PRIORITIES FOR PAPUA NEW GUINEA AGRICULTURAL RESEARCH - AN ACIAR PROJECT

<u>Returns to Cocoa Research 1965 to 1980 in Papua New Guinea</u>

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<u>Returns to Research on Insect Pollination of Oilpalm in Papua New Guinea</u>

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Introduction

The project "Priorities for Papua New Guinea Agricultural Research" is financed by the Australian Centre for International Agricultural Research. It is one of four country studies building on the in-house priority excercise carried out at ACIAR (Davis, Oram and Ryan 1987). Research is being carried out at the University of New England, in cooperation with the PNG Department of Agriculture and Livestock as well as other government and non-government instrumentalities in PNG, with the objective of assisting decision-makers in their task of research resource allocation.

In contrast with the situation that prevails in several other countries, quantitative analyses of the effectiveness of past PNG agricultural research are not available. Partly for this reason, agricultural research has something of a credibility problem in the country. To help redress the situation, a limited *ex-post* component has been included within what is principally an *ex-ante* oriented study. A mere two past research projects have been selected and analysed. Selection has been on the basis of expected returns. The analyses thus do not pretend to be representative of all past PNG agricultural research. Rather, they are intended to demonstrate that some economically successful research has been carried out in PNG.

The present conference paper contains the two separate analyses of research on cocoa and oilpalm in PNG.

Returns to Cocoa Research 1965 to 1980 in Papua New Guinea*

George Antony and Gae Kauzi

1 Cocoa in the PNG Economy

It is held that cocoa was introduced into Papua New Guinea around 1905 by German settlers. However, the commercial development of the crop proceeded at a very slow pace. With the substantial rise in world demand after World War II, the then Department of Agriculture and Livestock promoted the expansion of the industry.

In the 1950s and 1960s there was a rapid expansion of cocoa plantings, thus the total planted area increased from about 4700 hectares in 1951/52 to around 49.5k in 1965/66. Over the same period production increased from 485 t to 15 kt, with the plantation sector producing 95 per cent of the total production in 1965/66. In subsequent years, production from the smallholder sector rose at a fast rate as a result of increased adoption by villagers, especially in the provinces of New Britain and North Solomons. By 1970/71 the smallholder production had increased its share of the total production from five per cent in 1965/66 to about 20 per cent. Smallholder plantings continued to increase and, by 1975/76, smallholder production accounted for around 40 per cent of the total. Today its share of the total national production averages around 70 per cent. While the smallholder sector increased its production from 1965 onwards, there has been a steep decline in estate production. Total national production has been stagnating until very recently, as the increase in smallholder production has more or less offset the decline in largeholder production.

More recently, production has been expanding with the large areas that underwent redevelopment and new development in the early 1980s coming into bear. Most of the production comes from the New Guinea Islands region, particularly from North Solomons and East New Britain, with the former accounting for 45 per cent of the national crop, and the latter for 34 per cent. Over the past 12 years, 1975 to 1986, annual cocoa production averaged at 32 kt, and cocoa bean export volume averaged at 30 kt. Papua New Guinea's share of global exports stands at about three per cent.

Cocoa has been the second most important crop after coffee in terms of export earnings for the country over the period 1975 to 1986. Cocoa-export income over the period averaged K57m, with a peak of K83m in 1977 (due to the high f.o.b. in the year), and a low of K29m in 1975. Over the same period, cocoa has contributed 18 per cent of agricultural export earnings , while its share of national total export earnings averaged about 8.5 per cent. In relation to the gross domestic product, cocoa contributes about three per cent.

Of the 314 thousand households in the coastal provinces (1980 census), 22 per cent were involved in cocoa production. In addition, the cocoa estate sector employs about 8000 people and provides additional employment in the service and processing industries.

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2 Cocoa Research in PNG

2.1 A Short History

The cocoa cultivar grown in PNG is Trinitario - a natural hybrid of the Criollo and Forastero types. Before WWII, a seed garden has been set up in Keravat, East New Britain Province, to collect specimens of the very diverse Trinitario material grown in the country. The war disrupted work, but selection and breeding commenced at the Lowlands Agricultural Experiment Station (LAES), in Keravat, soon after its end.

The Cocoa Improvement Programme of the time was aimed at the selection of material that is better yielding than what was available in the country while retaining its desirable characteristics in fat content, flavour, vigour and resistance to pests and diseases (LAES 1982). The main avenue followed at this time was that of selection and, increasingly, clonal propagation. The results of this first stage of PNG cocoa research were more than planting material that was better yielding. Painstaking documentation of every tree in the seedgarden resulted in detailed records about the available breeding material without which even today's breeding work would be far less effective (D. Loh, personnal communication).

The first round of Trinitario selection was about to be terminated and the breeding work to produce cocoa hybrids started when, in 1965, vascular-streak disease (VSD) appeared in PNG. Crop pathology had to be given utmost priority, and any other work was put on the back burner. VSD-resistant material has been selected and propagated after the successful identification and separation of the pathogen, first achieved at LAES. VSD-resistant clones were distributed from 1968 to 1973, saving the cocoa industry in East New Britain. In addition, the identification of the pathogen was quickly followed by strictly enforced quarantine measures which prevented the disease from spreading to New Ireland, Manus and North Solomons provinces to the present day.

The hybrid program was resumed in 1972, with first-generation hybrids released since 1980. The hybrids have significant advantages over the old Trinitario clones, primarily in yield and fertiliser response. Planting material from first-generation hybrids is still being distributed, and the first significant yields from hybrid stands have been harvested in 1985.

Cocoa research in PNG has been transferred from the public domain to the Cocoa Industry Board by 1986, and this can be expected to put funding on a firmer footing.

Present research includes the development of second-generation hybrids (expected to be released from 1988); entomology work on the pest Panthorhytes; pathology research of the Phytophtora palmivora that causes black pod and stem canker; and the research of post-harvest technologies.

2.2 Choice of Research Period for Evaluation

Quantitative analysis of PNG cocoa research from its very beginning is not possible because of data problems. Records of the costs of early research are scarce, if obtainable at all, and the quantification of research benefits from this period would be a similarly difficult task. Since the results of this early period - most of all the detailed records on the breeding materials used - contributed to the success of later work, ignoring the early work could result in a serious under-estimation of the costs of research. On the other hand, the early period has yielded research results of its own (most of all, a selection from the original Trinitario material that was higher yielding and better suited for the local conditions). The assumption that benefits from the early period were at least the same size as the costs is plausible, although supported only by anecdotal evidence. Consequently, not charging later research for the use of results from the earlier period is not expected to result in the overestimation of benefits.

More easily available are records on research costs since the mid-60s. The main benefits of the vascular-streak dieback (VSD) research work of that time are still to be reaped through the production-increasing effect of hybrids, whose parental material came partly from the VSD-resistant Trinitario clones. Partial replanting of VSD-susceptible stands with resistant Trinitarios since the late 60s resulted in increased production compared to what could have been harvested from a uniformly susceptible tree stock. However, this effect was a relatively minor one, compared with the role of the VSD-resistant clones as hybrid parents. Also, some resistant planting material would have been selected by growers, albeit in an un-coordinated way and results would have probably taken considerably longer to appear (P. Turner, personal communication).

On the other hand, no evaluation of PNG cocoa research would be realistic without at least considering the first-generation hybrids. Although most of their benefits still lay ahead, and thus have to be estimated (rather than measured in a potentially more precise manner), they are the first seemingly significant production-increasing results from decades of research activities.

3 Quantitative Analysis

3.1 Objectives

The objective in the present study is to estimate the net increase in welfare resulting from the introduction of the designated new technology. In addition, some indication about the distribution of welfare gains within the country is also intended to be elicited.

3.2 Method

Analyses of technical change are often based on the notion of economic surpluses (see Currie, Murphy and Schmitz 1971 for a rationale for this approach).

The increase in economic surplus due to technological change can be identified as the shaded area ABCD in Figure 1 (non-linear supply and demand curves shown, along with a proportional divergent shift of the

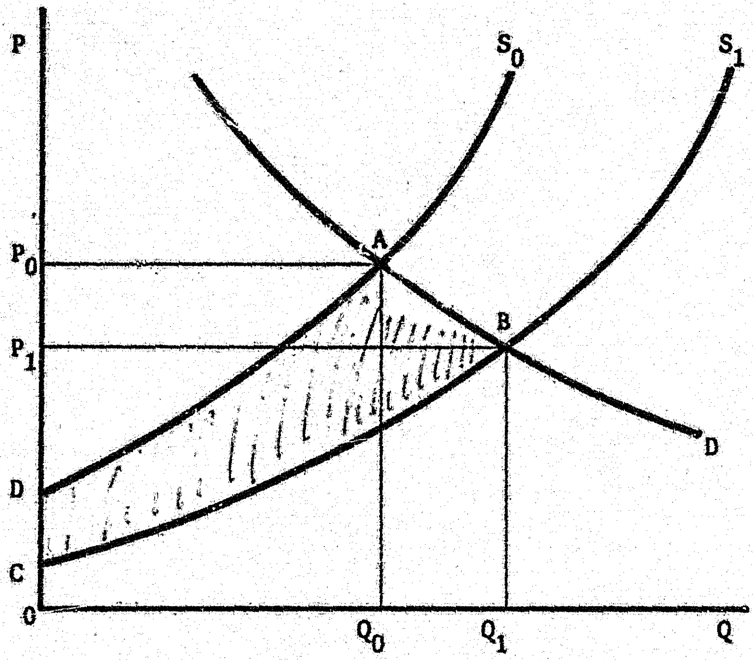

Figure 1 Change in Economic Surplus: A General Case

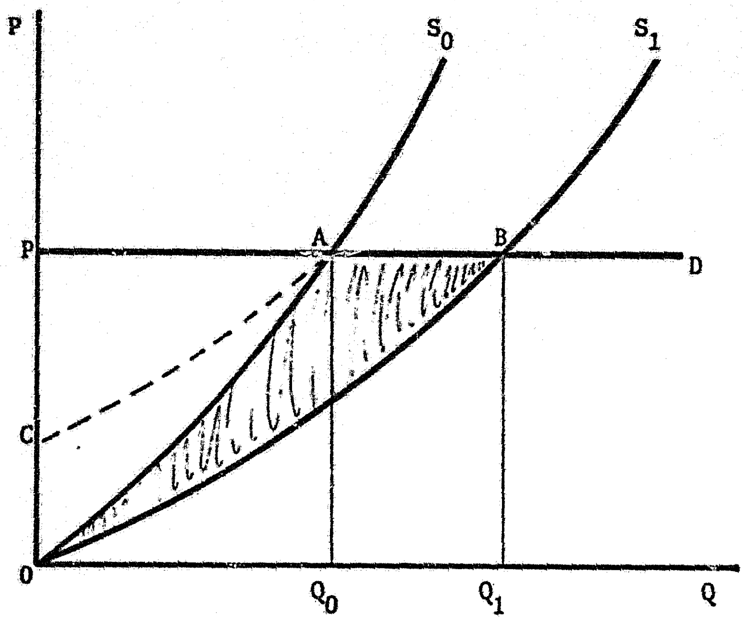

Figure 2 Change in Economic Surplus: Pivotal Supply Shift and Perfectly Elastic Demand

supply schedule)[1]. At the national level, the supply shift due to the introduction of cocoa hybrids is most probably convergent, as smallholders - the more marginal producers - can be expected to adopt the new technology more slowly and to a lesser extent than can plantations (see Lindner and Jarrett 1978 for a discussion of shift types)[2]. Separation of the national supply to smallholders and plantations, however, results in two reasonably homogeneous entities with supply characteristics different from one another.

The rate at which smallholders increase (decrease) production of cash crops in response to price increases (decreases) is generally accepted to be below that of plantations. In PNG, there is evidence among smallholders of "normal" supply response as well as of an inverse reaction, i.e., that a price increase can lead to the reduction in the quantity of produce supplied to the market (Anderson 1977). In the whole of the smallholder sector, this may well lead to a quite inelastic supply in the short run and to a long-run response well below that of the plantation sector. Even in the plantation sector, factors other than price often affect supply. Prominent among these is uncertainty about government policy towards plantations (Goldthorpe 1985).

The analysis by Akiyama and Duncan (1982; quoted by Jolly 1987) of the world cocoa market does not distinguish between the two sectors when deriving elasticity figures for PNG supply response. Short-run elasticity of supply to price changes was estimated to be between 0.095 and 0.26 in general, and 0.103 for PNG in particular. Long-term elasticities were quoted as being 0.11 to 0.59. In the present study, the figure of 0.1 is used for smallholders and 0.4 for plantations.

While there is no particular functional form that would be especially well suited for this study, linear formulation has been excluded as it would result in a negative intercept term - implying that farmers are ready to produce at negative prices. Instead, the constant elasticity of supply functional form has been chosen. The supply shift is unlikely to be uniform even within the sectors, as some smallholders will certainly not replace their existing stands and some plantations may not switch to hybrids either. There is no way of telling how divergent the resulting supply shifts will be, therefore the most conservative estimate, a pivotal shift, is estimated for both sectors. Figure 2 illustrates the position of supply and demand curves and the shaded area OAB estimated, as developed conceptually by Akino and Hayami (1975). The

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[1] A simpler and less accurate method for calculating benefits accruing to investment projects is an appraisal (Gittinger 1982) that, in very simplistic terms, consists of the multiplication of the additional production by its price. Its drawback is that it attributes all measured benefits to the project. Prices, however, change without-project supply independently of (say) a research project.

[2] The criticism of the reasoning of Lindner and Jarrett by Rose (1980) actually confirms its relevance in the present case, as cocoa-producing smallholders have very few real alternative cash crops. The low technology-intensity of the crop is unique among the available high-volume cash crops in its production regions. Also, smallholders are quite reluctant to cut down existing stands of producing crops to replace them with something totally different.

broken line CA, left of the without-research supply curve OA, indicates a possible extent of underestimation, due to the use of a pivotal shift.

Since PNG is a small supplier of the world cocoa market, the simplifying restriction of perfectly elastic demand for the country's produce is reasonable. No consumer's surplus is generated in such a situation: all benefits are captured by the producers, in this case by the exporting country, PNG.

Following Herruzo (1985), area OAB is approximated as:

$$OAB = \frac{h}{\beta + 1} P\, Q_1$$

where: h = the relative measure by which the with-research supply curve would shift to the left in the absence of the new technology, i.e., $h = (Q_1 - Q_0)/Q_1$;

Q_0 = quantity of produce supplied without the new technology;

Q_1 = quantity of produce supplied with the new technology;

P = real price of the produce; and

β = price elasticity of supply.

The net present value of the difference between the streams of producer's surpluses and of research costs is calculated separately for smallholders and plantations as well as at the national level. Some of the variable (primarily transport) costs necessary for the production of the additional produce are in payment for imported goods and, thus, represent outflows reducing the benefits accruing to PNG. National gross producer's surpluses, calculated at f.o.b. prices, are reduced by the amount of these costs to determine net economic surpluses, while the price used in calculating sectoral benefits (farmgate price) is already net of these costs (as well as others that are not outflows at the national level). All values are expressed in real prices and discounted to account for the opportunity cost of resources.

$$NPV = \sum_{n}^{i=1} \left[\frac{(P_i - VC_i)\,(Q_{1i} - Q_{0i}) / (1 + \beta)}{(1 + r)^i} - \frac{RC_i}{(1 + r)^i} \right]$$

where: P_i = real price of produce in year i;

VC_i = variable-cost cost component of the extra production in real values in year i;

Q_{0i} = quantity of produce supplied in year i, without the new technology;

Q_{1i} = quantity of produce supplied in year i, with the new technology;

RC_i = real value of research cost in year i;

r = discount rate; and

n = number of years.

The discount rate used is 10 per cent, the same figure that is used by the Department of Agriculture and Livestock (DAL) for project appraisal.

National benefits are calculated for the elicitation of the returns to research. In addition, distributional effects are also considered. Apart from the distribution between smallholders and plantations, benefits redistributed to the government, the financier of the research, are worked out. (Only export tax is calculated, since company taxation and the effect of new technology on it could not be covered in the study.) The expected balance of stabilisation funds is computed. No other redistributive or multiplier effects in the economy are included in the analysis; the lack of the latter necessarily results in a further source of underestimation of total benefits to PNG.

3.3 Calculation of Research Costs

Over the period 1965 to 1980, the centre for PNG cocoa research has been the Lowlands Agricultural Experiment Station (LAES), Keravat, East New Britain Province. This period of research can be divided into two sections: selection of VSD-resistant Trinitario clones and the actual hybridisation. VSD research was, in a sense, an "overhead cost" of the hybrid program, and its benefits will continue to be reaped through the second generation of hybrids about to be released. Since second-generation hybrids were not subject to analysis in this study, all costs of VSD research have been charged against the first-generation program. This is an over-estimation of actual costs for the first-generation hybrid program.

Historically, some 65 per cent of the LAES budget was used in cocoa breeding, agronomy and VSD research between 1965 and 1980. This did not include the salary of research officers (ROs) employed either by the Department of Primary Industries or by various other organisations and working at LAES.

On the basis of recent years' data, the total budget of the LAES is quite close to the sum of the salary costs of researchers and of non-wage expenditures in cocoa research. (N.B., salaries for LAES ROs do not constitute a part of the LAES budget, rather they are sent directly from Port Moresby.) Since funds for non-wage research costs have been more restricted in recent years than earlier, and since research on crops other than cocoa used to be relatively more important than it has been lately, total LAES costs are probably well in excess of funds actually used in cocoa research in earlier years, and a good (probably conservative) approximation overall.

As exact figures were not known, it was assumed that if land, buildings and instruments belonging to LAES would have had to be bought at the beginning of the research program, the cost would have been K25k at 1965 prices (K108k in 1987). It was further assumed that, of these, only land had a salvage value of K26k in 1980, the final year of the research work scrutinised (K40k at 1987 prices). Most other capital items used in research (vehicles, for example) were hired, and their cost is already included in the research costs.

The best alternative use of LAES land would have been commercial cultivation of cocoa. However, cocoa produced in variety trials and other experiments was sold, with yields above those of good commercial farms. Consequently, not only was there no income forgone by using LAES land in cocoa experiments, but the opportunity cost was, in fact, negative.

3.4 Evaluation of Benefits from Research

a.) Without-research scenario

Cocoa research in PNG, carried out up to 1965, resulted in planting material more suited to local conditions, and probably better yielding than the original imported Trinitario selection base. If no cocoa research had been done since the mid-60s, the industry today would still produce from trees of basically the same genetic makeup as then. Quarantine regulations would rule out the importation of planting material, and selection would only be carried out by growers, or happen naturally through disease and pest infestation. Total production of the industry would likely to be below present actual levels, since VSD would still cause some yield losses, and resistant stands would be established far more slowly than with the use of resistant Trinitario clones selected in Keravat.

b.) With-research scenario

Although the replanting of still-producing Trinitarios with hybrids since 1980 means that production is forgone until the maturity of the new stand is reached, the consensus among the researchers at LAES was that this reduced production was amply compensated by the yield advantage of VSD-resistant Trinitario clones over the first-selection material. Even though some of these VSD-resistant stands were cut out to give way to hybrids, their higher yield still resulted in overall production in PNG remaining static between the start of replanting with hybrids and the first significant yields from them, in 1985. This yield gain is not accounted for in calculating research benefits, and there was agreement among LAES researchers that its magnitude was comparable with that of the production forgone between the cutting out of existing stands and the maturity of hybrids planted instead. If this balance is true in quantity terms, the fact that the unaccounted-for gains preceded the forgone yield by many years would make them considerably greater when measured in discounted values, resulting in an underestimation of the real returns to research resources.

Planting of the first-generation hybrids has started in 1980 and, although the producing life of many of these should extend beyond the year 2000, it was felt that including a benefit stream from beyond that year is too difficult to justify. Cutting off at the year 2000 is likely to result in an under-estimation of actual results, unless some unexpected development (e.g., a new disease or pest) necessitates early replacement of all the first-generation hybrids. Given the geographical structure of the industry, as well as the apparent success of past quarantine measures in stopping the spread of VSD short of North Solomons, a sudden decimation of all existing stands is very unlikely.

The introduction of the first-generation hybrids did not lead to an increase in input use. Recommended fertiliser levels are the same as for Trinitarios, while plant-protection costs even decreased due to better disease resistance. The only difference is in harvesting and processing. The most important resource used in harvesting is labour, priced at K14 per man day for smallholders (see Appendix 1) and at the rural minimum wage (K3.54 per day) for plantations. Transport costs are viewed as outflows at the national level. Farm-to-fermentary costs are K40/t dry bean for both sectors, fermentary-to-ship costs K30/t dry bean. As for processing, existing plants are capable of handling the increased yield without the need of installing extra capacity.

Although all income from cocoa sales at LAES is goes to government revenue, only the 500 kg/ha yield advantage over good commercial farms (due to using experimental hybrids) is considered as a direct research benefit. This is added to government revenue from taxing all cocoa exports.

Cocoa-Board forecasts expect a total of 60 kt of cocoa to be produced by 1996. This forecast was made the Board's ex-economist Hugh Coulter, mainly on the basis of sales of planting material (P. Turner, personal communication). This prediction includes the more uncertain effect of the second-generation hybrids as well. First-generation hybrids have featured significantly in PNG production since 1985. They are expected to reach the maximum contribution of 12.5 kt/year (over the without-research Trinitario level of 30 kt/year) by 1995, and to continue at that level beyond the cut-off year 2000 (chosen on the basis of a panel discussion at LAES).

The smallholder-to-plantation production ratio has been 7 to 3 over the period 1983-86. However, due to the expected lower adoption rate of the hybrids by smallholders, 60 per cent of the increased production is assumed to come from plantations and 40 per cent from smallholders. Production costs have been obtained from DAL. Price projections used are as used by DAL, based on World Bank forecasts.

4 Discussion

Despite the very "conservative" form of this analysis, returns to funds used in cocoa research can be expected to be satisfactory.

By the year 2000, the additional production of first-generation cocoa hybrids will have amounted to 137 kt, representing a 28 per cent increase over the scenario that no cocoa hybrids are used in PNG during the period 1977-2000. The distribution of this production gain is largely speculation, but - on the basis of assumptions about adoption (section 4.4.b) - smallholder production is anticipated to increase by 55 kt (or 16 per cent over without hybrids) and plantation production by 82 kt (57 per cent).

The accuracy of the production estimates is crucial for the reality of the above figures, and these and the World Bank price forecasts have to be fulfilled for the financial analysis to be a reliable prediction. With these qualifications, however, the financial analysis is believed to be a serious underestimation of the benefits to be actually reaped. This is because of the conservative data used throughout, and in reality may well be 100 per cent greater.

In financial terms, the benefits, measured as the additional discounted economic surplus, can be expected to be at least K94.3m at 1987 prices. On the other hand, cocoa research carried out between 1965 and 1980 has cost about K11.4m, expressed on a discounted basis in 1987 prices. In other words, had no cocoa research been undertaken during the period 1965-80, K11.4m (1987) could have been saved, at the expense of not earning K94.3m (1987) between 1977 and 2000.

National benefits are 8.3 times the costs, and the internal rate of return (i.e., the effective earnings on funds used) is around 22 per cent.

Provided that the assumptions about the distribution of physical production gains are correct, the smallholders' share of the gross national benefits is expected at K26m. Plantations will have increased their takings, through to the introduction of the hybrids, by some K34m.

Although the hybrids may well be more widely adopted by plantations that by smallholders, those smallholders who do replant with hybrids will gain relatively more than plantations. The reason for this is the price elasticity of supply being lower for smallholders than for plantations. That is, plantations would have responded to price changes by varying their production even in the absence of hybrids more than smallholders would have.

Employment effects of the increased production have not been investigated in much detail. If there are no presently unused labour reserves, increased labour requirements on smallholders' plots might mean that food will have to be bought instead of produced. This worst-case scenario has been used in calculating smallholders' benefits in the form of a "wage" being charged against gross benefits (see Appendix). If labour reserves do exist, actual smallholder benefits will be greater by the amount of this "cost". Increased labour costs for plantations, on the other hand, mean additional income for employed labourers. This is an example of the secondary effects of new technology in the economy that have not been looked at.

In addition to the establishment of the extent of national benefits, it is worthwile to identify some transfer payments in the economy. By 2000, the PNG government will have earned about an additional K2.7m as the result of successful hybridisation research in cocoa. This figure includes additional export-tax takings and the additional production at LAES, but does not contain any possible increase in company taxes.

The additional production could well cause problems for the stabilisation fund. Assuming the continuation of the present regime, K2.8m more will have to be used for price support with the hybrids entering production that without them, over the period 1985-2000.

Regional effects of the new technology have not been investigated in this analysis. Cocoa is probably the most dispersed of all cash crops in PNG. If regional differences in the adoption of hybrids emerge, regional differences in the distribution of benefits will necessarily follow.

5 Conclusions

Production by the first generation of PNG cocoa hybrids from 1985 heralded the first substantial returns to cocoa research since 1965. Benefits are expected to continue beyond the year 2000, but is was felt prudent to terminate the flow of benefits from them in that year. Expected benefits from the research are substantial in both physical and financial terms. While returns may not be among the most outstanding reported in the literature (Ruttan 1982), they are nevertheless better than those of most commercial alternatives.

The observed research is, in many ways, typical of PNG agricultural research. General returns to PNG agricultural research may well have been handicapped by the fact that initially much "basic" research had to be done that did not yield direct benefits. Plant collection, taxonomy work, establishment of plant collection, testing of strains of local and imported plants or animals in local conditions, all have to be done before actual yield-increasing research can commence.

It is just not reasonable to expect instantaneous financial returns from groundwork-type research. Benefits will appear at later stages, building on knowledge and material generated earlier. As an illustration, if VSD research had not been included in the present analysis, i.e., only costs occurring after 1972 had been considered, returns to the hybridisation program proper would have been much higher.

Once the groundwork is done, research can be expected to start to deliver results usable in increasing production and to show more favourable returns on funds invested. This will be the case with the second-generation cocoa hybrids in particular, and, hopefully, with PNG agricultural research in general.

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APPENDIX 1
Calculation of the Opportunity Cost of Subsistence Labour

The assumption is that labour is fully utilised in the initial equilibrium situation, thus additional labour use in cash cropping is impossible without the reduction of leisure time or of time used in subsistence food production. The ensuing reduction in subsistence food production has to be covered by purchasing food, and the opportunity cost of labour will be the cost of replacement food. The most widespread staple food throughout PNG is sweet potato, while the most commonly used purchased staple food is rice. It is a reasonable assumption that a shortfall in subsistence staples would be made up by purchasing rice.

One man-day of labour produces 80 kg of sweet potato at the medium-intensity yield level of 15 t/ha per annum (J. Whitworth, DAL, personal communication). On the basis of Densley's (1978) conversion factors of traditional PNG staples to milled-rice equivalent (MRE), 80 kg of sweet potato is equivalent to 23 kg of rice, the latter costing K14 at K0.60/kg retail.

The opportunity cost of K14 per man-day is quite high when compared to the rural minimum wage of K18.59 per week (at March 1987), and it is only applicable for pricing additional labour requirements.

APPENDIX 2

Calculation of Returns to Cocoa Research

	Parameters	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Discount rate (%)	10																		
Base year	1987																		
CPI (1987 = 100%)		24.8	25.9	26.6	26.9	26.8	27.2	29	30.7	33.4	41.1	45.4	48.8	51.9	54.9	58.0	65.0	70.3	74.1
Farm-gate price, constant 1987 value (K/t dry bean)													1978	4201	3308	2790	1510	1354	1149
Levy(-), Bounty(+) (K/t)																			
Bean f.o.b. price, constant 1987 value (K/t)													2547	5409	4259	3592	2459	1744	1430
Production without research (Trinitario material) (t dry bean)																			
Smallholders														14291	16005	15000	14231	18552	16054
Plantations														14697	15262	12557	13318	13384	10572
Total														28988	31267	27557	27549	31936	26626
Production gain (Hybrid over Trinitario) (t dry bean)																			
Smallholders																			
Plantations																			
Experiment Station														4	4	4	4	4	4
Total														4	4	4	4	4	4
Gross producers' surplus (K'000)																			
National														22	17	14	10	7	6
Smallholders																			
Plantations																			
Experiment Station (VNP)														17	13	11	8	5	5
Transport costs (K'000)																			
Farm-factory K/t	40													0	0	0	0	0	0
Factory-ship K/t	30													0	0	0	0	0	0
Harvest costs (labour and material) (K'000)																			
Smallholders K/t	33																		
Plantations K/t	22																		
Net producers' surplus (Incremental gross benefits) (K '000, constant nominal values)																			
National														21	17	14	10	7	6
Smallholders																			
Plantations																			
Stabilization funds																			
Export tax & LAES revenue														17	14	12	8	6	5
Net producers' surplus (Incremental gross benefits) (K '000, constant discounted values)																			
National														55	40	30	19	12	9
Smallholders																			
Plantations																			
Stabilization funds																			
Export tax & LAES revenue														45	32	25	15	10	8
Research costs current (K '000)		42	21	18	17	11	11	28	41	97	113	142	172	231	163	200	161		
Research costs, 1987 constant (K '000)		169	81	68	63	41	40	97	134	290	275	313	352	445	297	345	248		
Discounted 1987 value of research costs		1379	600	455	387	228	204	444	558	1103	949	982	1006	1154	700	739	483		
Net benefits at 1987 value (K '000)	82925																		
Benefit/cost ratio	8.3																		
Internal rate of																			
	Parameters	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
return (%)	21.5%																		

(cont'd)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total
Discount rate (%)																			
Base year																			
CPI (1987 = 100%)	80.8	86.0	89.4	94.3	100.0														
Farm-gate price, conguess guess guess guess																			
1987 value (K/t dry	1412	1760	1745	1518	1349	1211	1078	1011	981	995	1014	1024	1051	1078	1089	1111	1143	1178	
Levy(-), Bounty(+) (K/t)			390	370	352	324	231	110	51	27	18	0	0	-15	-49	-68	-77	-80	
Bean f.o.b. price, constant																			
1987 value (K/t)	1818	2276	2247	1954	1737	1591	1524	1568	1602	1636	1669	1703	1737	1786	1835	1885	1934	1983	
Production without research (Trinitario material) (t dry bean)																			
Smallholders	19198	23505	20046	23650	21000	21000	21000	21000	21000	21000	21000	21000	21000	21000	21000	21000	21000	21000	337696
Plantations	9046	9443	8827	9301	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000	144128
Total	28244	32948	28873	32951	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	481824
Production gain (Hybrid over Trinitario) (t dry bean)																			
Smallholders			200	490	1000	1400	1800	2600	3400	4200	4800	4920	5000	5000	5000	5000	5000	5000	54720
Plantations			300	600	1500	2100	2700	3900	5100	6300	7200	7380	7500	7500	7500	7500	7500	7500	82080
Experiment Station	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	64
Total	4	4	504	1004	2504	3504	4504	6504	8504	10504	12004	12304	12504	12504	12504	12504	12504	12504	136064
Gross producers' surplus (K'000)																			
National	7	9	936	1620	3590	4601	5665	8416	11243	14181	16533	17292	17924	18429	18935	19451	19956	20462	199327
Smallholders			317	552	1226	1541	1764	2398	3032	3799	4425	4580	4777	4900	4950	5050	5195	5355	53854
Plantations			403	700	1557	1956	2239	3033	3849	4822	5616	5813	6063	6219	6283	6410	6594	6796	68353
Experiment Station	6	7	7	6	5	5	4	4	4	4	4	4	4	4	4	4	5	5	146
Transport costs (K'000)																			
Farm-factory K/t	0	0	20	40	100	140	180	260	340	420	480	492	500	500	500	500	500	500	
Factory-ship K/t	0	0	15	30	75	105	135	195	255	315	360	369	375	375	375	375	375	375	
Harvest costs (labour and material) (K'000)																			
Smallholders K/t			7	13	33	47	60	87	114	140	160	164	167	167	167	167	167	167	
Plantations K/t			7	13	33	46	59	85	112	130	158	162	164	164	164	164	164	154	
Net producers' surplus (Incremental gross benefits) (K '000, constant nominal values)																			
National	7	9	901	1550	3415	4356	5350	7961	10648	13446	15693	16430	17048	17554	18060	18575	19081	19587	189745
Smallholders			311	538	1193	1495	1784	2303	2919	3659	4264	4416	4610	4733	4783	4883	5028	5180	52026
Plantations			396	687	1524	1910	2180	2945	3737	4684	5458	5652	5899	6055	6118	6245	6430	6632	66556
Stabilization funds			-161	-305	-726	-936	-858	-590	-358	-234	-179	0	0	155	505	701	794	825	-1365
Export tax & LAES	6	7	30	47	95	120	146	214	285	359	417	436	452	465	478	491	503	516	512[illegible]
Net producers' surplus (Incremental gross benefits) (K '000, constant discounted values)																			
National	10	12	1090	1705	3415	3960	4421	5981	7272	8349	8858	8431	7953	7445	6963	6511	6080	5674	94295
Smallholders			376	592	1193	1359	1400	1730	1993	2272	2407	2266	2151	2007	1844	1711	1602	1503	26415
Plantations			479	756	1524	1737	1801	2215	2552	2908	3081	2900	2752	2568	2359	2189	2049	1921	33791
Stabilization funds			-195	-336	-726	-851	-709	-443	-244	-145	-101	0	0	66	195	246	253	239	-2751
Export tax & LAES	9	10	37	51	95	109	121	161	195	223	236	224	211	197	184	172	160	150	2678
Research costs current (K '000)																			1468
Research costs, 1987 constant (K '000)																			3258
Discounted 1987 value of research costs																			11370
Net benefits at 1987 value (K '000)																			
Benefit/cost ratio																			
Internal rate of return (%)																			
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Total

Returns to Research on Insect Pollination of Oilpalm in Papua New Guinea*

George Antony, Gae Kauzi and Bob Prior

1 Oil palm in the PNG Economy

The first oil palms for commercial use were introduced to Papua New Guinea in the 1930s. At that time only the seed was exported for its oil content. The first plantings were very small, and no further development took place until 1966 when the government of PNG planted 12 four-hectare trial plots of oil palm in several lowland regions of the country. At about the same time, the first large-scale oilpalm development began at Hoskins, in West New Britain Province, by Harisons and Crosfield, in partnership with the PNG government.

Agronomic conditions for oil palm in Papua New Guinea have proven to be extremely favourable. This has resulted in very good yields, with the average PNG yield being above the world average.

In its initial production stage, most of the PNG production came from the largeholder sector. Smallholder production then expanded, and today its share of the total national production is 50 per cent.

There has been a rapid increase in the production of the crop since its introduction. In 1971/72, a total of 3.4 kt was produced. Production then rose sharply to a peak of nearly 130 kt (excluding palm kernel) in 1986, despite very low prices in the world market that year. For ten consecutive years, 1977 to 1986, each year's production exceeded that of the preceding year, despite fluctuations in prices. The continual increase in production can be attributed to increased plantings, through the new oilpalm projects starting to come into production. At present, production is concentrated in West New Britain and Oro provinces.

For the ten-year period, 1977 to 1986, export volumes averaged 68.9 kt/year for palm oil and 8.6 kt/year for palm kernel. The export volume has grown from 24.5 kt of oil and 3 kt of kernel in 1977, to 128.9 kt of oil and 14.4 kt of kernel in 1986: a five-fold increase.

Export earnings over the same period averaged K27.2m, with a peak of K75.7m in 1984 (due to improved prices and increased production). The crop contributed, on average over the period, about 7.5 per cent of agricultural export earnings, and 3.6 per cent of total PNG export income. Its contribution to the gross domestic product stands at around one per cent.

A total of about 53 thousand rural households are involved in the industry as producers, while the number of people directly employed in the industry is about 5 thousand.

The country is a marginal supplier of the world market in vegetable oils. Although PNG provided 2.4 per cent of the world's palm oil exports in 1985 (against 1.0 per cent in 1980), its share of the wider market of easily substitutable vegetable oils was still only about 0.8 per cent in 1985 (FAO, various years).

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2 Oilpalm Research in PNG

2.1 A Short History

From 1967, both agronomic and entomological studies were carried out by the PNG government and the New Britain Palm Oil Development Ltd. (NBPOD), the latter setting up agronomic and plant-breeding facilities at the Dami oilpalm research station, in West New Britain Province. Government research input was focused on results from agronomic and entomological work on the trial plots and the first commercial plantings.

Further expansion of the commercial oilpalm development occurred in the 1970s, and this lead to an industry-funded research organisation being set up in 1980. The organisation, the Papua New Guinea Oil Palm Research Association (PNGOPRA) has its headquarters at Dami, alongside the NBPOD plant-breeding station. Agronomic and pest research is now run by PNGOPRA, while plant breeding and seed production remains under complete commercial control. Funding for PNGOPRA's research is obtained by a variable cess on all producers' fruit production as well as by direct government contribution. Research results have been summarised in annual reports since 1981.

2.2 The Research Project

Of all oilpalm research undertaken in PNG, it was probably the work on the introduction of pollinating insects that has had the biggest impact on the industry. This research project is easy to separate from the rest of oilpalm research in its costs and effects, and it is well documented.

Prior to the introduction of the pollinating weevil, production in PNG palm-oil plantings depended upon the hand pollination of each individual palm over some 40 000 ha. Teams of men on the estates, and from Government centres responsible for the smallholdings, collected fresh pollen regularly and mixed it with talcum powder. This mixture was distributed twice a week to estate workers and smallholders whose job it was to shake or blow the pollen, using specially-desigend applicators, into the receptive female inflorescences in the crowns of every palm. As the palms grew taller, this operation became much less efficient, and yields diminished. Difficulties in application during the wet season also resulted in poor pollination. Similar problems were also experienced in Malaysia where the oil palm was also an introduced crop, and where hand pollination was practised.

In 1977, research by the Commonwealth Institute of Biological Control, sponsored by the Malaysian subsidiary of Unilever, identified insects as the pollinating agent in Cameroon where oil palm is indigenous (Syed 1978). The weevil Elaeidobius kamerunicus was identified as the most efficient pollinator and, after exhaustive testing on a range of host plants (jointly funded by Malaysian and PNG commercial interests), it was cleared for introduction to Malaysia and PNG in 1980. Work on the PNG side has been - and is being - carried out by R.N.B. Prior.

After the arrival on 10 November 1980 in PNG of 1000 pupae of E. kamerunicus, the weevil underwent many generations in strict quarantine conditions away from any of the main oilpalm developments. It was further tested against important indigenous plants and declared safe to field test in April 1981 on an isolated four-hectare block near the quarantine laboratory in Morobe Province.

After the excellent initial reports from Malaysia, field testing was cut by several months. Multiplication of the population to many thousands in the laboratory was followed by the first plantation release in June 1981, in a central position in one plantation in each area of the oilpalm developments of both West New Britain and Oro Provinces. After two months, five hectares around the release sites were saturated with the weevils. Distribution to the whole development followed, using entire male inflorescences cut from the original five-hectare sites, with one inflorescence being placed in every 20 hectares of oil palm. Within five months the whole 40 000 ha were saturated with weevils, and hand pollination ceased - principally because pollen was no longer available from the weevil-covered inflorescences.

3 Quantitative Analysis

The Director of Research of the Papua New Guinea Oil Palm Research Association (PNGOPRA), Tremar Menendez, decided that the effect of insect pollination should be analysed only on the basis of "firm and final" data. Such figures could presently be obtained only up to 1986: so this study is concentrated on the period 1982 to 1986 only. Since the effects of the introduction of pollinating insects are likely to continue for a very long time (or indefinitely, if the insects do not disappear for some reason), such a restriction of the study period will result in a very substantial underestimation of total expected benefits.

3.1 Objective

The objective in the present study is to estimate the net increase in welfare resulting from the introduction of this particular new technology. Moreover, some indication is also to be elicited of the distribution of welfare gains within the country. To this end, a financial analysis of the national effects of the new technology is intended to show the shares accruing to the main participants in the industry: smallholders, plantations (together with oilmills) and the government.

3.2 Method

The increase in economic surplus due to technological change can be identified as the shaded area ABCD in Figure 1 (non-linear supply and demand curves shown, along with a proportional divergent shift of the supply schedule). In the restrictive case of perfectly inelastic supply (i.e., no change in produced quantities following price changes) and perfectly elastic demand (i.e., no change in price following increased production) (Figure 2), the increase in economic surplus is the area ABQ_0Q_1: this special case is assumed in many VMP studies.

Lindner and Jarrett (1978) drew attention to the importance of identifying the type of the supply shift in analyses based on the notion of economic surplus. In the present case of insect pollination of oil palm in Papua New Guinea, the type of the research-induced supply shift

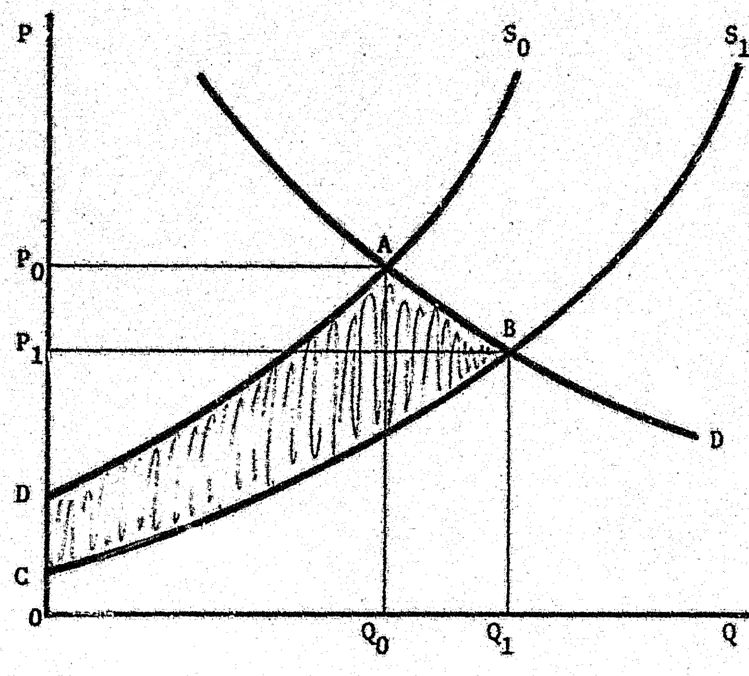

Figure 1 Change in Economic Surplus: A General Case

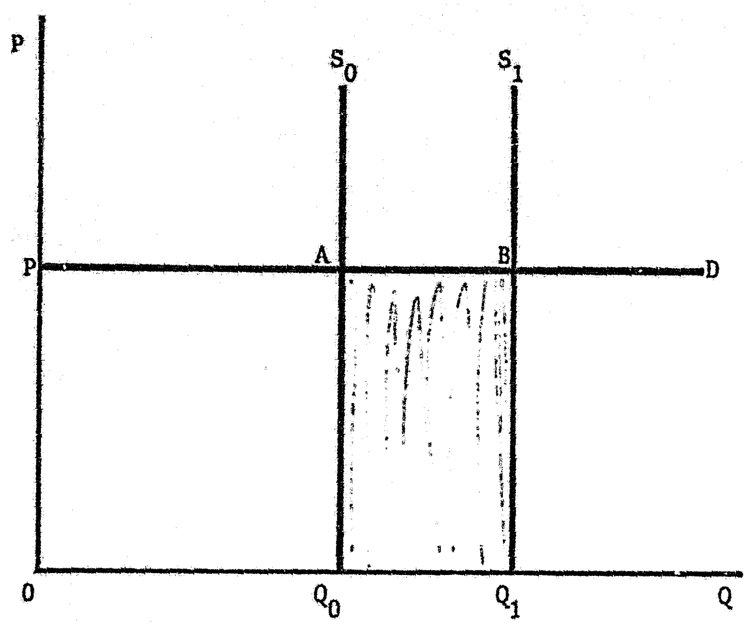

Figure 2 Change in Economic Surplus: Parallel Shift of Perfectly Inelastic Supply Curves and Perfectly Elastic Demand

is presumed to be divergent. "Adoption rate" of the new technology is 100 per cent, due to its nature. However, according to local sources, pollination was carried out less proficiently by smallholders than by plantations, therefore the relative size of yield gain is greater for smallholders and, thus, the supply shift diverges[1]. (PNGOPRA researchers did not differentiate between small- and largeholders in working out the yield increase, hence uniform figures are used in this analysis.) Since all producers experienced yield increases, the possibility of a pivotal shift can be ruled out.

A previous study of the PNG oilpalm industry could not be found that would have included the quantification of the price elasticity of supply. On the basis of industry history, supply is expected to have shown little response to price changes. Plantings date back over less than two decades, and have been perceived by the government rather as a means of resettlement and employment creation than a purely commercial excercise. The companies appear to have a long-term view about the desirable extent of the industry, thereby reducing the effects of short-term price movements on new plantings.

Evidence from local sources points to the existence of an inverse short-run supply response by smallholder producers. This may well counteract conventional response by commercial producers and, consequently, supply must be even more inelastic in the short run. The value of 0.1 (used by Fleming and Piggott (1980) for palm-oil supply for the whole of the South Pacific) is thus very realistic for PNG.

Demand for PNG oilpalm products can safely be taken as perfectly elastic, since the small-country assumption is applicable. Given these assumptions, VMP is identical to the increase in producers' surpluses in the present case.

For internal consistency when investigating the distribution of research benefits, as well as for ease of calculation, the discounted net present VMP, resulting from the adoption of new technology, is calculated:

$$NPV = \sum_{n}^{i=1} \left[\frac{(Q_{1i} - Q_{0i})P_i}{(1 + r)^i} - \frac{C_i}{(1 + r)^i} \right]$$

where: Q_{0i} = quantity of produce supplied in year i, without the new technology;

Q_{1i} = quantity of produce supplied in year i, with the new technology;

P_i = real price of produce in year i;

C_i = real value of research costs in year i;

[1] If assisted pollination had been equally effective throughout the industry under the old-technology regime, the shift would have been parallel - as the yield-increasing effect is uniform, and no cost factors other than pollination were affected.

r = discount rate; and

n = number of years.

VMP has been interpreted in this study as incremental net benefits less research costs. In order to calculate incremental net benefits, the incremental gross benefits (i.e., the value of the extra production) has to be reduced by the amount of increases in relevant variable costs. These are costs that are proportional to the quantity of throughput, such as harvesting and transportation costs. All other unchanged costs were treated as overheads from the point of view of the present analysis, and the incremental net benefits were calculated as the difference between the with- and without-research gross margins:

$$NPV = \sum_{n}^{i=1} \left[\frac{(Q_{1i}P_i - VC_{1i}) - (Q_{0i}P_i - VC_{0i})}{(1 + r)^i} - \frac{RC_i}{(1 + r)^i} \right]$$

where: VC_{0i} = total variable costs in real values in year i, without the new technology;

VC_{1i} = total variable costs in real values in year i, with the new technology;

RC_i = real value of research costs in year i;

The range of variable costs is determined by the level of aggregation examined. At the national level, only transportation and mill processing costs were considered since these constitute mainly foreign-exchange expenditures and thus outflows from the point of view of the national economy. Similarly, at more disaggregated levels, the costs and benefits relevant to the analytical level were included in the analysis.

The discount rate used was 10 per cent, the same figure that is used for project appraisal by the Department of Agriculture and Livestock (DAL).

3.3 Calculation of Research Costs

Costs of the research consisted of: (1) the employment of one entomologist on the project; (2) "overhead" (capital, consumable and administration) costs of the research institute, allocated on a per-research-scientist basis; and (3) payments made to the Malaysian company to contribute to the costs of the original research on insect pollination.

3.4 Evaluation of Benefits from Research

a.) Without-research scenario

Costs associated with assisted pollination were incurred by the provincial DPI and plantations in connection with pollen collection and distribution. Data on DPI cost could not be obtained, thus they had to be guessed: K50 000/year for WNB, and K20 000 in 1982, K30 000 in 1983 and K40 000 in the following years for Oro, all in 1986 values. Pollination was carried out by the producers, costing some K65/ha (supposedly including collection costs as well) for plantations in 1980 (Prior 1983). Smallholders were expected to spend two-and-a-half days every week pollinating their trees but, according to local sources, one-and-a-half day was closer to the actual time spent.

Since the pollination by insects is superior to that attempted by people, a greater number of flowers develop into fruit. The likely yield-reducing effect of the absence of the weevil has been estimated by PNGOPRA scientists. It was put forward that yields in West New Britain would have been some 40 per cent less in 1982 than the actual, and around one third less in the following years. In Oro province, the improvement in fruit set was far less dramatic, and a yield-reduction figure of four per cent was agreed on in discussion at PNGOPRA.

Another result of better fruit set is the increase in extraction rates in the oil mills, as the fruit-to-frame ratio in the bunches increases. It was assumed that, without insect pollination, the extraction rates of oil and kernel would have stayed at the same level as before the introduction of the weevil. In fact, this is a very generous assumption, and one that causes the benefits of insect pollination to be underestimated. As palms grow taller, assisted pollination becomes quite difficult, fruit set declines, and so do the extraction rates. This stage would have already been reached by now in some of the earlier plantings in West New Britain. However, the yield-reducing effect of trees growing tall was not accounted for when estimating without-project yields or extraction rates. Essentially, before-project figures were used throughout.

b.) With-research situation

At the national level, the benefit is the added production. When it comes to distributional effects, the value of the cessation of assisted pollination can be accurately quantified in money terms for the plantation sector as well as for DPI. For the smallholders, however, there is little opportunity of finding paid employment to utilise the day and one half a week that they suddenly do not have to work. This extra time is most likely to be used partly for gardening - thus improving the supply of subsistence food and, thereby, nutritional status - but mainly as leisure time. No satisfactory way could be found for the quantification of either of these effects in financial terms, and thus the substantial gain of time by smallholders, or its spinoff benefits, were not used in calculating total benefits.

Since separate data series cou' be found for smallholder and plantation production in West New Britain and Oro provinces (DAL sources), a corresponding br kdown of benefits can be provided. However, benefits accruing to plantations had to be amalgamated with those of the oil mills, for the accounting prices used in valuing fresh fruit between these entities were not known. Still, this is of little consequence, as the plantations and oil mills mostly belong to the same companies.

Financial effects on price-stabilisation funds could be monitored by valuing smallholder production at both gross settlers' (i.e., before stabilisation) and farm-gate (stabilised) prices. However, these prices being averages across the estates, the resulting total figures are only an approximation of the actual stabilisation payments.

Some government benefits from the new technology could be measured quite precisely, as the export tax of 2.5 per cent ad valorem is levied on all exports, and the difference between the actual and without-project situations is just a matter of subtraction. Companies pay tax, and collection could increase due to an increase in production. The PNG government is a shareholder in the plantations, thus sharing in the dividends from these companies. Yet another area of government benefits, in this case the provincial governments', is the cessation of provincial DPI duties associated with pollen collection and distribution.

Data were drawn from both industry and DAL sources. A full data set was not yet available for 1986, and the missing data (such as extraction rates for WNB) have been extrapolated on the basis of previous years' figures.

4 Discussion

Notwithstanding the very conservative analysis (most of all, the termination of the accounting period as of 1986), returns to the research project proved quite outstanding. Due to the more effective pollination, an extra 425 kt of fresh fruit bunch (FFB) has been produced during the period 1982 through 1986. On the basis that one tonne of FFB required around one man-day of assisted pollination under the old technology, more than two million man days (say, 20 thousand man years) of labour have been freed in all sectors over the same period. While the plantation sector made direct cash savings through lower labour requirements, it is just about anybody's guess as to exactly in what way the smallholders used their freed time.

When looking at the financial effects at the national level, in discounted values and at 1986 prices, a K315 thousand investment resulted in a gross financial benefit of K51m, as compared to the without-research scenario. In other words, had research on insect pollination of oil palm in Papua New Guinea not been undertaken, and the resulting new technology not introduced, K315 thousand could have been saved in direct costs, at the expense of not earning K51m.

The rate of return (IRR) on the investment was about 680 per cent; considerably higher than that reported in most previously documented cases (e.g., Ruttan 1982).

With the exception of profits repatriated by the companies, all benefits of the research were captured by Papua New Guinea. Due to the country's marginal supplier role, increased PNG production could not have driven down international vegetable-oil prices: and in [illegible]s case producers get the same price for their extra produ[illegible] before the technological change.

Within the country, the biggest beneficiaries have been shareholders (including the Government of Papua New Guinea) in the companies owning plantations and oil mills. However, their share of a K45.5m increase in gross margin has still left them running a negative margin on operations (after the deduction of only those production costs that are proportional to harvested quantities) of around K32m over the period. The reason for this was that the increase in settlers' prices has been relatively greater than that for the export prices of oil and kernel.

In contrast, smallholders had a net increase in their revenue estimated at K8.6m. It has to be kept in mind, however, that labour savings were not priced for smallholders. Labour savings of the plantation sector were around K4m, on a production approximately the same size as that of the smallholders.) Because of the depressed palm-oil prices for much of the 1982-86 period, a considerable part of the financial gain was price support from the stabilisation fund. [redacted].

Labour savings by the plantations meant cost savings for them, but loss of income-earning opportunity for the displaced labourers. Just as with the smallholders, too little is known about the possible alternative uses of this freed labour to put a monetary value on the actual losses. Most of the people employed were probably the smallholders around the nucleus estates; thus, with the end to this money-earning opportunity, they could have spent more time on their own plantings but earning less cash.

The stabilisation fund showed a net gain of K116 thousand, as a result of increased production by 1984 (a year of good prices). This year and 1985 were more than enough to balance the outflows of the previous three years.

The public purse shared in the benefits from the new technology in four ways. Benefits accruing to the provincial administrations worked out at around K300 thousand for WNB and around K200 thousand for Oro for the period, on the basis of guesses about the costs of assisted pollination. Second, the national government profited from the cost savings and production increases in the plantation sector as a shareholder. Since neither the payment of dividends by the companies nor the effect of new technology on dividends have been investigated in the present analysis, the government's share as a shareholder has not been assessed here. Third, the export tax is one of the redistributive processes, and this has yielded the PNG government some K2.5m in excess of what the revenue would have been with the old technology, over the five-year period 1982 to 1986. Fourth, tax collection from companies may well have increased, but this has not been investigated either.

Regional effects of the new technology have been uneven. While the labour-saving effects of the cessation of assisted pollination have been similar in West New Britain and Oro provinces (depending only on the age and, therefore, the height of the palms) the yield increase has been much smaller in Oro, for reasons yet unknown. Consequently, smallholders gained less in terms of money income in Oro than did plantations (through wage savings) or did smallholders in West New Britain.

5 Conclusions

The research on insect pollination of oil palm in PNG proved a well-chosen project, with outstanding economic results. Not only were the total benefits significant, but their distribution also included the smallholders, as well as the public sector. In fact, benefits to smallholders and the public sector have been seriously underestimated in this summary analysis, due to measurement problems and lack of data.

The measurement of total benefits has been restricted to a short past period. Since the new technology can be reasonably expected to have quite a few more years of useful life, total benefits may well eventually be many times those of calculated in the present study.

The lack of evidence about the effect of the new technology on previously hired labourers and smallholders through the very significant labour savings is the main shortcoming of the present study. Without such data, the evaluation of distributional consequences is far from satisfactory.

It has to be emphasised that very few conclusions can be drawn about PNG agricultural research in general - or, indeed, agricultural research elsewhere - on the basis of the present analysis. The research project scrutinised was an adaptive piece of research. Most agricultural research in PNG is likely to fall in this category, but most will cost considerably more to complete than the research project examined in this paper. This means higher expenditures and lower returns on research funds, especially if there is a long lag between research expenditures and adoption of the resulting new technology (i.e., benefits are heavily discounted compared to costs). The advantage of the new technology over the old is usually far narrower than in the present case. Unavoidably, some research will inevitably fail to achieve its planned objectives.

What this study demonstrates, however, is that the potential for high returns to research in PNG most definitely exists. A realistic identification of problems and possible research options can increase the probability of research success, and improve research returns in the longer run. Or, turned around, if there is an awareness of the whole research-adoption process involved, and research projects are selected from the beginning on the basis of a clear set of criteria and expected returns, there should be less of a chance of such research results being generated that do not contribute to the improved welfare of the country.

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Calculation of Benefits to Oilpalm Research

		1979	1980	1981	1982	1983	1984	1985	1986	Total
Discount rate (%)	10									
Base year	1986									
CPI (1986 = 100%)			71.2	75.1	80.3	87.2	91.1	95.0	100.0	
Farmgate prices (K/t FFB)										
WNB			16.1	10.6	23.6	34.7	62.3	48.1	20.6	
Oro			21.1	10.6	11.8	41.1	51.3	30.6	24.9	
Gross settlers' prices (K/t FFB)										
WNB			21.0	10.0	12.0	34.0	89.0	53.0	.3	
Oro			21.0	10.0	12.0	34.0	89.0	53.0	.3	
Oil price (FOB, K/t)			358	323	282	305	570	493	229	
Kernel price (FOB, K/t)			177	117	143	152	323	221	81	

1 HAND POLLINATION: Without Project

		1979	1980	1981	1982	1983	1984	1985	1986	Total
Production (FFB, t)										
WNB	S/H				119217	114440	159250	163766	148375	
	Pl				105751	98560	99548	112970	125448	
	Total				224969	213000	258798	276736	273824	1247326
Oro	S/H				23039	43526	64050	75000	98077	
	Pl				57386	75562	76199	102996	95566	
	Total				80425	119088	140249	177996	193643	711401
Stabilization costs (K '000)										
WNB	S/H				1383	80	-4252	-802	3012	
Oro	S/H				-5	309	-2417	-1682	2412	
Pollination costs, DPI (K '000)										
WNB					40	44	46	48	50	
Oro					16	26	36	38	40	
Pollination field costs (K/ha)										
WNB	S/H		0	0	0	0	0	0	0	
	Pl		65.10	64.70	69.2	75.1	78.5	81.8	86.2	
Oro	S/H		0	0	0	0	0	0	0	
	Pl		65.1	64.7	69.2	75.1	78.5	81.8	86.2	
Yields (FFB, t/ha)										
WNB	Pl		18	18	18	18	18	18	18	
Oro	Pl		18	18	18	18	18	18	18	
Pollination field costs (K/t FFB)										
WNB	Pl		3.6	3.6	3.8	4.2	4.4	4.5	4.8	
Oro	Pl		3.6	3.6	3.8	4.2	4.4	4.5	4.8	
Harvesting and transport costs (K/t FFB)										
WNB	S/H				9.31	10.11	10.56	11.38	11.98	
	Pl				10.51	11.41	11.92	11.48	12.08	
Oro	S/H				9.31	10.11	10.56	11.38	11.98	
	Pl				10.51	11.41	11.92	11.48	12.08	

(cont'd)

	1979	1980	1981	1982	1983	1984	1985	1986	Total
Smallholder gross margin (K '000)									
WNB S/H				1704	2814	8240	6013	1279	
Oro S/H				57	1349	2607	1439	1266	
S/H crop at settlers' price (K '000)									
WNB				1431	3891	14173	8680	45	
Oro				276	1480	5700	3975	29	
Extraction Rates (% of FFB)									
WNB Oil				18.0	18.0	18.0	18.0	18.0	
Kernel				3.7	3.7	3.7	3.7	3.7	
Oro Oil				21.0	21.0	21.0	21.0	21.0	
Kernel				3.7	3.7	3.7	3.7	3.7	
Produce quantities (t)									
WNB Oil				40494	38340	46584	49813	49288	
Kernel				8324	7881	9576	10339	10131	
Oro Oil				16389	25008	29452	37379	40665	
Kernel				2976	4406	5180	6586	7165	
Produce values (K '000)									
WNB				12610	12892	29646	26820	12108	
Oro				5188	8297	18464	19883	9893	
Processing and produce-transport costs									
WNB Processing (K/t FFB)				37.7	64.4	118.0	85.7	90.2	
Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
Total (K/t FFB)				38.2	64.9	118.4	86.2	90.7	
Oro Processing (K/t FFB)				37.7	64.4	118.0	85.7	90.2	
Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
Total (K/t FFB)				38.2	65.0	118.4	86.2	90.8	
Planters' and processors' gross margin (K ' 000, after listed costs only)									
WNB				758	-6680	-17526	-8186	-15192	
Oro				883	-2304	-5548	-1586	-9570	
Gov't tax revenue on oil exports				445	530	1203	1168	550	

2 WEEVIL POLLINATION: With Project

Production (FFB, t)	1980	1981	1982	1983	1984	1985	1986	Total
WNB S/H	108810	96919	166904	148772	207025	212836	192888	(1982 to
Pl	81256	86481	148052	128128	129412	146861	163083	1986)
Total	190066	183400	314956	276900	336437	359757	355971	1644021
Oro S/H	339	5352	23961	45267	66612	78000	102000	(1982 to
Pl	7246	22203	59681	78584	79247	107116	99389	1986)
Total	7585	27555	83642	123851	145859	185116	201389	739857

(cont'd)

	1979	1980	1981	1982	1983	1984	1985	1986	Total
Stabilization costs (K '000)									
WNB S/H				1936	104	-5528	-1043	3916	
Oro S/H				-6	321	-2514	-1750	2508	
Harvesting and transport costs (K/t FFB)									
WNB S/H				9.31	10.11	10.56	11.38	11.98	
Pl				10.51	11.41	11.92	11.48	12.08	
Oro S/H				9.31	10.11	10.56	11.38	11.98	
Pl				10.51	11.41	11.92	11.48	12.08	
Smallholder gross margin (K '000)									
WNB S/H				2385	3659	10711	7818	1663	
Oro S/H				59	1402	2711	1497	1317	
S/H crop at settlers' price (K '000)									
WNB				2003	5058	18425	11283	58	
Oro				288	1539	5928	4134	31	
Extraction Rates (%)									
WNB Oil				21.0	23.0	23.9	22.8	22.8	
Kernel				3.5	4.7	4.6	4.4	4.4	
Oro Oil				21.8	21.8	21.7	21.7	22.4	
Kernel				4.4	3.6	3.5	3.4	3.7	
Produce quantities (t)									
WNB Oil		36068	34260	70172	64104	84200	83966	81161	
Kernel		4392	3296	11221	11375	13680	13860	15663	
Oro Oil		1499	5903	18616	27025	38436	43860	45111	
Kernel		215	1093	3750	4986	6104	6950	7451	
Produce values (K '000)									
WNB		13590	11452	21393	21281	52413	44458	19855	
Oro		575	2035	5786	9000	23880	23159	10934	
Processing and produce-transport costs									
WNB Processing (K/t FFB)				37.7	64.4	118.0	85.7	90.2	
Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
Total (K/t FFB)				38.2	65.0	118.5	86.3	90.8	
Oro Processing (K/t FFB)				37.7	64.4	118.0	85.7	90.2	
Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
Total (K/t FFB)				38.3	65.0	118.4	86.2	90.8	
Planters' and processors' gross margin (K ' 000, after listed costs only)									
WNB				5258	-3782	-8735	-660	-14997	
Oro				1525	-1708	-865	1256	-8853	
Gov't tax revenue from export levy				679	757	1907	1690	770	

(cont'd)

	1979	1980	1981	1982	1983	1984	1985	1986	Total
Incremental Gross Benefits (K '000, current nominal values)									
1 National benefits				4869	3859	17347	12074	-491	37658
2 Share of some protagonists									
1.1 Smallholders									
WNB				682	844	2472	1804	384	6186
Oro				2	54	104	58	51	269
1.2 Stabilization funds				-553	-36	1372	308	-1000	91
1.3 Planters and processors									
WNB				4500	2898	8791	7526	195	23910
Oro				642	596	4684	2842	718	9480
1.4 Government									
National				235	227	705	523	220	1909
WNB				40	44	46	48	50	227
Oro				16	26	36	38	40	157

	1979	1980	1981	1982	1983	1984	1985	1986	Total
Incremental Gross Benefits (K '000, constant nominal values)									
1 National benefits				6064	4425	19042	12709	-491	41749
2 Share of some protagonists									
1.1 Smallholders									
WNB				849	968	2713	1899	384	6813
Oro				3	62	114	61	51	290
1.2 Stabilization funds				-689	-42	1506	324	-1000	100
1.3 Planters and processors									
WNB				5604	3323	9650	7922	195	26694
Oro				799	683	5141	2991	718	10332
1.4 Government									
National				292	261	773	550	220	2096
WNB				50	50	50	50	50	250
Oro				20	30	40	40	40	170

	1979	1980	1981	1982	1983	1984	1985	1986	Total
Incremental Gross Benefits (K '000, constant discounted values)									
1 National benefits				8878	5890	23041	13980	-491	51298
2 Share of some protagonists									
1.1 Smallholders									
WNB				1243	1289	3283	2089	384	8287
Oro				4	82	138	67	51	342
1.2 Stabilization funds				-1008	-56	1823	357	-1000	116
1.3 Planters and processors									
WNB				8204	4423	11676	8714	195	33213
Oro				1170	910	6221	3290	718	12308
1.4 Government									
National				428	347	936	605	220	2535

(cont'd)

		1979	1980	1981	1982	1983	1984	1985	1986	Total
WNB					73	67	61	55	50	305
Oro					29	40	48	44	40	202
Research costs current (K '000)		9.0	5.0	57.4	16.5	45.8	11.1	24.7	11.7	181
Research costs, 1986 constant (K '000)		13	7	76	21	53	12	26	12	219
Discounted 1986 value of research costs		25	12	123	30	70	15	29	12	315
Net present value	50982									50982
Benefit/cost ratio	163									
Internal rate of return (%)	677									