BUILDING CROP HEALTH MANAGEMENT CAPACITY IN THE LAO PDR

A Benefit-Cost analysis conducted for the Crawford Fund

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1. Executive Summary

This report presents the results of a Benefit-Cost Analysis (BCA) of the Crawford Fund's investment in building the capacity of farmers and government agencies in crop health management in the Lao PDR. The BCA generated estimates of the Net Present Value (NPV) generated from the investment over a 20-year period (2009 – 2028).

Some of the identified benefits and costs of the investment were judged to be unquantifiable in monetary terms. In particular, the potentially significant capacity building benefits enjoyed by both Laotian and Australian collaborators fall into this category. These benefits and costs have not been included in the NPV estimation. The quantified benefits included in the BCA primarily represented the avoided production losses small-holder farmers in Savannakhet and Champasak province have enjoyed from employing integrated plant disease and pest management strategies promoted through the investment. Avoided production losses were quantified in terms of additional revenues compared to a counterfactual under which these strategies were not employed.

For a constructed 'base case' scenario representing moderate investment success, the NPV of the Crawford Fund investment for the time period from 2009 to 2028 is $343,655 (BCR of 2.81).

The data used in the BCA was severely limited and subject to a significant level of uncertainty. As a result, a range of NPVs was estimated for a range of informed assumptions regarding factors that are subject to uncertainty. This 'sensitivity analysis' was conducted to test the robustness of the NPV to these assumptions. The lower and upper NPV bounds (2009 to 2028) are about -$180,519 (BCR of 0.04) and $5,576,923 (BCR of 30.52), respectively. This wide range of potential NPVs reflects the high levels of uncertainty that are embedded in the data used in this BCA.

It is crucial to stress that the BCA results underestimate both the costs and benefits of the investment due to the omission of unquantifiable costs and benefits. The extent of unquantified costs have been judged to be smaller than the unquantified benefits, noting especially the potential significance of the capacity building aspects of the mentoring programme. This implies that the actual NPV of the investment is most likely larger than estimated in this BCA.

In summary, the results of the BCA demonstrate that the Crawford Fund investment has most likely produced a net social benefit for the Lao, Australian and international communities.

2. Introduction and purpose of the study

In mid-2018, Environmental and Resource Economics (ERE) was commissioned to conduct a Benefit-Cost Analysis (BCA) of the Crawford Fund's investment in building the capacity of farmers and government agencies to manage crop health issues in the Lao PDR.

In response, ERE has undertaken a data collection exercise that involved interviews with key stakeholders, data base interrogation, scrutiny of both Australia and Lao PDR documents, a formal survey of relevant entities and a field trip to Lao PDR (4-13 December 2018). Data analysis was conducted to consider a 20-year time-period (2008 – 2028) in order to estimate the Net Present Value (NPV) of the Crawford Fund investment using the BCA conceptual framework.

BCA is a widely used tool to analyse the relative efficiency of alternative resource allocations. It allows an understanding of potential welfare changes to society resulting from an investment by comparing benefits and costs associated with the reallocation of resources resulting from the investment relative to what would have occurred without that investment (the 'counter-factual').

The core tasks involved in conducting the BCA were:

- Defining the Crawford Fund investment in crop health management capacity building in the Lao PDR.
- Identifying the contributions made by other entities involved in the capacity building task.
- Specifying the actions taken under the investment.
- Setting out the costs and benefits generated through the investment.
- Attributing the quantifiable benefits and costs across the entities involved in the investment.
- Valuing the quantifiable costs of the investment from 2009 to 2018.
- Valuing the quantifiable benefits of the investment from 2009 to 2028.
- Consolidating the so estimated benefit and cost values into a discounted NPV analysis.
- Performance of a sensitivity analysis focused on key parameters found to be subject to high levels of uncertainty.
- Providing recommendations to improve investment efficiency.

Of particular note in this BCA is the importance of sensitivity analysis. Over the course of the exercise it became apparent that the data required to conduct a complete BCA was very limited. As well as some data not being available, other data were contradictory across sources. As a result, many of the data collected were subject to uncertainty, with some being based on informed assumptions. Because of these data inadequacies, sensitivity testing is of key importance. Where data were regarded as being subject to significant levels of uncertainty, ranges of parameter values were used to calculate the NPV of the investment. As a result, a single NPV of the investment is not reported. Rather, a range of NPV has been estimated corresponding to a range of data assumptions. The sensitivity of the NPV to various underlying data assumptions has thus been assessed with the goal of observing how robust the conclusions drawn on the basis of the NPV calculation are.

This report is structured around the core BCA tasks as set out above.

3. The investment

3.1 Definition

This BCA assessed the Crawford Fund's investment into the crop health management capacity building component of the 'Crawford Fund Capacity Building Program in the Lao PDR in Trade, Crop and Livestock Health, Biosecurity and Food Safety'. The investment which has been made from 2009 to 2018 was concentrated on initiatives located in Savannakhet Province and Champasak Province, the two major centres of agricultural production in the Lao PDR. It was focused on the training of small-holder farmers and staff from the Lao provincial and district governments to support healthy crop production. The investment also provided professional development experiences for Lao and Australian volunteers who were key to the conduct of the activities undertaken under the investment.

The Mentoring Program, which forms the core of the Crawford Fund's crop health management capacity building component was established largely through the initiative and commitment of Prof Lester Burgess AM. Prof Burgess played a pivotal role in directing and coordinating the Program throughout the life of the investment and continues to do so. He deserves much credit for the achievements of this Crawford Fund program.

The mentors who have been part of the programme were experienced scientists with expertise in plant pathology, entomology and weeds. They were volunteers who shared their skills and knowledge with Lao agricultural scientists, Lao government staff, Lao volunteers, and Lao small-holder farmers. They provided technical assistance and worked with farmers to find solutions to crop health problems. They also played a key role in encouraging, strategically placing, and mentoring Australian volunteers who worked within the crop health management initiative during their assignment in Lao. The initiative also involved collaboration with e-mentors who, in contrast to the mentors, interacted with the mentors, Australian volunteers, and Lao partners mostly online. The e-mentors were also highly skilled scientists with access to technology and resources unavailable in Lao. In 2018, the Lao crop health management capacity building component, included collaboration with five mentors and with a network of over forty Australian and international e-mentors and associated laboratories.

The Crawford Fund investment has been inseparably linked to a crop health component of the investment made by the Australian Government's Department of Foreign Affairs and Trade through their Australian Volunteers for International Development (AVID) Programme. The

AVID program has funded the assignment of Australian volunteers to Lao within their initiative 'Volunteers for food security in Laos'. The initiative has been managed by Australian Volunteers International, an Australian not-for-profit organisation committed to achieving economic and social development outcomes across Asia, the Pacific and the world[1]. The Australian volunteers have been scientists who are specialised in plant pathology or entomology. They have usually been placed in the Provincial Agricultural and Forestry Offices (PAFO) of Savannakhet and Champasak and engaged in capacity building and technical assistance.

The Crawford Fund mentors and the Australian volunteers have worked collaboratively. Volunteer assignments and regular mentor visits have provided continuity and consolidation through their combined efforts.

The main partners of the Crawford Fund and Australia Volunteers International have been PAFO and DAFO, Lao agricultural scientists, and Lao volunteers. Other key collaborators have included the Australian Centre for International Agricultural Research, the International Collection of Microorganisms from Plants in NZ, The Royal Botanic Garden Sydney, and several non-government organisations located in the Lao PDR.

The investments from the Crawford Fund, the Australian Volunteers International Development Program, and their main collaborators have been complemented by further financial and in-kind contributions (see section 3).

The overall investment assessed by this BCA was defined as the sum of all investments and contributions mentioned above. The BCA was used to assess the NPV of the overall investment as well as the specific investment of the Crawford Fund.

3.2 Activities

The overall investment provided technical assistance and capacity building activities.

The technical assistance included:

- Establishment of functioning laboratories at the PAFOs.
- Development of manuals on laboratory processes and procedures.
- Development of plant disease and pest identification posters and checklists.

[1] The program was previously managed by Scope Global.

- Development of an information management database (plant disease and pest surveillance).
- Conduct of crop surveys and surveys on priority plant diseases, pest and beneficial insects.
- Diagnoses of plant diseases (about 150), pest insects (about 150) and beneficial insects (about 100) through in-field, laboratory and e-diagnostics processes.
- Preservation and sequencing of plant pathogens.
- Development of training programs in integrated plant disease and pest management for PAFO/DAFO staff and small-holder farmers.
- Development of training programs in plant disease and pest diagnostic for PAFO/DAFO staff and small-holder farmers.
- Publication of research papers, reports and compendia.
- Construction of a greenhouse.

The capacity building activities included:

- Provision of training courses in plant disease and pest diagnostic as well as integrated plant disease and pest management for PAFO/DAFO staff.
- Provision of train-the-trainer workshops in plant disease and pest diagnostic and workshop facilitation.
- Provision of workshops on plant disease and pest diagnostic as well as integrated plant disease and pest management for small-holder farmers.
- Provision of in-field consultations with key farmers.
- Mentoring of the Australian volunteers by mentors and e-mentors.
- Mentoring of PAFO staff through the Australian Volunteers.
- Connecting the Australian Volunteers, PAFO staff and Lao scientists with the e-mentor and laboratory network.
- Enabling research visits for PAFO staff to Australian research organisations.
- Enabling student internships at PAFO in Savannakhet.
- Teaching English Language skills to PAFO/DAFO staff.

4. Costs

This section sets out the costs of the investment. These include both financial and in-kind contributions.

The following entities provided financial and/or in-kind contributions[2]:

- Crawford Fund
- Australian Volunteers International, Department of Foreign Affairs and Trade
- Australian-ASEAN Council, Department of Foreign Affairs and Trade
- Australian Embassy in the Lao PDR, Department of Foreign Affairs and Trade
- American Phytopathological Society
- An anonymous private donor
- Australian Centre for International Agricultural Research
- Global Association for People and the Environment, Helvetas
- International Collection of Microorganisms from Plants
- Royal Botanic Garden Sydney
- Provincial and District Agricultural and Forestry Offices of the Lao Ministry of Agriculture and Forestry
- Chinese Government
- Mentors and e-mentors
- Australian volunteers
- Lao volunteers
- Lao agricultural scientists
- Various other non-government organisations
- Small-holder farmers (mainly from Savannakhet and Champasak)

The Crawford Fund allocated funds that covered costs associated with the deployment of mentors, delivery of capacity building workshops and training courses, delivery of in-field consultations and crop surveys, travel research awards, laboratory equipment, and minor financial support to the International Collection of Microorganisms from Plants. The Crawford Fund additionally provided significant in-kind contributions through administrative and media support.

[2] To the best of our knowledge.

Mentors and e-mentors made significant in-kind contributions (labour) and potentially financial contributions (covering some expenses not covered by the Crawford Fund during their deployments in Laos).

Australian Volunteers International provided funds that covered the costs associated with the deployment of the Australian volunteers. The Australian volunteers were instrumental in the delivery of capacity building workshops and training courses, delivery of in-field consultations and crop surveys. The Australian volunteers made in-kind contributions (labour uncovered by compensation payments received through Australian Volunteers International) and potentially financial contributions (covering some expenses not covered by the Crawford Fund during their deployments in Laos). The staff of Australian Volunteers International contributed through administrative and media support. Additionally, the Australian-ASEAN Council and the Direct Aid Program of the Australian Embassy in the Lao PDR awarded grants for the delivery of capacity building workshops.

The delivery of capacity building workshops was additionally supported through funds from Australian Centre for International Agricultural Research, the Global Association for People and the Environment, and an anonymous private donor. The American Phytopathological Society granted funds that were used for the delivery of capacity building workshops and the purchase of textbooks and compendia. Laboratories from various countries provided in-kind contributions (labour and equipment) through their support in diagnosing plant diseases and pest insects. The International Collection of Microorganisms from Plants in New Zealand contributed through accessioning, preserving, and sequencing pathogen cultures. The Royal Botanic Garden Sydney made in-kind contributions through the sequencing of pathogens. Valuable advice and insights were provided by Australian Centre for International Agricultural Research[3], and the Royal Botanic Garden Sydney. Several non-government organisations provided alternative avenues for dissemination of advice to small-holder farmers.

The Chinese Government allocated funds to purchase laboratory equipment.

The Provincial and District Agricultural and Forestry Offices of the Lao Government provided in-kind contributions (e.g., labour, transportation, rooms for workshops). Their staff and Lao volunteers were instrumental in the delivery of capacity building workshops and training courses, delivery of in-field consultations and crop surveys.

[3] ACIAR Manual Number 129 was used as a template for the training curricula: Diagnostic manual for plant diseases in Vietnam. 2008. Lester W. Burgess, Timothy E. Knight, Len Tesoriero, Hien Thuy Phan.

Farmers involved in the program faced additional cost of production if they applied the crop health strategies. These costs mainly involved labour and equipment.

5. Benefits

This section sets out the benefits generated through the collaborative effort of all contributing entities (section 3). The overall investment generated both quantifiable and unquantifiable benefits.

- Benefits associated with avoided crop production losses enjoyed by Lao small-holder farmers.
- Benefits associated with human capital development (career enhancement; additional advantage in job markets) enjoyed by mentors, e-mentors, Australian volunteers, PAFO/DAFO staff, Lao volunteers, and student interns.
- Benefits associated with personal fulfilment through mentoring, e-mentoring, and training activities enjoyed by mentors, e-mentors, and Australian volunteers.
- Benefits associated with reputational upgrades of partner organisations.
- Benefits associated with the generation of knowledge (through the publication of papers and compendia) enjoyed by the public, internationally.
- Benefits associated with reduced health and environmental impacts due to a reduction of pesticide mismanagement enjoyed by the Lao farmers and the broader Lao public.
- Capacity building benefits enjoyed by e-mentors, mentors, collaborating scientists, staff of laboratories, and Australian volunteers.
- Research benefits enjoyed by e-mentors, mentors, collaborating scientists, staff of laboratories, and Australian volunteers.
- Benefits associated with a contribution to meeting WTO and ASEAN standards for agricultural export enjoyed by the Lao public.

6. Key parameters of the Benefit-Cost Analysis

The BCA framework used as the basis for this report is consistent with the principles of welfare economics and allows the rigorous assessment of public sector investments. However, it is data intensive, requiring the benefits and costs resulting from an investment, relative to the counterfactual, to be estimated in monetary terms. In the context of the crop health management investment, the full data requirements of the BCA framework could not be met, particularly given the developing country context involved. As a result, information on the key parameters underpinning the estimation of the investment's benefits and costs was limited. In this section, the process of estimating the benefits that could be quantified in monetary terms is outlined. The data available to achieve this quantification are reported along with the identification of data gaps. The various approaches to filling those data gaps are outlined and the consequences for the analysis are set out. In particular, data gaps have often been filled through the use of informed assumptions. Where such assumptions have been made, the report is at pains to ensure they are fully revealed.

6.1 Scope

The BCA produced estimates of the NPV generated through the investment over a 20-year period (2009 – 2028). Some benefits and costs that were judged to be unquantifiable in monetary terms have not been included in this analysis. The likely impact of their omission is discussed in the results section.

The range of NPV estimates reported results from sensitivity analyses performed to test how sensitive the NPV of the investment is to a number of different assumptions that relate to data inadequacies. This approach allows for the incorporation of uncertainties in a data poor context by establishing likely lower and upper bounds for the investment NPV.

6.2 Valuation of costs

In this section, the process used to estimate the elements of cost that could be quantified is outlined. The available costs data were used to estimate the annual costs of the investment made by each contributing entity between 2009 and 2018[4]. Cost estimates were grouped into the Crawford Fund investment and the contributions made by all other collaborators.

[4] Australian financial year ending 30 June.

Cost data were available for funds provided by the Crawford Fund, the Australian-ASEAN Council, the Australian Embassy in the Lao PDR, the American Phytopathological Society, and a private donor.

The estimates for the periodic contributions provided by Australia Volunteers International for the deployment of the long-term Australian volunteers between 2009 and 2018 were based on an estimate of the costs of a 12-month employment contract provided by one of the mentors[5,6]. This cost estimate was assumed constant over the assessed time period. This has likely resulted in an underestimation of costs.

All cost estimates were adjusted for inflation using data on the Australian Consumer Price Index. Cost estimated in Lao Kip (₭) were converted into Australian Dollars ($)[7].

Cost data for the grants made by the Australian Centre for International Agricultural Research, the Global Association for People and the Environment, and the Chinese Government were not available. Also not included in the BCA are the potentially substantial in-kind (non-monetary) contributions from the Crawford Fund, mentors and e-mentors, Australian and Lao volunteers, International Collection of Microorganisms from Plants, Royal Botanic Garden Sydney, the Provincial and District Agricultural and Forestry Offices of the Lao Government, the Australian Centre for International Agricultural Research, other non-government organisations, and any additional costs faced by the farmers from employing the integrated plant disease and pest management strategies.

6.3 Valuation of benefits

The available benefit data were used to estimate the quantifiable benefit stream over a 17 year period (2012 – 2028)[8] jointly generated by all collaborator through their respective investments. The quantified benefits were attributed to the various collaborating entities on a *pro rata* basis according to their quantified costs. This approach implies an equal rate of return across all investment contributor components. It also implies that all benefits can be attributed exclusively to the collaborating entities who made contributions quantified in monetary terms. Both assumptions are practical to implement but are likely to have been breached.

[5] AUS$65,000.
[6] Cost data for short-term Australian Volunteer deployment were not available and hence were not included into the BCA. This has resulted in an underestimation of costs.
[7] Oanda currency converter: ₭1 = A$0.00017 (31 Dec 2018).
[8] Australian financial year ending 30 June).

The benefit side of the BCA primarily involved the estimation of the avoided production losses small-holder farmers in Savannakhet and Champasak province have enjoyed from employing integrated plant disease and pest management strategies promoted through the investment since the initialisation of farmer training in 2012. Avoided production losses were estimated against a counterfactual under which these strategies were not employed, and consequently no production losses were avoided. Avoided production losses were quantified in terms of additional revenues[9] compared to the counterfactual. Note that the costs of farmers to implement the plant health management strategies have not been estimated. This means that the benefits of the investment are estimated by the gross additional revenues enjoyed by farmers rather than the net additional revenues. This approach necessarily causes an overestimation of investment benefits.

Due to a deficiency of production data for individual farmers targeted by the investment, the benefit estimation was based on the construction of an 'average farmer' using production data at the provincial level[10]. This involved production data of a list of vegetables and fruits for which production losses could be reduced if the integrated plant disease and pest management strategies were to be applied (target crops). This list includes 29 target crops and was compiled based on expert opinion collected in an online survey and interviews with key stakeholders. The analysis included all nominated target crops for which production data were available (about 83% of all crops).

Total revenues (estimated in ₭) for each province and target crop were estimated using data on seasonal, target crop specific production areas (hectares)[11], yields (kg/hectare)[12], and market prices (₭/kg)[13]. Additional total revenue was estimated as a percentage of avoided production losses. Data on production losses avoided because of the investment were based on expert

[9] It is acknowledged that an unspecified number of farmers produce the target crops for subsistence use.
[10] It is acknowledged that the 'average farmer' approach only approximates the actual situation.
[11] Lao Agricultural Census 2011 and 2017 records of the Provincial Agricultural and Forestry Office (Savannakhet and Champasak). Data on production areas missing either for 2011 or 2017 were extrapolated using the growth rate averaged across all target crops for which these data were available for both 2011 and 2017.
[12] Provincial Agricultural and Forestry Office (Savannakhet and Champasak) records for 2017. For the Champasak Province, only average crop yield data (averaged across the dry and wet season) were available. Crop yield data from Savannakhet Province from the dry (wet) season was used if data for Savannakhet for the wet (dry) were unavailable. If crop yield data for either season in Savannakhet Province were unavailable, the crop yield data averaged across both seasons from Champasak Province were used. Crop yield data unavailable for the Lao context were sourced from other country contexts and adjusted if deemed necessary.
[13] A random sample of prices for each target crop was drawn from local markets in Savannakhet and Pakse in December 2018. Prices for target crops unavailable in Savannakhet and Pakse were collected in Vientiane City. Prices unavailable in local markets were sourced from the online literature and adjusted if deemed necessary. Whenever possible, farm gate prices were collected.

opinion collected in an online survey and interviews with key stakeholders. The additional revenue earned by an 'average farmer' who benefited from the investment was estimated by dividing the additional total revenue by the total number of farmers in each province[14]. The additional revenue generated as a result of the investment was estimated by multiplying the additional revenue of an 'average farmer' for each of the two target province by the number of farmers estimated to have applied the integrated plant disease and pest management strategies. The relevant data were based on expert opinion collected by an online survey and interviews with key stakeholders. The data included estimates of the number of workshops, the average number of farmer participants per workshop, uptake rates (the proportion of farmers attending the workshops who took action as a result), and spin-off effects (the number of farmers who did not attend the workshops but who 'learnt' from farmers who did attend and subsequently took action).

The benefit estimates were adjusted for inflation using the Lao Consumer Price Index.

The process of estimating additional revenues from avoided production losses was based on the following assumptions:

- All districts of each of the two target provinces were equally targeted by the investment. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- The nominated target crops, the crop health management strategies, and their estimated effectiveness in reducing production losses remained the same between 2012 and 2028. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- Avoided production losses associated with crops for which data were unavailable were zero. This conservative approach most likely led to an underestimation of production impacts.
- The annual production area between 2012 and 2018 equalled the average of the production area of 2011 and 2017. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- The annual production area between 2019 and 2028 will equal the production area of 2017. This conservative approach likely led to an underestimation of production impacts.

[14] Lao Agricultural Census 2011 and Lao Census of Population and Housing 2005 and 2015. The number of farmers in 2018 was extrapolated from 2011 data using the population growth rate estimated based on data from 2005 and 2015.

- The protocols to collect and compile data on production areas are the same across all data sources. It remains unclear whether this assumption led to an over- or underestimation of production.
- Data on production areas that were missing either for 2011 or 2017 from the existing records were equal to (either forwards or backwards) extrapolations based on the growth rate averaged across all target crops for which data were available for both 2011 and 2017. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- Yields between 2012 and 2028 equal the yields of 2017. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- Dry and wet season yields in Champasak Province equal the yields averaged across the two seasons. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- The protocols to collect and compile data on yields are the same across all data sources. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- Crop yield data sourced from the dry (wet) season, the Champasak Province, and other country contexts equals the wet and dry season specific crop yields of the Savannakhet Province. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- Crop yield data sourced from the Savannakhet Province and other country contexts equals the wet and dry season specific crop yields of the Champasak Province. It remains unclear whether this assumption led to an over- or underestimation of production impacts.
- The subsistence value of the target crops equals their market value. It remains unclear whether this assumption led to an over- or underestimation of revenue impacts.
- Crop prices between 2012 and 2028 equal the prices of October 2018 collected in local markets in Savannakhet, Pakse and Vientiane (inflation adjusted). Prices unavailable in local markets equal Lao prices found in online sources. Prices are constant across time, seasons and locations. It remains unclear whether this assumption led to an over- or underestimation of revenue impacts.
- The prices of all target crops are producer (farm-gate) prices. It remains unclear whether this assumption led to an over- or underestimation of revenue impacts.

- The number of farmers at the provincial level between 2012 and 2018 equalled the average of number of farmers recorded in the Lao Agricultural Census in 2011 and the number of farmers extrapolated for 2017 using population growth rates from the Lao Population and Housing Census 2005 and 2015. It remains unclear whether this assumption led to an over- or underestimation of the number of farmers impacted.
- The number of farmers at the provincial level between 2019 and 2028 equals the number of farmers extrapolated from 2011 to 2017. It remains unclear whether this assumption led to an over- or underestimation of the number of farmers impacted.
- The number of annual workshops, average number of farmer participants per workshop, uptake rates, and spin-off effect equal the estimates made for the time period 2012 to 2018. It remains unclear whether this assumption led to an over- or underestimation of the number of farmers who were trained, who apply the integrated plant disease and pest management strategies and who learnt from trained farmers.
- Trained farmers apply the crop health strategies perfectly. This approach most likely led to an overestimation of avoided production losses.
- Trained farmers will apply the crop health strategies continuously until 2028. This approach may have led to an overestimation of avoided production losses.

7. Estimation of Net Present Value

The estimated costs and benefits over the time frame of the analysis were aggregated to calculate the NPV of the investment to account for the time value of money. The costs and benefits estimated for the time period from 2009 to 2018 were compounded, whereas the benefits estimated for the time period from 2019 to 2028 were discounted. The NPV was estimated for discount/interest rates of three and five percent. Benefit-Cost Ratios (BCR) were also calculated to evaluate the return on investment: a BCR larger than one indicates a positive return on investment.

The NPV is estimated in the absence of any new investment beyond 2018.

8. Results

The results of the BCA presented in this section are those of a 'base case' in which an initial set of underpinning assumptions is established. The base case is designed to be representative of a scenario in which the investment achieves moderate success and was constructed using averages of data based on expert opinions collected during interviews and an online survey with key stakeholders. The key assumptions of the base case are:

- Increase in crop yield resulting from improved crop health management – 34%
- Workshops per year in each province – 1.9
- Farmers participating in each workshop – 23.9
- Uptake rate of farmers who attended the workshops – 63%
- Trained farmers who train neighbours – 50%
- Trained neighbours per trained farmer – 3.2

The results of the BCA are given in Table 1 (Crawford Fund investment) and Table 2 (overall investment) for discount rates of three and five percent. Both tables present the relevant analysis for two time periods. The first is from the start of the investment in 2009 through to the time of this assessment. The second includes forecasts of investment benefits for a further 10 years. Note that in the forecasting of benefits for a further 10 years, it is assumed that no additional farmers learn any of the improved crop health management strategies. This causes a potential underestimation of future benefits.

At a three percent discount rate, the NPV of the Crawford Fund investment for the time period from 2009 - 2018 is about -$11,180, with a BCR of 0.94 indicating a negative return on investment. The return on investment becomes positive (BCR 2.81) with a NPV of $343,655 if the time period from 2009 to 2028 is considered. Because the benefits were apportioned between the Crawford Fund and the overall investment according to the cost split, the rates of return (BCR) to the overall investment are the same as for the Crawford Fund component. Only the magnitudes of the NPVs are different.

Table 1: BCA results: Crawford Fund investment

	2009 - 2018		2009 - 2028	
	Discount rate 3%	Discount rate 5%	Discount rate 3%	Discount rate 5%
Present value of costs	$188,906	$207,281	$188,906	$207,281
Present value of benefits	$177,726	$186,346	$531,561	$509,126

Net present value	-$11,180	-$20,935	$343,655	$301,845
Benefit-cost ratio	0.94	0.90	2.81	2.46

Table 2: BCA results: Overall investment

	2009 - 2018		2009 - 2028	
	Discount rate 3%	Discount rate 5%	Discount rate 3%	Discount rate 5%
Present value of costs	$870,040	$947,332	$870,040	$947,332
Present value of benefits	$818,550	$851,653	$2,448,200	$2,326,849
Net present value	-$51,490	-$95,679	$1,578,159	$1,379,517
Benefit-cost ratio	0.94	0.90	2.81	2.46

The implication of these results is that, to date, the investment has yet to achieve a positive rate of return. However, with the improved revenues enjoyed by those farmers who have adopted the crop health management strategies continuing through time, the investment can be expected to produce a financial return.

There are a number of important points to make regarding the extent of the rate of return calculated.

First, it is important to stress that the BCA results presented for the 'base case' underestimate both the costs and benefits of the investment due to the omission of unquantifiable costs and benefits. Given that the extent of unquantified benefits are judged to outweigh the unquantified costs, the actual NPV of the investment is most likely much larger than estimated in this BCA. The bulk of the unquantified benefits involve the skills improvements enjoyed by both Australian and Lao participants, notably the volunteers and Lao PAFO/DAFO staff. These benefits will be manifest not only in the career opportunities achieved for the people involved but also through the net benefits they will be able to generate in the work they do across a multitude of other projects. They are likely to be substantial. In contrast, the unquantified costs relate largely to the costs of implementing the crop health management strategies developed under this investment. Because the focus of the strategies developed is cost effectiveness, these costs are unlikely to be as substantial.

Second, the assumption made is that once a trained farmer has passed on their knowledge to adjacent farmers, there are no further 'spill-over' effects over time. In the process of projecting benefits over time, this is likely to be a conservative assumption. As farmers observe the

success of other farmers' management actions, the spread of techniques can be exponential. Again, the BCA reported here understates the likely return on investment: it essentially sees benefits grow but then plateau over the next 10 years as the spill over effects are constrained. For continued growth, further investments in extension activities would be required.

As a counter to the first two point, which both suggest that an understatement of the investment NPV, the third point relates to the issue of attribution. The analysis presented implies the assumption that the investment under consideration is the only source of crop health management improvement available to Lao farmers. This assumption is made through the definition of the counterfactual as essentially being a continuation of the context prior to the investment commencement. The reality is that in the absence of the investment, other sources of improvement in crop yields may have become available. Put simply, the counterfactual may not have been as 'bad' as the BCA implies. While this reality does imply an overstatement of the investment returns, taking it into account is virtually impossible as 'what might have been' without the investment cannot be determined with any accuracy.

9. Sensitivity analysis

As was stressed throughout this report, the BCA conducted has necessarily been based on a series of informed assumptions due to the paucity of the relevant data. To test how sensitive the estimates presented in the previous section for the 'base case' are to some of the key assumptions made, the NPV and BCR of the Crawford Fund investment were estimated under a number of different assumptions. The sensitivity analysis was performed at a three percent discount rate. The results are summarised in Table 3 and Table 4. For each of the key assumptions, two additional scenarios are considered – one which is lower than the base case assumption and one which is higher. The impacts of the alternative assumptions are presented in terms of the level of benefits, the NPV and the BCR. Those impacts are considered for each assumption alone and then as a combination of all the 'up-side' assumptions and all the 'down-side' assumptions combined. This allows the estimation of a lower and upper bound around the base case rates.

Table 3: Sensitivity analysis results (2009 – 2018)

	Change in PV benefit on base estimate	PV benefits	NPV	BCR
Base case estimate		$177,726	-$11,180	0.94
Increase in crop yield – 10%	-$124,784	$52,942	-$135,964	0.28
Increase in crop yield – 55%	+113,455	$291,181	$102,275	1.54
Workshops per year in each of the two provinces– 1	-$85,572	$92,145	-$96,752	0.49
Workshops per year in each of the two provinces– 2.9	+85,572	$263,298	$74,392	1.39
Farmers participating in each workshop – 12	-$88,331	$89,395	-$99,511	0.47
Farmers participating in each workshop – 35	+83,010	$260,736	$71,830	1.38
Uptake rate – 30%	-$92,418	$85,309	-$103,597	0.45
Uptake rate – 90%	+$78,199	$255,926	$67,020	1.35
Trained farmers who train neighbours – 10%	-$87,496	$90,230	-$98,676	0.48
Trained farmers who train neighbours – 90%	+87,496	$265,222	$76,316	1.40
Trained neighbours per trained farmer – 1	-$75,192	$102,534	-$86,372	0.54
Trained neighbours per trained farmer – 5	+$61,521	$239,247	$50,341	1.27
Total upside scenario	+$1,750,066	$1,927,792	$1,738,886	10.21
Total downside scenario	-$174,922	$2,804	-$186,102	0.01

The maximum bound for the BCR is 10.21, with a NPV of about $1,738,886. On the downside, the minimum BCR is 0.01, with an NPV of about -$186,102.

Table 4: Sensitivity analysis results (2009 – 2028)

	Change in PV benefit on base estimate	PV benefits	NPV	BCR
Base case estimate		$531,561	$342,655	2.81
Increase in crop yield – 10%	-$373,217	$158,344	-$30,562	0.84
Increase in crop yield – 55%	+$339,331	$870,892	$681,986	4.61
Workshops per year in each of the two provinces– 1	-$255,937	$275,624	$86,718	1.46
Workshops per year in each of the two provinces– 2.9	+$255,937	$787,497	$598,591	4.17
Farmers participating in each workshop – 12	-$264,189	$267,372	$78,466	1.42
Farmers participating in each workshop – 35	+$248,274	$779,834	$590,929	4.13
Uptake rate – 30%	-$276,411	$255,149	$66,243	1.35
Uptake rate – 90%	+$233,887	$765,447	$576,541	4.05
Trained farmers who train neighbours – 10%	-$261,691	$269,869	$80,963	1.43
Trained farmers who train neighbours – 90%	+$261,691	$793,252	$604,346	4.20
Trained neighbours per trained farmer – 1	-$224,891	$306,670	$117,764	1.62
Trained neighbours per trained farmer – 5	+$184,002	$715,562	$526,656	3.79
Total upside scenario	+$5,234,268	$5,765,829	$5,576,923	30.52
Total downside scenario	-$523,174	$8,387	-$180,519	0.04

The maximum bound for the BCR is 30.52, with a NPV of about $5,576,923. On the downside, the minimum BCR is 0.04, with an NPV of about -$180,519.

Clearly, these upper and lower bounds present a wide range of potential values. They reflect the levels of uncertainty that are embedded in the data used in the analysis. Furthermore, they demonstrate that the assumptions made have an important impact on whether or not the investment can be judged to have yielded a positive (financial) return. In such circumstances, the importance of lowering the levels of data uncertainty becomes apparent.

10. Conclusions

The high levels of uncertainty surrounding the data that underpin the BCA conducted on the Crawford Fund investment into improving crop health management capabilities in Lao PDR make the drawing of strong conclusions challenging. However, two stand-out points can be made.

First, the rate of return on the investment is likely to be positive. The monetary based BCA for the base case set of assumptions reported indicates that, with a combined ex post and ex ante approach, a BCR of around 3 and an NPV of around $300,000 are likely. Importantly, when the non-monetary benefits associated with the potentially significant capacity building aspects of the investment are taken into account, the rate of return on the investment is likely to be significantly higher. These results demonstrate that the Crawford Fund investment has produced net social gains for the Lao, Australian and international communities.

Second, the ‘error bounds’ on the estimates of BCR and NPV are relatively large as could be anticipated given data uncertainties. Not only are the error bounds large, but they also demonstrate that there are circumstances where the first conclusion is over-turned. That is under some conditions, the investment will not have driven net social benefits.

It is largely in response to the second conclusion that a number of recommendations are set out in the next section.

11. Recommendations

Based on the BCA, a number of follow up actions are recommended. The recommendations are aimed at reducing data uncertainty for this investment (as well as other investments that may be subjected to assessment in the future) and enhancing the net benefits of the crop health management investment that may be achieved in the future.

1. **Record activities undertaken and collect data on key impacts of the investment on a regular basis.**

The Crawford Fund should instigate a reporting process for its future investments through which project leaders provide formal up-dates on an annual basis that include details of funds spent (costs) and achievements made (benefits). Such a reporting system would require the setting of goals and milestones at the project development stage that would need to be monitored. The required monitoring would involve project leaders collecting data from their key collaborators that are relevant to the estimation of benefits and costs generated through an investment. This would include records of activities undertaken to achieve the milestones and the collection of data on their key impacts to achieve the goals. Consultation with a project evaluation economist at the stage of establishing the project monitoring procedures would be beneficial.

The following section sets out the data that would make a useful contribution to the process of project evaluation in the case of the crop health investment.

Data on financial and in-kind contributions:

- made by the Crawford Fund (funding, labour related to media support, administration, management);
- of mentors (covering some expenses not covered by the Crawford Fund during their employment as well as their labour);
- of e-mentors and laboratories (labour, equipment use, material);
- of Australian Volunteers International (costs of Australian volunteer employment);
- of Australian volunteers (covering some expenses not covered by the Crawford Fund during their employment and labour uncovered by compensation payments received through Australian Volunteers International);
- of all other collaborators (funding, labour, equipment, material);

- of the Provincial and District Agricultural and Forestry Offices of the Lao Government; and,
- of the farmers associated with applying the crop health strategies (labour, equipment, material, based on expert opinion of workshop trainers and through conversation with farmers during workshops and in-field consultations).

Data on activities undertaken and key impacts achieved:

In general, all project activities should be recorded in detail (date; location; goal; participants and their roles). Furthermore, the following data should be collected and reported:

- training material, manuals, posters, guidelines, and checklists (title, date of completion/publication, authors' affiliations);
- completed surveys (date; purpose; surveyors' affiliations);
- in-field consultations (date; purpose; number, role and affiliation of participants including the facilitators);
- diagnosed plant diseases, pest insects, and beneficial insects through in-field, laboratory and e-diagnostics processes (list of plant diseases, pest, and beneficial insects including date of diagnosis);
- publications of research papers, reports, and compendia (title; date; authors' affiliations);
- workshops, including the train-the-trainers workshops (date; location; workshop topics including targeted crops; number, role, and affiliation of participants including the trainers);
- in-field consultations (date; location; activity; number, role, and affiliation of participants including the facilitators/experts);
- laboratory training of PAFO/DAFO staff and other collaborating researchers (date; location; activity; number, role, and affiliation of participants including the trainers); and,
- Data on e-mentoring activities (date; location; activity; affiliation of e-mentors).

Data on key impacts:

- crop health strategy uptake rates (average percentage of farmers applying the crop health strategies after participating in a workshop) collected through conversation with volunteers, mentors, farmers and PAFO/DAFO staff during workshops and in-field consultations;
- spin-off effects (average number of farmers - who did not participate in a workshop but who applied the crop health strategies - per workshop participant) collected through

conversation with volunteers, mentors, farmers and PAFO/DAFO staff during workshops and in-field consultations;

- crop health strategy effectiveness collected through conversation with volunteers, mentors, farmers and PAFO/DAFO staff during workshops and in-field consultations (average percentage of increased yields); and,
- capacity building achievements made by mentors, Australian volunteers, Lao volunteers, and PAFO/DAFO staff (maintaining a data base on the people who have been involved with the investment that includes subsequent positions held, professional impacts achieved in subsequent positions either through publications or other schemes initiated or impacted that follow on from their initial involvement[15]).

Data on external factors:

- Average crop 'farm gate' prices targeted by the crop health strategies (price per kg collected for dry and wet season each year) through conversations with farmers during workshop and in-field consultations for each relevant province;
- Production data for all target crops from PAFO officials who conduct annual crop surveys covering the wet and dry season (area of production in hectares and productivity in yield/ hectares).

2. Store all relevant data and documents in an organised, central data bank managed by the Crawford Fund.

The annual reports submitted to the Crawford Fund should be stored along with relevant associated data and documents in a central data base. Data and documents associated with funding and in-kind contributions provided by entities other than the Crawford Fund should also be included in the data base.

3. Explore prospects to increase number of farmers trained in crop health strategies and associated uptake rates.

The NPV of the investment is highly responsive to farmer uptake. Future investments could focus on increasing the number of participants per workshop (low marginal costs), searching for collaborators that may have the capacity to focus on extension, and investing in expanding

[15] Note that there are considerable complexities involved in establishing the counterfactual in regards to capacity building benefits. Put simply, it is difficult to determine what advancement would have been made by individuals if they had not been involved in the project. Establishing a monetary value for the change involved shares this complexity along with issues associated with non-pecuniary advantages associated with greater job satisfaction.

the number of trainers capable of training farmers. The latter may be achieved by encouraging a more active involvement of DAFO staff in in-field consultations, surveys, and farmer workshops conducted by volunteers, mentors, and PAFO staff.

4. **Explore a collaboration with the Faculty of Agriculture of the University of Laos.**

A collaboration may provide the prospect to incorporate knowledge on crop health accumulated through the investment into course curricula. It may also expand the opportunities for student internships currently provided by PAFO in Savannakhet.

5. **Explore opportunities to deploy a volunteer qualified in weed diagnostic and management relevant for rice production in Savannakhet.**

Representations from Lao collaborators indicate that this may be a valuable investment.

6. **Explore opportunities to encourage longer volunteer assignments.**

Representations from Lao collaborators indicate that longer volunteer assignments achieve larger impacts.

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Appendix

A. List of contacted stakeholders

Australia:

- Dr Collin Charters (CEO, Crawford Fund)
- Dr Helen Scott-Orr (NSW Coordinator, Crawford Fund)
- Ms Marchien Vanoostende (Office Manager, Crawford Fund)
- Mr Phillip Jackson (Financial Controller, Crawford Fund)
- Dr Richard Sheldrake (Chair, NSW State Committee, Crawford Fund)
- Dr Denis Blight (Crawford Fund)
- Prof Lester Burgess (Mentor, Crawford Fund)
- Prof Deidre Lemerle (Committee Member NSW Branch, Crawford Fund)
- Dr Kylie Ireland (Mentor, Crawford Fund and ex-Australian volunteer)
- Dr Madeleine Healy (Mentor, Crawford Fund and ex-Australian volunteer)
- Mr Nick Pain (ex-Australian volunteer)

Savannakhet, Savannakhet Province:

- Mrs. Phonesavanh, Vice-head, Agricultural Section, PAFO
- Mrs. Kaisone, Academic Officer, Agricultural Section, PAFO
- Mrs. Mayouly, Academic Officer, Agricultural Section, PAFO
- Small-holder farmer

Pakse, Champasak Province:

- Dr. Somlit Vialvong, Vice-Head, PAFO
- Dr. Phuvong, Vice-Head, Agricultural Section, PAFO
- Mrs. Seng, Academic officer, Agricultural Section, PAFO
- Mr. Souliya, Head of Management and Planning Section, PAFO
- Small-holder farmer

B. List of participants of online survey

- Dr Kylie Ireland (Mentor, Crawford Fund and ex-Australian volunteer)
- Dr Madeleine Healy (Mentor, Crawford Fund and ex-Australian volunteer)
- Mr Nick Pain (ex-Australian volunteer)
- Mrs. Phonesavanh, Vice-head, Agricultural Section, PAFO
- Mrs. Kaisone, Academic Officer, Agricultural Section, PAFO
- Dr Phuvong, Vice-Head, Agricultural Section, PAFO