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AN ECONOMIC ANALYSIS OF A PLANT DENSITY EXPERIMENT FOR TEA IN CHINA

Dan M. Etherington [1]

Economics Department, Research School of Pacific Studies,
Australian National University
Canberra, ACT 2601

ABSTRACT

Average tea yields in China are low by international standards and are extremely low when compared to yields obtained on experiment stations. This paper reports on a ten year plant density trial undertaken by the Tea Research Institute in Hangzhou, Zhejiang Province. The green tea, vegetatively propagated, clonal variety used in the trial is called "Longjing 43". At the high densities used, this variety has yields more than ten times greater than the average for Zhejiang Province. Four different plant density levels were used in the trial. The economic analysis examines the performance in terms of conventional investment criteria: SNPV, Perpetual Annuity, B/C ratio, IRR and the Discounted payback period. The optimum time to prune is also calculated for each of the trials and sensitivity analyses are undertaken using various assumptions as to the relative performance farmers might attain.

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AN ECONOMIC ANALYSIS OF A PLANT DENSITY EXPERIMENT FOR TEA IN CHINA

1. BACKGROUND

1.1. National Yields

China, with over one million hectares, has more than twice as much land in tea as her closest rival, India. However tea yields in China are very low by international standards so that recorded production is only two-thirds that of India [Table 1].[2] Current yields are also low compared to historical records. In 1914, China was producing 324 thousand metric tons of tea from about 354 thousand hectares (see Perkins 1969). Tea is grown in many parts of the country: eighteen of China's twenty nine Provinces produce tea but their average yields are all low and do not depart markedly from the national average [Table 2]. However, the low average yields mask the very much higher yields that occur within the country and, consequently, the considerable potential for further increases in China's tea production (Etherington and Forster 1988).

Table 1 International Tea Yields for 1985

Country	Total Output 1985	Total Area 1982	Average Yield
	(000 t)	(000 ha)	(kg/ha)
India	659	395.0	1668
China	440	1096.7	401
Sri Lanka	215	242.1	888
USSR	155	78.7	1970
Kenya	147	81.1	1813
Indonesia	132	109.5	1205
Turkey	123	64.5	1907
Japan	96	61.0	1574
Bangladesh	43	44.7	962
Malawi	40	18.5	2162
Argentina	33	41.4	797
Viet Nam	22.5	49.6	454
Total	2105.5	2282.8	922

Source: Calculated from International Tea Committee Annual Bulletin of Statistics 1986, and Supplement

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2 Yields should be calculated on mature area rather than total area. The three year yield lag in Table 1 attempts to allow for this. The figures in Table 1 are all drawn from the one source and show minor discrepancies with official Chinese data.

The very low tea yields are a major concern because tea in China has a cultural significance beyond that of being simply a cheap hot beverage. Following brief introductions to the crop, the institutional setting and the geographical region, this paper reports on an economic analysis of a plant density experiment of a clonal tea with very high yields.

Table 2. Provincial Tea Production Statistics for China 1979 and 1985

Province	1979 Output	1979 Area	1979 Yield	1985 Output	1985 Area	1985 Yield
	(000 t)	(000 ha)	kg/ha	(000 t)	(000 ha)	kg/ha
National	277.15	1050.33	263.87	432.42	1044.87	413.85
Jiangsu	4.75	10.80	439.81	9.20	14.33	641.86
Zhejiang	65.45	164.60	397.63	93.15	177.93	523.51
Anhui	29.95	96.20	311.33	42.55	118.60	358.77
Fujian	22.80	99.73	228.61	40.55	122.27	331.65
Jiangxi	9.20	59.93	153.50	14.30	63.80	224.14
Shandong	1.05	5.40	194.44	.70	2.40	291.67
Henan	1.15	12.87	89.38	1.80	15.93	112.97
Hubei	17.00	82.60	205.81	22.75	69.73	326.24
Hunan	57.35	167.47	342.46	77.70	114.93	676.04
Guangdong	10.55	42.00	251.19	22.65	46.00	492.39
Guangxi	7.05	27.07	260.47	9.95	20.67	481.45
Sichuan	28.35	115.60	245.24	52.50	108.87	482.24
Guizhou	6.25	39.47	158.36	10.60	28.40	373.24
Yunnan	14.85	98.33	151.02	31.10	114.13	272.49
Tibet	v/s	v/s	v/s	.04	.20	175.00
Shaanxi	1.35	28.20	47.87	2.80	26.20	106.87
Gansu	.05	.07	750.00	.09	.47	182.14

Note: v/s = very small
Source: Calculated from China Agricultural Yearbook 1980 and Statistical Yearbook of China 1986

1.2. Tea Basics

There are two broad divisions in commercial teas: 'black tea' and 'green tea'. Both are produced from varieties of **Camellia senensis** but are processed quite differently. Black tea includes in its processing a period of fermentation while green tea is unfermented. Within both types of tea there are many quality distinctions resulting from plant varieties, specific environmental conditions (climate, elevation, soils), tea garden management and the quality of 'plucking', as well as the care and skill in processing. Tea prices reflect both the unique conditions which cannot be emulated and the quality control in field management and processing. In general, but not exclusively, black tea is made from the leaves of C. sinensis var assamica and green tea from C. sinensis var sinensis. The former tends to be a larger bush with relatively broad leaves while the latter is smaller of leaf and is better suited to the harsher climates of the northern tea producing areas such as Zhejiang Province. This province produces both green and black tea from var sinensis.

1.3. The Institute and its location

The results reported upon in this paper are based on a long term experiment conducted by the Tea Research Institute (TRI) of China. The Institute is located about 15 Km outside the city of Hangzhou, the capital of Zhejiang Province and about 100 Km SW of Shanghai.[3] The TRI has national responsibility for tea research and collaborates with and encourages the research of 15 Provincial tea research centres (six of which are TRIs). The Institute currently employs 202 people of whom 130 are scientists.[4]

The Institute is organised around eight Departments. The Tea Culture Department was responsible for the experiment which provided the data used in this paper.

Hangzhou is one of the famous garden cities of China but certainly has a harsh climate when compared to most other tea producing regions of the world. The Institute is located at about 120 E, 31 N (about the same latitude as New Orleans in the US, or Coffs Harbour but has a more extreme climate than either). The elevation is only about 30m above sea level. There are extremes in temperature with the annual average of 16C. Mean January temperature: 3C; mean July 28C. The overall maximum is about 40 and minimum -13C. There are about 285 frost free days. Annual rainfall is about 1,300mm with July/August (Summer) being the dry season but humidity is always high.

The marked seasonal temperature differences result in a distinct seasonal yield pattern in the northern tea producing provinces. The peaked time profile for plucking mature tea fields in the Hangzhou area is depicted in Figure 1. Here it is seen that 50 per cent of output (in two qualities) comes off in just three weeks - from mid April to about the first week of May. However, the peak in the value of production is even greater (nearly 80%) because the highest quality tea is produced at this time.[5]

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[3] A map of the Provinces and major cities is given in Appendix 1.

[4] The TRI is one of the institutes established in 1958 under the overall management of the Chinese Academy of Agricultural Sciences (CAAS). The CAAS now has 36 Institutes plus three additional laboratories and libraries with a total staff in excess of 10,500, including over 1,000 Senior Scientists and 3,400 research staff.

[5] The competition with other crops is acute in Spring and tea tends to lose its reputation as a "free time" crop. (This is a common expression referring to the fact that plucking can be done by family and friends whenever they are free - timeliness is not generally crucial).

Figure 1. Time Profile of Tea Plucking, Hangzhou

Item		MONTHS											
Quality	Price	J	F	M	A	M	J	J	A	S	O	N	D
		Output of Made Tea											
Grade	Yuan/Kg *	Kg/Mu **											
1st (Longjing) ***	16.00				|——| 15kg								
2nd													
3rd	1.60							|——	35kg	——|			
4th	1.60					|—| 35	|—— 15kg	——|					

Total Leaf Production (made tea)	50	+	15	+	35	=	100 kg/Mu
Total Leaf Value (Yuan)	296	+	24	+	56	=	376
% of total value	79	+	6	+	15	=	100 %

Source: Personal communication from TRI scientists.
Notes: * About 3.7 Yuan to US$. ** 15 Mu = Hectare.
*** "Longjing" (Dragon Well) tea is the most notable tea of Hangzhou.

2. THE EXPERIMENT

2.1. The Data

Given the low tea yields in China, it is not surprising that the Tea Research Institute has undertaken a large number of field experiments on fertilizer use, pruning practices, variety and plant density trials. Results of these are typically published in the TRI's Journal of Tea Science. For example, the report by Yao Guokun and Ge Tiejun of the plant density experiment from which the data for this study are drawn is in Vol.6 No.1 (1986) of the Journal (p. 21-27 with English abstract on p.28).

The plant density experiment had been running over 10 years during which time detailed records were kept of all inputs and outputs. The condition of the bushes above and below ground was also careful monitored. Four plots were planted with the TRI's "Longjing 43" clonal tea.[6] Single 1 Mu (1/15 hectare) blocks were used with plant densities of 4,000, 8,000, 12,000 and 16,000 plants per Mu. These densities are equivalent to 60, 120, 180, and 240,000 plants per hectare. Such plant densities are quite

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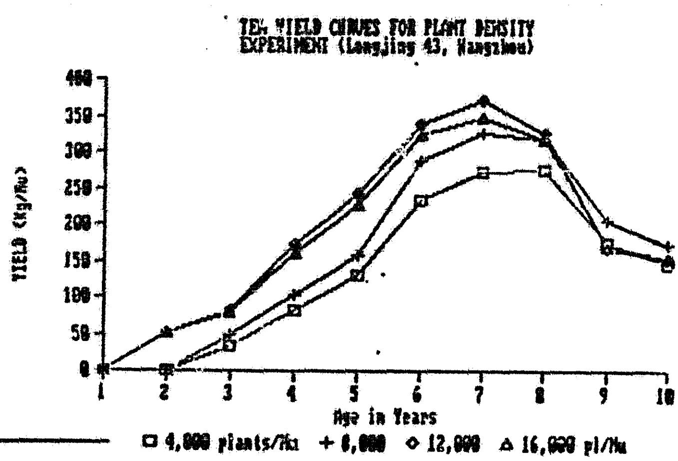
[6] The name "Longjing 43" given to this clone uses the name of the district's most famous made (green) tea as a brand name. The clonal name and the final product should not be confused, i.e. the leaf of "Longjing 43" can be used to produce a variety of different teas not just "Longjing" cha.

extraordinary by standards using Assam type tea varieties when 15,000 plants per hectare would be considered 'dense planting'. The Kenya Tea Development Authority recommended rates of less than 10,000 plants per hectare. The Indian standard is also about 10,000 plants per hectare (ICAR 1980, p.867) while the World Bank recommended 13,000 plants per hectare for a replanting program in Indonesia (World Bank 1971). The quantum difference in plant densities needs some explanation. Two factors are significant: <u>first</u>, there is the historical fact that the experiment was started during the Cultural Revolution when specific emphasis was placed on the intensification of agriculture with high density planting and intercropping. A <u>second</u> explanation is the Chinese practice of planting in 'hedges' with no training of bushes to achieve lateral spread.[7] In the experiment there is no report of any pruning.

The high density planting is the mechanism for obtaining a lateral spread of branches. The lowest density of plot has rows of plants at 150cm intervals. Three cuttings are placed in each plant hole spaced at a (calculated) distance of about 40cm. With the second plot, each hedge consists of two close rows (33cm apart) but with the distance between the centres of the hedges kept at 150cm. In a similar fashion, the third and fourth plots have three and then four 'within-hedge' rows at 33cm intervals. The plots were maintained with 'standard' management practices which included fertilizer and supplementary irrigation.

The report on the experiment excluded any economic analysis but during a visit to the TRI I was asked to undertake the task as a didactic demonstration. With the help of the Tea Cultivation Department, the original, rather than the published results, were accessed for the analysis. Figure 2. shows the yield curves for the four trials. These are annual data plotted in terms of kilograms of made tea per Mu (Yao et al, 1986, Table 1, p.22). The economic analysis that follows uses output of green leaf (not made tea) on a seasonal basis.

Figure 2



[7] This is in contrast to the standard practice in most countries growing **Camellia sinensis var assamica** where bushes are trained by pegging out lateral branches and pruning and tipping at a series of intermediate heights during the first three years of a bush's formation (see Harler 1966 or Etherington 1973, p.14 and Appendix I).

Standard Chinese plucking procedures which maintain a convex crown to the hedges rather than the flat 'table-top' typical of most countries producing black tea were used. The convex crown increases the plucking surface of the tea bushes. The plucking was conventionally fine (two leaves and a bud) for standard (Chunmee) green tea rather than the ultra fine (bud) plucking required for Longjing tea.

All prices are in constant 1987 terms. Spring tea leaf was priced at Y1.32 per kilogram, Summer tea at Y0.92 and Autumn teas at Y1.12. Two labour wage rates are used: Y3.50 per day for TRI staff and Y2.00 for casual pickers. Net returns take into account all costs other than land.

2.2. Method of Analysis

The analysis of the experiment is undertaken by using a special purpose software package called "MULBUD". MULBUD is an interactive computer package designed to assist in the economic analysis of land-use systems operating over long time horizons. The package, ideal for a long life crop like tea, gets its name from its concern with MULtiple-enterprises, -products, and -time periods and provides farm BUDgets of such systems (Etherington et al 1985). This specialist simulation package has elements of both 'data base' and 'spreadsheet' packages: enterprise 'records' with specifically designed 'fields' can be analyzed or merged together to form more complex budgets. Each 'record' is a 'Minimum Consistent Enterprise Data Set' which the user is led to define. A data set consists of descriptors, inputs and outputs with names, units, quantities and prices defined over the specified time horizon. 'Time Period Vectors' are defined in terms of both years and intra-year 'seasons'. The package can handle up to 200 time periods (Year x Seasons). One data set or 'record' is established for each of the experimental plots. Each data set has forty time periods made up of 10 years each with four seasons. Season 1 is Spring and covers March, April and May. The descriptive and analytical tables that are printed out in final report format by MULBUD form the basis of the following results.

All values[8] in the following tables are expressed in Yuan. The Area Unit is one Mu. A basic assumption of the analysis is that the grower delivers the freshly plucked leaf to a 'factory'. Thus the results are simply for the field operations of growing, maintaining and harvesting (plucking) the tea. The analysis assumes that the land is 'free' to the grower, that is, no opportunity cost for the land has been included. However, the first year of the ten year data set is taken up with land preparation for Spring planting in the second year.

Terminal values were calculated so that the economic results would reflect perpetual income streams. Simple but conservative estimates were used. The initial annuity of the ten years was multiplied by seven which implies a perpetual life at a discount rate of 15% (or 17 years at 12%).

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[8] To convert these values to US$ per hectare at the official exchange rate (in July 1987) of Y3.71 = US$ and with 15 Mu to the hectare, values should be multiplied by 4 (ie 15/3.71 = 4.0432).

Table 3 Summary Results for Lowest Density Plot

Experiment: 4,000 Plants per Mu Area Unit: Mu

SUMMARY RESULTS

**Year	*Season	Total Labour 8HrDay	Costs: Labour Costs Yuan	Costs: Material Costs Yuan	Costs: Total Costs Yuan	Gross Revenue Yuan	Returns: Net Revenue Yuan	Returns: N.R./8HrDay Yuan	SNPV @ 15.00% Yuan
1	1	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-10.13
	2	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-19.93
	3	16.00	56.00	87.00	143.00	0.00	-143.00	-8.93	-148.70
	4	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-157.83
2	1	8.00	28.00	304.00	332.00	0.00	-332.00	-41.50	-436.61
	2	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-445.12
	3	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-453.34
	4	1.00	3.50	0.00	3.50	0.00	-3.50	-3.50	-455.99
3	1	14.31	50.11	26.70	76.81	18.15	-58.66	-4.09	-498.82
	2	17.69	61.91	5.00	66.91	79.44	12.52	0.70	-489.99
	3	12.23	42.80	60.00	102.80	44.35	-58.45	-4.77	-529.79
	4	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-536.70
4	1	19.20	67.20	7.50	74.70	105.27	30.56	1.59	-517.29
	2	26.22	89.94	39.00	128.94	160.66	31.71	1.20	-497.84
	3	16.46	57.64	87.00	144.64	78.23	-66.40	-4.03	-537.16
	4	3.00	10.50	0.00	10.50	0.00	-10.50	-3.50	-543.17
5	1	20.95	73.33	10.00	83.33	172.20	88.86	4.24	-494.10
	2	31.49	100.49	9.50	109.99	251.07	141.08	4.48	-418.88
	3	20.15	70.54	89.50	160.04	134.04	-26.00	-1.29	-432.27
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	-440.97
6	1	35.08	107.67	15.00	122.67	460.02	337.34	9.61	-279.01
	2	48.03	133.57	12.00	145.57	431.89	286.31	5.96	-146.27
	3	20.13	70.46	92.00	162.46	133.67	-28.79	-1.43	-159.16
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	-166.72
7	1	47.34	132.19	15.00	147.19	678.67	531.48	11.22	55.15
	2	42.30	122.10	12.00	134.10	360.54	226.44	5.35	146.44
	3	25.19	87.88	92.00	179.88	210.22	30.34	1.20	158.26
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	151.68
8	1	40.33	118.17	15.00	133.17	553.67	420.49	10.42	304.33
	2	42.38	122.26	12.00	134.26	361.56	227.29	5.36	384.01
	3	25.90	89.30	92.00	181.30	221.03	39.72	1.53	397.46
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	391.74
9	1	32.18	101.86	15.00	116.86	408.14	291.28	9.05	483.69
	2	37.68	112.86	12.00	124.86	303.14	178.27	4.73	538.03
	3	15.94	55.80	92.00	147.80	70.28	-77.52	-4.86	515.21
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	510.24
10	1	24.57	86.02	15.00	101.02	272.51	171.49	6.97	557.32
	2	35.54	108.59	12.00	120.59	276.59	156.00	4.38	598.67
	3	12.95	45.33	92.00	137.33	25.03	-112.30	-8.67	569.92
	4	5.00	17.50	0.00	17.50	0.00	-17.50	-3.50	565.59

Source of data: Tea Research Institute, Hangzhou

2.3. Results

Table 3 (above) presents the Summary Results for the first (lowest density) plot. Each column represents another detailed table. For example, the package gives a Labour Requirements table with ten labour operations and a breakdown of labour costs between family and hired labour. Similarly, thirteen Material Inputs exist 'behind' the Material Costs column. Note that at maturity (years 7,8 & 9) Gross Revenue is as strongly peaked in the first season as Figure 1 suggested. Net Revenue is even more peaked.

Table 4 gives the Overall Summary for the lowest density plot. Such results for all four plots are pooled in Table 5 which also shows the terminal values used in the analysis.

Table 4 Overall Summary Results of the Lowest Density Plot

O V E R A L L S U M M A R Y

Experiment: 4,000 Plants per Mu **Area Unit: Mu**

Item	Yuan	6. Labour Use :	8HrDay
1. Terminal Value	930.00		
2. SNPV (@ 15.00%)	765.49		
3. Amortized values :		Overall Total	740.34
.1 (per year)	152.52	Av. Total / year	74.03
.2 (per season)	36.15	Av. Total / season	18.50
4. SNPV / LUI at Maturity	765.49	Av. Hired / year	14.47
5. SNPV / 8HrDay	1.03	Av. Hired / season	3.61
7. Sum of Present Values :		8. Benefit/Cost Ratios :	
a) Gross Revenue + T.V.	2599.50		
b) Total	-1834.00	[a] / |b|	1.417
c) Material Costs	-742.32	[2 - c] / |c|	2.031
d) Cash Costs	-856.35	[2 - d] / |d|	1.894
e) Fixed Costs	-170.76	[2 - e] / |e|	5.483

Source of data: Tea Research Institute, Hangzhou (Analyzed with MULBUD)

The summary results (Table 5, below) give a clear ranking by all economic criteria for the second highest density planting (12,000 plants per Mu or 160,000 per hectare). As long as the costs of the planting materials are not too high, such dominance could be anticipated from the yield curves in Figure 2. The returns are very high, with an IRR >50%. At 15% the overall Benefit Cost ratio is over 1.8 and the discounted payback period is the first season of the sixth year. A high (subjective) discount rate is used because of the very high IRR. In all cases yields peak in the seventh year. The maximum yields are high by world standards and quite extraordinary when compared to national and provincial averages. The best plot, at over 5.5 tons per hectare, yields more than ten times Zhejiang Province's annual average yield in 1985 (Table 2). The returns are high compared to survey results for other crops in the Province in 1984. For example, profits in Yuan per Mu were for wheat, Y1.34, rice Y41, maize Y98, and cotton Y139.[9] These should be compared to the average annual returns (the Annuity) of Y395 per Mu. By international standards a return of over US$1500 per hectare is very good.

Table 5 Summary of Overall Economic Results from Four "Longjing 43" Tea Planting Density Trials

	Plants per Mu			
Criteria	4,000	8,000	12,000	16,000
	Plot I	Plot II	Plot III	Plot IV
1. Sum of Net Present Values (SNPV)(Yuan) @ 15% *	765.49	1270.81	1981.18	1688.27
2. Perpetual Annuity (Yuan) *	152.52	253.21	394.75	336.39
3. Benefit Cost Ratio	1.41	1.63	1.85	1.70
4. Internal Rate of Return (IRR %)	34.0	40.6	54.5	45.8
5. Discounted Payback Period (Year:Season)	7:1	7:1	6:1	6:1
6. Average Annual Labour Use (days)	74	83	94	92
7. Maximum Yields (Yr)	7	7	7	7
Kg per Mu **	273	330	374	350
Kg per Hectare **	4095	4950	5610	5250
[Terminal Values(Yuan)	930	1550	2450	2315]

* To convert to equivalent US$ per hectare, multiply by 4.

** 'Made tea equivalent', converted at 4.0kg green leaf per kg made tea. This is the rate used in the original article and contrasts with the conversion rate of 4.5 usually used for black tea.

[9] Based on the 'Household Cost and Income in Agriculture, Animal Husbandry and Fisheries Products Sample Survey, 1984' reported in the China Agricultural Yearbook 1986 (English Edition) p.309-312.

2.4. Sensitivity Analysis

The results reported thus far have been based directly on the physical input/output data of the experiment together with 1987 prices. Since the crucial difference between the plots is number of plants per Mu, it is important to check on the sensitivity of the results to changes in the cost of the planting materials. The 'base' cost of the vegetatively propagated (VP) clonal plants was only 30.00 Yuan per 1,000 or .03 each which is less than 1 US cent per plant. On the assumption that this is an internal TRI price and that farmers would be faced with higher prices, particularly if the planting materials have to be transported any distance, prices of 60, 100 and 150 Yuan per 1,000 plants were used in the sensitivity analysis [Figure 6].

As would be anticipated, the relative economic performances narrow and the slope of the lines linking the annuities of the different plant densities increase as the number of plants increases. Among the three less dense plots the ranking does not change but at the highest price of planting material considered, the highest density plot has the lowest return. It has the lowest return at any price of the planting materials in excess of Y123 per thousand. In terms of the IRR (not shown), Plot IV has the lowest return at prices exceeding Y72 per thousand plants. At a plant price of Y150 per thousand, the IRR of the other three plots virtually coincide but Plot III just retains its premier position (22.7% as against 21.7% for Plot I, 20.6% for Plot II and 15.6% for Plot IV). Further sensitivity analysis of Plot III is undertaken in Table 6.

Figure 3 Sensitivity of Economic Returns to Changes in the Price of Planting Material for Four Tea Plant Density Trials

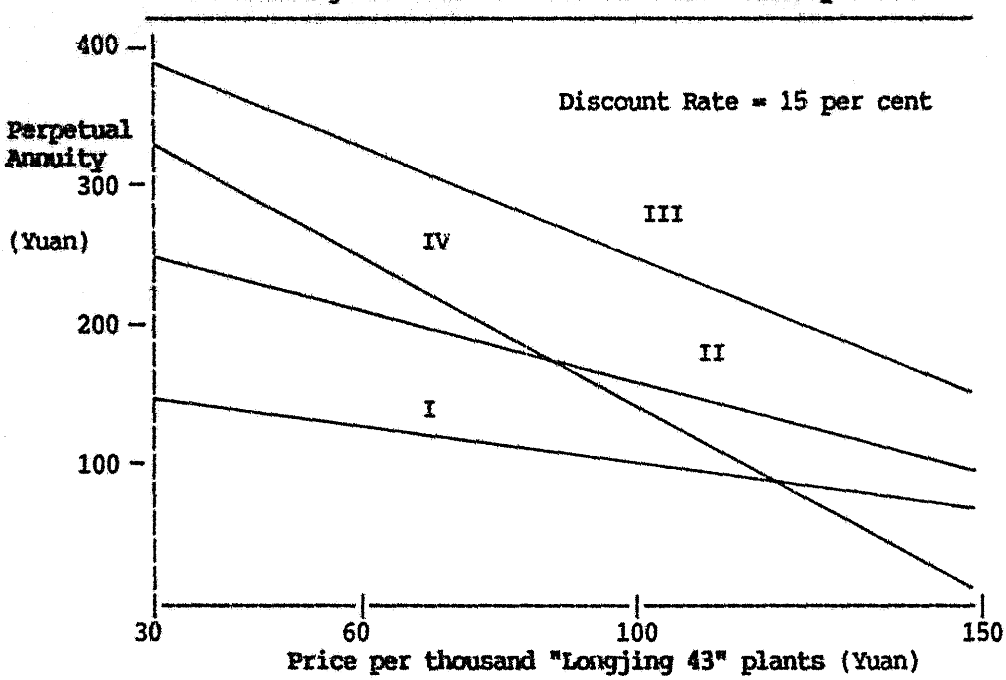

Table 6 shows the sensitivity of the perpetual annuity (using a discount rate of 8 per cent) to percentage changes in costs and returns. The middle cell of the matrix shows that the average annual return on the basis of the data of the experiment, using 1987 prices but with the price of planting materials at Y100 per thousand, is about 390 Yuan per Mu per Year or about US$1,500 per hectare per year. If all Material Costs were to increase by 40% and remain at that level, the annuity would decrease to about Y275 (or 29%, giving an elasticity with respect to Material Costs of 0.735). The results are very much more sensitive to the yield and product price assumptions (which together make Gross Revenue). Thus if a (good) farmer obtains yields only 20 per cent less than the experimental yields, the net annual returns would decline by 49 per cent to about Y197 (or US$800). This implies an elasticity of 2.465 which means that tea farmers' returns are highly dependant on how closely they are able to match the TRI's management level.

Table 6 Sensitivity Matrix of Costs and Returns of Plot III

Experiment: 12,000 Plants per Mu
Costing Y100 per 1,000

Area Unit: Mu

Annuity in Yuan at 8.0 per cent per annum

Horizontal axis = % change in MATERIAL COST
Vertical axis = % change in GROSS REVENUE

40.0 %	20.0 %	0.0 %	-20.0 %	-40.0 %	
659.28	716.60	773.92	831.24	888.56	40.0%
467.13	524.45	581.77	639.09	696.41	20.0%
274.98	332.30	389.62	446.94	504.26	0.0%
82.83	140.15	197.47	254.79	312.11	-20.0%
-109.31	-51.99	5.32	62.64	119.96	-40.0%

(By MULBUD)

While the annual net (discounted) returns to this technology are highly sensitive to changes in yields and product price, Plot III 's less sensitive than the other plots.

3. SIMULATION: Optimal Pruning Date

3.1. The Problem and the Theory

The marked decline in yields over the last three years of the experiment is a typical pattern with cultivated tea. Pruning the tea is the normal agronomic practice used to restore yield levels. It is then of interest to know when to prune. The basic data were used to simulate optimal pruning dates using standard optimal replacement theory (Perrin 1972, Etherington 1977).

For a continuous income stream, the Sum of the Net Present Value (SNPV) of earnings for one cycle is given by

(1) $$SNPV_{(s,1)} = \int_0^s R(t)\, e^{-it} dt$$

Where the subscripts s and 1 refer to the optimal length of cycle (s periods) for a single (1) cycle. R(t) is the net revenue in each time period 't'. 'i' is the continuous discount rate.

For the case of a series of identical cycles of an asset, the self replacement problem is to find the date 's' which maximises the value of an entire income stream. This stream is:

(2) $$SNPV_{(s,oo)} = SNPV_{(s,1)} + SNPV_{(s,1)} e^{-is} + SNPV_{(s,1)} e^{-i2s} + \ldots$$

This cycle reduces to (3) as the number of cycles increases towards infinity.

(3) $$SNPV(s,oo) = \frac{1}{1 - e^{-is}} SNPV(s,1)$$

Maximising (3) with respect to the replacement date 's' we obtain the following first order condition

(4.1) $$R(s) = \left[\int_0^s R(t)\, e^{-it} \right] \frac{i\, e^{it}}{e^{it} - 1}$$

Equation (4.1) states that the annual (marginal) returns must equal the annuity formed from the discounted total flow of earnings. Since the equality condition is unlikely to hold and yield is not completely continuous, it is more useful to check the inequalities in (4.2) for the discontinuous case

(4.2) $$R(s) > \left[\sum_{o}^{s} R(t)\, (1 + r)^{-t} \right] \frac{r\, (1 + r)^s}{(1 + r)^s - 1} > R(s+1)$$

Here 'r' is the discrete, as opposed to the continuous, discount rate.

3.2. The Method

In the particular case of tea production in the environment of northern Zhejiang Province, pruning takes place after the completion of the Spring flush. Furthermore, pruning does not return yields to 'year zero' but, rather, to more mature yields. Two simulations were undertaken. In the first (Assumption A) it was assumed that in the year after pruning yields return to their levels in year four of the experimental results and then continue along the relevant yield curve. In the second (Assumption B), yields after pruning proceed along the yield curves commencing in year five. Thus the Summation in the square brackets in (4.2) will run from year 4 (or 5) to 's' - the optimal pruning date. The cost of pruning (¥20, 30, 40, and 50 for the successive Plots) is charged against the first season of each new cycle.

MULBUD Summary Results (see Table 3) were written to a disk file and read into a spreadsheet package where they were shortened (to commence in year four and five) and then sequential seasonal and annual amortised values were calculated. Because of the seasonal nature of production, the seasonal amortised returns are 'wavy' an annual local maximum. The global maximum for each plot takes place with the Summer harvest included. However, it is assumed that good agronomic practice requires pruning to take place immediately after the Spring flush rather than in Autumn. Hence the optimal date to prune was selected by choosing the higher Spring amortised value on either side of the global Summer maximum. This procedure was repeated for three different interest rates (5,10 and 15 per cent). In general, for continuous cropping situations, higher interest rates lengthen the optimal length of cycle.

3.3. The Results

Table 7 gives the optimal year for first pruning. The optimal length of the pruning cycle is then three years less in the case when the new cycle yields start in year 4 (Assumption A) and four years less when the new cycle yields start in year 5 (Assumption B) of the research results. Thus for the best plot, Plot III, pruning should take place every five years under Assumption A or every four years if Assumption B is correct. The results are robust with respect to variations in the interest rate.

Table 7 Optimal Year of First Pruning

Assumption	'r'	Plot I	Plot II	Plot III	Plot IV
	%	Years			
A	5,10,15	9	9	8	8
B	5,10	8	8	8	8
	15	8	9	8	8

The iterative procedure for establishing the optimal pruning dates also gives the seasonal (and annual) amortised values. These are given for the best plot in Table 8. Here it will be seen that variations in the interest rate make little impact compared to the move from Assumption A to B. The values have been used to recalculate terminal values (TVs) used in the earlier analysis and it is seen that there is a large discrepancy. In other words, these terminal values (TVs) should be compared to the very conservative values used in Table 5 (e.g. Y2,450 for Plot III). With a TV of Y5,600 (6,916), the overall annuity for Plot III increases from Y394.75 to Y530 (Y586). These results imply average annual returns of well over US$2,000 per hectare. If the price of planting materials to the farmer were Y150 per thousand plants and the TV is Y5,600, then the annuity would be Y289 per year. Furthermore, the enterprise would still give an IRR of over 26 per cent and could sustain a further 20 per cent increase in Material Costs and a 20 per cent decrease in Gross Revenue to at least break even using a 15 per cent discount rate.

Table 8 Maximum Seasonal Amortised Values for Plot III

Assumption	Annual interest rates (%)		
	5	10 (Yuan)	15
A	207	204	200
Terminal Values *	5,786	5,712	5,600
B	249	248	247
Terminal Values *	6,972	6,944	6,916

* Terminal Values are calculated as seven times the annual amortised value.

4. CONCLUSION

This paper gives the results of an economic analysis of a ten year plant density experiment undertaken by the Tea Research Institute of China in the Institute's fields at Hangzhou, Zhejiang Province. The clonal tea variety used was "Longjing 43" bred at the Institute. The experiment was the subject of 'standard' TRI management with the use of fertilizer and supplementary irrigation. The results indicate that of the four trials, a density of 12,000 plants per Mu (180,000 plants per hectare) gave the highest returns - equivalent to over US$1,500 per hectare.

If indeed the remarkably high plant densities used in this experiment do not have negative long term effects on the yield performance of the bushes then the optimal pruning analysis suggests that the excellent results recorded in Table 5 must be considered to be conservative. Furthermore, it takes radical reductions in yields (and/or output prices) and increases in input costs to lead to financial losses in the enterprise. Given these results then, in the environments for which "Longjing 43" is suited, not only this clone but also the very high density planting should be promoted strongly as one mechanism for raising tea yields above the very low levels reported for Zhejiang Province and for the country.

REFERENCES

ETHERINGTON, D.M. (1973). **An Econometric Analysis of Smallholder Tea Production in Kenya.** (Nairobi, East African Literature Bureau)

ETHERINGTON, D.M. (1977). 'A stochastic model for the optimal replacement of rubber trees.' **Australian Journal of Agricultural Economics**, Vol.21 No.1 p.40-58

ETHERINGTON, D.M. & FORSTER, K.(1988). 'The resurgence of the tea industry in China.' A paper presented to the Annual Conference of the Australian Agricultural Economics Society, La Trobe University, February.

ETHERINGTON, D.M. & MATTHEWS, P.J.(1985). **MULBUD User's Manual.** (Canberra, Australian National University).

GOVERNMENT OF CHINA (1980, 1986). **Agricultual Yearbook of China.** (Beijing Agricultural Publishing House).

GOVERNMENT OF CHINA (1985 to 1979). **Statistical Yearbook of China.** (Beijing and Hong Kong, State Statistical Bureau).

HARLER, C.R. (1966). **Tea Growing.** (London, Oxford University Press).

INDIAN COUNCIL OF AGRICULTURAL RESEARCH (1980). **Handbook of Agriculture** (New Delhi).

INTERNATIONAL TEA COMMITTEE (1986) **Annual Bulletin** (London)

PERKINS, D.H. (1969). **Agricultural Development in China 1368-1968.** (Chicago, Aldine Press).

PERRIN, R.K. (1972). 'Asset replacement principles.' **American Jounal of Agricultural Economics**, Vol. 54, p.60-67

WORLD BANK (1971). 'Tea Project: Indonesia' Report No. PA-78b. (Washington D.C.).

YAO Guokun and GE Tiejun, (1986). 'Effect of closeplanting on output and quality of tea and the ecoenvironment of tea garden.' (Chinese with English abstract) **Journal of Tea Science**, Vol. 6 No. 1. p.21-28.

Appendix 1

Map of the Provinces of China