has a greater proportion (28%) of the population engaged in agricultural activities. There are 1250 acres of cultivable land in Nelpathur and 2000 acres in Thirunagari. The number of agricultural workers is 1500 in Thirunagari and 1200 in Nelpathur. There is no noticeable forest cover in any of these villages. In Thirunagari, government canals irrigate 1100 acres of cultivable land while such canals in Nelpathur irrigate 700 acres.

Figure 1 here

The survey data were collected for 137 farmers of the Nelpathur village and 83 farmers of Thirunagari, for the period 1995–1999. Farmers were asked questions regarding their land holdings, crops grown, output produced, inputs used and ownership of factors of production. Data was also collected on the price paid by the farmers for the factor inputs used and the price they receive for their output (both from the traders and the government). Information was obtained for the number of plots owned by the farmers, the size of each of these plots and the crops grown in these plots. Questions regarding the outputs of different crops grown by the farmers and the revenue obtained from these crops were also a part of the questionnaire. Farm input data is in terms of the quantity and the total cost spent on seeds, fertilizers, irrigation, bullocks, cartage, manure and machinery, general labor, labor for land preparation, and labor for harvesting and threshing. Tables 1 to 2 and Figures 2 to 7 describe the data.

Tables 1 to 2 and Figures 2 to 7 here

IV. Methodology

The basis for our empirical investigations is the estimation of a generalized translog cost function (Christensen and Green 1976) of the form:

$$\ln C_{it} = \alpha_0 + \alpha_Y \ln Y_{it} + \frac{1}{2}\gamma_{YY}(\ln Y_{it})^2 + \theta \ln(\mathrm{X}_{it}) + \sum_i \alpha_i \ln P_{it} + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_{it} \ln P_{jt} + \sum_i \gamma_{Yi} \ln Y_{it} \ln P_{it} \quad (1)$$

where $\gamma_{ij} = \gamma_{ji}$, C_{it} is total cost of production of *i*-th farmer in *t*-th year, Y_{it} is output, and the P_{it}'s are the prices of the factor inputs and, X_{it} is the variable with respect to which scale economies have to be tested. X_{it} can be farm-size, number of plots cultivated or the average plot-size (only one X_{it} variable is used at any one time). In order to correspond to a well-behaved production function, a cost function must be homogeneous of degree one in prices, i.e., for a fixed level of output; the total cost must increase in proportion to the increases in prices. This implies the following relationship among the parameters,

$$\sum_i \alpha_i = 1, \quad \sum_i \gamma_{Yi} = 0, \quad \sum_{\mathrm{i}} \gamma_{ij} = \sum_{\mathrm{i}} \gamma_{ij} = \sum_i \sum_{\mathrm{j}} \gamma_{ij} = 0$$

In the presence of constant returns to scale, θ =1. Scale economies are indicated by a coefficient of less than one and scale diseconomies by a coefficient that is grater than one. Analogously the effects of fragmentation and landsize on yields may be estimated using a translog production function,

$$\ln y_{it} = \alpha_0 + \sum_i \beta_i \ln x_{it} + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln x_{it} \ln x_{jt} \quad (2)$$

where $\beta_{ij} = \beta_{ji}$, and x_{it}'s are per acre input factors and y_{it} is the output per acre.

Production function estimation may also be used to test for possible heterogeneity in the productivity of labor input. In particular, consider

$$\ln Y_{it} = \alpha_0 + \sum_i \beta_i \ln X_{it} + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln X_{it} \ln X_{jt} + \theta \ln(p_{it}) \quad (3)$$

where $\beta_{ij} = \beta_{ji}$, and *Y* is the logarithm of the outputs of Samba, Black Gram and Cotton, X_i's are the inputs namely various kinds of labor inputs, acreage, fertilizer, pesticide, bullocks, machinery and irrigation (number of hours), and, p_{it} is defined below, depending on the nature of heterogeneity being tested:

a) For intra-activity labor heterogeneity:

p_{it} = hired labor/(hired labor + family labor)

b) For inter-activity labor heterogeneity :

p_{it} = hired labor in activity A/(hired labor in activity A + Hired labor in activity B).

In case of intra-activity labor heterogeneity, a negative and significant θ indicates that hired labor is inefficient as compared to family-provided labor. A positive and significant but below unity value suggests that hired labor is more efficient, but the difference in marginal productivity of these two types of labor declines as hired labor increases in importance in the labor force. A positive but greater than unity value of θ indicates that hired labor is more efficient and the difference in marginal productivity of these two types of labor increases as hired labor increases in importance in the labor force. An insignificant value of θ suggests that there is no difference between the marginal productivity of the two kinds of labor. To address whether supervision decreases labor heterogeneity one may also condition production on levels of supervision in different activities.

$$\ln Y_{it} = \alpha_0 + \sum_i \beta_i \ln X_{it} + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln X_{it} \ln X_{jt} + \theta \ln(p_{it}) + S_{ait} + S_{bit} \quad (4)$$

where, S_{ait} and S_{bit} represent the supervision hours devoted to activity A and B respectively.

Examination of technical efficiency is carried out using a translog functional form. Consider the stochastic frontier production function[5] for panel data,

$$Y_{it} = f(X_{it}, t, \beta) + V_{it} - U_{it} \quad (5)$$

where Y_{it} is the output (or the logarithm of the output) of the *i*-th farmer in the *t*-th time period; X_{it} is a (k×1) vector of (transformations of the) input quantities of the *i*-th farmer in the *t*-th time period; *f*(.) is a suitable functional form of the production function, β is a (1×k) vector of unknown parameters to be estimated; *t* is a time trend representing technical change; V_i's are random errors which are assumed to i.i.d. N(0, σ_v^2), and independent of the U_i's; the U_i's are non-negative random variables assumed to account for technical inefficiency in production and are assumed to be independently distributed, such that U_i is obtained by truncation (at zero) of the normal distribution with mean, $z_i\delta$, and variance, σ_u^2;

[5] See Battese, Coelli and Rao (1999).

z_i is a (m×1) vector of explanatory variables associated with technical inefficiency of production of farmers over time; and δ is an (1×m) vector of unknown coefficients.

Equation (5) specifies the stochastic frontier production function in terms of the original production values. However, the technical inefficiency effects, the U_i's are assumed to be a function of a set of explanatory variables, the z_i's, and an unknown vector of coefficients, δ. The explanatory variables in the inefficiency model may include some input variables in the stochastic frontier, provided the inefficiency effects are stochastic. If the first *z*-variable has value one and the coefficients of all other *z*-variables are zero, then this case represents the model specified in Stevenson (1980) and Battese and Coelli (1988, 1992). If all elements of the δ-vector are equal to zero, then the technical inefficiency effects are not related to the *z*-variables and so the half-normal distribution originally specified in Aigner, Lovell and Schmidt (1977) is obtained. If interactions between farm-specific variables and input variables are included as *z*-variables, then a non-neutral stochastic frontier, proposed in Huang and Liu (1994), is obtained.

The technical inefficiency effect, U_i, in the stochastic frontier model (5) could be specified in equation (6),

$$U_i = z_i\delta + W_i \qquad (6)$$

where the random variable, W_i, is defined by the truncation of the normal distribution with zero mean and variance, σ_u^2, such that the point of truncation is $-z_i\delta$, i,e., $W_i \geq -z_i\delta$. These assumptions are consistent with U_i being a non-negative truncation of the N($z_i\delta, \sigma_u^2$)-distribution.

Huang and Liu (1994) proposed an interesting generalization of the above specification. They permitted interaction effects between the variables in the stochastic production frontier, X_i, and the determinants of inefficiency, z_i. Thus the frontier itself is subjected to non-neutral shifts. In this case the U_i in equation (6) are modified to read:

$$U_i = z_i\delta + z_i^* X_i\delta^* + W_i \qquad (7)$$

where $z_i * X_i$ is a vector of values of appropriate interaction terms between the variables in z_i and X_i and δ^* is a vector of unknown parameters to be estimated.

The method of maximum likelihood is proposed for simultaneous estimation of the parameters of the stochastic frontier and the model for the technical inefficiency effects. The likelihood function and its partial derivatives with respect to the parameters of the model are presented in Battese and Coelli (1993). The likelihood function is expressed in terms of the variance parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma^2{}_u / \sigma^2{}_s$.

The technical efficiency of production for the *i*-th firm is defined by (7),

$$TE_i = \exp(-U_i) = \exp(-z_i\delta - W_i) \quad (7)$$

The prediction of the technical efficiencies is based on its conditional expectation, given the model assumptions.

The reduced form representation of the translog production function is as follows,

$$\begin{aligned} \ln(Y_{it}) = \beta_0 + \sum_j \beta_t \ln X_{ijt} + \frac{1}{2}\sum_j\sum_k \beta_{jk} \ln X_{ijt} \ln X_{ikt} \\ + \beta_t t + \beta_{tt} t^2 + V_{it} - U_{it} \end{aligned} \quad (8)$$

where the technical inefficiency effects are assumed to be defined by

$$U_{it} = \delta_o + \sum_j (\delta_{jz} z_{ijt}) + \delta_t t + \delta_{tt} t^2 + W_{it} \quad (9)$$

where the subscript *i* and *t* represent the *i*-th farmer and the *t*-th year of operation, Y_{it} is (the logarithm of) the Tornqvist index of the outputs of Samba and Blackgram or Samba and Cotton;[6] β's and δ's are the unknown parameters to be estimated; $t = 1, \ldots 5$ is a time trend for the duration of the panel. V_{it} and W_{it} are as defined in the previous section; X_{it} are the independent variables, the inputs; z_{ijt} are the variables that are supposed to determine the inefficiency. Table 7 lists the X_i variables and z_i variables used in the estimation.

Table 7 here

We use both male-female wage gap and wage gap between farm labor and non-farm labor as determinants of inefficiency. The wage gap (between farm labor and non-farm labor) is

[6] If Y_{ikt} represents the outputs of crop *k* in period *t* produced by farmer *i*, and W_{ikt} the value share for output of crop *k* in period *t*, then the Tornqvist index in its log-change form is given by,

$$\ln Y_{st} = \sum_i \left(\frac{W_{ikt} + W_{ikt}}{2} \right) (\ln Y_{ikt} - \ln Y_{ikt})$$

where *s* and *t* represent the time periods.

defined as the difference between the wage paid to the hired agricultural worker and the wage received by the same agricultural worker during off-farm season in brick-kilns and prawn farms. This gap appeared around 1994–95 and has led to a rise in agricultural wages. In addition to this the viability of the second crop after Rice (especially Samba rice) is dependent on the availability of hired labor. The second crop usually is grown when the brick-kilns and the prawn farms are in operation. Hence the labor supply during the period when the second crop is grown is seriously truncated. This has consequences in the form of less than the optimal quantity of labor being available to the farmers growing the second crop. Therefore we believe that the wage gap will impact the technical efficiency of cultivation of the crop sequences.

The inefficiency frontier model (8)-(9) accounts for both technical change and time-varying inefficiency effects. The time variable in the stochastic frontier (8) accounts for Hicksian neutral technological change. However, the time variable in the inefficiency model (9) species that the inefficiency effects may change linearly with respect to time. The distributional assumptions on the inefficiency effects permit the effects of technical change and time-varying behavior of the inefficiency effects to be identified, in addition to the intercept parameters, $\beta_{o,}$ and δ_o, in the stochastic frontier and the inefficiency model. Time outside the frontier is used as a factor that could create non-neutrality. This is in line with the logic that with the passage of time, the technology in use could influence the rate of substitution between factors of production. The fixed effects from the estimation of equation (4) for the different crops are used as determinants of inefficiency. These fixed effects explain the impact of fragmentation on technical efficiency.

V. Estimation Procedure

The general model of the stochastic frontier (4) along with the technical inefficiency effects (5) can be simultaneously estimated by maximum likelihood method with the null hypothesis for no technical inefficiency effects $H_0 : \gamma = 0$. The parameter γ lies between 0 and 1 and this range can be searched to provide a good starting value for use in the iterative maximization process such as Davidson-Fletcher-Powell (DFP) algorithm. We use the FRONTIER 4.1 of Coelli (1996) to estimate the models. If the null hypothesis is accepted this would mean that σ_u^2 is zero and therefore would mean that the U_i's should be removed from the model, leaving a specification with parameters that can be consistently estimated using ordinary least squares.

VI. Results

We turn to discussing the results of the estimation procedure used to examine the relationship between fragmentation and technical efficiency. We proceed to discuss the results progressively.

i. There is a significant positive relationship between farm size, average plot size and yield. This test is conducted for two dominant crop sequences in these villages namely Samba-Blackgram and Samba-Cotton. However there is a negative relationship between number of plots cultivated and the yields of these crop-sequences. More importantly, the magnitude of this relationship differs as one goes from Samba-Blackgram to Samba-Cotton.

Table 3a here

From these results one can infer that fragmentation (as measured by number of plots) has a negative impact on yields and consequently is a problem to be addressed.

ii. The test for no economies of scale with respect to number of plots cultivated is strongly rejected in the case of both Samba-Blackgram and Samba-Cotton. This then implies that it will be optimal for the farmers to have the land holdings in fewer plots. In fact it is interesting and revealing to note that complete fragmentation might not be a desired outcome for all the farmers in these villages. This is evident by the shape of the SRAC curve with respect to fragmentation. This then suggests that consolidation should result in farmers holding "optimal number of plots".

Figure 8 here

However there are significant economies of scale with respect to both farm-size and plot-size. This result is interesting in the context of current distribution of land holdings in these villages that suggests a preponderance of small and marginal landholders. Hence farmers should be provided incentives to consolidate their land holdings. Farmers should also look into the possibility of increasing farm-size through leasing-in, purchases, co-operative farming etc.

Table 3b here

iii. There is strong evidence to suggest that the family-provided labor is less efficient than the hired labor for different crops and for different activities for each crop.

Table 4 here

These results suggest that farmers can achieve the desired level of efficiency by hiring labor for different activities. The results also indicate that for Samba-Blackgram the current level of input-mix (hired and family-provided) is about close to optimal (indicated by low values of the coefficient). However for Samba-Cotton the hired labor intensities could be increased.

iv. Given the preceding result there will be tendency on the part of the farmers to hire inputs. Hired inputs need not be homogeneous in terms of their respective efficiency. Input heterogeneity (especially labor heterogeneity) can lead to significant reduction in technical efficiency. Hence it is important for us to determine the magnitude of such heterogeneity. The results indeed show that there are significant levels of heterogeneity in performance of hired labor across different activities for different crops.

Table 5 here

It is believed that most of this labor heterogeneity is caused by land fragmentation. However this is a proposition that needs to be tested. Impact of land fragmentation needs to be empirically tested. Impact of land fragmentation on efficiency of specific factors of production is as such a phenomenon yet to be established. Farmers, who have hired factor inputs, engage in a level of supervision to ensure efficiency of these inputs. We are able to show that hired supervision is able to reduce labor heterogeneity significantly. These results are shown in tables. We posit here that any residual labor heterogeneity is caused by land fragmentation.

a) The impact of fragmentation on labor heterogeneity is estimated after controlling for fixed effects for fragmentation on output. We are able to establish a clear causation between fragmentation and fixed effects for different crop sequences. We find that a significant number of these fixed effects are caused by fragmented landholdings. When equation (4) was estimated controlling for fragmentation we find both positive and negative fixed effects. This causality suggests that there could be returns to fragmentation for such farmers (reinforced by our finding on the shape of the average short run cost curve). Irrespective of the sign of the fixed effects we find a significant causality between fragmentation and fixed effects which suggests that the impact of fragmentation on technical efficiency is likely to be indirect rather than direct.

Figures 9 here

In order to fully capture the impact of these fixed effects on technical efficiency we choose to use these as factors determining inefficiency.

vi. The estimates of the stochastic frontier are shown in Tables 6. The variables used for estimation are described in Table 7.

Tables 6, and, 7 here

The joint frontier is accepted in favor of independent frontier. We note that following significant results from the estimation process -

a) Farm size has a positive impact on technical efficiency.
b) The male-female wage-gap is a significant phenomenon in these villages. Such a wage-gap contributes significantly to technical inefficiency. However we note that this gap matters only for the crop sequence Samba-Cotton.
c) In both these villages localized non-farm employment is on the rise. Brick-kiln and prawn-farms are popular sources of non-farm employment during specific seasons that overlaps the cultivation of second crop (Blackgram or Cotton). The wage-gap between farm and non-farm activity significantly tends to reduce technical efficiency.

d) We test the impact of fragmentation on technical efficiency by using the fixed effects caused by fragmentation on different activities. These fixed effects on an average tend to produce significant negative impacts on technical efficiency. Hence we are not able to completely reject the hypothesis that fragmentation has a negative impact on technical efficiency. This is an added evidence to suggest that farmers on an average want to posses their holdings in optimal number of plots.

VII. Conclusions

This paper has shown that fragmentation has a significant impact on technical efficiency. The policies must be designed to allow for consolidation to take place. However one should understand that even if markets are allowed to function. Potential consolidation may not take place and farmers may choose to hold a specific number of plots. We in fact see such a phenomenon when the average variable cost is examined in relation to fragmentation.

The impact of fragmentation as measured by fixed effects illustrates the fact that fragmentation has both negative and positive effects on technical efficiency. In fact we indeed find some of the positive effects of such fixed effects quite significantly large. Hence if consolidation has to occur through markets than a level of fragmentation is inevitable.

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Table 1 : Village wise summary of crops grown and main inputs used

	Average	Std.Dev.	Minimum	Maximum	Number of farmers
Nelpathur					
Samba					
Acreage (acre)	3.15	5.44	0.28	48.04	137
Output (Kg)	5740.62	9910.15	276	85800	137
Yield (Kg/acre)	1359.50	387.37	360.87	2819.55	137
Black Gram					
Acreage (acre)	2.96	5.37	0.28	48.29	124
Output (Kg)	906.64	1547.37	80	13308	124
Yield (Kg/acre)	261.46	67.76	72	451.12	124
Cotton					
Acreage (acre)	2.64	1.55	0.66	6.60	18
Output (Kg)	2695.11	1269.44	800	6000	18
Yield (Kg/acre)	1184.8	190.8	900	1875	18
Total inputs used					
Cartage (no. of trips)	11	16	2	125	113
Hired labor (no. of labor days)	307	449	26	3906	137
Family provided Labor (no. of labor days)	65	27	2	123	86
Seed purchases (Kg)	164	346	2	1575	30
Seed family provided (Kg)	179	276	16	2149	128
Pesticide (Ltr)	272	1187	8	13241	135
Thirunagari					
Samba					
Acreage (acre)	1.54	1.01	0.32	6.13	83
Output (Kg)	2982.29	1792.68	900	10800	83
Yield (Kg/acre)	1656.1	255.25	1194.69	2531.25	83
Black Gram					
Acreage (acre)	1.52	0.95	0.32	6.13	80
Output (Kg)	496.31	275.42	180	1800	80
Yield (Kg/acre)	294.5	51.81	206.9	506.25	80
Cotton					
Acreage (acre)	2.21	1.60	0.79	3.95	3
Output (Kg)	2733.33	1921.80	1000	4800	3
Yield (Kg/acre)	1248	28.5	1215.19	1265.8	3
Total inputs used					
Cartage (no. of trips)	6	4	2	24	79
Hired labor (no. of labor days)	164	110	46	655	83
Family provided Labor (no. of labor days)	70	15	4	98	61
Seed purchases (Kg)	30	47	3	100	4
Seed family provided (Kg)	81	48	29	300	82
Pesticide (Ltr)	68	70	14	462	83

Table 2 : Profit margin and coefficient of variation*

	Small farmers		Medium farmers		Large farmers	
Year	Avg profit	CV	Avg profit	CV	Avg profit	CV
			Samba			
1995	0.1	23.61	-0.02		0.13	9.37
1996	0.3	9.36	0.19	14.47	-0.09	
1997	0.68	4.76	0.24	16.81	0.69	1.5
1998	0.86	3.38	0.72	4.05	0.94	0.73
1999	1.03	2.75	0.46	10.03	1.39	0.55
			Black Gram			
1995	6.85	0.09	6.83	0.1	6.16	0.23
1996	6.92	0.1	6.94	0.11	6.07	0.21
1997	11.92	0.06	11.86	0.07	11.33	0.16
1998	8.02	0.09	8.14	0.1	7.45	0.22
1999	11.58	0.07	11.68	0.09	11.25	0.16
			Cotton			
1995	9.76	0.07	9.87	0.06	10.22	0.04
1996	11.26	0.08	11.38	0.07	11.76	0.04
1997	11.94	0.07	11.9	0.09	12.49	0.04
1998	13.9	0.1	13.67	0.08	14.67	0.09
1999	15.16	0.09	14.92	0.07	15.8	0.09
			Samba-Black Gram			
1995	6.93	0.38	6.71	0.46	6.42	0.31
1996	7.21	0.42	7.06	0.44	6.01	0.36
1997	12.6	0.27	11.85	0.41	12.14	0.18
1998	8.96	0.35	8.8	0.37	8.41	0.24
1999	12.75	0.23	11.86	0.45	12.62	0.17
			Samba-Cotton			
1995	9.06	0.24	10.34	0.13	10.03	0.07
1996	10.97	0.22	12.1	0.13	12.03	0.07
1997	11.68	0.25	12.89	0.15	13.3	0.06
1998	13.22	0.21	15.32	0.14	15.15	0.06
1999	15.18	0.22	16.51	0.14	16.62	0.04

* Small farmers : Farmers with less than 2 acres.
Medium farmers : Farmers with 2 to 4 acres.
Large farmers : Farmers with 4 or greater than 4 acres

Table 3:

3.a: Yield as a function of farm size, Number of plots cultivated and Average plot size

	Farm size	Number of plots cultivated	Average plot size
Samba-Blackgram	0.0344	-0.0244	0.0301
	(0.002)	(0.01)	(0.001)
Samba-cotton	0.2509	-0.2407	0.1518
	(0.006)	(0.000)	(0.000)

3.b: Testing for Economies of scale w.r.t. Farm size, Number of plots and Average plot size

	Farm size	Number of plots cultivated	Average plot size
Samba-Blackgram	0.050	1.844	0.119
	(0.000)	(0.000)	(0.000)
Samba-cotton	0.049	2.912	0.047
	(0.000)	(0.002)	(0.001)

Table 4: Test of heterogeneity between hired and family labor[7]

Samba	
	Hired
Land preparation	0.2843
	(0.029)
Sowing	0.0257
	(0.560)
Transplanting	0.2598
	(0.002)
Fertilizer and Pesticide Application	0.3369
	(0.238)
Harvesting	0.3316
	(0.000)
Black Gram	
Sowing	0.0701
	(0.008)
Harvesting	0.0304
	(0.837)
Cotton	
Land preparation (earthing)	0.6983
	(0.165)
Sowing	0.6583
	(0.010)
Harvesting (picking)	0.0265
	(0.932)

[7] No family labor was employed for weeding operations.

Table 5 : Test of heterogeneity between hired labor employed for various activities[*]

5.1.a Samba: Pre supervision efficiency gap

	land preparation	Sowing	transplanting	irrigation	weeding	fertilizer/pesticide application	harvesting
Land preparation	0						
Sowing	0.1568	0					
	(0.103)						
Transplanting	0.0678	1.112	0				
	(0.193)	(0.089)					
Irrigation	-0.1969	0.7831	-0.5746	0			
	(0.028)	(0.084)	(0.012)				
Weeding	0.2149	0.1172	0.9325	0.1247	0		
	(0.037)	(0.097)	(0.001)	(0.004)			
Fertilizer/pesticide application	0.4616	0.1769	0.3796	0.5569	0.2129	0	
	(0.129)	(0.061)	(0.054)	(0.000)	(0.069)		
Harvesting	-0.3272	1.6813	-0.4063	0.7504	0.8335	1.2678	0
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

5.1.b Samba: Post supervision efficiency gap

	land preparation	Sowing	transplanting	irrigation	weeding	fertilizer/pesticide application	harvesting
Land preparation	0						
Sowing	0.1449	0					
	(0.131)						
Transplanting	0.054	0.954	0				
	(0.302)	(0.137)					
Irrigation	-0.0154	0.313	-0.1023	0			
	(0.073)	(0.011)	(0.110)				
Weeding	0.1934	0.1139	0.7561	-0.0104	0		
	(0.063)	(0.101)	(0.008)	(0.835)			
Fertilizer/pesticide application	0.4301	0.1683	0.2033	0.3744	0.1943	0	
	(0.157)	(0.067)	(0.308)	(0.020)	(0.100)		
Harvesting	-0.319	1.5191	-0.3897	0.3721	0.8009	1.0636	0
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

[*] The activities in the rows are in the numerator and the activities in the columns form the denominator.

5.2.a Black Gram: Pre supervision efficiency gap

	sowing	Harvesting
Sowing	0	
Harvesting	0.02639 (0.073)	0

5.2.b Black Gram: Post supervision efficiency gap

	sowing	Harvesting
Sowing	0	
Harvesting	0.02637 (0.074)	0

5.3.a Cotton: Pre supervision efficiency gap

	Earthing	sowing	irrigation	weeding	fertilizer/pesticide application	picking
earthing	0					
sowing	2.0902 (0.087)	0				
irrigation	0.4089 (0.264)	0.5677 (0.105)	0			
weeding	-0.4904 (0.260)	0.6454 (0.007)	-0.6599 (0.000)	0		
fertilizer/pesticide application	0.3661 (0.138)	0.9317 (0.005)	-0.5044 (0.092)	-0.5617 (0.049)	0	
picking	0.4102 (0.388)	0.8102 (0.080)	0.6135 (0.003)	0.3587 (0.020)	0.3109 (0.124)	0

5.3.b Cotton: Post supervision efficiency gap

	Earthing	sowing	irrigation	weeding	fertilizer/pesticide application	picking
earthing	0					
sowing	1.1144 (0.465)	0				
irrigation	0.3418 (0.406)	0.4006 (0.283)	0			
weeding	-0.1912 (0.648)	-0.1227 (0.675)	-0.178 (0.352)	0		
fertilizer/pesticide application	0.0533 (0.890)	-0.1577 (0.684)	-0.2539 (0.416)	-0.1432 (0.644)	0	
picking	0.177 (0.721)	-0.435 (0.629)	0.1851 (0.414)	-0.0918 (0.623)	-0.0289 (0.898)	0

Table 6.a : Stochastic Frontier Results for both villages :Samba-Blackgram

	Coefficient	t-ratio	Variable
beta 0	10.561	24.546	intercept
beta 1	3.363	15.258	ln(acreage)
beta 2	0.040	0.227	ln(harvesting-threshing labor)
beta 3	-0.602	-4.097	ln(threshing-machine)
beta 4	-0.138	-1.328	ln(general labor)
beta 5	0.244	2.831	ln(nursery labor)
beta 6	0.013	2.402	ln(bull)
beta 7	-2.127	-16.348	ln(seeds)
beta 8	-0.009	-0.190	ln(irrigation-hrs)
beta 9	-0.019	-0.810	ln(potash)
beta10	0.298	10.701	ln(acreage)^2
beta11	0.105	6.306	ln(land-preparation-labor)^2
beta12	0.004	0.940	ln(pesticide)^2
beta13	0.040	4.374	ln(cartage)^2
beta14	0.015	1.111	ln(general-labor)^2
beta15	0.020	0.953	ln(nursery-labor)^2
beta16	0.017	2.856	ln(seeds)^2
beta17	-0.007	-0.876	ln(irrigation-hrs)^2
beta18	0.007	0.888	ln(DAP)^2
beta19	-0.003	-0.686	ln(urea)^2
beta20	0.016	3.102	ln(potash)^2
beta21	0.051	10.030	time
beta22	-0.075	-1.733	ln(acreage)*ln(supervision-labor)
beta23	-0.162	-5.599	ln(land-preparation-labor)*ln(supervision-labor)
beta24	-0.238	-4.579	ln(harvesting-threshing-labor)*ln(supervision-labor)
beta25	-0.058	-2.619	ln(pesticide)*ln(supervision-labor)
beta26	0.121	2.573	ln(threshing-machinery)*ln(supervision-labor)
beta27	-0.052	-2.239	ln(supervision-labor)*ln(nursery-labor)
beta28	0.345	12.640	ln(supervision-labor)*ln(seeds)
beta29	0.002	0.286	ln(supervision-labor)*ln(irrigation-hrs)
beta30	-0.675	-15.167	ln(acreage)*ln(seeds)
beta31	0.246	8.279	ln(harvesting-threshing-labor)*ln(seeds)
beta32	0.049	2.564	ln(pesticide)*ln(seeds)
beta33	0.019	0.759	ln(threshing-machinery)*ln(seeds)
beta34	0.018	1.674	ln(seeds)*ln(DAP)
beta35	-0.014	-2.433	ln(seeds)*ln(potash)
sigma-squared	0.375	6.686	
gamma	0.964	145.436	
delta 1	1.194	5.538	Time
delta 2	-0.107	-5.714	Time^2
delta 3	0.957	6.075	Village dummy
delta 4	0.610	5.893	Wage gap (brick kiln)
delta 5	0.215	7.446	Owned no. of plots
delta 6	-6.026	-4.705	Weeding vs. land preparation (fixed effects)
delta 7	-11.423	-5.022	Transplanting vs. sowing labor (fixed effects)
delta 8	7.327	7.033	Irrigation vs. sowing labor (fixed effects)
delta 9	-38.529	-8.316	Sowing vs. weeding labor (fixed effects)
delta10	-2.765	-2.209	Sowing vs. pesticide labor (fixed effects)
delta11	37.058	6.913	Sowing vs. harvesting labor (fixed effects)
delta12	9.675	7.154	Transplanting vs. weeding labor (fixed effects)
delta13	-10.824	-7.749	Transplanting vs. pesticide labor (fixed effects)
delta14	11.319	6.239	Transplanting vs. harvesting labor (fixed effects)
delta15	10.441	5.444	Pesticide vs. harvesting labor (fixed effects)
delta16	-0.051	-3.347	Acreage

log of the likelihood function: 353.087 LR test of the one-sided error: 206.722

Table 6.b: Stochastic Frontier Results for both villages: Samba-Cotton

	Coefficient	t-ratio	variable
beta 0	-15.782	-13.325	ln(output)
beta 1	1.433	8.167	ln(acreage)
beta 2	5.708	6.390	ln(land-preparation labor)
beta 3	-0.351	-4.841	ln(harvesting-threshing labor)
beta 4	-0.651	-0.869	ln(pesticide)
beta 5	0.194	1.446	ln(cartage)
beta 6	16.371	24.879	ln(general labor)
beta 7	-14.209	-19.849	ln(nursery labor)
beta 8	-0.949	-6.462	ln(bull)
beta 9	2.773	8.272	ln(seed)
beta10	-1.312	-17.125	ln(irrigation-hrs)
beta11	-3.683	-5.787	ln(DAP)
beta12	-1.382	-3.867	ln(urea)
beta13	-0.192	-5.390	ln(potash)
beta14	0.662	11.089	ln(acreage)^2
beta15	-0.682	-6.631	ln(land-preparation labor)^2
beta16	-0.019	-0.239	ln(pesticide)^2
beta17	-0.123	-5.276	ln(machinery-day)^2
beta18	-0.190	-4.805	ln(cartage)^2
beta19	-1.698	-24.404	ln(general labor)^2
beta20	0.126	9.775	ln(supervision labor)^2
beta21	3.138	18.599	ln(nursery labor)^2
beta22	0.168	6.375	ln(bull)^2
beta23	-0.199	-6.784	ln(seed)^2
beta24	0.092	7.032	ln(irrigation-hrs)^2
beta25	0.360	5.125	ln(DAP)^2
beta26	0.116	3.499	ln(urea)^2
beta27	0.011	10.147	time^2
sigma-squared	0.009	6.643	
gamma	1.000	5031.547	
delta 1	-0.075	-0.905	Time
delta 2	0.021	1.759	time^2
delta 3	0.204	2.124	Dummy
delta 4	0.072	1.870	Wage gap (male-female)
delta 5	0.145	2.704	wage gap (brick-kiln)
delta 6	0.029	3.717	total no. of plots cultivated
delta 7	-0.710	-0.718	land preparation vs. transplanting labor (fixed effects)
delta 8	-0.694	-0.727	land preparation vs. irrigation labor (fixed effects)
delta 9	-1.014	-1.053	Weeding vs. land preparation labor (fixed effects)
delta10	0.161	0.173	land preparation vs. pesticide labor (fixed effects)
delta11	-0.817	-0.884	sowing vs. pesticide labor (fixed effects)
delta12	1.137	1.238	Transplanting vs. harvesting labor (fixed effects)
delta13	1.268	1.082	Irrigation vs. pesticide labor (fixed effects)
delta14	0.228	0.187	Pesticide vs. harvesting labor (fixed effects)
delta15	-0.006	-0.906	Acreage

log likelihood function: 133.720
LR test of the one-sided error: 21.685

Table 7: Description of variables used in frontier

7.1.a Samba-Blackgram :Inputs

S. no	Variable	Description	Unit of measurement
1	ln(acreage)	Acreage commitment to the crop	Acres
2	ln(harvesting-threshing labor)	Labor for harvesting and threshing operations	Labor-days
3	ln(threshing by machinery)	Tractors used for threshing	Days
4	ln(general labor)	Labor used for weeding, irrigation and application of pesticides and fertilizers	Labor-days
5	ln(nursery labor)	Labor used in nursery for land preparation and seeding	Labor-days
6	ln(bull)	Bullocks used for land preparation and threshing	Number of bullocks
7	ln(seeds)	Quantity of seeds used	Kilograms
8	ln(irrigation-hrs)	Irrigation of the crops	Hours
9	ln(potash)	Fertilizer	Kilograms
10	ln(acreage)^2		
11	ln(land-preparation-labor)^2		
12	ln(pesticide)^2		
13	ln(cartage)^2		
14	ln(general-labor)^2		
15	ln(nursery-labor)^2		
16	ln(seeds)^2		
17	ln(irrigation-hrs)^2		
18	ln(DAP)^2		
19	ln(urea)^2		
20	ln(potash)^2		
21	Time	Year of production	
22	Ln(acreage)*ln(supervision-labor)		
23	Ln(land-preparation-labor)*ln (supervision-labor)		
24	ln(harvesting-threshing-labor)*ln(supervision-labor)		
25	ln(pesticide)*ln(supervision-labor)		
26	ln(threshing-machinery)*ln(supervision-labor)		
27	ln(supervision-labor)*ln(nursery-labor)		
28	ln(supervision-labor)*ln(seeds)		
29	ln(supervision-labor)*ln(irrigation-hrs)		
30	ln(acreage)*ln(seeds)		
31	ln(harvesting-threshing-labor)*ln(seeds)		
32	ln(pesticide)*ln(seeds)		
33	ln(threshing-machinery)*ln(seeds)		
34	ln(seeds)*ln(DAP)		
35	ln(seeds)*ln(potash)		

7.1.b Samba-Blackgram: factors causing inefficiency

S. no	Variable	Description	Unit of measurement
1	Time	Year of production	
2	time^2		
3	village dummy	Dummy variable indicating membership to Nelpathur village	
4	wage gap for brick kiln	Wage gap between brick kiln workers and hired labor	Rupees
5	owned no. of plots	Total number of plots owned by the farmer	
6	weeding -land preparation (fixed effects)	Fixed effects from the comparison of land preparation labor vs weeding labor	
7	transplanting -sowing labor (fixed effects)	Fixed effects from the comparison of sowing labor vs transplanting labor	
8	irrigation -sowing labor (fixed effects)	Fixed effects from the comparison of sowing labor vs irrigation labor	
9	sowing -weeding labor (fixed effects)	Fixed effects from the comparison of sowing labor vs weeding labor	
10	sowing-pesticide labor (fixed effects)	Fixed effects from the comparison of sowing labor vs pesticide application labor	
11	sowing -harvesting labor (fixed effects)	Fixed effects from the comparison of sowing labor vs harvesting labor	
12	transplanting -weeding labor (fixed effects)	Fixed effects from the comparison of transplanting labor vs weeding labor	
13	transplanting -pesticide labor (fixed effects)	Fixed effects from the comparison of transplanting labor vs pesticide application labor	
14	transplanting –harvesting labor (fixed effects)	Fixed effects from the comparison of transplanting labor vs harvesting labor	
15	pesticide-harvesting labor (fixed effects)	Fixed effects from the comparison of pesticide application labor vs harvesting labor	
16	Acreage	Acreage commitment to the crop	Acre

7.2.a Samba-Cotton :Inputs

S. no	Variable	Description	Unit of measurement
1	Acreage	Acreage commitment to the crop	Acres
2	Land-preparation labor	Labor for leveling, seeding, transplanting nad land preparation	Labor-days
3	Harvesting-threshing labor	Labor for harvesting and threshing operations	Labor-days
4	Pesticide	Quantity of pesticides used	Litres
5	Cartage	Carts used for transporting output to threshing mills or to the market	Number of cart trips
6	General labor	Labor used for weeding, irrigation and application of pesticides and fertilizers	Labor-days
7	Nursery labor	Labor used in nursery for land preparation and seeding	Labor-days
8	Bull	Bullocks used for land preparation and threshing	Number of bullocks
9	Seed	Quantity of seeds used	Kilograms
10	Irrigation-hrs	Irrigation of the crops	Hours
11	DAP	Fertilizer-Diammonium Phosphate	Litres
12	Urea	Fertilizer	Kilograms
13	Potash	Fertilizer	Kilograms
14	ln(acreage)^2		
15	ln(land-preparation labor)^2		
16	ln(pesticide)^2		
17	ln(machinery-day)^2		
18	ln(cartage)^2		
19	ln(general labor)^2		
20	ln(supervision labor)^2		
21	ln(nursery labor)^2		
22	ln(bull)^2		
23	ln(seed)^2		
24	ln(irrigation-hrs)^2		
25	ln(DAP)^2		
26	ln(urea)^2		
27	time^2		

7.2.b Samba-Cotton :factors causing inefficiency

S. no	Variable	Description	Unit of measurement
1	Time	Year of production	
2	time^2		
3	Dummy	Dummy variable indicating membership to Nelpathur village	
4	wage male-female	Wage gap between male and female labor	Rupees
5	wage brick-kiln	Wage gap between brick kiln workers and hired labor	Rupees
6	total no. of plots	Total number of plots being cultivated by a farmer	
7	land preparation-transplanting labor (fixed effects)	Fixed effects from the comparison of land preparation labor vs transplanting labor	
8	land preparation-irrigation labor (fixed effects)	Fixed effects from the comparison of land preparation labor vs irrigation labor	
9	weeding -land preparation labor (fixed effects)	Fixed effects from the comparison of land preparation labor vs weeding labor	
10	land preparation-pesticide labor (fixed effects)	Fixed effects from the comparison of land preparation labor vs pesticide application labor	
11	sowing -pesticide labor (fixed effects)	Fixed effects from the comparison of sowing labor vs pesticide application labor	
12	transplanting –harvesting labor (fixed effects)	Fixed effects from the comparison of transplanting labor vs harvesting labor	
13	irrigation -pesticide labor (fixed effects)	Fixed effects from the comparison of irrigation labor vs pesticide application labor	
14	pesticide -harvesting labor (fixed effects)	Fixed effects from the comparison of pesticide application labor vs harvesting labor	
15	Acreage	Acreage commitment to the crop	Acre

Figure 1: Location of Nelpathur and Thirunagari villages

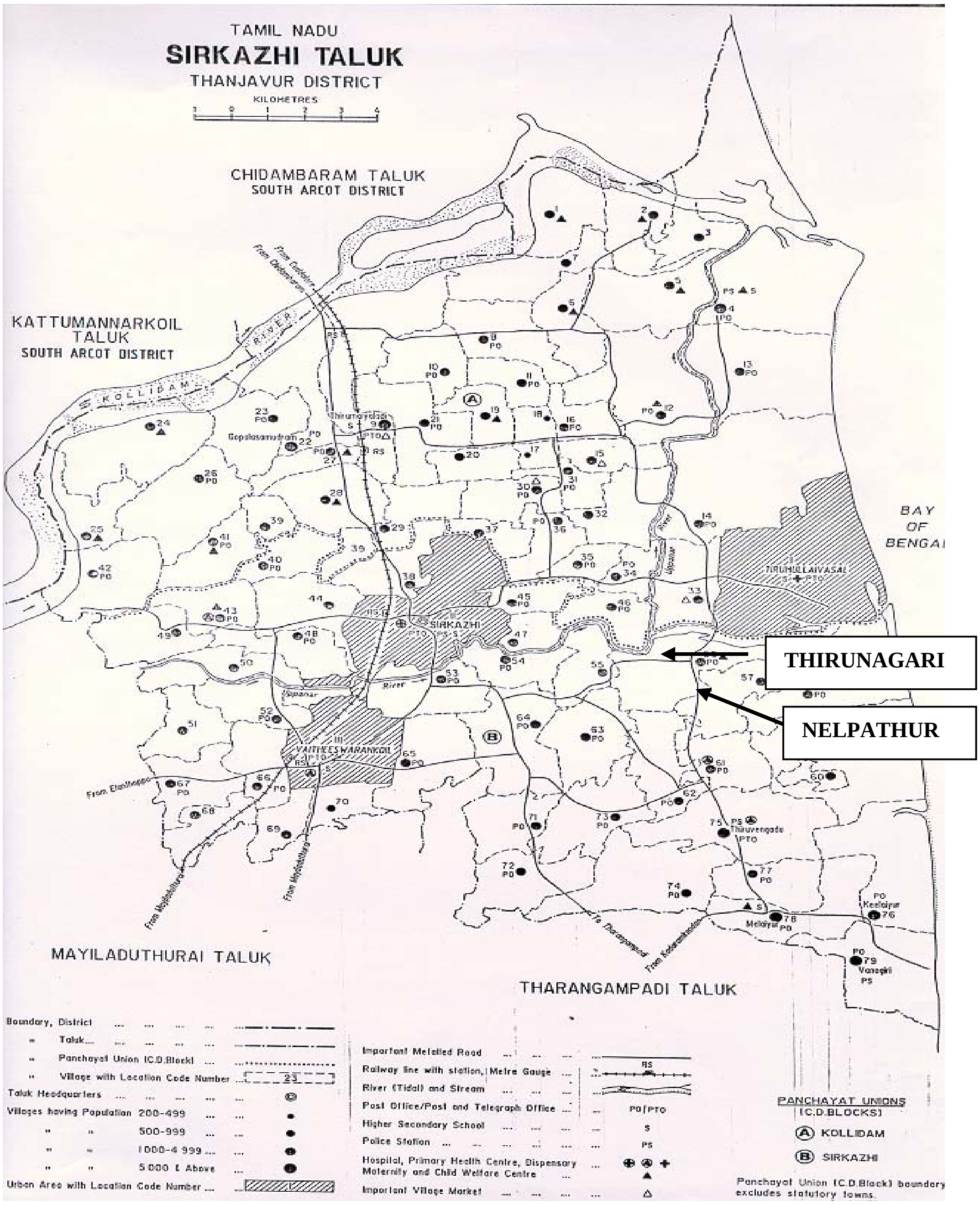
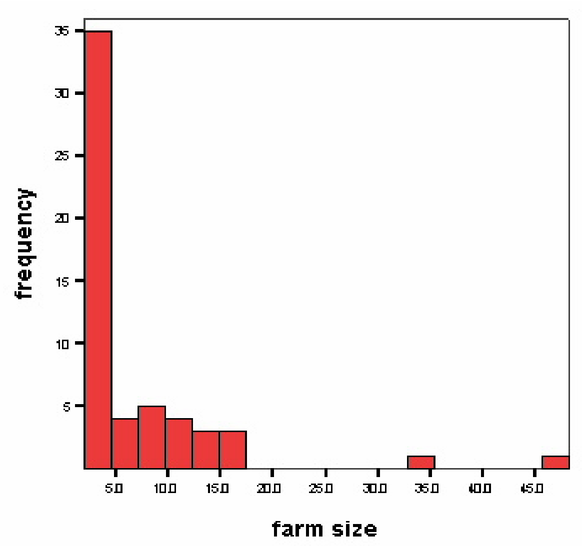
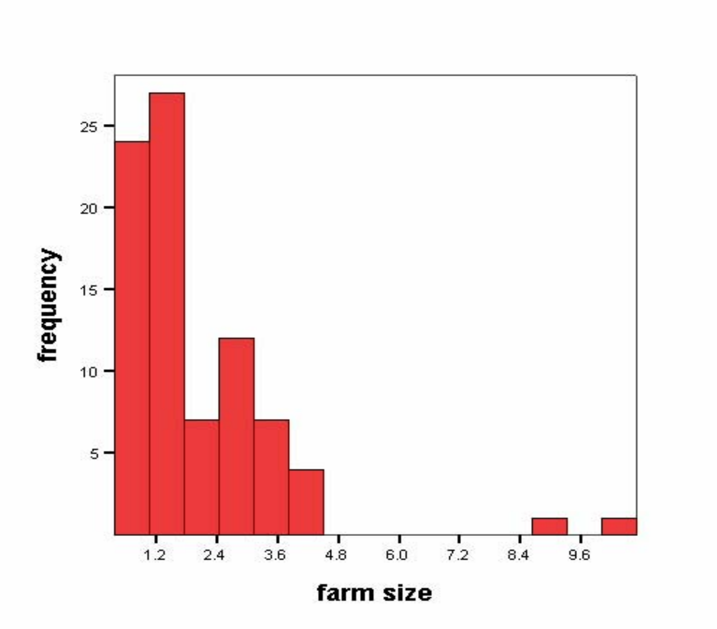


Figure 2 : Distribution of farm size in Nelpathur and Thirunagari

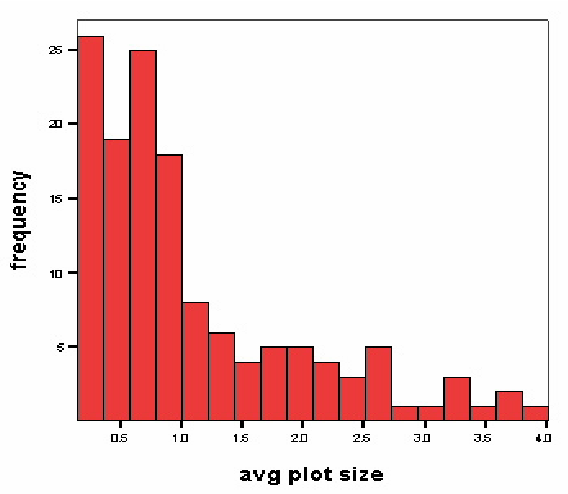


2.a Nelpathur

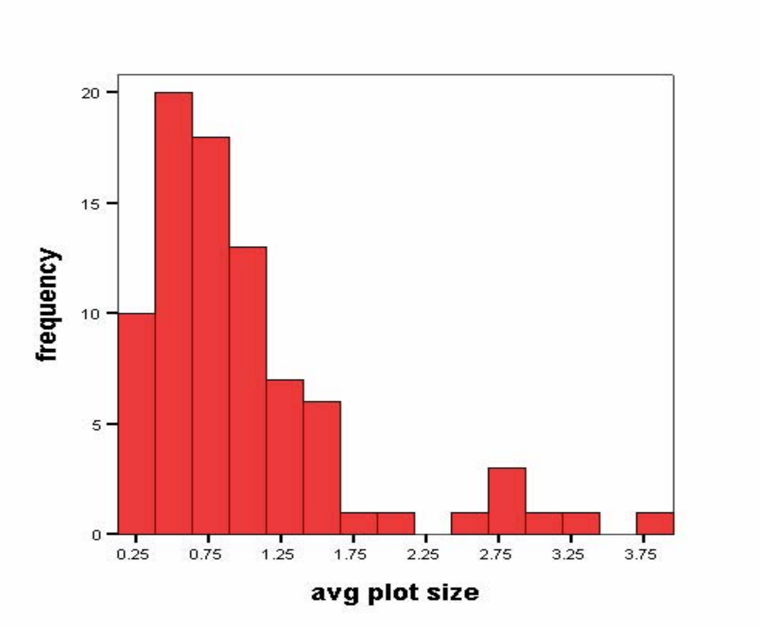


2.b Thirunagari

Figure 3 : Distribution of average plot size in Nelpathur and Thirunagari

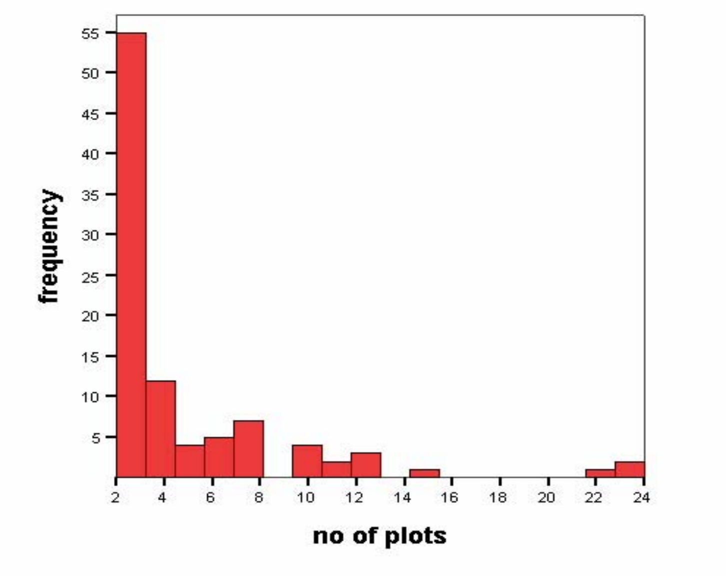


3.a Nelpathur

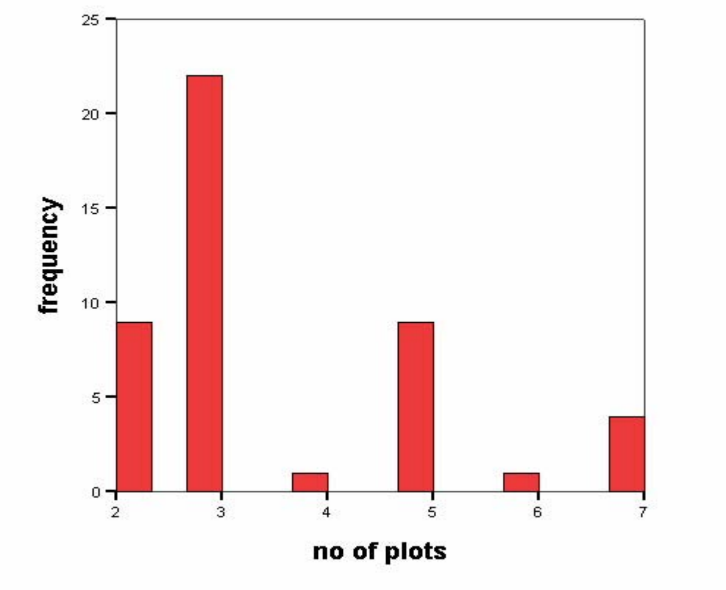


3.b Thirunagari

Figure 4 : Pattern of holding of plots by farmers in Nelpathur and Thirunagari[8]



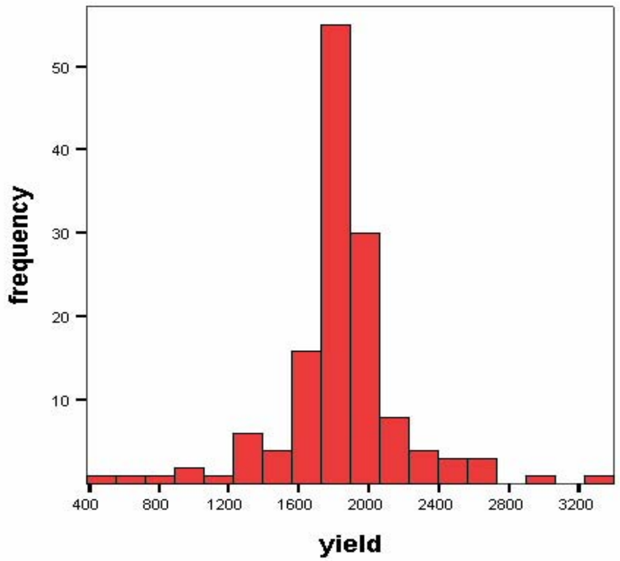
4.a Nelpathur



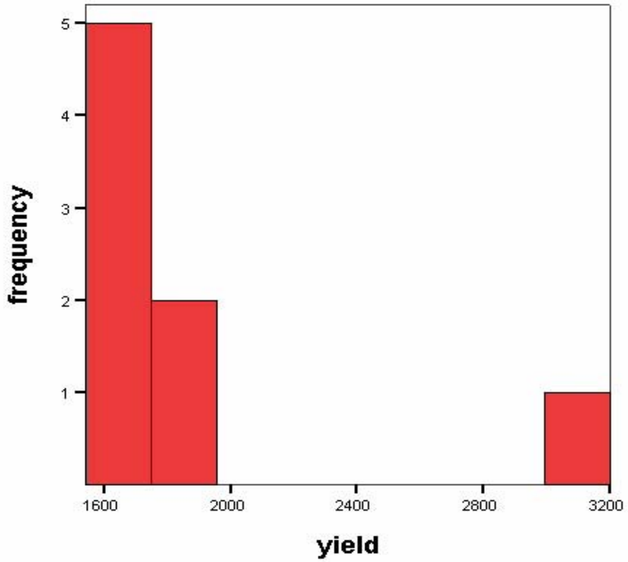
4.b Thirunagari

[8] These figures do not include farmers owing a single plot

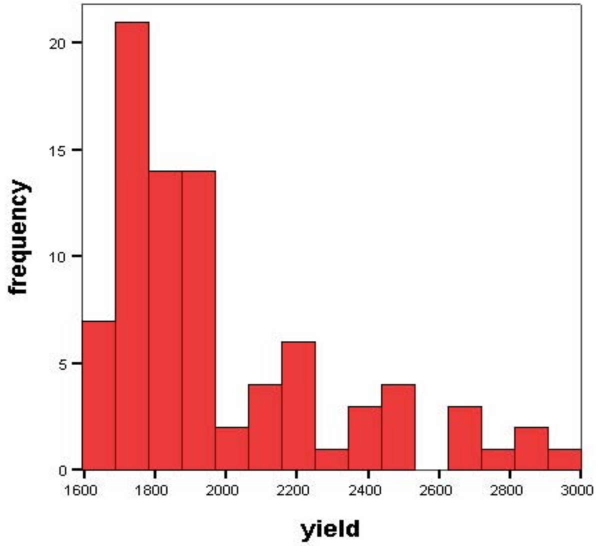
Figure 5 : Distribution of Rice Yield in Nelpathur and Thirunagari



5.a **Nelpathur : Samba (Rabi Rice)**

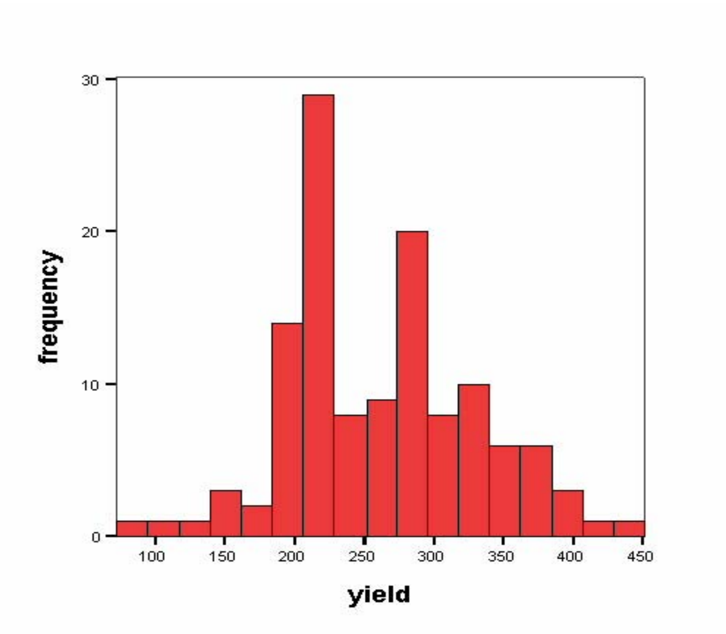


5.b Nelpathur: Kuruvai (Kharif Rice)

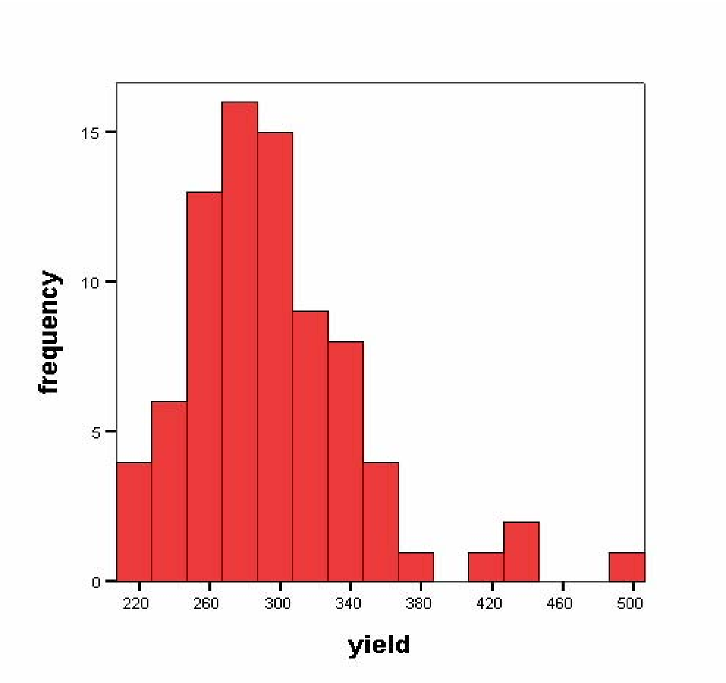


5.c Thirunagari :Samba (Rabi Ric

Figure 6 : Distribution of Black Gram yield in Nelpathur & Thirunagari

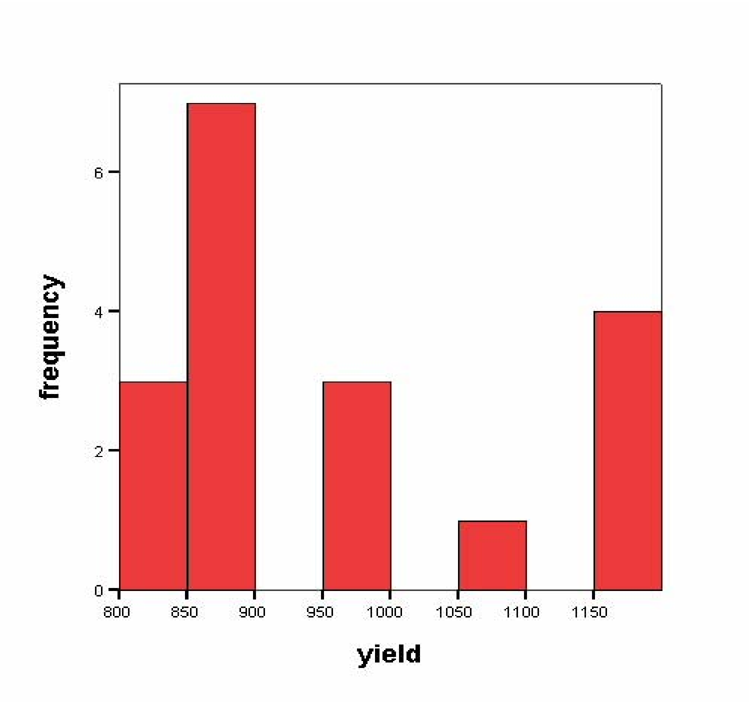


6.a Nelpathur : Black Gram



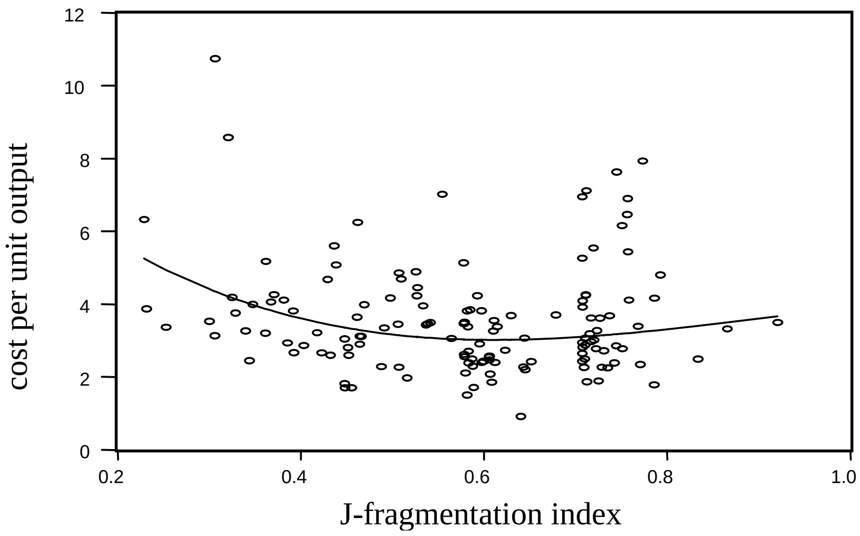
6.b Thirunagari :Black Gram

Figure 7 : Distribution of Cotton yield in Nelpathur

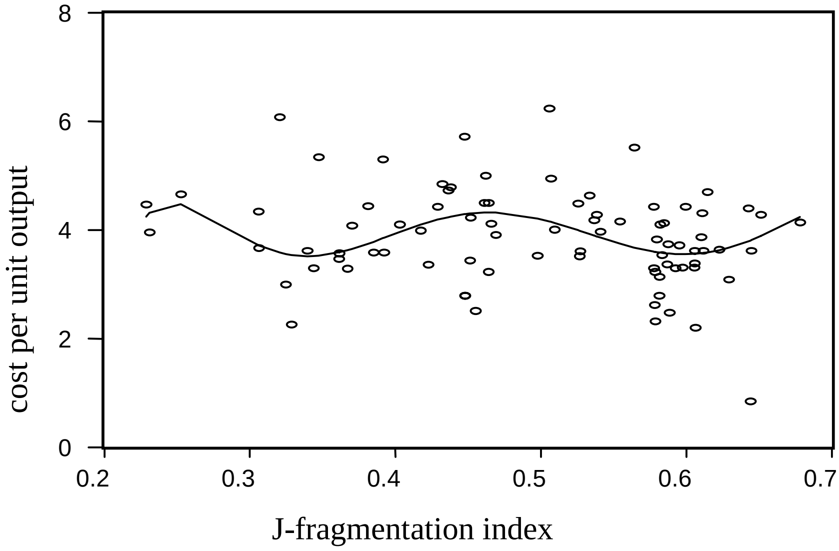


7.a Nelpathur :Cotton

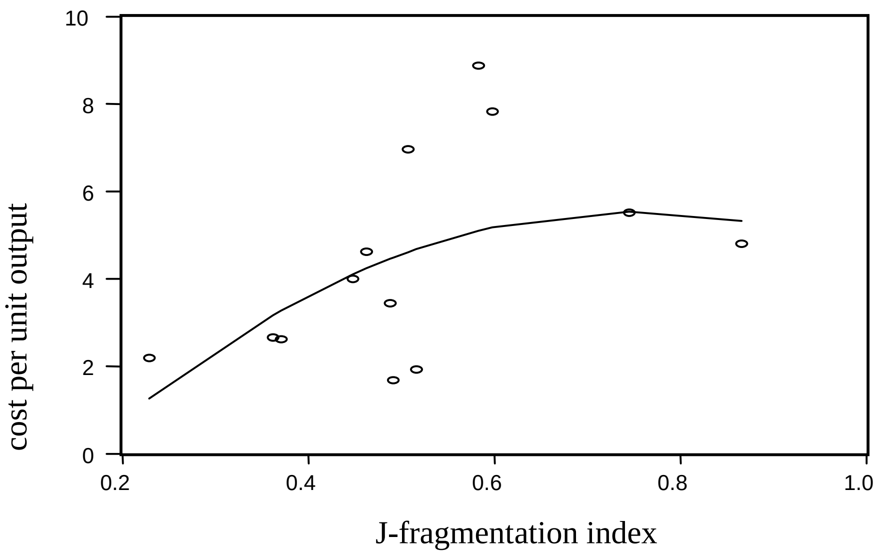
Figure 8: Relation between cost per unit output and fragmentation



8.a Samba



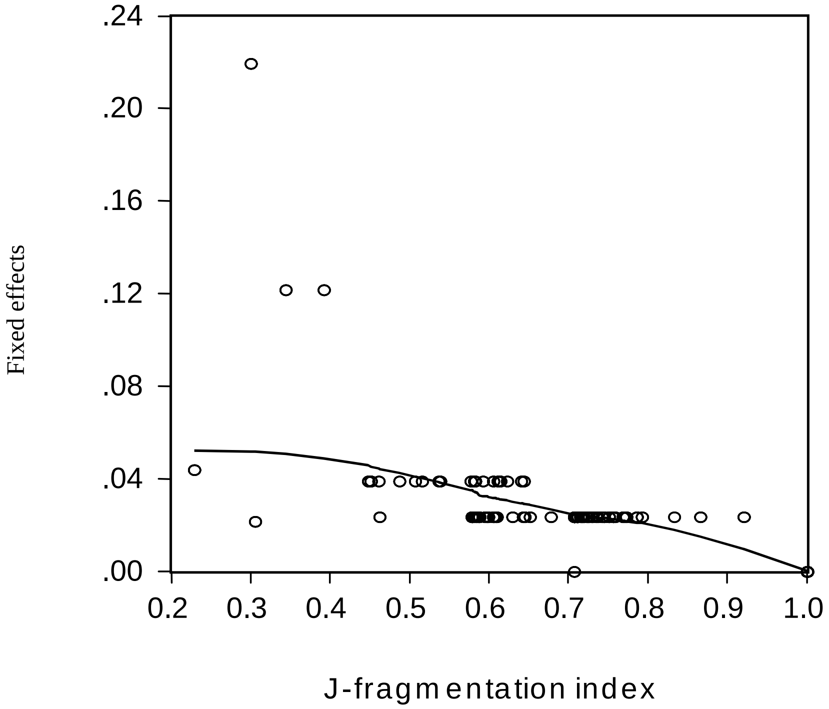
8.b Black Gram



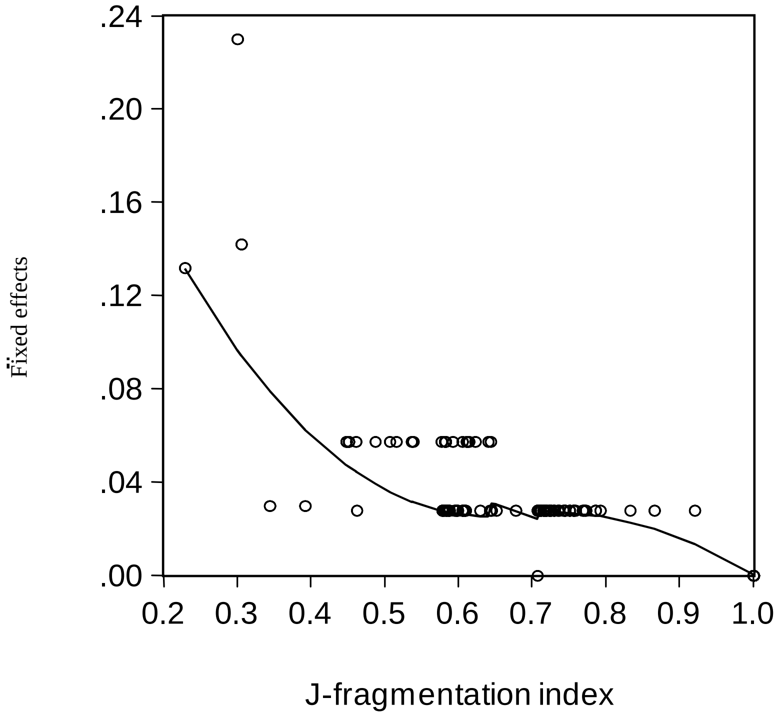
8.c Cotton

Figure 9: Relationship between fixed effects and J-fragmentation index (Samba)

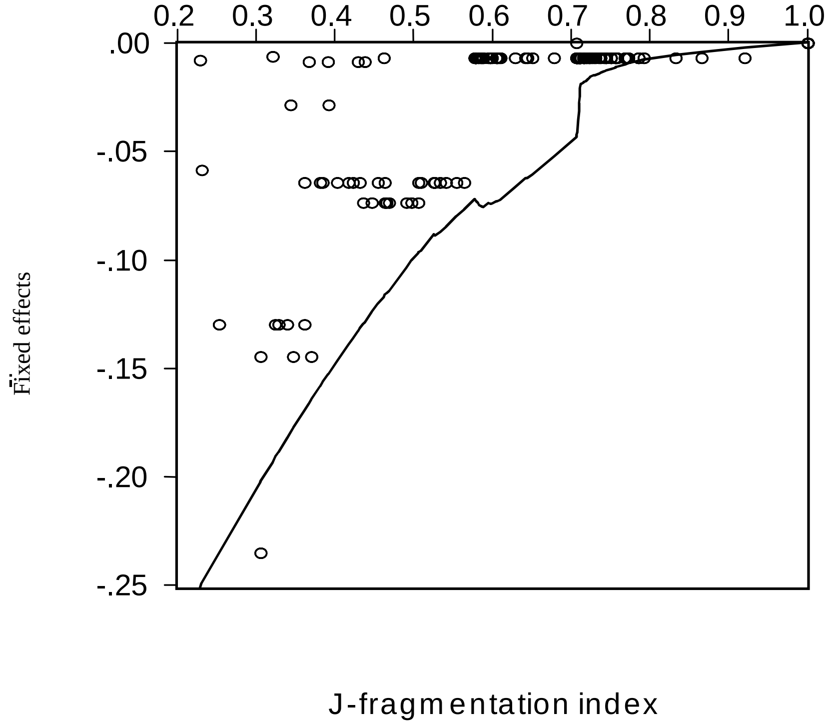
a) Tranplanting vs. Sowing Labor



b) Sowing vs. Weeding Labor



c) ***Transplanting vs. Harvesting Labor***



c) Weeding vs. Labor for Pesticide application