6. Variable Selection and Data Sources

6.1 Data Availability

Supply response studies for perennial crops are often restricted by a lack of data, especially in developing countries. Data are usually available on output, prices and cultivated area. However, for PNG, only output and price data are currently collected.

Smallholder economic data were predominantly obtained from the smallholder cocoa and coconuts survey carried out under ACIAR Project Number 8734, *Designing Monitoring Systems for Smallholder Agriculture in Papua New Guinea* (Yarbro and Noble 1989).[1] The survey covered the major cocoa-producing provinces: ENB, East Sepik, Oro and Madang (North Coast region and Karkar Island). North Solomons was not included because of the continuing civil unrest in Bougainville. Given that, in 1990/91, the four provinces accounted for 75 per cent of smallholder production and 44 per cent of total cocoa production, the survey was considered representative of smallholder cocoa producers. A total of 135 respondents were interviewed of which 38 were in ENB, 40 in Madang (21 on Karkar Island and 19 on the North Coast Road), 44 in East Sepik and 13 in Oro. The survey covered 43 villages: 11 in ENB, 16 in East Sepik, nine in Madang and seven in Oro. From these data, a series of average economic variables were estimated for the smallholders including yields per hectare, tree density per hectare, cash costs of production, labour inputs per hectare and per tonne, and returns to labour for cultivating cocoa and copra.

Data on largeholder cocoa growers were collected between 1985 and 1987 under ACIAR Project Number 8383. The survey was carried out by the Queensland Department of Primary Industries in collaboration with the PNG Department of Agriculture and Livestock and the Cocoa and Copra Marketing Boards. CCRI

[1] *The survey was carried out by economists from the Department of Agriculture and Livestock, the Cocoa Board and a consultant appointed by the Research School of Pacific Studies, Australian National University.*

largeholder costs of production surveys provided more current production and cost estimates for the period 1994 to 1997 (Fripp 1996; Omuru 1997).

Natural resource and cocoa area information was obtained from two information systems: the Mapping Agricultural Systems Project (MASP) in the Department of Human Geography, Research School of Pacific and Asian Studies, the Australian National University (or the Land Management Project), and PNGRIS and PNGLES[2], in the Department of Agriculture and Livestock (DAL). Information was also obtained form a two-week field trip to PNG by the author in August to September 1997. Visits were made to the Cocoa Board, CCRI, CCEA, DAL, National Agricultural Research Institute (NARI) and National Research Institute (NRI) to gain current data and information on the cocoa industry.

6.2 Area Module

6.2.1 Area under cocoa

The area under cocoa production in PNG has not been estimated since 1979. As a result, an initial attempt was made to derive the estimated area under cocoa from PNGRIS and MASP which contained information on cocoa cash-earning activities from the PNG Census, 1990. Despite having to reject the area estimates for the analysis, the exercise identified areas under cocoa and the soil and climatic conditions associated with the area (see Appendix H).

Area under cocoa was then estimated by using average sector and provincial production data over the past five years and yield estimates per hectare (see Table 6.1).

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[2] *PNGLES is based on the FAO Framework for Land Evaluation (FAO 1976) whereby land qualities and land characteristics are matched with land use requirements of a specific land utilisation type to derive suitability ratings (Rossiter and Wambeke 1991). Land utilisation is defined by crop and levels of inputs. Decision trees are established for 18 smallholder crops under low, medium and high input production systems. Suitability ratings of each land quality in relation to that required to produce optimum levels of the crop are determined by the decision trees.*

Table 6.1 Area under cocoa by sector and province

Sector	ENB (hectares)	East Sepik (hectares)	Madang (hectares)
Smallholders*	34 399	15 349	9 025
Largeholders**	11 146	-	4 105

Sources: *Yarbro and Noble (1989), **Densley and Barker (1987), CCRI (1997).

To estimate the FBE area, the total area figures were disaggregated by variety and then by age group and incorporated into the yield profiles (see Tables 6.2 and 6.3). Data did not exist on either the adoption rates of different varieties by sector or the proportional share of each variety per unit area. Estimates were extracted from the smallholder cocoa survey (Yarbro and Noble 1989), NRDC statistics, the largeholder cocoa survey (Densley and Barker 1987) and planting material sales from 1981 to 1997 (Peter 1997). It was assumed that sales made between 1981 and 1988 were SG1s and sales made between 1989 to 1997 were SG2s.

6.2.2 New plantings and replantings

Given the lack of data on cocoa plantings, sales of planting material were used to estimate total plantings (CCRI 1997; Peter 1997). The CCRI Planting Material Unit had records from 1995 to mid 1997 on the number of seeds distributed by sector and province and the number of pods, seeds, seedlings and buds distributed by province. For the years when disaggregation by sector was not possible, the total plantings were divided according to the proportion of production by the sector (Manning 1992). In converting the planting material to area figures, 722 trees per hectare and a 66 per cent survival rate were assumed (Manning 1992). A state-space model with a Kalman filter was then used to obtain parameter values for the replanting and new planting equations for both sectors (see Appendix F). A survey was planned by DAL in 1988 under SCCREP, to collect smallholder data on planting responses, but it did not eventuate. During the two-week field trip to PNG, qualitative information was collected on planting responses and the expected trend in new plantings and replantings by sector and province.

Table 6.2 Disaggregation of area under cocoa for smallholders, 1996

	ENB			East Sepik			Madang		
Year	***trinitario*** (ha)	***SG1*** (ha)	***SG2*** (ha)	***trinitario*** (ha)	***SG1*** (ha)	***SG2*** (ha)	***trinitario*** (ha)	***SG1*** (ha)	***SG2*** (ha)
1	0	0	332	0	0	208	0	0	291
2	0	0	332	0	0	208	0	0	291
3	0	0	332	0	0	208	0	0	291
4	0	0	332	0	0	208	0	0	291
5	0	0	332	0	0	208	0	0	291
6-9	722	10905	664	734	2551	415	1687	380	581
10-15	914	11177		1712	1842		1493	107	
16-30	3175	5180		6725	331		3310	13	
total hectares	**4811**	**27262**	**2326**	**9171**	**4724**	**1454**	**6490**	**500**	**2035**

	ENB			East Sepik			Madang		
	trinitario	***SG1***	***SG2***	***trinitario***	***SG1***	***SG2***	***trinitario***	***SG1***	***SG2***
1	0%	0%	14%	0%	0%	14%	0%	0%	14%
2	0%	0%	14%	0%	0%	14%	0%	0%	14%
3	0%	0%	14%	0%	0%	14%	0%	0%	14%
4	0%	0%	14%	0%	0%	14%	0%	0%	14%
5	0%	0%	14%	0%	0%	14%	0%	0%	14%
6-9	15%	40%	29%	8%	54%	29%	26%	76%	29%
10-15	19%	41%		19%	39%		23%	21%	
16-30	66%	19%		73%	7%		51%	3%	

Table 6.3 Disaggregation of area under cocoa for largeholders, 1996

	ENB			Madang		
Year	*trinitario* (ha)	*SG1* (ha)	*SG2* (ha)	*trinitario* (ha)	*SG1* (ha)	*SG2* (ha)
beg.1	0	0	187	0	0	163
2	0	0	187	0	0	163
3	0	0	187	0	0	163
4	0	0	187	0	0	163
5	0	0	187	0	0	163
6-9	856	1653	374	178	710	327
10-15	1084	1694		225	728	
16-30	3766	785		781	337	
total hectares	**5706.04**	**4131.96**	**1307.6**	**1184**	**1776**	**1144.15**

	ENB			Madang		
	trinitario	*SG1*	*SG2*	*trinitario*	*SG1*	*SG2*
beg.1	0%	0%	14%	0%	0%	14%
2	0%	0%	14%	0%	0%	14%
3	0%	0%	14%	0%	0%	14%
4	0%	0%	14%	0%	0%	14%
5	0%	0%	14%	0%	0%	14%
6-9	15%	40%	29%	15%	40%	29%
10-15	19%	41%		19%	41%	
16-30	66%	19%		66%	19%	

6.2.3 Age-yield profiles

CCRI on-farm trials were set up only in 1996/97 to monitor the yields of HYV SG2-mod. on smallholders' plots. It is premature to obtain on-farm yield data on the SG2-mod.; however, expected yields have been predicted by CCRI for smallholders and largeholders. The yield profile of SG1 was also predicted by CCRI for largeholders and ADB (1997) estimated a yield profile for smallholders (see Table 6.4). Since it is assumed that new plantings are HYVs, the Trinitario variety is expected only for older trees, yielding about 300 kg per hectare (Densley and Barker 1987).

To incorporate changes in yields associated with the age of the cocoa trees and the total number of bearing cocoa trees, weights were given to the bearing trees according to their age groups. The trees in the age category of six to nine years were considered fully mature and at their maximum yield, and hence they received a weighting of one. Given the largeholder yield profile created by CCRI for the SG2-mod., data weights of the different age groups were established as follows:

$\gamma 1 = 150/1500 = 0.10$

$\gamma 2 = 700/1500 = 0.47$

$\gamma 3 = 1300/1500 = 0.87$

$\gamma 4 = 1500/1500 = 1.00$

$\gamma 5 = 1300/1500 = 0.87$

$\gamma 6 = 900/1500 = 0.60$

$\gamma 7 = 500/1500 = 0.33$

$\gamma 8 = 475/1500 = 0.32$

Table 6.4 Age-yield profiles by sector

Largeholdings

SG1			SG2		
Age	yield profile *	TWT	Age	yield profile**	TWT
0			0-2		
1			3	150	0.10
2	436	0.29	4	700	0.47
3	548	0.37	5	1300	0.87
4	791	0.53	6	1500	1.00
5	1068	0.71	7	1300	0.87
6-9	1255	0.84	8	900	0.60
10-15	647	0.43	9	500	0.33
16-30	440	0.29	10	475	0.32

Sources: * Gimbol (1993), **Effron (1997).

Smallholdings

SG1			SG2		
Age	yield profile *	TWT	Age	yield profile**	TWT
0	-	-	0-2	-	-
1	-	-	3	100	0.08
2	200	0.15	4	500	0.38
3	350	0.27	5	700	0.54
4	650	0.50	6	900	0.69
5	700	0.54	7	600	0.46
6-9	700	0.54	8	400	0.31
10-15	700	0.54	9	450	0.35
16-30	700	0.54	10	450	0.35

Sources: *Ryan (1997), **Effron (1997).

6.3 Cocoa Suitability Module

Area figures for the land suitability categories of cocoa were obtained from PNGLES in the DAL Land Use Section (Venema and Daink 1992). PNGLES was run using resource data from PNGRIS to compute land suitability ratings for crops in each province (Trangmar et al. 1995) (see Figures 6.1, 6.2 and 6.3). Estimates from Bleeker and Freyne (1981) are presented in Table 6.5 and from PNGLES in Table 6.6.

Table 6.5 Area and proportion of land suitable for cocoa production

Province	Area planted*		Estimated areas of province						Total
			Very high		High		Moderate		
	km^2	% total	km^2	%	km^2	%	km^2	%	km^2
Madang	68.0	3.7	500	1.8	370	1.3	980	3.50	1850
East Sepik	13.4	1.1	-	-	-	-	1230	2.90	1230
ENB	553.9	62.2	770	4.1	-	-	120	0.65	890

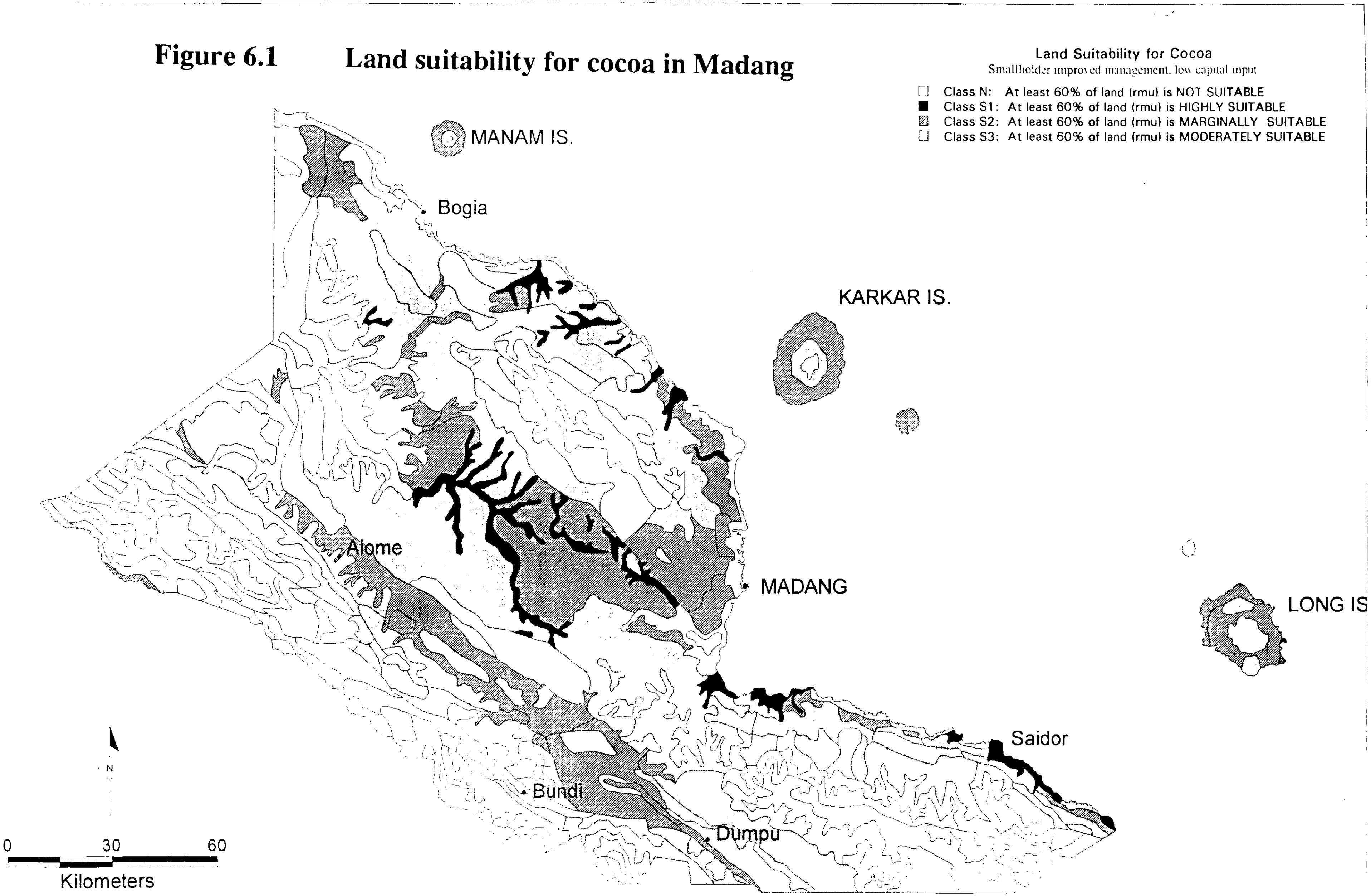
Sources: Bleeker and Freyne (1981),* Bureau of Statistics and Department of Primary industry figures (1975).

Table 6.6 Land suitability for cocoa under high and low input systems

Province	Management	Suitability rating*	Ratings by RMU (a)		Ratings by med. env. type (a)		DAL (b)	
			area (km^2)	% area	area (km^2)	% area	area (km^2)	% area
Madang	high-input	1	1 058	3.7	1 328	4.6		
	high-input	2	4 690	16.4	2 739	9.6		
	high-input	3	2 013	7.0	1 437	5		
	low-input	1	914	3.2	944	3.3	1 034	3.6
	low-input	2	4 758	16.6	3 313	11.6	3 667	12.8
	low-input	3	11 211	39.1	12 440	43.6	9 139	31.8
East Sepik	high-input	1	1 025	2.4	1 551	3.6		
	high-input	2	4 299	9.9	3 442	7.9		
	high-input	3	577	1.3	487	1.1		
	low-input	1	1 022	2.3	1 548	3.6	1 142	2.6
	low-input	2	3 611	8.3	2 748	6.3	3 811	8.7
	low-input	3	9 273	21.3	10 938	25.1	9 000	20.6
ENB	high-input	1	178	1.2	25	0.2		
	high-input	2	2 078	13.8	2 276	15.1		
	high-input	3	5 958	39.4	5 930	39.2		
	low-input	1	183	1.2	30	0.2	237	1.6
	low-input	2	2 861	18.9	2 928	19.4	2 238	14.8
	low-input	3	10 598	70.1	10 816	71.6	10 617	70.3

Sources: (a) Trangmar (1995); (b) DAL (1997), *1 = high; 2 = moderate; 3 = marginal; 4 = unsuitable.

Figure 6.1 Land suitability for cocoa in Madang



Produced by DAL Land Utilization Section from PNGRIS and PNGLES Konedobu (September 1997)

Figure 6.2 Land suitability for cocoa in East Sepik

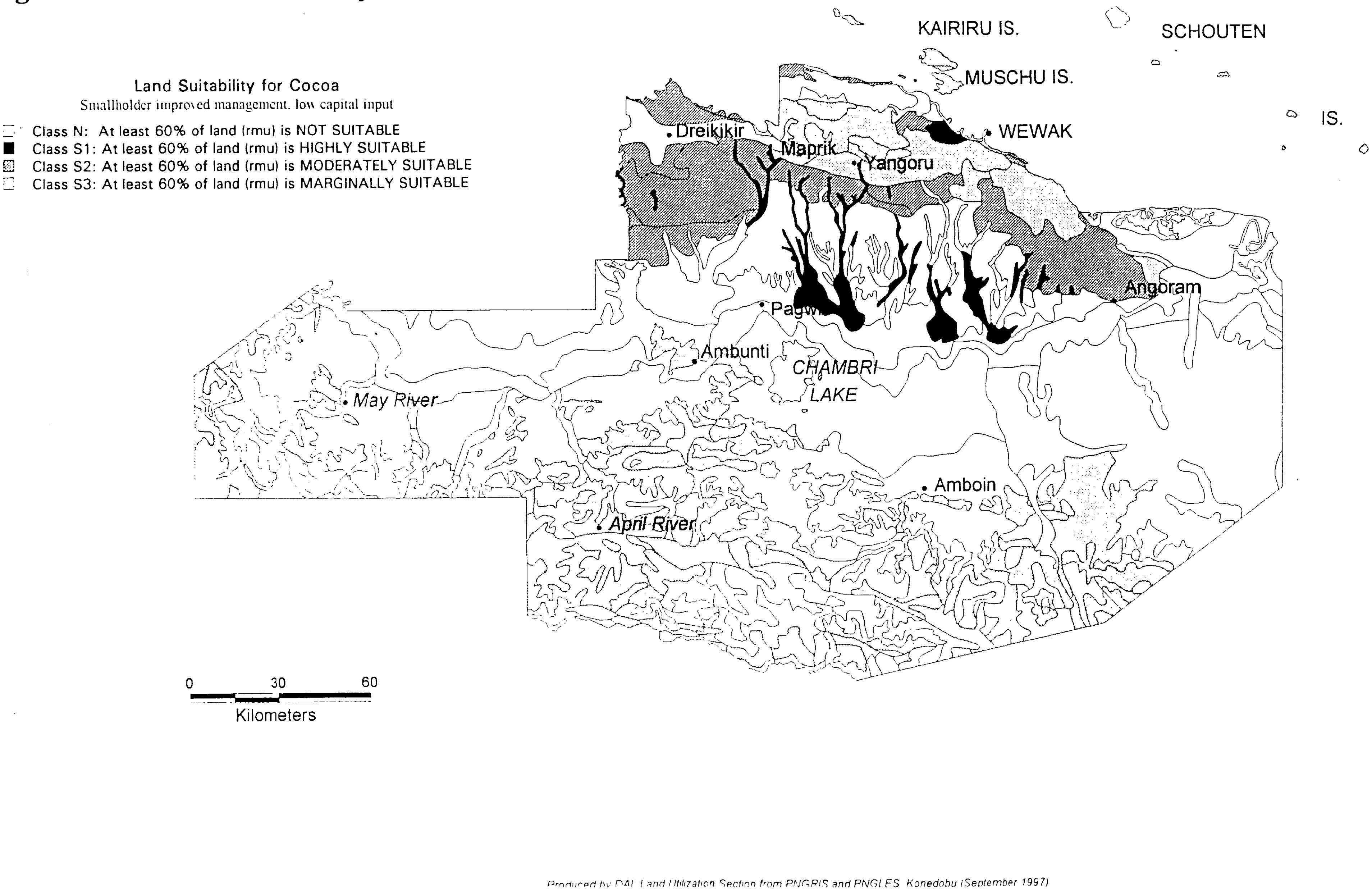
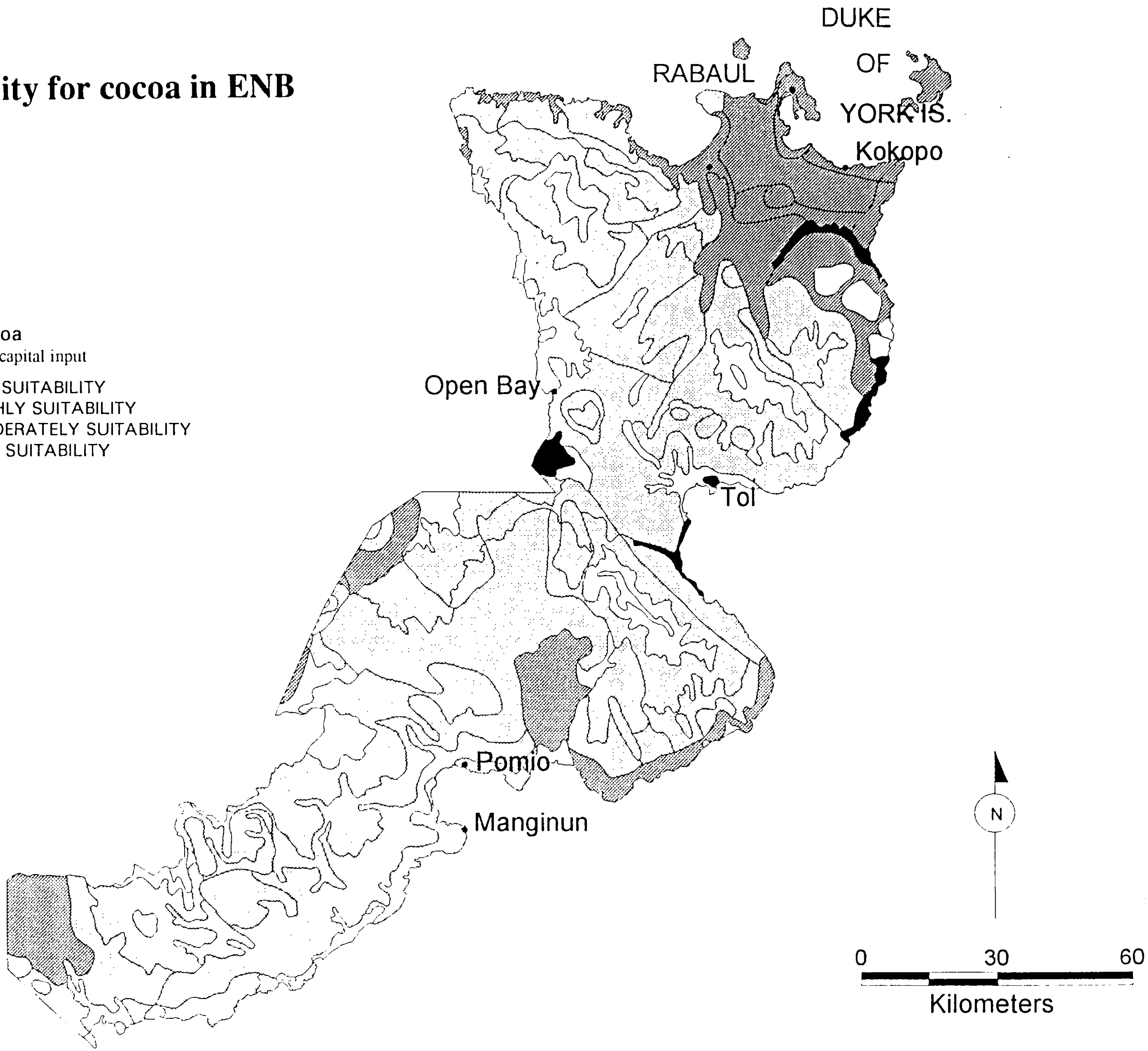


Figure 6.3 Land suitability for cocoa in ENB

Land Suitability for Cocoa

Smallholder improved management, low capital input

- ☐ Class N: At least 60% of land (rmu) is NOT SUITABILITY
- ■ Class S1: At least 60% of land (rmu) is HIGHLY SUITABILITY
- ▨ Class S2: At least 60% of land (rmu) is MODERATELY SUITABILITY
- ☐ Class S3: At least 60% of land (rmu) is NOT SUITABILITY



6.4 Output and Production Module

In estimating the production functions for both smallholder and largeholder cocoa producers, the following variables were selected: cocoa bean output, labour use, fertiliser use, and prices of fertiliser, labour and cocoa.

6.4.1 Smallholder costs of production

Smallholder production cost figures for the three provinces were obtained from the smallholder cocoa survey (Yarbro and Noble 1989). Most of the farmers surveyed sold wet beans, so a conversion factor of 40 per cent was used for dry bean equivalent.

6.4.2 Largeholder costs of production

To date, survey work on costs of production for largeholdings has been concentrated in ENB. CCRI carried out surveys in 1993 to 1997 but again the surveyed plantations were predominantly in ENB. Hence, the 1987 costs of production survey (Densley and Barker 1987) was the major source since it covered all provinces in the study.

6.4.3 Labour

Hired labour is used in the plantation sector, where wages on average are about K3.00 to K4.00 per day (Omuru 1997). Family labour is predominantly used for smallholder production. For the analysis, labour was costed at the market price, although smallholders may tend to work for below the market price if cash income is needed immediately.

Yield elasticities with respect to labour were obtained from previous studies (see Table 6.7).

Table 6.7 Yield elasticities with respect to labour

Province	ENB	East Sepik	Madang
Smallholders*	0.54	0.55	0.50
Smallholders**	0.396	0.270	0.176
Largeholders(L/TC)***	0.48	-	0.36

Sources: *Gimbol 1993, **Fleming 1998, ***Yarbro and Noble 1987 (these figures were derived by share of costs paid to factors of production).

6.4.4 Fertiliser

Smallholder elasticities of yield with respect to fertiliser were estimated from 22 observations in the smallholder cocoa survey, of which the majority of farmers came from ENB (Yarbro and Noble 1989). Largeholder elasticities were estimated from cost of production data (Densley and Barker 1987) (see Table 6.8).

Table 6.8 Yield elasticities with respect to fertiliser

	ENB	East Sepik	Madang
Smallholders*	0.01	0.01	0.01
Largeholders**	0.21		0.37

Sources: *Yarbro and Noble (1989), **Densley and Barker (1987).

The price of fertiliser was obtained from a local retailer and initially assumed for all three provinces. It is realised that fertiliser prices will differ between the provinces but data were not available.

6.4.5 Cocoa prices

Data on FOB, DIS and estimated producer prices, and bounties and levies were available from the Cocoa Board (Peter 1997). The producer prices were calculated by adding (subtracting) the amount of the bounty (levy) from the DIS price.

6.4.6 Yields

Largeholders yields were estimated by the World Bank (1992) at an average of 1.5 tonnes after five years. However, CCRI costs of production surveys estimated largeholder yields at between 0.59 to 0.79 tonnes per hectare (Fripp 1996; Omuru 1997). For the study, ENB largeholders were assumed to produce 700 kg per hectare, given the higher quality volcanic soils and higher use of inputs (Omuru 1997) while Madang largeholders were assumed to produce 500 kg per hectare, given that many of the plantations, originally owned by Catholic missions, are no longer well maintained (Woruba 1997). Yarbro and Noble (1989) estimated average yields for smallholders (see Table 6.9).

Table 6.9 Average yields of smallholder cocoa

Province	Yield (kgs/ha)
East New Britain	320
East Sepik	170
Madang (NCR)	100
Madang (Karkar)	80

Source: Yarbro and Noble (1989).

6.5 Data Limitations

There is a general lack of data on cocoa production and planting decisions in PNG for both largeholders and smallholders. The study relies on survey data from the late 1980s which does not include the impacts of the release of the SG2, problems in Bougainville, the ENBSDP and the volcanic eruption in Rabaul. A major limitation of the smallholder survey was the lack of record keeping by smallholders, thereby increasing the reliance on farmers' best estimates of wet bean production, labour use and age of trees. At the time of the survey, cocoa prices were low and, assuming smallholder cocoa producers are price-responsive and allocate their labour accordingly, underestimations of labour use may have occurred (Gimbol 1993).

Budget information was available for the 'average' smallholder and plantation but not with respect to different technologies. This therefore prevented a comparison of production functions for the three technologies—Trinitario, SG1 and SG2—and an estimate of adoption rates based on these figures.

A lack of documented information on planting decisions severely limited the study in regard to estimating the expansion in area under cocoa and the planting responses. Although CCRI on-farm trials and trials in different agro-ecological zones began in 1997, time series yield data are limited for sector and provincial analysis.

7. Results and Discussion

7.1 Introduction

In this chapter, the results are reported and discussed for simulation runs of five models: smallholders in ENB, East Sepik and Madang, and largeholders in ENB and Madang. The base runs are discussed initially, followed by the policy scenarios. For each scenario, the sub-sectors are examined in terms of changes in estimated annual output and the NPV of output over the 20-year period.

7.2 Results of Base Runs

Summary results of the base runs for each module are presented below. More detailed simulation run results for the sub-sectors are reported in Appendix G.

7.2.1 Prices

Prices are simulated over the 20-year period. FOB prices range between K274 per tonne and K2108 per tonne and DIS prices between K171 and K1840. The producer prices fluctuate between the support price (K1300 per tonne) and K1742 per tonne. Given the low FOB values, bounties are received in 14 of the 20 years and levies paid out in one period (see Table 7.1).

7.2.2 Area and land suitability

The area in FBE for smallholders is influenced by the planting decisions and the variety of cocoa planted. In ENB, due to smallholder projects, 80 per cent of the area under cocoa is SG1 in the first year. Since the SG1 peaked in yield after six years and then dramatically declined, the SG1 currently still in the ground is only, at the most, 50 per cent of its maximum yield. With an inelastic new planting response, the FBE area decreases over the period. In Madang and East Sepik, much less of the SG1 was planted by smallholders; hence, the change in FBE area initially falls marginally but increases towards the end of the period. In contrast, the FBE area for the largeholders increases throughout the 20-year period. Their elastic replanting response with respect to price increases the rate of removals of the lower yielding Trinitario and SG1 for the higher yielding SG2-mod. (see Figure 7.1).

Table 7.1 Prices in base run

Year	Producer (Kina)	DIS (Kina)	FOB (Kina)	Bounty (Kina)	Levy (Kina)
Initial	1 300.00	935.85	1 114.66	364	0
1996	1 300.00	1 235.94	1 444.43	64	0
1997	1 300.00	739.01	898.36	561	0
1998	1 300.00	602.48	748.32	698	0
1999	1 300.00	1 102.19	1 297.45	198	0
2000	1 300.00	171.18	274.36	1129	0
2001	1 300.00	617.43	764.75	683	0
2002	1 300.00	926.24	1 104.10	374	0
2003	1 570.22	1 570.22	1 811.77	0	0
2004	1 300.00	978.79	1 161.85	321	0
2005	1 300.10	1 300.10	1 514.94	0	0
2006	1 300.00	987.65	1 171.58	312	0
2007	1 300.00	1 027.51	1 215.39	272	0
2008	1 395.27	1 395.27	1 619.52	0	0
2009	1 300.00	1 144.62	1 344.08	155	0
2010	1 742.31	1 840.11	2 108.35	0	98
2011	1 300.00	1 053.69	1 244.16	246	0
2012	1 300.00	727.27	885.45	573	0
2013	1 443.56	1 443.56	1 672.58	0	0
2014	1 300.00	1 168.66	1 370.49	131	0
2015	1 489.10	1 489.10	1 722.63	0	0

Source: Appendix G.

The base run for the land suitability module shows that, given the inelastic new planting response by smallholders, there are no shortages of suitable land for cocoa over the next 20 years in any province (see Table 7.2).

Figure 7.1 Base run for sub-sector area, 1996-2015

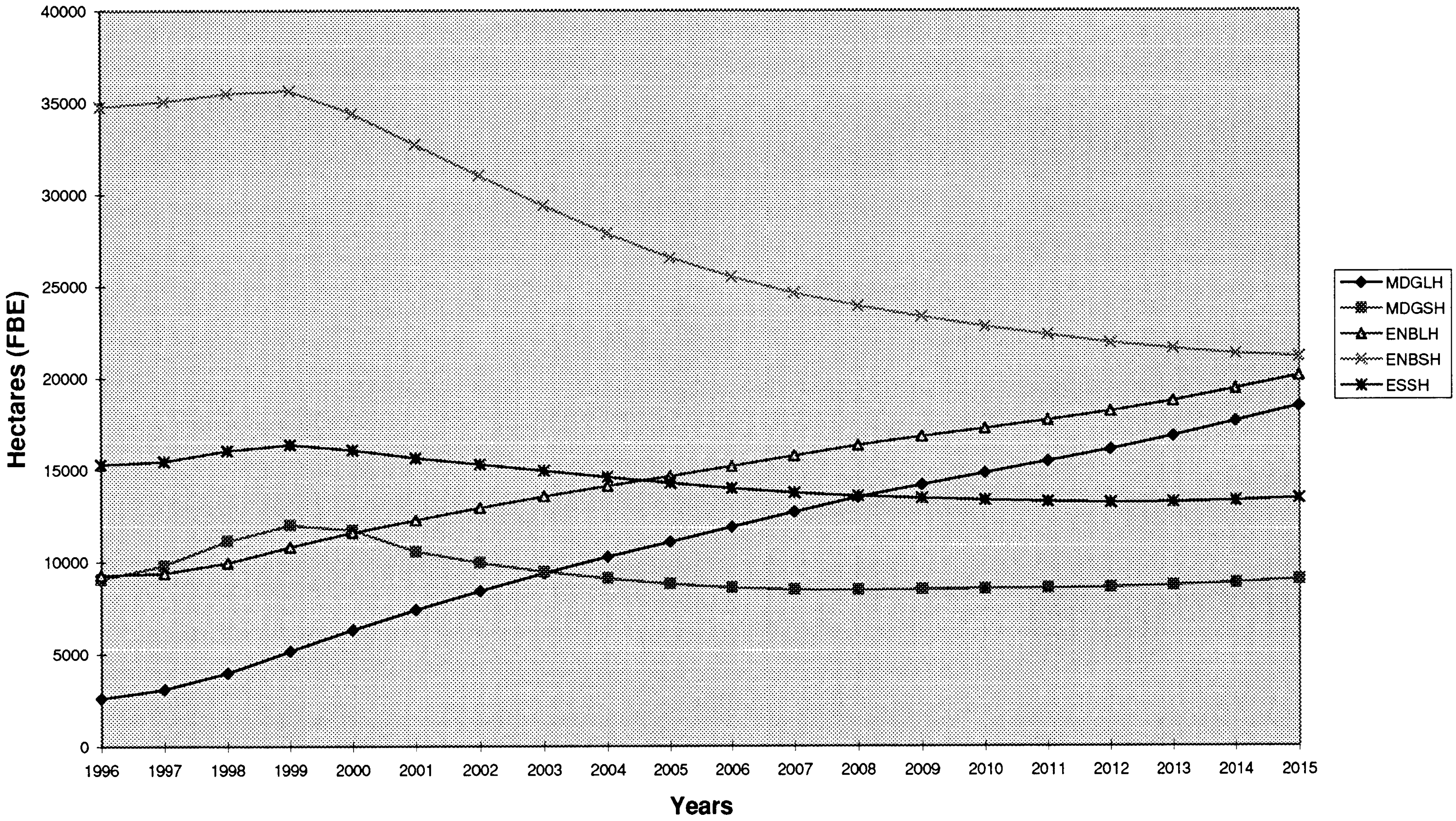


Table 7.2 Availability of highly suitable land for smallholder expansion

Year	ENB (hectares)	East Sepik (hectares)	Madang (hectares)
1996	23 064	113 564	102 764
1997	22 429	112 929	102 129
1998	21 793	112 293	101 493
1999	21 158	111 658	100 858
2000	20 522	111 022	100 222
2001	19 887	110 387	99 587
2002	19 251	109 751	98 951
2003	18 615	109 115	98 315
2004	17 848	108 348	97 548
2005	17 212	107 712	96 912
2006	16 577	107 077	96 277
2007	15 941	106 441	95 641
2008	15 305	105 805	95 006
2009	14 623	105 123	94 324
2010	13 988	104 488	93 688
2011	13 136	103 636	92 836
2012	12 500	103 000	92 201
2013	11 865	102 365	91 565
2014	11 159	101 659	90 860
2015	10 523	101 023	90 224

Source: Appendix G.

7.2.3 Input use

Given the low prices for cocoa throughout the period and the highly inelastic yield response with respect to fertiliser, the quantity of fertiliser used by smallholders is close to zero. In ENB, under the ENBRDP, smallholders are beginning to use small amounts of fertiliser (average of 100 kg per hectare per year) but in East Sepik and Madang, none is applied (see Table 7.3) (Yarbro and Noble 1989; Gimbol 1993). ENB producers, on average, spend nearly twice as many labour days maintaining and harvesting their cocoa as East Sepik smallholders and nearly three times more labour days than Madang smallholders. The greater availability and efficiency of extension services in ENB has increased the maintenance work performed by smallholders, hence impacting positively on annual yields.

Madang largeholders vary their fertiliser input from 600 kg to 1.24 tonnes per hectare compared with ENB with 500 kg to 1.1 tonnes per hectare per year. ENB largeholders spend on average more labour days maintaining and harvesting their cocoa than Madang largeholders (see Table 7.4).

Table 7.3 Base run for smallholder input demand

Year	ENB		East Sepik		Madang	
	Fertiliser demand (kg/ha)	Labour demand (days/ha)	Fertiliser demand (kg/ha)	Labour demand (days/ha)	Fertiliser demand (kg/ha)	Labour demand (days/ha)
1996	100	73	0	41	0	20
1997	100	100	0	41	0	20
1998	100	73	0	41	0	20
1999	100	73	0	41	0	20
2000	100	73	0	41	0	20
2001	100	73	0	41	0	20
2002	100	73	0	41	0	20
2003	100	73	0	41	0	21
2004	100	110	0	62	0	30
2005	100	73	0	41	0	20
2006	100	73	0	41	0	20
2007	100	73	0	41	0	20
2008	100	73	0	41	0	20
2009	100	85	0	48	0	24
2010	100	73	0	41	0	21
2011	100	138	100	78	0	37
2012	100	73	0	41	0	20
2013	100	73	0	41	0	20
2014	100	91	0	52	0	25
2015	100	73	0	41	0	20

Source: Appendix G.

Table 7.4 Base run for largeholder input demand

Year	ENB		Madang	
	Fertiliser demand (tonnes/ha)	Labour demand (days/ha)	Fertiliser demand (tonnes/ha)	Labour demand (days/ha)
1996	0.50	74	0.60	26
1997	0.50	74	0.60	26
1998	0.50	74	0.60	26
1999	0.50	74	0.60	26
2000	0.50	74	0.60	26
2001	0.50	74	0.60	26
2002	0.50	74	0.60	26
2003	0.50	81	0.60	31
2004	0.78	106	0.96	35
2005	0.50	74	0.60	26
2006	0.50	74	0.60	26
2007	0.50	74	0.60	26
2008	0.50	77	0.60	28
2009	0.59	85	0.72	29
2010	0.50	86	0.60	34
2011	1.01	130	1.24	42
2012	0.50	74	0.60	26
2013	0.50	78	0.60	29
2014	0.64	90	0.78	31
2015	0.50	79	0.60	30

Source: Appendix G.

7.2.4 Output

In the smallholder sector, annual output remains stable over the period for Madang and East Sepik producers. In Madang it varies from 800 to 1100 tonnes per year and, in East Sepik, between 2300 and 3300 tonnes per year. In ENB, output declines from about 10 900 to 6700 tonnes per year. This is probably due to the high proportion of SG1 planted in the 1980s which is being slowly replaced with the higher yielding SG2-mod.

In contrast, largeholder output in both provinces trends up over the 20-year period. For Madang largeholders, the output increases from 1000 tonnes to 5000 tonnes annually and, for ENB largeholders, output increases by 65 per cent from 7100 tonnes per year to 11 800 tonnes per year. The introduction of the high-yielding varieties and the elastic replanting response have a positive impact on the industry output (see Figure 7.2).

It is interesting to note that for ENB, where the smallholder sector currently produces 60 per cent of the provincial output, the largeholder output surpasses smallholder output after seven years. Note that the impact of the ENBRDP is not included in the smallholder analysis. For Madang, largeholders continue to dominate the industry in terms of output.

7.2.5 Break-even price

In the base run for the break-even price module, smallholders in every province operate above the break-even price for the 20-year period. For the largeholders, ENB producers fall below the minimum price in two years, while Madang largeholders, who use more imported inputs than ENB largeholders, fall below the minimum price in 11 out of the 20 years (see Table 7.5). On average, the Madang largeholders are losing K66.35 per tonne while for ENB largeholders the average return is K183 per tonne.

Figure 7.2 Base run for sub-sector output, 1996-2015

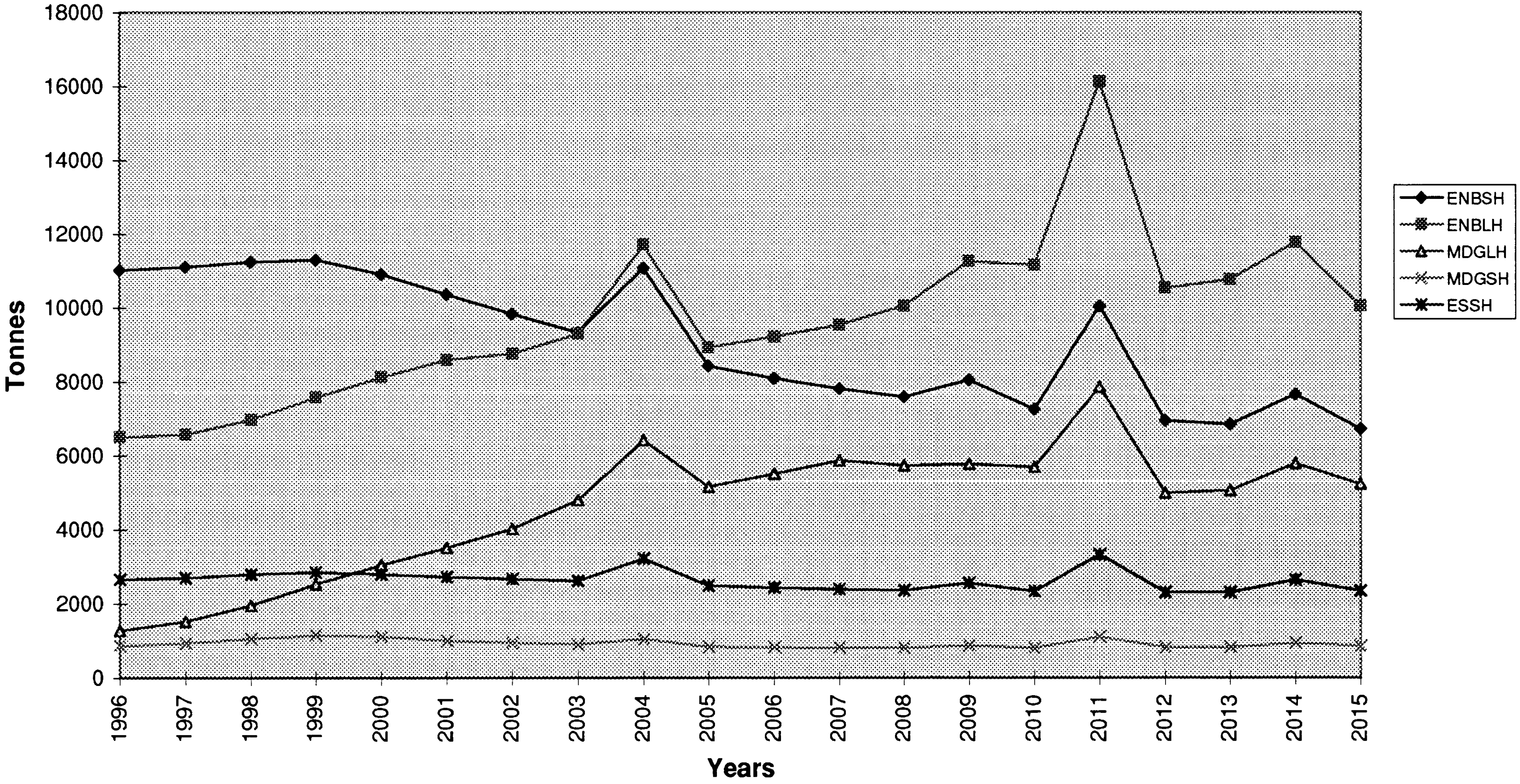


Table 7.5 **Base run for return per tonne of cocoa**

Year	ENBSH (K/tonne)	ENBLH (K/tonne)	MDGSH (K/tonne)	MDGLH (K/tonne)	ESSH (K/tonne)
1996	189.31	255.98	61.28	34.19	101.35
1997	189.31	255.98	61.28	34.19	101.35
1998	189.31	255.98	61.28	32.59	101.35
1999	189.31	255.98	61.28	30.99	101.35
2000	189.31	255.98	61.28	21.40	101.35
2001	189.31	255.98	61.28	11.80	101.35
2002	189.31	226.37	61.28	15.00	101.35
2003	275.22	400.17	87.04	181.44	148.51
2004	180.56	72.90	58.87	-135.05	96.13
2005	189.35	137.61	61.28	-0.94	101.36
2006	189.31	135.23	61.28	-2.64	101.35
2007	189.31	132.98	61.28	-4.20	101.35
2008	219.56	197.39	70.33	-18.69	117.95
2009	188.64	103.39	61.04	-186.57	100.9
2010	330.09	437.47	103.54	38.36	178.64
2011	163.70	-87.87	54.56	-552.38	86.24
2012	189.31	98.82	61.28	-202.55	101.35
2013	234.91	163.14	74.94	-179.65	126.38
2014	187.30	-41.68	60.66	-350.06	100.1
2015	249.39	73.46	79.29	-194.52	134.33

Source: Appendix G.

7.3 Impact of Devaluation

The impact of the exchange rate devaluation on the cocoa industry is measured in terms of the net effects of the changes in fertiliser costs and cocoa prices, and consequently the change in output. Simulations are run for a 5 per cent, 10 per cent and 15 per cent devaluation, under the existing AGPS and compared with the base run.

7.3.1 Smallholders

Prior expectations were for a positive short-run impact of a devaluation on smallholder output (World Bank 1992; Fallon King and Zeitsch 1995; Trivedi and Akiyama 1993). However, the 5 per cent devaluation has a negligible but negative impact on smallholder output in the first eight years (see Figure 7.3). This is primarily due to the existence of the price support, neutralising the effects of the devaluation (Omuru et al. 1995). Since smallholders purchase very small amounts of imported fertiliser, there are minimal effects on their costs of production. When DIS prices rise above the support price, the 5 per cent devaluation has a positive impact on smallholder output. The percentage changes in output from a 10 per cent and 15 per cent devaluation have even greater positive impacts (see Figures 7.4 and 7.5).

Compared with the base year, the NPV of output increases for all smallholders for the three devaluation runs (see Table 7.6). The greatest change in output is in Madang, followed by East Sepik and ENB. In line with expectations, the greater the percentage devaluation of the kina, the larger the increase in the NPV of output.

Table 7.6 Devaluation effects on smallholder NPV of output under price support

Province	Base	5 per cent		10 per cent		15 per cent	
	tonnes	tonnes	% change	tonnes	% change	tonnes	% change
East Sepik	27 804	28 037	0.8	28 388	2.1	28 755	3.4
ENB	104 565	105 258	0.7	106 408	1.8	107 604	2.9
Madang	19 314	19 552	1.2	19 804	2.5	20 069	3.9

Source: Appendix G.

7.3.2 Largeholders

For largeholders, the 5 per cent devaluation has a significant negative impact in the first six years. The higher fertiliser prices reduce fertiliser use and hence output. In addition, largeholders are removing older trees and replacing them with the SG2-mod. Not until the sixth year are the new plantings at their maximum yield. During the periods when the producer price is greater than the support price, the impact on largeholder output is positive. For ENB largeholders, the largest percentage change from the base year is 5.7 while for Madang largeholders, it is lower at four per cent. For the 10 per cent and 15 per cent devaluations, the percentage fall in output from the base year is even greater (see Figures 7.3 to 7.5).

Figure 7.3 Percentage impact of 5 per cent devaluation on annual output, 1996-2015

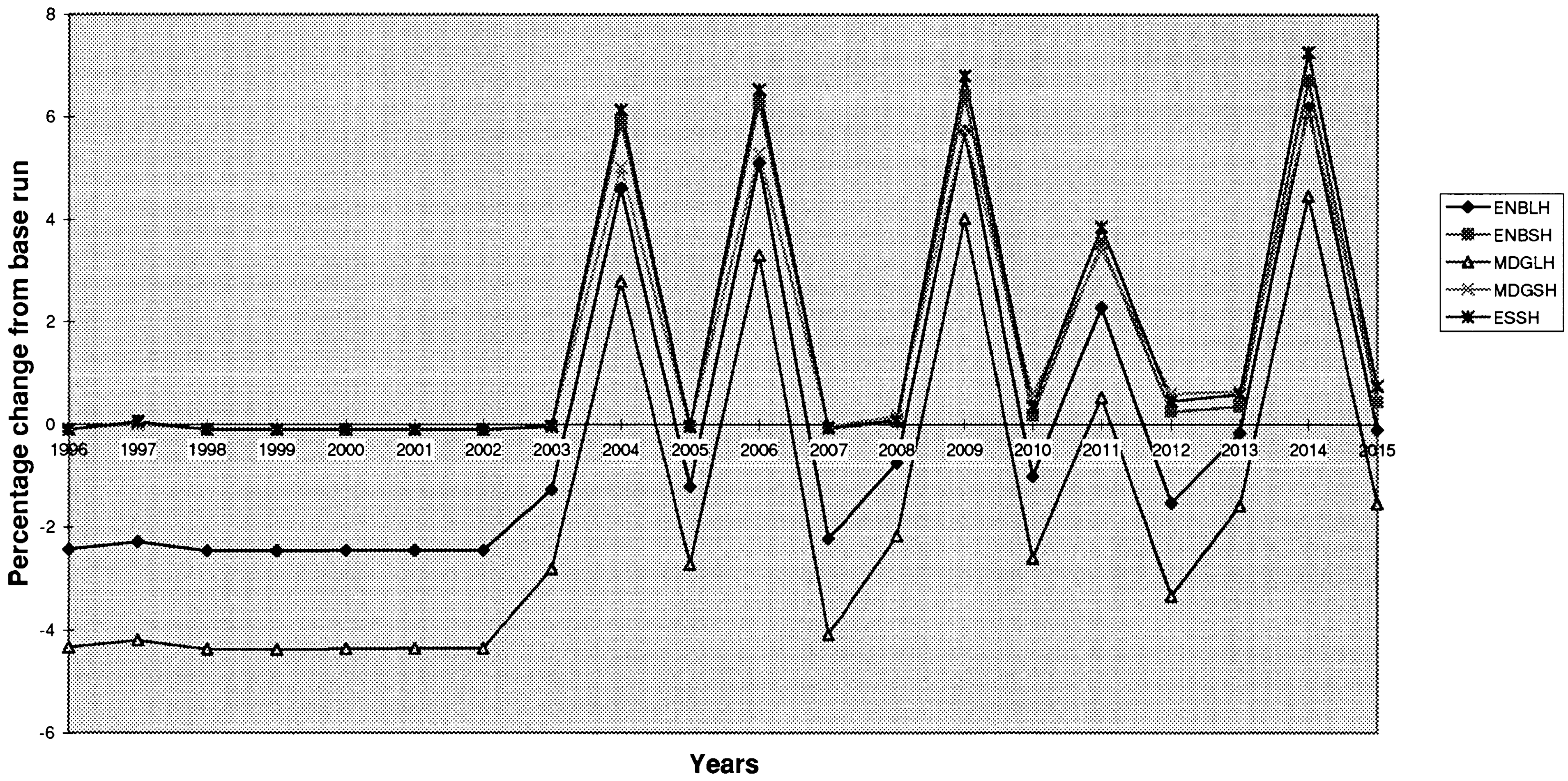


Figure 7.4 Percentage impact of 10 per cent devaluation on annual output, 1996-2015

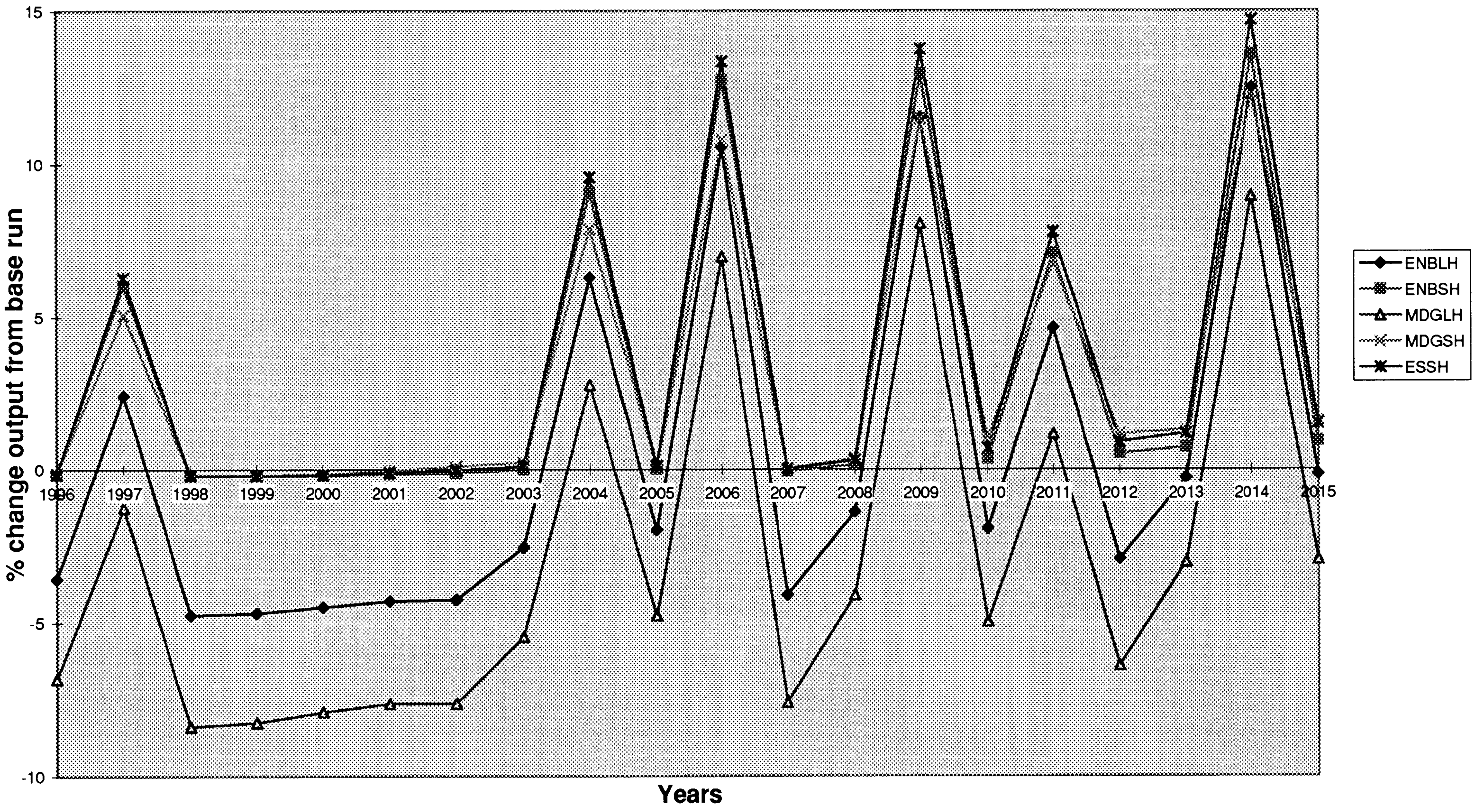
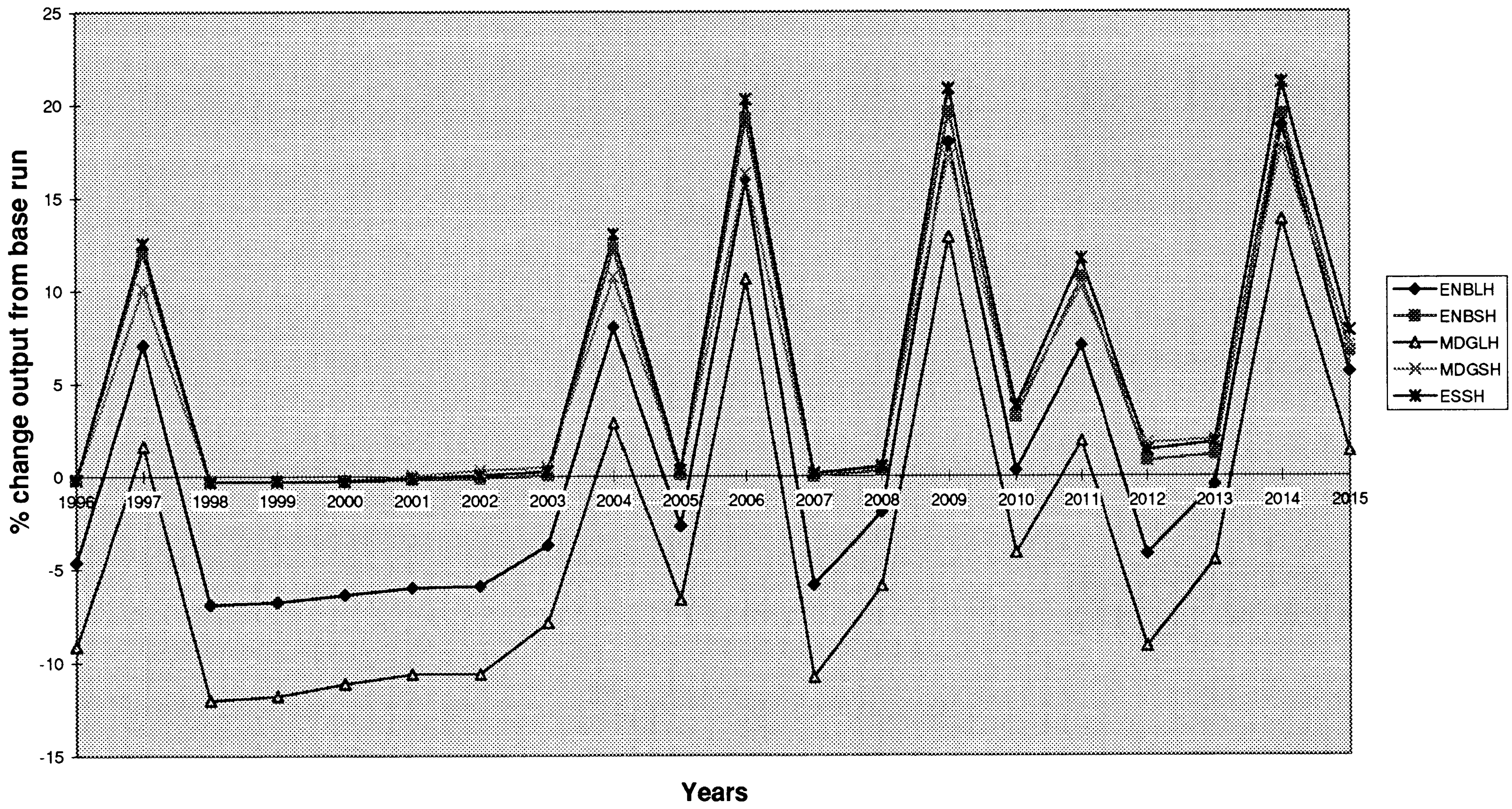


Figure 7.5 Percentage impact of 15 per cent devaluation on annual output, 1996-2015



In NPV terms, the devaluation has a negative impact on both the Madang and ENB largeholders, with output remaining below the base-run levels for all three scenarios (see Table 7.7). The price support neutralises the expected gains from the devaluation effects on cocoa prices but the cost of increased input prices is still incurred by producers. Under a 15 per cent devaluation, increased producer prices are beginning to impact positively on the NPV of output for ENB producers. However, in Madang, the net effect of the devaluation is still negative given the larger use of fertilisers.

Table 7.7 Devaluation effects on smallholder NPV of output under price support

	Base	5 per cent		10 per cent		15 per cent	
Province	tonnes	tonnes	% change	tonnes	% change	tonnes	% change
ENB	80 557	80 007	-0.68	79 936	-0.80	80 037	-0.65
Madang	33 999	33 322	-2.00	32 813	-3.50	32 420	-4.60

Source: Appendix G.

For Madang largeholders, the average annual returns to cocoa per tonne are negative for the base and devaluation scenarios, with losses increasing as the percentage of devaluation rises. For ENB largeholders, the average return is positive but decreasing marginally with increasing percentage devaluation (see Table 7.8). Note that Fripp (1996) also calculated net losses to largeholders in 1996 of K107 per tonne (see Table 2.5 in section 2.3.2).

Table 7.8 Average annual returns per tonne to largeholders

	Base	5 per cent	10 per cent	15 per cent
Province	(Kina)	(Kina)	(Kina)	(Kina)
ENB	182.92	178.92	174.36	171.33
Madang	-66.34	-75.40	-84.27	-94.03

Source: Appendix G.

7.4 Impact of the Removal of Price Support

The removal of the price support is measured in terms of the changes in annual output and the NPV of output and the cost savings to the government over the 20-year study period. The FOB prices during the period are frequently below the price support price; hence removal of the scheme is expected to have an adverse impact on industry output. Further simulations are run for the removal of the price support under a 5, 10 and 15 per cent devaluation.

7.4.1 Smallholders

The percentage changes in output from the removal of the price support are depicted in Figure 7.6. As expected, the smallholder output for all provinces is reduced with the removal of price support. The impact is greater on East Sepik and ENB smallholders (35 per cent decrease), than Madang smallholders (26 per cent).

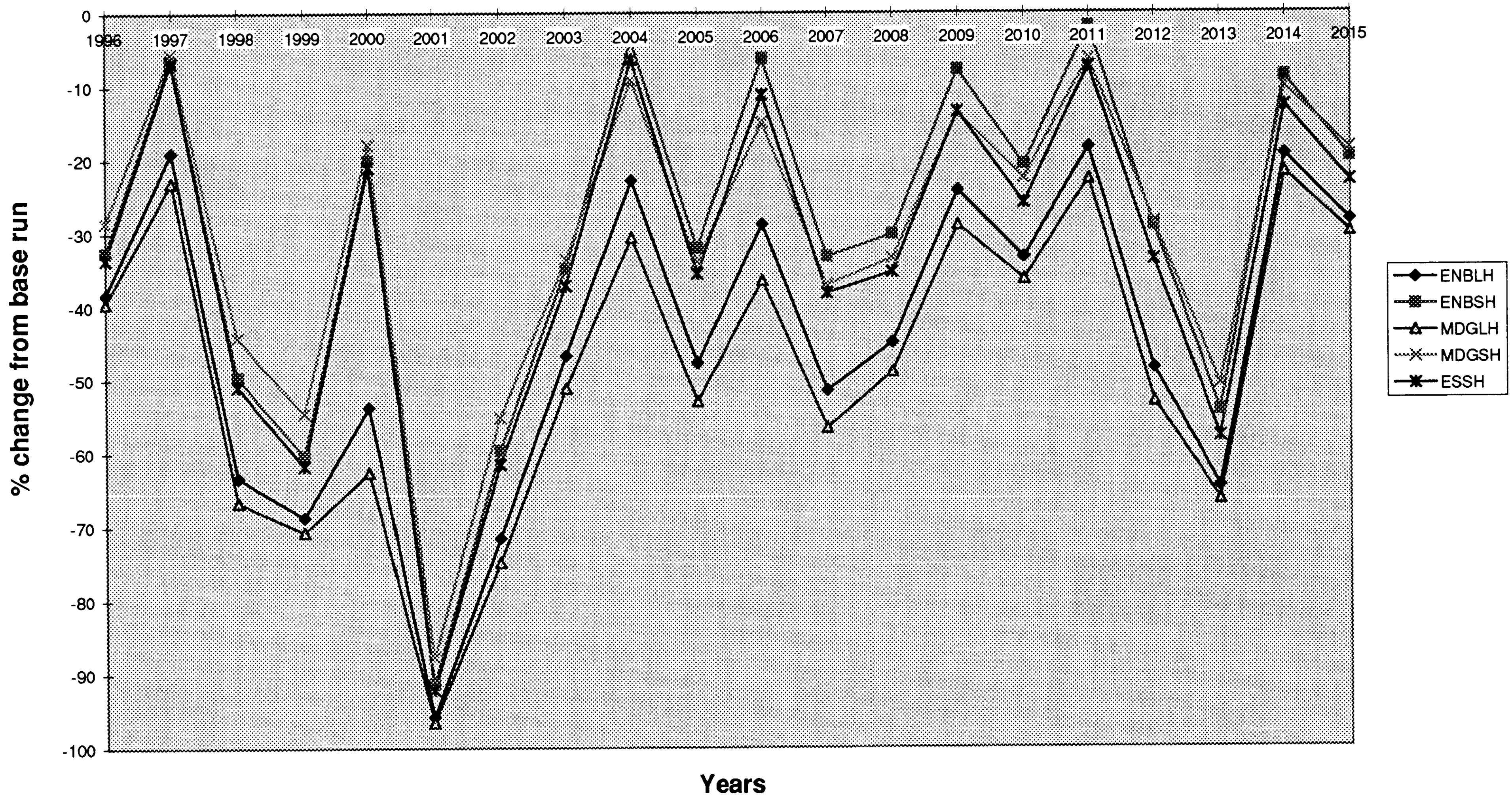
The effects of the devaluation after the removal of the price support are as expected. The greater the devaluation, the higher the rise in the NPV of smallholder output in each of the provinces (see Table 7.9).

Table 7.9 Effects of devaluation on the NPV of smallholder output without price support

Province	Base	5 per cent		10 per cent		15 per cent	
	tonnes	tonnes	% change	tonnes	% change	tonnes	% change
East Sepik	17 880	19 182	10.8	20 152	12.7	21 868	22.3
ENB	68 854	73 491	6.7	78 193	13.6	82 960	20.5
Madang	14 329	15 150	5.7	15 976	11.5	16 806	17.3

Source: Appendix G.

Figure 7.6 Impact of the removal of price support on annual ouput, 1996-2015



7.4.2 Largeholders

The percentage changes in output from the removal of price support are shown in Figure 7.6. The removal of the price support significantly reduces largeholder output for every year of the simulation. Output has fallen by around 50 per cent for Madang largeholders and 45 per cent for ENB. Without the price support, the devaluation effects for largeholders are as expected. As the percentage devaluation increases, the NPV of output increases (see Table 7.10).

Table 7.10 Effects of devaluation on the NPV of largeholder output without price support

Province	Base	5 per cent		10 per cent		15 per cent	
	tonnes	tonnes	% change	tonnes	% change	tonnes	% change
ENB	44 854	48 545	8.2	52 357	16.7	56 290	25.5
Madang	16 987	18 344	8.0	19 751	16.3	21 200	24.8

Source: Appendix G.

7.4.3 Cost of price support

In costing the price support, only the net costs of the bounties less levies were calculated. Costs for administering the scheme were not included. In NPV terms, the government pays out a total of 78 million kina to the three provinces over the 20-year period. The costs for individual sub-sectors are given in Table 7.11. This is compared to the loss in gross value and net value output from the removal of the support. The losses in value of output are probably underestimated because they do not account for producers temporarily leaving the market when prices fall below the average variable cost of production. Note that given the absence of an industry supply curve, economic surplus could not be calculated in the standard way. Hence, an alternative and less precise measure has been adopted. Instead of calculating the changes in costs per tonne with changes in producer prices, average costs per tonne are used.

For ENB and East Sepik smallholders, the cost to the government of price support is greater than the loss in gross value of output. Madang smallholders marginally benefit from the price support scheme since the loss in value of output from the removal of the scheme is greater than the cost of the scheme. Seemingly, largeholders are also benefiting from the scheme, with the cost of the scheme being 25 per cent less than the loss in the value of output from its removal.

In net value terms, where the saved cost in inputs is also calculated, the loss in value of output from the removal of the scheme is less than the cost of the scheme for every sub-sector. Under constantly depressed prices, the effects of price support seem to have a negative effect on the economy. This suggests that resources are being diverted into the cocoa industry under supported producer prices which could have distortionary effects on the economy.

Table 7.11 Effects from the removal of price support

Province	East Sepik	ENB		Madang	
	SH (Kina)	SH (Kina)	LH (Kina)	SH (Kina)	LH (Kina)
Cost to government (1)	8 379 332	31 188 083	24 844 711	2 941 337	10 958 212
Loss in value of output (2)	8 262 524	27 683 810	32 763 968	2 962 333	15 118 263
Aggregate cost saved (3)	650 258	4 461 173	13 171 263	104 267	4 879 798
Loss in net value of output (4 = 2-3)	7 612 266	23 222 638	19 592 705	2 858 067	10 238 465
Net loss (5 = 1-4)	767066	7 965 445	5 252 006	83 270	719 756

Note: Losses in value output are calculated using DIS prices and all values are calculated in net present value terms.
Source: Appendix G.

7.5 Increasing FOB Prices

The scenarios above have been based on low FOB prices over the 20-year period and the subsequent impacts of devaluation and the removal of the price support. The following scenario investigates whether *increasing* FOB prices lead to a similar outcome on the removal of the price support. Results of the simulation runs are given in Appendix G..

Using World Bank price projections (1997), the bounty is only received by growers in the first two years. No bounties or levies are paid or collected for the following six years, after which increasing levies are incurred by producers (see Table 7.12).

Table 7.12 Prices, bounties and levies

Year	Bounty	Levy	FOB	DIS	Producer price
1996	483.05	0	984	816.95	1 300.00
1997	185.48	0	1 311	1 114.52	1 300.00
1998	0	0	1 702	1 470.33	1 470.33
1999	0	0	1 787	1 547.68	1 547.68
2001	0	0	1 802	1 561.33	1 561.33
2002	0	0	1 832	1 588.63	1 588.63
2003	0	0	1 862	1 615.93	1 615.93
2004	0	0	1 893	1 644.14	1 644.14
2005	0	13.93	1 924	1 672.35	1 658.43
2006	0	28.49	1 956	1 701.47	1 672.99
2007	0	43.05	1 988	1 730.59	1 687.55
2008	0	58.06	2 021	1 760.62	1 702.56
2009	0	73.08	2 054	1 790.65	1 717.58
2010	0	88.09	2 087	1 820.68	1 732.59
2011	0	103.56	2 121	1 851.62	1 748.06
2012	0	119.49	2 156	1 883.47	1 763.99
2013	0	135.41	2 191	1 915.32	1 779.91
2014	0	135.41	2 191	1 915.32	1 779.91
2015	0	135.41	2 191	1 915.32	1 779.91

Source: Appendix G.

With increasing prices over the period, the NPV of cost of the scheme in the smallholder sector is less than the NPV of loss in net value of output from the removal of the scheme (see Table 7.13). Although the results suggest that the scheme has a positive effect on smallholder value of output and the economy, it must be noted that the levies incurred in the last years of the analysis are heavily discounted compared with the bounties paid out in the first two years.

In the largeholder sub-sector, the government collection of levies is greater than the amount paid out in bounties (see Appendix F). With rising prices over the period, the rate of replantings increases, and hence output also begins to increase more rapidly. Over the period, Madang largeholder and ENB largeholder annual output increases sevenfold and fivefold, respectively. When levies are imposed in year nine, the output levels are already over 100 per cent higher than in the base year and hence the NPV amount in levies is greater than the initial amount given out in bounties. In contrast, the removal of the scheme also generates a gain in net value of output, especially for ENB largeholders. After 12 years, the level of annual output is greater without the scheme and the gain in net value of output for ENB largeholders is over five times greater than the net levies generated from the price support. Given the more rapid increase in output for Madang largeholders over ENB largeholders, the NPV amount collected in levies is 3.3 times greater than the NPV amount paid out in bounties. Hence, over the period, net levies from the price support are marginally greater than the gain in net value output from the removal of the scheme.

Table 7.13 Effects of the removal of price support with increasing FOB prices

Province	East Sepik	ENB		Madang	
	SH (Kina)	SH (Kina)	LH (Kina)	SH (Kina)	LH (Kina)
Cost to government (1)	591 314	7 336 520	(1 151 257)	377 871	(1 829 791)
Loss in value of output (2)	1 674 262	15 373 358	7 349 915	1 080 981	101 908
Aggregate cost saved (3)	158 675	5 405 373	13 504 727	51 227	946 811
Loss in net value of output (4 = 2-3)	1 515 586	9 967 987	(6 154 813)	1 030 238	(1 048 719)
Net loss (gain) (5 = 1-4)	(924 272)	(2 631 467)	5 003 556	(652 367)	(781 072)

Source: Appendix G.

7.6 Introduction of High-Yielding Varieties

To capture the effects of the introduction of HYVs, the scale factor is adjusted to double the initial yields. Adjustments to scale factors for each province are reported in Table 7.14. Given the lack of production data on HYVs, the input elasticities for all varieties are assumed identical and there is also no accounting for rates of adoption. More meaningful analysis could be performed with increased availability of data (see section 8.3).

Table 7.14 Scale factors for existing and new technologies

Province	East Sepik	ENB		Madang	
	SH	SH	LH	SH	LH
Scale factor—traditional	0.024	0.033	0.103	0.023	0.183
Scale factor—new	0.032	0.045	0.133	0.032	0.236

Source: Appendix G.

Under base run conditions, Madang largeholders more than double the NPV of output from 34 000 tonnes to 69 500 tonnes. Producers still do not break even in every year, operating below their average cost in seven of the 20 years. ENB largeholders more than double their NPV of output, making a loss in only one year. Smallholders double their annual output in NPV terms (see Table 7.15).

Table 7.15 NPV of output with and without impact of HYVs

Province	East Sepik	ENB		Madang	
	SH (tonnes)	SH (tonnes)	LH (tonnes)	SH (tonnes)	LH (tonnes)
Base run	27 804	104 565	80 557	19 314	34 000
Base run with HYV	54 355	210 445	161 474	38 737	69 500
% change	95	101	100	100	104

Source: Appendix G.

7.7 Expansion of the Smallholder Sector

Under the above scenarios, there is no expansion of new plantings onto less suitable land. However, in ENB, where over 60 per cent of the highly suitable land has been planted to cocoa, concern has been raised as to the sustainability of the resource base with the expansion of the sector (Bleeker and Freyne 1981). ENB extension services and projects are encouraging smallholders into the industry, leading to further expansion of the area under cocoa.

In an attempt to capture the effects of extension projects in the model, a constant is added to the new planting equation, representing the annual number of hectares planted to cocoa under smallholder projects. If, on average, 530 hectares of land are planted to cocoa over the next 20 years, the amount of highly suitable land becomes zero. Given this level of smallholder expansion, cocoa holdings may be established on more marginal lands where yield potentials would be reduced and more inputs would be required to maintain yields (see Table 7.16).

Table 7.16 Availability of suitable land in ENB with smallholder project

Year	NP1	NP2	NP3	Suit1	Suit 2	Suit 3
1996	1 165.57	0	0	22534	223 800	1 061 700
1997	1 165.57	0	0	21369	223 800	1 061 700
1998	1 165.57	0	0	20203	223 800	1 061 700
1999	1 165.57	0	0	19038	223 800	1 061 700
2000	1 165.57	0	0	17872	223 800	1 061 700
2001	1 165.57	0	0	16707	223 800	1 061 700
2002	1 165.57	0	0	15541	223 800	1 061 700
2003	1 165.57	0	0	14375	223 800	1 061 700
2004	1 297.68	0	0	13078	223 800	1 061 700
2005	1 165.57	0	0	11912	223 800	1 061 700
2006	1 165.62	0	0	10747	223 800	1 061 700
2007	1 165.57	0	0	9581	223 800	1 061 700
2008	1 165.57	0	0	8415	223 800	1 061 700
2009	1 212.15	0	0	7203	223 800	1 061 700
2010	1 165.57	0	0	6038	223 800	1 061 700
2011	1 381.81	0	0	4656	223 800	1 061 700
2012	1 165.57	0	0	3490	223 800	1 061 700
2013	1 165.57	0	0	2325	223 800	1 061 700
2014	1 235.76	0	0	1089	223 800	1 061 700
2015	1 089.00	0	0	0	223 800	1 061 700

Source: Appendix G.

7.8 Policy and Research Implications

Under price support and in times of low world prices, smallholders benefit more from devaluations than largeholders, given their low imported input costs. The neutralising effect of price support causes the devaluations (5, 10 and 15 per cent) to have a significantly negative impact on annual output levels and the NPV of output for ENB and Madang largeholders and returns for largeholders in Madang. The low prices suppress plantings and, as already mentioned by Fripp (1996), decreasing returns per tonne lower the levels of maintenance and hence reduce future output levels. The results suggest that exchange rate policy to increase industry output should not be implemented under price support.

The cost of the price support scheme, under low world price conditions, generates income losses in every sub-sector. This suggests if low world prices are likely to prevail, the price support scheme will not be beneficial to the industry or economy as a whole.

If the world prices are expected to increase over the next 20 years, the price support would be beneficial to the smallholder sub-sector and the Madang largeholders. The rising prices increase the levels of plantings, significantly increasing output in the largeholder sector. The collection of levies under higher prices reduces the cost of the scheme to the government and to the economy. However, this result assumes producers are certain of increased prices over the period.

On the research side, the adoption of HYVs—and the consequent changes in the use of inputs, expected yields and income for both smallholders and largeholders—needs to be investigated further. A more meaningful and complete analysis should be carried out when more input-output data become available (see section 8.3 on further research).

Given the elastic replanting response by largeholders, and the following expansion of the sub-sector output, further work is required on the impacts of soil fertility from continuous planting, especially if the SG2 mod. variety is adopted, requiring more nutrients than the traditional varieties.

In the ENB smallholder sub-sector, the expected expansion of the industry needs to be monitored, given the limited availability of highly suitable land. If smallholders move onto less suitable land, they will require increased fertiliser inputs to maintain the average yields, thereby increasing their average costs. If fertilisers are not applied, the fall in yields will adversely affect their income levels.

8. Summary, Limitations and Recommendations for Further Research

The study has provided a preliminary framework by which policy makers can assess the impacts of policies on cocoa producers. Although it has been limited to exchange rate and price support effects, the model could also be used for simulating the impacts of many other policy changes, with the relevant data. The model is also useful in its attempt to define the key variables and relationships within the cocoa production system and where policies are most likely to have an impact. By doing so, it helps to identify where key data are lacking in policy analyses.

8.1 Summary of Findings

The policy scenarios were designed to assess the impacts on output and producer returns of smallholders and largeholders in three provinces. The major findings showed that the impact of the devaluation and price support depended on the expected world prices. The price support was found to be more beneficial when world prices increased over the period rather than under depressed world prices.

More specifically, under low world prices and the existing price support, the 5 per cent devaluation of the currency had a negligible effect on smallholders, given the neutralising impact of the price support. However, as the devaluation was increased to 10 and 15 per cent, the impact on smallholders' output levels was increasingly positive. For largeholders, especially in Madang where imported costs were significantly high, the increased input costs and the neutralising effect of price support caused the devaluations (5, 10 and 15 per cent) to have an increasing and significantly negative impact on annual output levels and the NPV of output.

Under low world prices and the removal of the price support, output levels initially reduced by up to 35 per cent in the smallholder sector and 50 per cent in the largeholder sector. However, the cost of the price support scheme generated net income losses in every sub-sector.

Under increasing prices, the price support benefited the smallholder sub-sector and the Madang largeholders. The fund was in surplus in the largeholder sub-sector and the cost in the smallholder sub-sector was less than the loss in value of output from the removal of the scheme.

As expected, the adoption of the higher yielding variety, SG2-mod., increased the output by around 50 per cent in all sub-sectors. However, lack of data limited the analysis.

8.2 Limitations of the Study

In comparison with the vintage-capital approach, the production function-based model has several limitations. The coefficients in the model are determined with a limited amount of data. Hence, sensitivity tests were needed to evaluate their impact on supply elasticities before including the coefficients in the model. Being a partial equilibrium model, the impacts of individual sub-sectors on aggregate variables, such as wages and interest rates, were not included. However, given the flexibility of the model, wages and interest rates can be dependent on the demand for inputs, either manually or through equations linking these variables (Akiyama and Coleman 1993).

Being a study on the short-run effects of policy changes, the production function only considered the variable costs. The inclusion of fixed costs, however, may be of importance to the largeholder sub-sector and significantly influence their supply and planting decisions.

The lack of data on producer behaviour, planting responses, effects of management practices, technological change and climate and soils severely limited the scope of analysis. With more information on the cocoa production system, policy makers would be better equipped to analyse and recommend the effects of policy changes on the industry.

8.3 Recommendations for Further Research

In recommending further research, the data requirements are also discussed. Other policy scenarios and extensions and improvements to the existing framework are considered.

8.3.1 Policy issues

Extension and research policy

Analysis of the impacts of research and extension would require further data on the adoption rates of HYVs by both smallholders and largeholders in different provinces, data on the cost of converting to new technologies, variable costs of the different technologies, and the elasticity of yield with respect to fertiliser and labour inputs (Akiyama and Coleman 1993). Since adoption rates are influenced by both economic and social factors, social variables may need to be included in the adoption rate equation. It was noted that many smallholders adopt a new technology in order to look progressive to other growers (Woruba 1997). Credit availability and risk have also been considered critical factors in the adoption of HYVs (Ruf 1995; Barlow and Jayasuriya 1986).

In addition, it has been suggested that adoption rates increase with closer proximity to research stations (Effron 1997). Hence, it may be useful to carry out a spatial analysis, assessing whether there is any change in the adoption rates in relation to the distance from the research station.

Extension policy in ENB is concentrated on increasing smallholder incomes through the adoption of driers and fermentaries. Ryan (1997) raised concern that the strategy would not be beneficial to the smallholders unless they also practised disease control. The model could capture this with the inclusion of management variables in the production function (see section 8.3.3).

Credit policy

The impact of credit policy on cocoa producers is currently an issue, with the encouragement by extension services of smallholder investment in driers and fermentaries (Omuru 1996). With the exception of palm oil, cash crops grown in the village sector have been established without loans or other forms of rural credit. However, with the introduction of fermentaries and driers to the smallholder sector, smallholders are now receiving subsidised loans which may alter their supply and planting decisions.

In the model, credit availability and changes in the rates of interest would need to be included in the planting decision equation. The current indebtedness of largeholders may also influence supply decisions. Largeholders may continue to supply cocoa even when prices fall below the minimum price.

8.3.2 Supply and planting responses

The existing model only accounts for changes in the current production period. Given the nature of perennial crops, where decisions made this period have an impact on future yields, the model could be extended to show the policy impacts on production in the current year as well as future yields. With low prices, producers tend to decrease their use of inputs and level of management, and hence lower the potential yields of future crops. This would require information on the yields of the different ages of trees, labour hours and purchased inputs over a period of at least six years.

The significant difference between estimated and actual plantings suggests more research is required on new planting and replanting responses. Currently, there is no information collected on new plantings and replantings. Ideally, data should be collected on the estimated level of new plantings and replantings by sector and province. The factors influencing the planting responses also need to be considered, such as price responsiveness, market access, price of inputs, climatic factors and other activities producers may engage in.

Smallholders often suffer from a shortage of labour during flush periods. A modification to the harvest response may be needed to incorporate labour supply constraints. Hence, information would be required on labour hour requirements for harvesting and the seasonal supply of labour.

Cocoa supply is determined by social, economic and ecological factors (Ruf 1995). Further research adopting a 'farming systems' approach would provide policy makers with a more comprehensive framework of the cocoa-based farming system. However, this type of research is restricted by its large data requirements, making it more suited to case study research.

8.3.3 Management

To assess the impacts of research and extension policy on the cocoa industry, it would be useful to extend the existing model to incorporate different management strategies. Changes of management practices impact on current and future yields and vary according to the age of trees. Modifications of the yield profiles and production functions could then be made to reflect different management strategies such as fertiliser use, shade, pruning, spacing, and pest and disease management. However, to achieve this, a more sophisticated software package maybe required such as Matlab.

Fertiliser use

Given the introduction of the HYVs, research is needed on the impact of fertiliser use on industry output. Given their vigorous growth rate, HYVs require fertiliser if high yields are to be maintained. If no fertiliser is used, yields are expected to fall. This is most relevant to the smallholders who currently use very little fertiliser.

Since CCRI trials have shown little yield-fertiliser response, few fertiliser response trials are being carried out. However, it may be useful if on-farm trials are carried out to estimate HYV yields with and without fertiliser use, to assess if there is any impact on output.

Shade management

As shaded cocoa is a complex system, process-oriented models are needed for a quantitative assessment of the interactions and feedback processes (Gerritsma 1993).

The economic returns to different cocoa-shade and cocoa-perennial crop combinations need to be analysed and compared with the results of unshaded cocoa. The benefits of shade vary according to management strategies, the age of cocoa and under different climatic and soil conditions. These issues would need to be considered in the collection of data.

The yields presented in Table 8.1 are the average yields for a 10-year period of mature cocoa in a climate similar to the conditions found at BAL estates, Malaysia. As the shade canopy increased, the reduction in yields is greater (Gerritsma 1993).

Table 8.1 The influence of shade on cocoa yields, Malaysia

Treatment	Dry bean yield (tonne/ha/y)
Control: no shade	2.7
LAI_{shade} = 1, shade canopy layer 2-7m	2.1
LAI_{shade} = 2, shade canopy layer 2-7m	1.6
LAI_{shade} = 2, shade canopy layer 8-10m	1.5

Source: Gerritsma (1993).

However, estimated cocoa yield profiles for North Solomons province showed that yields were higher under intercropping with coconuts until the sixth year, when shade is no longer necessary for the mature cocoa (Densley and Barker 1987) (see Table 8.2).

Table 8.2 Largeholder cocoa yield profiles for intercropping and monocropping, North Solomons Province

Year	0	1	2	3	4	5	6	7-12	13-15
Monocrop	0	0.1	0.4	0.75	1.0	1.6	1.6	1.6	1.5
Intercrop	0	0.1	0.35	0.75	1.1	1.6	2	2	2

Source: Densley and Barker (1987).

Disease and pest control

Black pod disease has been a major cause of crop loss in Papua New Guinea. In capturing its likely impact on the industry, the susceptibility of varieties to diseases such as black pod would need to be known. Climatic data would also need to be included in the model, since high levels of rainfall increase the incidence of the disease (Cazorla, Santos and Gasparetto 1995). CCRI has run trials on the incidence of black pod on different varieties of cocoa. Chemical control packages have been recommended by researchers, along with the encouragement by extension services to improve pruning methods to reduce the incidence of the disease.

Research is now required on the change in profitability and output to farmers from adopting disease control strategies. The production function could be expanded to include a third variable for disease control. However, consideration would need to be given to the impacts of disease control on current and future yields and if there is any difference according to the age of the trees.

8.3.4 Economic surplus

Given the negative price elasticity found in Ruhle and Fleming's (1998) study, further research is required on estimating the supply response of cocoa producers. Due to time and space constraints, changes in economic surplus were not calculated in the model. However, by deriving a profit function with respect to producer price, the producers' supply function could be obtained. Since the production function used in the model is a Cobb-Douglas, the profit function takes on the same form. Using the first-order conditions, already in the model, the corresponding maximum profit, as given by Sadoulet and Janvry (1995), is:

$$\pi = a^{1/1-\alpha}\alpha^{\alpha/1-\alpha}(1-\alpha)\, Z^{\beta/1-\alpha} p^{1/1-\alpha} w^{\alpha/1-\alpha}$$

where p is the price of output, w is the price of inputs and z is a vector of fixed factor quantities. This function can only be accepted as a profit function if it is non-negative, monotonically increasing in prices of outputs, convex and homogeneous (Sadoulet and

Janvry 1995). The Hotelling duality lemma is then applied to the profit function to obtain the supply curve:

$$\partial\pi/\partial p^{i}\,(p,w,z) = q^{i}.$$

Hence, the supply curve is:

$$q = a^{1/1-\alpha}\,(\alpha p/w)^{\alpha/1-\alpha}\,Z^{\beta/1-\alpha}.$$

Economic surplus (equated to producer surplus given perfectly elastic demand for PNG cocoa) could then be estimated from the supply curve.

8.3.5 Sustainability and environmental issues

The sustainability of the cocoa production system is relevant in terms of the expansion of the smallholder sector and the continuous cropping practised by largeholders. The long-term impacts of government policy on the cocoa industry need to be measured so as to study the sustainability of the cocoa production system (Ruf 1995).

Time series data would be required on the changes of yields under major cocoa soil types for replanting and new planting areas. Alternatively, given that the model is assessing potential impacts, yield prediction models, such as Plantgro (Hackett 1991), could be used to estimate potential impacts and incorporated into the production function. Natural resource information is available from PNGRIS, which may allow for the incorporation of a biophysical model. This would capture the changes in plant growth and soil conditions and its impact on cocoa yields under differing agro-ecological conditions. This in turn could be incorporated into the production function through soil fertility and climate variables.