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PROJECT DEVELOPMENT ASSESSMENT: THE APPLICATION OF PLANT TISSUE CULTURE TECHNIQUES TO THE PROPAGATION AND BREEDING OF TEA IN INDONESIA

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ABBREVIATIONS

ACIAR: Australian Centre for International Agricultural Research
FAO: Food and Agriculture Organization of the United Nations

1. INTRODUCTION

1.1 Background information

Tea is a very important crop not only in Indonesia, but also in a number of other countries in the world. Table 1 shows production of tea while Table 2 shows consumption of tea in 64 countries or regions of the world. Table 3 shows tea production and the areas devoted to tea in Indonesia by the three production sectors. Table 4 shows past trends for the average price of tea on the international market.

Table 1. The production of tea (thousands of tonnes) in 64 regions or countries of the world: 1981 to 1990.

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	**AUSTRALIA**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2	BANGLADESH	39	41	42	38	43	38	38	41	44	39
3	BHUTAN	0	0	0	0	0	0	0	0	0	0
4	INDIA	560	561	581	640	656	621	665	701	684	715
5	NEPAL	1	1	1	1	1	1	1	1	1	1
6	PAKISTAN	0	0	0	0	0	0	0	0	0	0
7	SRI LANKA	210	188	179	208	214	211	213	227	207	233
8	MYANMAR	0	0	0	0	0	0	0	0	0	0
9	**INDONESIA**	**109**	**93**	**110**	**126**	**127**	**136**	**126**	**134**	**141**	**149**
10	TIMOR	0	0	0	0	0	0	0	0	0	0
11	KAMPUCHEA	0	0	0	0	0	0	0	0	0	0
12	LAOS	0	0	0	0	0	1	1	1	1	2
13	MALAYSIA	3	3	3	5	4	5	5	5	5	5
14	PHILIPPINES	0	0	0	0	0	0	0	0	0	0
15	THAILAND	1	2	2	2	3	3	3	5	5	5
16	VIETNAM	21	25	27	27	28	30	29	30	32	31
17	CHINA	343	397	401	414	432	460	509	545	535	540
18	MONGOLIA	0	0	0	0	0	0	0	0	0	0
19	FIJI	0	0	0	0	0	0	0	0	0	0
20	PAPUA NEW GUINEA	9	8	10	10	8	8	8	8	8	8
21	SAMOA (WEST)	0	0	0	0	0	0	0	0	0	0
22	SOLOMON ISLAND	0	0	0	0	0	0	0	0	0	0
23	TONGA	0	0	0	0	0	0	0	0	0	0
24	VANUATU	0	0	0	0	0	0	0	0	0	0
25	CHRISTMAS IS	0	0	0	0	0	0	0	0	0	0
26	COCOS IS	0	0	0	0	0	0	0	0	0	0
27	COOK IS	0	0	0	0	0	0	0	0	0	0
28	GUAM	0	0	0	0	0	0	0	0	0	0
29	KIRIBATI	0	0	0	0	0	0	0	0	0	0
30	NAURU	0	0	0	0	0	0	0	0	0	0
31	NEW CALEDONI	0	0	0	0	0	0	0	0	0	0
32	NIUE	0	0	0	0	0	0	0	0	0	0
33	POLYNESIA (FRENCH)	0	0	0	0	0	0	0	0	0	0
34	SAMOA (AMERICAN)	0	0	0	0	0	0	0	0	0	0
35	TOKELAU	0	0	0	0	0	0	0	0	0	0
36	TUVALU	0	0	0	0	0	0	0	0	0	0
37	WALLIS & FUT	0	0	0	0	0	0	0	0	0	0
38	BURUNDI	2	2	2	3	4	4	4	4	4	4
39	RWANDA	7	7	7	6	8	10	12	12	13	13
40	KENYA	91	96	119	116	147	143	156	164	181	197
41	TANZANIA	16	18	15	17	16	14	17	16	17	20
42	UGANDA	2	3	3	5	6	3	4	4	5	7
43	ZAIRE	5	4	5	5	5	5	3	3	3	3
44	ETHIOPA	0	0	0	0	0	0	0	0	0	1
45	SUDAN	5	5	5	5	5	5	5	6	5	4
46	MADAGASCAR	0	0	0	0	0	0	0	0	0	0
47	CAMEROON	2	2	2	2	3	3	3	3	3	3

48	GHANA	0	0	0	0	0	0	0	0	0	0
49	IVORY COAST	0	0	0	0	0	0	0	0	0	0
50	NIGERIA	0	0	0	0	0	0	0	0	0	0
51	ANGOLA	0	0	0	0	0	0	0	0	0	0
52	MALAWI	32	38	32	38	40	39	32	40	39	39
53	MOZAMBIQUE	22	21	15	11	7	5	3	2	2	2
54	ZAMBIA	0	0	0	0	0	0	0	1	1	1
55	ZIMBABWE	10	11	11	12	14	16	15	17	18	17
56	OTHER AFRICA	11	12	14	17	18	18	18	17	19	19
57	WEST ASIA/ NORTH AFRICA	76	103	137	157	170	189	184	196	164	167
58	LATIN AMERICA	322	346	371	382	408	433	479	465	468	476
59	OTHER ASIA	25	24	25	25	24	25	26	24	22	23
60	USSR	137	140	146	151	152	146	156	123	131	115
61	NORTH AMERICA	0	0	0	0	0	0	0	0	0	0
62	JAPAN	102	99	103	93	96	94	96	90	91	90
63	EUROPE	0	0	0	0	0	0	0	0	0	0
64	OTHER DEVELOPED	0	0	0	0	0	0	0	0	0	0
	WORLD—TOTAL	**2162**	**2251**	**2369**	**2517**	**2640**	**2667**	**2812**	**2884**	**2848**	**2927**

Source: Food and Agriculture Organisation data tapes, June 1994.

Table 2. The consumption of tea (thousands of tonnes) in 64 regions or countries of the world :1981 to 1990 .

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	**AUSTRALIA**	**22**	**23**	**21**	**22**	**20**	**20**	**19**	**19**	**19**	**18**
2	BANGLADESH	7	2	11	4	17	8	15	11	20	17
3	BHUTAN	0	0	0	0	0	0	0	0	0	0
4	INDIA	321	372	380	431	448	425	453	502	468	507
5	NEPAL	1	1	2	2	2	2	2	2	2	2
6	PAKISTAN	65	68	81	96	84	83	93	90	104	107
7	SRI LANKA	12	12	12	13	12	14	13	12	12	18
8	MYANMAR	0	0	0	0	0	0	0	0	0	0
9	**INDONESIA**	**38**	**29**	**42**	**40**	**37**	**57**	**36**	**42**	**73**	**45**
10	TIMOR	0	0	0	0	0	0	0	0	0	0
11	KAMPUCHEA	0	0	0	0	0	0	0	0	0	0
12	LAOS	0	0	0	0	0	1	1	1	1	2
13	MALAYSIA	8	8	9	10	9	10	10	8	7	7
14	PHILIPPINES	0	0	0	0	0	0	0	0	1	1
15	THAILAND	1	2	2	2	3	2	4	5	5	5
16	VIETNAM	14	15	16	16	18	19	17	15	18	18
17	CHINA	260	291	275	269	296	302	347	363	334	350
18	MONGOLIA	4	4	5	6	6	5	5	4	4	7
19	FIJI	1	1	1	1	1	1	0	1	1	1
20	PAPUA NEW GUINEA	2	2	3	2	1	3	2	2	3	3
21	SAMOA (WEST)	0	0	0	0	0	0	0	0	0	0
22	SOLOMON ISLAND	0	0	0	0	0	0	0	0	0	0
23	TONGA	0	0	0	0	0	0	0	0	0	0
24	VANUATU	0	0	0	0	0	0	0	0	0	0
25	CHRISTMAS IS	0	0	0	0	0	0	0	0	0	0
26	COCOS IS	0	0	0	0	0	0	0	0	0	0
27	COOK IS	0	0	0	0	0	0	0	0	0	0
28	GUAM	0	0	0	0	0	0	0	0	0	0
29	KIRIBATI	0	0	0	0	0	0	0	0	0	0
30	NAURU	0	0	0	0	0	0	0	0	0	0
31	NEW CALEDONI	0	0	0	0	0	0	0	0	0	0
32	NIUE	0	0	0	0	0	0	0	0	0	0
33	POLYNESIA (FRENCH)	0	0	0	0	0	0	0	0	0	0
34	SAMOA (AMERICAN)	0	0	0	0	0	0	0	0	0	0
35	TOKELAU	0	0	0	0	0	0	0	0	0	0
36	TUVALU	0	0	0	0	0	0	0	0	0	0
37	WALLIS & FUT	0	0	0	0	0	0	0	0	0	0
38	BURUNDI	0	0	0	0	0	0	0	0	0	0

39	RWANDA	0	0	0	0	0	0	0	0	0	0
40	KENYA	17	13	22	21	25	30	22	24	25	45
41	TANZANIA	2	3	2	4	3	4	7	6	6	5
42	UGANDA	1	1	2	3	2	2	2	1	1	2
43	ZAIRE	3	1	3	2	2	2	2	2	0	1
44	ETHIOPA	3	2	1	2	1	3	2	2	2	3
45	SUDAN	15	13	15	14	16	14	12	12	13	5
46	MADAGASCAR	0	0	0	0	0	0	0	0	0	0
47	CAMEROON	1	1	0	0	3	2	2	3	2	2
48	GHANA	0	0	0	0	0	0	0	0	0	0
49	IVORY COAST	0	0	0	0	0	0	0	0	0	0
50	NIGERIA	4	3	2	1	2	1	1	1	0	0
51	ANGOLA	0	0	0	0	0	0	0	0	0	0
52	MALAWI	0	0	0	0	0	0	0	0	0	0
53	MOZAMBIQUE	1	2	2	3	3	4	2	2	2	1
54	ZAMBIA	1	0	0	0	0	1	0	1	1	1
55	ZIMBABWE	4	3	2	2	4	4	5	4	5	5
56	OTHER AFRICA	32	30	37	35	32	36	35	35	38	38
57	WEST ASIA/ NORTH AFRICA	232	263	323	371	375	417	384	505	373	390
58	LATIN AMERICA	299	314	332	342	364	390	435	437	429	441
59	OTHER ASIA	43	44	44	45	46	47	49	53	47	59
60	USSR	204	197	197	216	243	251	286	251	342	367
61	NORTH AMERICA	99	102	96	99	88	83	85	94	123	105
62	JAPAN	114	108	113	105	117	119	122	119	122	126
63	EUROPE	238	280	247	289	260	277	249	236	264	228
64	OTHER DEVELOPED	6	6	6	6	6	5	5	6	5	5
	WORLD—TOTAL	**2076**	**2219**	**2307**	**2475**	**2546**	**2644**	**2725**	**2871**	**2729**	**2935**

Source: Food and Agriculture Organisation data tapes, June 1994.

Table 3. Tea production and areas devoted to tea by three production sectors in Indonesia, 1992.

Sector	Total area (Hectares)	Percent of total production area	Total production (tonnes)	Percent of total production	Yield (Kg/ha/year)
Private	24 567	18.13	43 385	21	1766
Smallholder	55 590	41.00	51 754	17	931
Government	55 413	40.87	115 425	62	2083
TOTAL	135 570	100.00	210 564	100	not applicable

Source: ACIAR (1993).

Table 4. The average price of tea in different markets, US$/tonne.

YEAR	London Auction	Sri Lanka Auction (Colombo)	India Auction (Calcutta)	India Auction (Cochin)	Kenya Auction (Mombasa)
1989	2066	1531	2424	2116	1516
1990	2052	1787	2782	2297	1493
1991	1995	not available	2400	1760	1426

Source: FAO (1992).

During the next five years the Indonesian government plans to extend plantings of tea by 20 000 hectares. At a planting rate of 10 000 to 12 000 plants per hectare, there is a need to produce as many as 240 million plants during the next five years. Production of such a large number of plants from cuttings is not possible because of the shortage of superior stock plants and the slow growth of those plants. If superior clonal material is not available, it is likely that smallholders will continue to make new plantings from seed, and this will produce lower-yielding plants.

There is, however the potential to produce the very large number of superior plants required for this project through the application of plant tissue culture techniques. Traditional methods of propagation are inadequate to supply high-yielding plants in the required numbers. Tissue culture techniques provide the potential to produce the required numbers of plants and to breed new improved varieties.

This project is designed specifically to improve the socio-economic position of the smallholder tea grower in Indonesia. Smallholders own less than 2 hectares per grower. The yield per hectare in the smallholder tea sector is about 931 kilograms, compared with 1766 kg/ha in the private commercial sector and 2083 kg/ha in the Government sector. One reason for the very low rate of productivity of tea in the smallholder sector is that the plantings used by smallholders have usually been made from seed or inferior clones with low-yield potential and low resistance to disease.

1.2 The outline of the paper

This paper describes a project-development assessment of ACIAR project PN9317 entitled 'The application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia.' The paper is organised as follows. Section 2 briefly outlines the project and its objectives. Section 3 discusses the approach used in the evaluation of the project. Section 4 discusses the results of the project-development assessment, while section 5 makes some concluding remarks.

2 THE PROJECT AND ITS OBJECTIVES

Project PN9317 has two main components:

- *the use of micropropagation for rapid clonal propagation.*

The project will develop a method to produce a large number of green tea seedlings from an existing Indonesian or other selected high yielding clone. The project will adapt this method for the commercial production of tea plants. This will give the Indonesian, smallholder, green tea producers access to higher yield green tea seedlings

- *the development of a PN9317 higher yield green tea clone.*

The project will develop new varieties with attributes such as higher yields, disease resistance and specific leaf characteristics.

3 THE ELEMENTS OF THE CONCEPTUAL FRAMEWORK

This paper uses a standard economic-surplus framework (see Davis et al. 1987) in the economic evaluation of this project. This framework has the following components:

- linear supply and demand functions for tea;
- the after research shift in the supply function for tea;
- the before research and the after research equilibrium;
- the national producer and consumer benefits;
- the applicability of the new technology;
- initial, adaptation research lags and the adoption pattern;
- adoption of new technology;
- technological spillovers between countries;
- world price spillovers; and
- the initial research, adaptation and research extension costs.

The following sections discuss each one of these components in the context of this project development assessment.

3.1 Linear supply and demand functions for tea

The research-evaluation model used in the analysis is based on a linear demand function for tea and two supply functions: a supply function describing farm level supply of tea before research and a supply function describing farm level supply of tea after research in a given country or region.

Given the long lags from the time tea is planted to the time it yields output, the elasticity of supply for tea is low—as is the case for other perennial crops (for example coffee and rubber) (Henneberry, 1986). In the absence of better estimates, the supply and demand elasticities for coffee are used in the analysis to approximate the demand and supply elasticities for tea. Analyses that check on the sensitivity of the base case results to changes in these values are discussed in the sensitivity analyses section, section 4.3.

Research on a traded commodity in a country that is a significant producer of it could change the commodity's world or regional price. Research on tea in Indonesia could have such an effect.

3.2 The after-research shift in the supply function for tea

After research there is a vertical shift in the farmer's supply function. This distance is a measure of the unit-cost saving from research and is referred to by the symbol 'k'.

In this paper, the estimation of the unit-cost saving 'k' is based on a cost analysis of tea production in the Indonesian smallholder sector. The cost analysis involved the following steps:

- estimating the before-research, farm-level costs for smallholders;
- estimating the after-research, farm-level costs for smallholders; and

• estimating the unit-cost reduction and thus the vertical shift in the smallholder's supply function.

3.2.1 The unit cost of production before research

The Research Institute for Tea and Cinchona provided data on the farm level costs incurred by smallholder tea producers in Indonesia. This information is summarised in Table 5.

Table 5. A before research cost analysis of the production of tea in the smallholder sector in Indonesia—assuming tea trees last for 25 years and trees produce from year 4 onwards.*

Inputs by a smallholder	Unit cost	Year: 0	1	2	3	4	5	6	7	8	9
Cost of seedlings	$0.07	$852	$71	$0	$0	$0	$0	$0	$0	$0	$0
Labour (site preparation)	$2.13	$852	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour(planting)	$2.13	$202	$17	$9	$0	$0	$0	$0	$0	$0	$0
Labour (to apply fertilizers)	$2.13	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fertilizers)	$0.24	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (weed and pest control)	$2.13	$0	$469	$383	$162	$181	$181	$192	$181	$181	$181
Labour (maintenance)	$2.13	$0	$128	$43	$43	$43	$43	$160	$43	$43	$43
Labour (harvesting)	$2.13	$0	$0	$0	$4	$4	$4	$4	$4	$4	$4
Land rental costs	$30.00	$0	$30	$0	$30	$0	$30	$0	$30	$0	$0
Irrigation infrastructure	$0.00	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total establishment costs		$1,936	$714	$465	$239	$0	$0	$0	$0	$0	$0
Compounded establish-ment costs		$2,178	$773	$483	$239	$0	$0	$0	$0	$0	$0
Total compound establish-ment cost (compounded to start of production)					$3,673	$0	$0	$0	$0	$0	$0
Total maintenance costs						$258	$258	$386	$258	$258	$258
Total compounded mainten-ance costs (compounded to average life of a tea tree)					$3,663	$0	$0	$0	$0	$0	$0
Annuity of the establishment costs					$0	$262	$262	$262	$262	$262	$262
Annuity of the compounded maintenance costs					$0	$261	$261	$261	$261	$261	$261
Annual per hectare cost (= sum of the two annuities)				$0	$523	$523	$523	$523	$523	$523	$523
Output/ha—experimental results				NA							
Field/ experimental results				NA							
Output/ha of tea					0	931	931	931	931	931	931
Unit cost per kg of tea					$0	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56

*Total input costs per hectare in $A, 1993.

Table 5 cont'd. A before research cost analysis of the production of tea in the smallholder sector in Indonesia—assuming tea trees last for 25 years and trees produce from year 3 onwards.*

Inputs by a smallholder	Year: 14	15	16	17	18	19	20	21	22

Cost of Seedlings	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (site preparation)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour(planting)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (to apply fertilizers)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fertilizers)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (weed and pest control)	$192	$181	$181	$181	$181	$181	$181	$192	$181
Labour (maintenance)	$160	$43	$43	$43	$43	$43	$43	$160	$43
Labour (harvesting)	$4	$4	$4	$4	$4	$4	$4	$4	$4
Land rental costs	$30	$30	$30	$30	$30	$30	$30	$30	$30
Irrigation infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Establishment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0
Compounded Establishment Costs	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total compound establishment cost (Compounded to start of production)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total maintenance costs	$386	$258	$258	$258	$258	$258	$258	$386	$258
Total compounded maintenance costs (compounded to average life of a tea tree)									
Annuity of the establishment costs	$262	$262	$262	$262	$262	$262	$262	$262	$262
Annuity of the compounded maintenance costs	$261	$261	$261	$261	$261	$261	$261	$261	$261
Annual per hectare cost (=sum of the two annuities)	$523	$523	$523	$523	$523	$523	$523	$523	$523
Output /ha—experimental results	NA								
Field/experimental results	NA								
Output/ha of tea	931	931	931	931	931	931	931	931	931
Unit cost per kg of tea	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56

*Total input costs per hectare in $A, 1993.

The smallholder tea producer incurs two types of costs: establishment costs and maintenance costs.

Establishment costs

Establishment costs are incurred in the first four years of tea production before the smallholder can generate output from the tea plants. Estimates by The Research Institute for Tea and Cinchona, Bandung (personal communication, 1993) indicate that the establishment costs include the following:

- the costs of seedlings for tea plants—a smallholder requires about 12 000 plantings per hectare in the initial year (year 0 in Table 5) and an additional 1000 plantings per hectare in year 1.
- the labour costs for site preparation—400 person days are required;
- labour for planting the tea trees—95 person days per hectare are required for this task.
- inputs for weed and pest control—the smallholder requires 220 person days per hectare in year 1, 180 person days in year 2 and 76 person days in year 3 of the tea plantation establishment phase for weed and pest control. The assumption is that before research almost no chemicals are used by the smallholder in weed and pest control.
- the smallholder requires 60 person days per hecatre in year 1 and 20 person days per hectare in year 2 and year 3 for maintenance purposes.

It is assumed that, before research, the low-yield varieties that smallholders currently use do not need and probably do not respond well to fertilisers. Thus the cost of fertilisers in the establishment period and for the life of the tea trees is zero.

In year t, t = 0,1,…,4; the establishment cost is the sum of the costs incurred in that year. These costs are converted into annual flows as follows. First the costs are compounded to the start of production. Let E_t be the establishment cost incurred in year t. Furthermore let E_{ct} be the compounded establishment cost in year t. Then E_{ct} is given by the following equation:

$$E_{ct} \quad = \quad E_t \, (1 + r)^{[t^* - t]} \qquad (1)$$

where: r is the compounding factor; and
t* is the year in which the smallholder first gets a tea crop from the plantation.

Let A_e be the amortised value over the life of a tree, of the compounded establishment costs. The amortised value of the establishment costs is estimated using the following equation.

$$A_e = [\Sigma_t E_{ct}(1 + r)]^T r/\{[(1 + r)^T - 1] \quad (2)$$

where: r is the rate of interest;
$?_t E_{ct}$ is the total compounded establishment cost;
t is equal to 0, …, t*; and
T is the productive life of a tea tree (tea trees last about 25 years).

Maintenance costs

Maintenance costs are assumed to be incurred from the time the tea plantation is fully established and the tea plantings are mature. Tea takes about four years to start generating output. Thus the costs incurred from year 4 onwards tend to be of a maintenance nature. These include:

- weed and pest control—about 85 person-days/ha are required by the smallholder per year for this purpose;
- maintenance costs (pruning, thinning and spraying)—the smallholder needs about 20 person days in year 4 and 5 for this purpose. Three or four years after first plucking the tea bushes are pruned. Plucking can be started again 3 months after pruning. This maintenance rotation is adhered to over the 25 years of life of the tea plantation.
- harvesting costs—the smallholder starts harvesting tea from the plantation in year 4, and requires about 2 person days/ha for this task. Despite the need for pruning in year 6 or 7, the harvesting costs do not change because harvesting continues shortly after pruning—usually no more than 3 months after pruning.

Let M_t be the maintenance cost incurred in year t. Furthermore, let M_{t*} be the compounded value in year t* of maintenance costs over the 25 years of the life of a tea plantation. Then M_{t*} is given by the following equation:

$$M_{t*} = ?_t\{M_t(1 + r)^{[t* - t]}\} \quad (3)$$

where: t = t*,…, T

Let A_m be the annuity of the before-research, compounded, maintenance costs. This annuity is given by the following equation:

$$A_m = [?_t M_t*(1 + r)]^T r/\{[(1 + r)^T - 1] \quad (4)$$

Fixed costs: land

In the analysis it is assumed that the annual rental value, R, of a hectare of land used for tea production by smallholders in Indonesia is about $A30 (S. Dharmadi, personal communication, Research Institute for Tea and Cinchona). The rental value of land is not affected by research.

Irrigation water costs

Before research, there are no irrigation costs.

Other costs: management input

Before research, management inputs, M, are minimal. Farmers rely on traditional practices and thus M is assumed to equal zero.

Let Q_0, be the before-research yield of tea per hectare per year, and the subscript 'b' denote before-research values. Then the unit cost of producing tea, U_b, before research is estimated by the following equation:

$$U_b = [A_{eb} + A_{mb} + R_b + M_b]/Q_0 \tag{5}$$

Table 5 summarises the estimates of costs of producing tea in the Indonesian smallholder sector before research.

3.2.2 The unit cost of tea production after research

Equations (1)–(5) are applied without modification to estimate the annual flow equivalents of the after-research establishment and maintenance costs.

When estimating the unit cost of tea production after research, the project scientists were asked to estimate the smallholder's farm level costs after research. The important issue was to determine at this stage whether new, high-yielding tea varieties use different levels of inputs, or new inputs, which lead to different costs compared to the before-research, farm-level technology.

Estimates by the Research Institute for Tea and Cinchona, Bandung (personal communication, 1993) indicate that the differences between the before-research and after-research production costs are:

- the seedlings for the higher-yielding variety are likely to be more costly than for the traditional variety;
- smallholders will need to use more fertilisers and pesticide inputs for the higher-yielding variety than for the traditional variety. However, smallholders have started using integrated pest management thus relying less on chemicals in the control of weeds and pests.

The cost for equipment is very small. For spraying, smallholders borrow a sprayer from the cooperative and pay a small amount to cover maintenance costs for the sprayer.

Irrigation water costs after research

Whereas before research there are no irrigation costs, after research the high yielding varieties require a higher level of water input. It is estimated that the smallholder requires about 25 person-days in the initial year, 20 person-days in year 1 and 2 and then 10 person-days/ha from then on for irrigation purposes.

Management input costs after research

Whereas before research management inputs, M, are minimal, this is not so after research. The smallholder has to decide when to apply fertilisers, how much fertiliser to apply, and when to irrigate and for how long, to maximise yields from the high-yielding clones.

To estimate the management costs that a smallholder is likely to incur after research, use is made of cost estimates from Barlow and Tomich (1991) for what they refer to as the dispersal system in Indonesia. Under the dispersal system, the Indonesian government assisted smallholders by providing them with extension services for tree crops. This included distributing improved planting materials and providing advice on the use of modern inputs, including fertilisers. Barlow and Tomich (1991) estimated that the dispersal system cost $A120–$A170 per improved hectare to bring a tree crop to maturity. This estimate is used as a proxy for the additional management inputs that a small holder has to incur after research.

The project proposes developing a green tea variety that can increase smallholder yields from the current levels of about 1000 kilograms per hectare to about 4000 kilograms per hectare. However, from the studies of Davidson and Martin (1965), and Dillon (1968), the average smallholder is likely to realise less than 60 per cent of the experimental yields.

The total cost per hectare increases, but the production cost per kilogram of tea decreases because each hectare produces a higher volume of output after research. Thus

$$U_a = [A_{ea} + A_{ma} + R_a + M_a]/Q_a \qquad (5)$$

where the subscript 'a' refers to after-research values.

The difference between U_b, the production cost per kilogram of tea before research and U_a, the cost of production per kilogram of tea after research gives the cost reduction due to research on the high yielding variety of tea.

Variable	*Before research*	*After research*	*Change*	*Percent change*
Estimated cost of production per hectare	$A523	$A1216	+$A693	133%
Green tea yield per hectare (tonnes)	931	2400	+1469	158%
Unit cost of production (per kg)	$A0.56	$A0.51	–$A0.05	9.8%

Overall, even applying the conservative assumption in the analysis, this project is likely to lead to a 9.8% reduction in smallholder production costs as shown in Table 6.

Table 6. An after research cost analysis of the production of tea in the smallholder sector in Indonesia—assuming tea trees last for 25 years and trees produce from year 4 onwards.*

Inputs	Unit cost	Year: 0	1	2	3	4	5	6	7	8	9
Cost of Seedlings	$0.15	$1,800	$150	$0	$0	$0	$0	$0	$0	$0	$0
Labour (site preparation)	$2.13	$852	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (planting)	$2.13	$202	$17	$9	$0	$0	$0	$0	$0	$0	$0
Labour (to apply fertilizers)	$2.13	$21	$51	$64	$45	$45	$45	$45	$45	$45	$45
Chemicals	$0.24	$60	$108	$108	$96	$120	$156	$180	$180	$180	$180
Labour (weed and pest control)	$2.13	$0	$469	$383	$162	$181	$181	$192	$192	$192	$192
Chemicals	$7.50	$0	$60	$90	$113	$135	$135	$135	$135	$135	$135
Labour (maintenance)	$2.13	$0	$128	$43	$43	$43	$43	$160	$160	$160	$160
Irrigation costs	$2.13	$53	$43	$43	$21	$21	$21	$21	$21	$21	$21
Labour (harvesting)	$2.13	$0	$0	$0	$4	$4	$4	$4	$4	$4	$4
Land rental costs	$30.00	$30	$30	$30	$30	$30	$30	$30	$30	$30	$30
Irrigation infrastructure	$0.00	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Management	$24.29	$24	$24.29	$24	$24	$24	$24	$24	$24	$24	$24
Total establishment costs per year	NA	$3,043	$1,079	$793	$538	$0	$0	$0	$0	$0	$0
Compounded establishment costs (Compounded to start of production)		$3,423	$1,168	$825	$538	$0	$0	$0	$0	$0	$0
Total compounded establishment costs					$5,953	$0	$0	$0	$0	$0	$0
Total maintenance cost per year						$603	$639	$791	$791	$791	$791
Compounded maintenance costs					$11,110	$0	$0	$0	$0	$0	$0
Annuity of the establishment costs						$424	$424	$396	$396	$396	$396
Annuity of the compounded maintenance costs						$792	$792	$792	$792	$792	$792
Annual per hectare cost (=sum of the two annuities, production starts in year 4)						$1,216	$1,216	$1,188	$1,188	$1,188	$1,188
Output per hectare—experimental results						4000	4000	4000	4000	4000	4000
Proportion of experimental results realised on field						0.60	0.60	0.60	0.60	0.60	0.60
Output/ hectare of green tea						2400	2400	2400	2400	2400	2400
Unit cost before research ($A/kg)						$0.56	$0.56	$0.56	$0.56	$0.56	$0.56
Unit cost after research ($A/kg)						$0.51	$0.51	$0.51	$0.51	$0.51	$0.51
Per cent decrease in unit cost						9.77%	9.77%	9.77%	9.77%	9.77%	9.77%
Unit-cost reduction per tonne						$54.862					
Unit-cost reduction per kg						$0.05					

*Total input costs per hectare in $A, 1993.

Table 6 Cont'd. An after research cost analysis of the production of tea in the smallholder sector in Indonesia—assuming tea trees last for 25 years and produce from year 3 onwards.*

Inputs	Year: 14	15	16	17	18	19	20	21	22
Cost of Seedlings	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (site preparation)	$0	$0	$0	$0	$0	$0	$0	$0	$0
Labour (planting)	$0	$0	$0	$0	$0	$0	$0	$0	$0

Labour (to apply fertilizers)	$45	$45	$45	$45	$45	$45	$45	$45	$45
Chemicals	$180	$180	$180	$180	$180	$180	$180	$180	$180
Labour (weed and pest control)	$192	$192	$192	$192	$192	$192	$192	$192	$192
Chemicals	$135	$135	$135	$135	$135	$135	$135	$135	$135
Labour (maintenance)	$160	$160	$160	$160	$160	$160	$160	$160	$160
Irrigation costs	$21	$21	$21	$21	$21	$21	$21	$21	$21
Labour (harvesting)	$4	$4	$4	$4	$4	$4	$4	$4	$4
Land rental costs	$30	$30	$30	$30	$30	$30	$30	$30	$30
Irrigation infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0
Management	$24	$24	$24	$24	$24	$24	$24	$24	$24
Total establishment costs per year									
Compounded establishment costs (compounded to start of production)									
Total compounded establishment costs									
Total maintenance cost per year	$791	$791	$791	$791	$791	$791	$791	$791	$791
Compounded maintenance costs									
Annuity of the establishment costs	$396	$396	$396	$396	$396	$396	$396	$396	$396
Annuity of the compoun-ded maintenance costs	$792	$792	$792	$792	$792	$792	$792	$792	$792
Annual per hectare cost (=sum of the two annuities)	$1,188	$1,188	$1,188	$1,188	$1,188	$1,188	$1,188	$1,188	$1,188
Output per hectare—experimental results	4000	4000	4000	4000	4000	4000	4000	4000	4000
Proportion of experimental results realised on field	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Output/ hectare of green tea	2400	2400	2400	2400	2400	2400	2400	2400	2400
Unit cost before research ($A/kg)	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56	$0.56
Unit cost after research ($A/kg)	$0.51	$0.51	$0.51	$0.51	$0.51	$0.51	$0.51	$0.51	$0.51
Unit-cost reduction per tonne		$54.862	$54.862	$54.862	$54.862	$54.862	$54.862	$54.862	$54.862
Unit-cost reduction per kg		$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05	$0.05
Per cent decrease in unit cost	9.77%	9.77%	9.77%	9.77%	9.77%	9.77%	9.77%	9.77%	9.77%

*Total input costs per hectare in $A, 1993.

3.3. The before-research and after-research equilibrium.

The data on production levels before research are from FAO (1994). This data is summarised in Table 1 for the regions and countries covered by the analysis in this paper. The FAO data in Table 1 suggests that Australia does not produce tea. However, Wood et al. (1992) state that the total area planted to tea in Australia is around 900 ha with approximately 700 ha being in north Queensland. The volume of tea production in 1990 in Queensland was 773 tonnes. The remaining area planted to tea is in New South Wales, but production from that state is still very small since the largest plantings have been made only in the last two to three years and are not yet mature (Wood et al. 1992). In this paper the estimate of 773 tonnes from Wood et al. (1992) is used to represent Australia's production level.

Based on data supplied by the Research Institute for Tea and Cinchona, Bandung (personal communication, 1993), it is estimated that the farm-gate price of tea in Indonesia is about $A0.625 per kilogram.

The next section briefly discusses the equations used in estimating the rate of return to the project.

3.4. The annual producer and consumer benefits.

The total annual benefit to research is equal to the change in economic surplus (ES) which is estimated by the following equation:

$$?ES \quad = \quad kQ_0 + 0.5\,k\,(Q_1 - Q_0) \qquad (6)$$

The total benefit from a research-induced supply curve is equal to the cost savings on the initial output Q_0 plus the economic surplus from the increment to production and consumption of the commodity. In equation (6), the cost savings on Q_0 is equal to Q_0 times the unit-cost reduction, k.

Solving for Q_1 in terms of the parameters of the demand and supply functions and substituting this in equation (6) leads to the following algebraically alternative but numerically equivalent expression for the total benefit:

$$?ES \quad = \quad kQ_0 + 0.5(Q_0/P_0)[\varepsilon_s\varepsilon_d k^2/(\varepsilon_S + \varepsilon_d)] \qquad (7)$$

where k is the absolute value of the cost reduction

ε_S is the elasticity of supply

ε_d is the elasticity of supply

The consumer surplus is given by equation (8):

$$?CS \quad = \quad Q_0k\varepsilon_s/(\varepsilon_s + \varepsilon_d) + 0.5(Q_0/P_0)\,[k_s/(\varepsilon_s + \varepsilon_d)]^2\varepsilon_d \qquad (8)$$

The producer surplus is in turn given by equation (9)

$$?PS = Q_0k[1 - \varepsilon_s/(\varepsilon_s + \varepsilon_d)] + 0.5(Q_0/P_0)\, k^2[1 - \varepsilon_s/(\varepsilon_s + \varepsilon_d)][k_s/(\varepsilon_s + \varepsilon_d)]\varepsilon_d \quad (9)$$

Equations (6)–(9) are for a closed economy. However, as Table 1 and Table 2 indicate, tea is a traded commodity. Thus an economic evaluation of a project focusing on tea needs to take into account the international traded nature of the commodity. Thus the evaluation uses generalisations of equations (6)–(9) which were developed by Davis et al. (1987).

3.5 The applicability of the new technology in Indonesia and Australia

This element of the framework requires the estimation of the proportions of the agricultural production which are likely to be affected by the research in the different countries. For example if a variety is developed that is drought resistant, and in a given country only ten percent of output is normally affected by drought, then Q_0 in equations (6)–(9) should be ten percent of total production. Using total national production will overstate the benefits of research.

The technology to be developed in the project is applicable to both black and green tea since the major difference between these two types of tea is in terms of postharvest processing of the tea leaves. The distinction between green and black tea is that black tea is fermented—the leaves are withered in the factory and this gives the tea its characteristic black colour. Green tea, on the other hand, is heat treated as soon as it arrives at the factory and the dried tea retains its green colour (ACIAR, 1993). However, this project is designed specifically to improve the socio-economic position of Indonesian smallholder tea producers who account for about 17% of total production in Indonesia. The project is intended to raise yields per smallholder hectare to the levels comparable to those in the commercial-private and government sectors. While the technology is applicable to commercial-private and government-sector producers of tea in Indonesia, the relatively higher yields already achieved in these sectors may reduce their impetus to adopt the new technology.

3.6. Initial research and adaptation research lags and the adoption pattern for the new technology

In evaluating the net impact of this research project account was taken of four time lags:

- the research lag—the time between the start of the project and the completion of research;
- the adaptive research lag period—this corresponds to the time needed to trial the new higher yielding tea varieties before they are released to farmers;
- adoption pattern—The release of a high-yielding tea variety does not necessarily mean that the variety is used by farmers. Adoption levels may, in the initial periods, be very low and may grow slowly as farmers become familiar with a cultivar; and
- ceiling adoption level—this gives the maximum proportion of farmers that are likely to adopt the new technology. It is rare that all farmers will adopt a new technology.

Table 7 summarises the assumptions made about these different lags in this paper for the higher yielding variety. The analysis is very conservative for adoption rates. This to some extent reflects the literature on adoption of high yielding varieties. For example Barlow and Tomich (1991, p. 38) say the following:

> 'The next step in transformation through yield improvements entails introducing higher yielding planting materials. Because this requires inputs external to tree crop communities, it is far harder to achieve. The prime factors preventing smallholders from moving to better tree varieties are shortage of cash and the absence of private long-term credit, fragmented information markets with virtually no agricultural extension, and the bottlenecks in the supply of new materials.'

While this project addresses the issue of availability of planting materials, it is not clear that the other bottlenecks will receive the attention they need to ensure higher adoption rates.

In this paper, it is assumed that only Indonesia and Australia, the two countries that collaborate in the project, will adopt the research results. Thus the costs of producing tea will fall in these two countries. Since tea is a traded product, this paper applies a traded-good, multi-country model which makes it possible to identify those countries that lose and those that gain as a result of this new technology.

Table 7. Assumptions about adoption of new high yielding variety of green tea.

Comment	Year	Percent of smallholders using the high yield green tea variety
Start research	1994	0
	1995	0
	1996	0
	1997	0
Complete PN9317 initial research	1998	0
	1999	0
	2000	0
	2001	0
Complete PN9317 adaptive research	2002	1%
	2003	2%
	2004	3%
	2005	4%
	2006	5%
	2007	6%
	2008	7%
	2009	8%
	2010	9%
	2011	10%
	2012 to 2024	10%

3.7. Technological spillovers between countries and regions within a country;

If the high yielding tea varieties developed for Indonesia can be grown in another region, then there is a potential technological spillover. However, the research impact in that other region is often lower than the impacts in the region for which the technology was developed. For example, the yield may be lower than in the original area but nonetheless higher than for the traditional cultivars in the two regions. Furthermore, the changes in input use and often the corresponding costs may be different between the two regions.

This paper while acknowledging that there are technological spillover effects from this research project, does not explicitly estimate them. Thus, estimates reported in the paper are likely to be conservative.

3.8. The world price spillovers

There is international trade in tea and thus there are price related spillovers to those regions that trade in tea. These spillovers are obtained through changes in the world or regional price of the commodity. The shift in the supply function in the country or region where research is undertaken leads to changes in the world or regional price. This, in turn, generates benefits to both the country where research was undertaken and to other countries that trade in the commodity targeted in the research project. This phenomenon of research in one region or country leading to benefits in some other region through changes in the regional or world prices of the commodity, is the so-called price spillover effect. Generally, producers in exporting countries who do not collaborate in the development of the new technologies are likely to lose, while consumers in all countries trading in the commodity are likely to gain from research.

3.9. The initial research and adaptation costs.

Having estimated the benefit side of a research project, it is necessary to determine the costs of research. The initial research costs are given in Table 8. These costs are incurred in the first 3 years of the project. It is common for projects that develop new cultivars or varieties of agricultural crops to require at least 3 years after the initial research is completed to try the new variety in different situations. This period after the initial research period addresses adaptive research issues. Table 8 also shows the adaptive research costs.

Table 8. Flow of benefits accruing to Australia, collaborating countries and the rest of the world: The application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia. (PN9317).*

Comment	Year number	Year	Australia	Indonesia	Rest of the world	Total benefits
Start project	1–4	1994	$0	$0	$0	$0
	2	1995	$0	$0	$0	$0
	3	1996	$0	$0	$0	$0
	4	1997	$0	$0	$0	$0
Complete research	5	1998	$0	$0	$0	$0
	6	1999	$0	$0	$0	$0
	7	2000	$0	$0	$0	$0
	8	2001	$0	$0	$0	$0
End adaptation research	9	2002	$0	$0	$0	$0
Start adopting new	10	2003	$0	$14	$18	$33
technology	11	2004	$0	$29	$36	$65
	12	2005	$0	$43	$54	$98
	13	2006	$0	$58	$72	$131

	14	2007	$1	$72	$90	$163
	15	2008	$1	$87	$108	$196
	16	2009	$1	$101	$126	$228
	17	2010	$1	$116	$144	$261
	18	2011	$1	$130	$162	$294
Ceiling adoption	19	2012	$1	$145	$180	$326
	20	2013	$1	$145	$180	$326
	21	2014	$1	$145	$180	$326
	22	2015	$1	$145	$180	$326
	23	2016	$1	$145	$180	$326
	24	2017	$1	$145	$180	$326
	25	2018	$1	$145	$180	$326
	26	2019	$1	$145	$180	$326
	27	2020	$1	$145	$180	$326
	28	2021	$1	$145	$180	$326
	29	2022	$1	$145	$180	$326
End of planning horizon	30	2023	$1	$145	$180	$326
Present value		$4	$476	$593	$1,073	$492
IRR					13%	

*$A'000, 1993.

4. PROJECT-DEVELOPMENT ASSESSMENT RESULTS

4.1 The base case

In the estimation of the net present value and the internal rate of return of this project, a 30 year planning horizon and a 8 per cent discount rate are assumed. The discount rate of 8% is based on a recommendation by the Australian Government Department of Finance. Table 8 summarises the benefits and cost flows generated by the project under the following base case assumptions:

The key assumptions made in the project-development assessment.

Variable		*Value*
Production		See Table 1
Farm gate price/tonne:	Australia	$A5000
	Rest of the world	$A625
Elasticity of supply:	Indonesia	1.05
	Australia	0.00
	Rest of the world	0.00 to 1.10
Elasticity of demand:	Indonesia	0.50
	Australia	0.20
	Rest of the world	0.00 to 0.50
Cost reduction due to research $A/Mt		$A163
Applicability of high yielding tea variety:	Australia	30%
	Indonesia	17%
Adoption ceiling		10%
Planning horizon		30 years
Time for initial research		3 years
Total initial research cost (1994–1997)		$A447 618
Time for the evaluation of higher yielding tea varieties		4 years
Cost of evaluating higher yielding tea varieties, per annum		$A40 000
Discount rate		8 % pa

Under these assumptions, the project is estimated to increase economic surplus by about $A1.073 millions, of which $A 0.476 million are estimated to accrue to Indonesian smallholders, $A0.004 million to accrue to Australia and $A0.593 million to accrue to the rest of the world. The low level of benefits accruing to Australia is because of the small scale of the tea industry in Australia.

In Table 8, the column headed research costs includes costs incurred by ACIAR, by Indonesia and the Queensland University of Technology. The costs in that column from year 5 to year 9 of the planning horizon are the costs of the adaptive research work for the new tea varieties, as estimated by the project scientists.

Overall, the project is estimated to generate an internal rate of return of 13 per cent and a net present value of $A0.582 million.

The project focuses on smallholder tea producers in Indonesia. This project aims to develop plant tissue culture techniques to make it possible to produce clonal material suited to green tea production and having higher yields than planting materials currently available to Indonesian smallholders. Figure 1 puts the strategy for yield improvements in the context of the spectrum of yield-increasing strategies available in Indonesia. The project is addressing the issue of increasing yields using what Barlow and Tomich (1991) refer to as the most difficult strategy.

Figure 1 Yield increasing strategies available to smallholders in the green tea sector in Indonesia

No	Strategy description	Yield on small holder plots	Impact on current practice	Added inputs required	Level of difficulty
		(kg/ha/yr)	(per cent)		
1.	Do nothing: continue with current best practice	931	0	Nil	Easy
2.	Technical change generated from within smallholder sector	931(a)	30 -40(b)	Nil	Already exhausted in Indonesia
3	Use seeds and cuttings from better performing traditional trees in smallholders vicinity	931(a)	10-15(c)	Nil	Already exhausted in Indonesia
4	Introduce higher yielding planting material	4000 (experimental result) (d)	400 (experimental result)(d)	Additional cash to buy high yielding seedlings; Fertilisers; Pesticides; Irrigation	Most difficult, but it seems it is the only option left

Notes

(a) The assumption is that strategies 2 and 3 have been implemented already. Barlow and Tomich (1991, p. 37-38) claim that these strategies have been implemented by smallholders in Indonesia over the last 40 to 50 years. Thus while they had some impact on yields in the past, they have been exhausted.

(b) These are impacts on yields attainable in what Barlow and Tomich (1991) refer to as the 'initial land-extensive' phase of tree crop production.

(c) These are impacts on yields attainable in what Barlow and Tomich (1991) refer to as the 'initial land-extensive' phase of tree crop production.

(d) These are the impacts that project PN9317 aims at the experimental stage.

Source: Based on Barlow and Tomich(1991)

Despite the potential difficulties associated with attempts to encourage smallholders to adopt higher-yielding tree crop varieties, Table 8 suggests that ACIAR project 9317 is likely to generate economic benefits in excess of the research costs invested in it by ACIAR, the Queensland University of Technology and Indonesia.

Table 8. Flow of benefits accruing to Australia, collaborating countries and the rest of the world: The application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia. (PN9317).*

Comment	Year number	Year	Australia	Indonesia	Rest of the world	Total benefits
Start project	1–4	1994	$0	$0	$0	$0
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	3	1996	$0	$0	$0	$0
	4	1997	$0	$0	$0	$0
Complete research	5	1998	$0	$0	$0	$0
	6	1999	$0	$0	$0	$0
	7	2000	$0	$0	$0	$0
	8	2001	$0	$0	$0	$0
End adaptation research	9	2002	$0	$0	$0	$0
Start adopting new	10	2003	$0	$14	$18	$33
technology	11	2004	$0	$29	$36	$65
	12	2005	$0	$43	$54	$98
	13	2006	$0	$58	$72	$131
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	16	2009	$1	$101	$126	$228
	17	2010	$1	$116	$144	$261
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	20	2013	$1	$145	$180	$326
	21	2014	$1	$145	$180	$326
	22	2015	$1	$145	$180	$326
	23	2016	$1	$145	$180	$326
	24	2017	$1	$145	$180	$326
	25	2018	$1	$145	$180	$326
	26	2019	$1	$145	$180	$326
	27	2020	$1	$145	$180	$326
	28	2021	$1	$145	$180	$326
	29	2022	$1	$145	$180	$326
End of planning horizon	30	2023	$1	$145	$180	$326
Present value		$4	$476	$593	$1,073	$492
IRR					13%	

*$A'000, 1993.

Figure 2 is a graph of the flow of benefits under the base-case scenario. The shape of the graph is dependent on the adoption pattern assumed, the estimates of benefits and the costs of research. The flattening of the graph in the later years reflects the fact that in the later phases of the adoption path, a ceiling adoption level is reached.

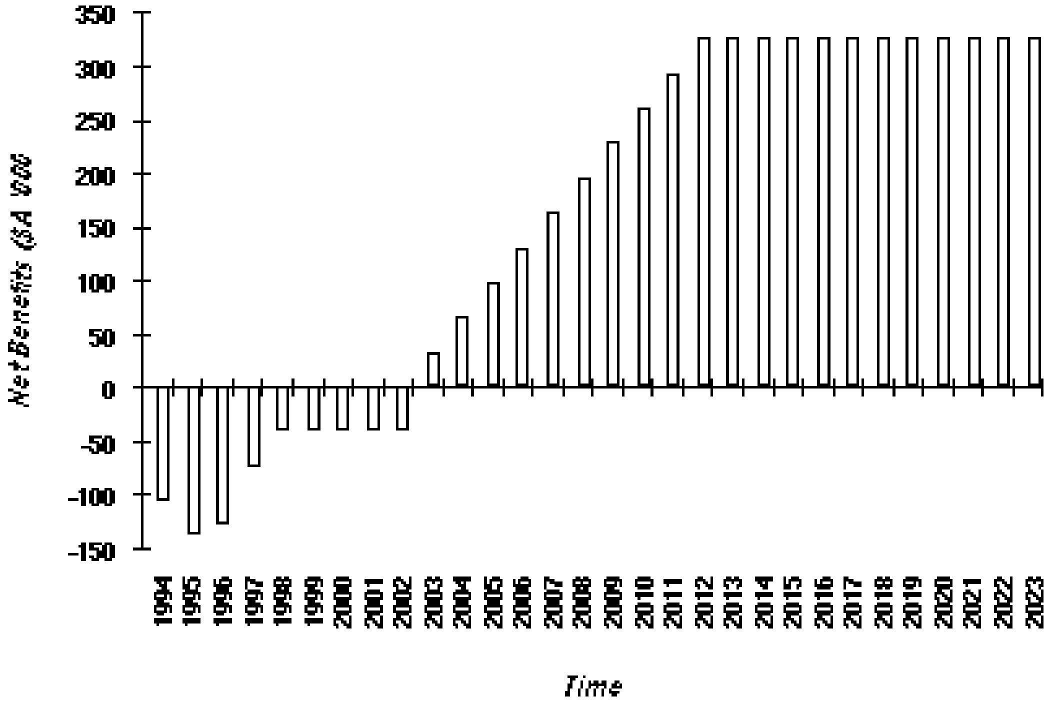

Figure 2. The flow of discounted net benefits over 20 years from the adoption of higher yielding tea varieties (ACIAR PN9317).

4.2 The distribution of benefits

The distribution of benefits from research has been discussed briefly in the preceding section. Table 9 shows a more detailed breakdown of the distribution of benefits between countries and between producers and consumers—within each country.

Table 9. The distribution of discounted (over 30 years at 8 % p.a) benefits under the base case scenario (ACIAR PN9317) The application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia.*

	Country or region	Producer	Consumer	Total	Comment
1	AUSTRALIA	$3	$1	$4	Importer
2	BANGLADESH	$0	$0	$0	Exporter
3	BHUTAN	$0	$0	$0	Non-trader
4	INDIA	($994)	$995	$1	Exporter
5	NEPAL	($2)	$4	$2	Importer
6	PAKISTAN	$0	$0	$0	Importer
7	SRI LANKA	($324)	$323	($1)	Exporter
8	MYANMAR	$0	$0	$0	Non trader
9	INDONESIA	$441	$35	$476	Major exporter
10	TIMOR/EAST T	$0	$0	$0	Non trader
11	KAMPUCHEA	$0	$0	$0	Non trader
12	LAOS	$0	$0	$0	Non trader
13	MALAYSIA	($7)	$14	$7	Importer
14	PHILIPPINES	$0	$0	$0	Importer
15	THAILAND	$0	$0	$0	Non-trader
16	VIETNAM	($43)	$43	$0	Exporter
17	CHINA	($751)	$752	$1	Exporter
18	MONGOLIA	$0	$0	$0	Importer
19	FIJI	$0	$0	$0	Importer

20	PAPUA NEW GUINEA	($11)	$11	$0	Exporter
21	SAMOA (WEST)	$0	$0	$0	Non trader
22	SOLOMON ISLAND	$0	$0	$0	Non trader
23	TONGA	$0	$0	$0	Non trader
24	VANUATU / NE	$0	$0	$0	Non trader
25	CHRISTMAS IS	$0	$0	$0	Non trader
26	COCOS IS	$0	$0	$0	Non trader
27	COOK IS	$0	$0	$0	Non trader
28	GUAM	$0	$0	$0	Non trader
29	KIRIBATI	$0	$0	$0	Non trader
30	NAURU	$0	$0	$0	Non trader
31	NEW CALEDONI	$0	$0	$0	Non trader
32	NIUE	$0	$0	$0	Non trader
33	POLYNESIA (FRENCH)	$0	$0	$0	Non trader
34	SAMOA (AMERICAN)	$0	$0	$0	Non trader
35	TOKELAU	$0	$0	$0	Non trader
36	TUVALU	$0	$0	$0	Non trader
37	WALLIS & FUT	$0	$0	$0	Non trader
38	BURUNDI	($6)	$6	$0	Exporter
39	RWANDA	($18)	$18	$0	Exporter
40	KENYA	($274)	$275	$1	Exporter
41	TANZANIA	($28)	$28	$0	Exporter
42	UGANDA	($9)	$9	$0	Exporter
43	ZAIRE	($4)	$4	$0	Exporter
44	ETHIOPA	($1)	$1	$1	Importer
45	SUDAN	($6)	$11	$6	Importer
46	MADAGASCAR	$0	$0	$0	Non trader
47	CAMEROON	($4)	$4	$0	Exporter
48	GHANA	$0	$0	$0	Non-trader
49	IVORY COAST	$0	$0	$0	Non-trader
50	NIGERIA	$0	$0	$0	Non trader
51	ANGOLA	$0	$0	$0	Non trader
52	MALAWI	($54)	$54	$0	Exporter
53	MOZAMBIQUE	($2)	$2	$0	Exporter
54	ZAMBIA	$0	$0	$0	Non trader
55	ZIMBABWE	($24)	$24	$0	Exporter
56	OTHER AFRICA	($27)	$54	$27	Importer
57	W.ASIA/ NORTH AFRICA	($232)	$462	$230	Exporter
58	LATIN AMERICA	($662)	$666	$3	Exporter
59	OTHER ASIA	($31)	$63	$31	Importer
60	USSR	($160)	$320	$159	Importer
61	NORTH AMERICA	$0	$0	$0	Importer
62	JAPAN	($125)	$250	$125	Importer
63	EUROPE	$0	$1	$0	Importer
64	OTHER DEVELOPED	$0	$0	$0	Importer
	WORLD TOTAL	**($3,355)**	**$4,429**	**$1,073**	

*($A, 000, 1993).

If the technology proposed succeeds, it is likely to reduce the cost of producing tea in Indonesia. This in turn is likely to lead to an increased supply of tea. Consequently the world price of tea is likely to fall. This fall in the world price of tea will advantage consumers of tea worldwide.

The technology is beneficial to producers in Indonesia and Australia where the technology will be developed and adopted. Most of the benefits accruing in Indonesia will accrue to Indonesian smallholders who account for about 17% of tea production in Indonesia.

Producers in the rest of the world are assumed not to have access to the technology to be developed under this project. These producers are likely to lose as a result of the project—at least in the short run before the technology spills over to those countries.

4.3. Sensitivity analyses

The estimates of benefits to research discussed in this paper depend on a number of assumptions. The impact of research itself is uncertain, so are other parameters used in the evaluation. This section discusses a set of analyses to assess the extent to which variations in key assumptions are likely to affect the net benefits from research. The assumptions assessed are the following:

- the cost of seedlings for high yielding variety;
- adoption rates for the high yielding varieties;
- realised yields; and
- the elasticity of demand and supply for tea in Indonesia.

Table 10 summarises the results from these sensitivity analyses.

Table 10. Sensitivity analyses in the assessment of PN9317: The application of plant tissue culture techniques to the propagation and breeding of tea in Indonesia.

	Base case	Realised yield equal to 70% of experimental result	Low elasticity of supply	Cost of seedlings equal to 1.5 times the base case cost of seedlings
Changing Cells:				
Elasticity of supply	1.05	1.05	0.38	1.05
Cost reduction in Australia ($A/MT)	54.8627783	127.261181	54.86277826	22.38585
Cost reduction in Indonesia ($A/MT)	54.8627783	127.261181	54.86277826	22.38585
Result Cells:				
Global producer gain ($A '000)	($3,355)	($7,709)	($3,675)	($1,376)
Global consumer gain ($A '000)	$4,429	$10,281	$4,801	$1,806
Total global gain ($A '000)	$1,073	$2,572	$1,126	$430
NPV ($A '000)	$582	$2,081	$634	($61)
IRR (percent)	13%	20%	14%	7%

Cost of seedlings of the high yield green tea clone

The first sensitivity analysis examined the impact of the cost of seedlings on the project. In the sensitivity analysis, the cost of seedlings for the high-yielding tea variety is increased by 50% from the $A0.15 assumed in the base case to $A0.23 per seedling. Increasing the cost of seedlings means that the cost reduction achievable from high-yielding tea varieties decreases from about $A55 per tonne to about $A 22 per tonne. This has the effect of reducing the Net Present Value of the project from $A 0.582 million to $A0.061 million and the internal rate of return from 13 to 7%.

Adoption rates for the high yield clones

The results are also sensitive to the rate of adoption of the high-yield clones by the smallholders. Lower adoption rates for this technology have impacts approximately similar to those of high cost of seedlings.

Realised yields

One of the key elements of uncertainty in the implementation stages of this project is whether Indonesian smallholders producing tea will have the financial resources to use the relatively more expensive inputs needed if the higher yields from the higher yield clone are to be realised. If smallholders adopt the higher-yield clones but do not use the required inputs (particularly fertilisers), then they will not realise the high yields promised by the technology. In the base case it is assumed that smallholders, on average, are likely to realise 60% of the experimental yields of 4000 kilograms per hectare per year promised by the project. That is, the after-research, realised yields are estimated at 2400 kilograms of tea per hectare per year.

Suppose that by using fertilisers and other inputs more effectively, the smallholder realises 70% of the experimental yields. From Tables 5 and 6, this is likely to mean that the reduction in costs to the smallholder tea grower is about $A127 per tonne of tea. Under this scenario Table 10 suggests that the internal rate of return is likely to rise to 20 per cent and the Net Present Value to rise to about $A2.0 million. However, if smallholders realise only 50% of the experimental yields, then the discounted costs of the project will exceed the discounted benefits from the project.

Elasticity of supply in Indonesia

In the base analysis it was assumed that the elasticity of supply for tea in Indonesia is about 1.05. In this sensitivity analysis it is assumed that the elasticity of supply for tea in Indonesia is about 0.38. This change leads to a slight rise of the net present value associated with the project from $A0.582 million to $A0.634 million and a slight increase in the internal rate of return from 13 to 14%.

5.2 Concluding remarks

This paper reports the results of a project-development assessment of a project proposing to apply plant tissue culture techniques to the propagation and breeding of tea in Indonesia. The assessment shows that there are significant benefits to be derived by Indonesia and the rest of the world from this project. The benefits to Australia in the short run are small, mainly because Australia’s tea industry is small.

What level of cost reduction will yield a zero net return to the project? For the project to yield a zero net return, the cost reduction to the grower due to the project will have to be about $A6.5 per tonne[1]. Under this scenario, the discounted benefits from the project under the base-case assumptions will just be equal to the discounted costs of the projects. In the base-case, it is estimated that the cost reduction from the project is likely to be about $A55 per tonne of tea. Thus, a zero rate of return would mean that the cost reduction has been overestimated by a factor of almost nine.

The rate of return to investment in the project is estimated to be about 13 per cent, but could be lower if the cost of seedlings of higher yield varieties is higher than estimated in the paper, or smallholders do not use the additional inputs (fertilisers and water) required by the higher yield varieties of tea. On the other hand, the rates of return could be higher—for example, if the adoption rates within the smallholder sector are higher than the 10% ceiling assumed in the paper.

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