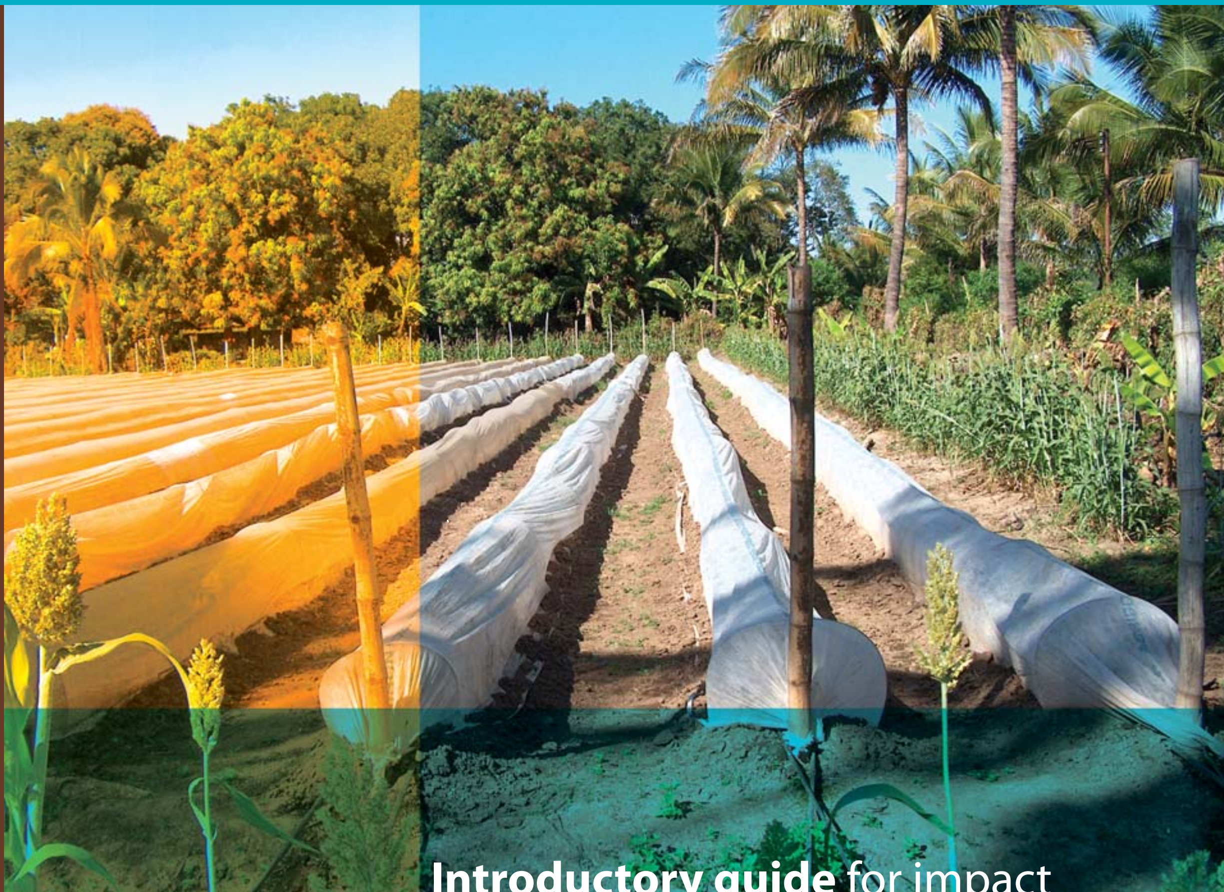

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Introductory guide for impact evaluation in integrated pest management (IPM) programs

Oscar **Ortiz** • Willy **Pradel**

INTEGRATED CROP MANAGEMENT DIVISION

Introductory guide for impact evaluation in integrated pest management (IPM) programs

Oscar Ortiz
Willy Pradel

International Potato Center
Tropical white fly IMP project, DFID

Introductory guide for impact
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International Potato Center
P.O. Box 1558, Lima 12, Peru
cip@cgiar.org • www.cipotato.org

Production Coordinator
Cecilia Lafosse

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Elena Taipe and contributors from Graphic Arts

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Prologue

In recent years there has been growing interest in evaluating the profitability of investment in projects or programs related to research and agricultural development. Donors, administrators, researchers, those involved in development programs, governments and farmers need to measure the impact of different projects, programs or institutions.

There is a wide diversity of research and development projects in agriculture. One type of project is related to Integrated Pest Management (IPM) programs, which are generally presented as an alternative to the indiscriminate use of pesticides. IPM makes use of various forms of control: biological, ethological, mechanical, physical, genetic, legal and chemical, which generally imply the farmer knows the biology and behavior of pests so he or she can make appropriate management decisions.

Unfortunately, few IPM projects have been sufficiently documented in terms of impact achieved. One of the reasons for this is that impact evaluation is not widely known. Few social scientists have specialized in this area. Also, in many cases, IPM programs do not include social scientists on their teams to support socioeconomic evaluation due to lack of qualified personnel or lack of funds to hire them.

An alternative for overcoming this limitation is to train personnel working in IPM research and development, most of whom are agricultural science researchers or biologists, in impact evaluation methodology, concurrently with providing methodological tools for social science personnel to do this type of work. This guide aims to help fill the gap in the literature related to impact evaluation of IPM projects, which, though based on Latin American experiences, can be adapted to other realities.

Acknowledgements

We would like to acknowledge the special contribution of the members of the socioeconomic team of the National Center of Agriculture and Forestry Technology (Centro Nacional de Tecnología Agropecuaria y Forestal; CENTA) of El Salvador, both for their comments on this document and for contributing two case studies on impact evaluation. We would also like to thank the PROINPA team from Bolivia and the Randi Randi team in Ecuador, who contributed with impact studies and provided valuable comments to improve this publication.

The present guide summarizes the work of the multi-disciplinary team from the former department of social sciences and of the participatory research team from the Integrated Crop Management Division of the International Potato Center over the last ten years. The validation of this guide has been possible thanks to the financial support of the Tropical White Fly IPM Project using funds from DFID (United Kingdom Department for International Development) provided through the International Center for Tropical Agriculture (CIAT).

Introductory guide for impact evaluation in integrated pest management (IPM) programs

SECTION I: INTRODUCTION AND PRESENTATION

This guide introduces principles and methods for evaluating impacts generated by IPM programs or projects in a user-friendly way, beginning with concepts and basic methods, and then presenting aspects of progressively more specific methodologies. References to methods and case studies have also been included for people who are interested in delving more deeply into the subject. It is, however, necessary to make clear that this guide is an introduction to the theme and is mainly oriented towards agriculture or biological science professionals, although it can also be useful for professionals specializing in impact evaluation who have no experience in IPM impact evaluation.

The philosophy of this guide is that the evaluation of IPM impact is not to be left for last, when the project is finished or almost finished. On the contrary, impact evaluation should be part of the project design and continue throughout the development of the project, so that at the conclusion, the pertinent information needs only to be completed.

The guide is organized in flow diagrams; the reader can easily follow the step-by-step explanation of the most appropriate methods for evaluating different types of IPM impact. In Section II is presented a collection of flow diagrams indicating the main questions to ask in IPM impact evaluation. Each flow diagram relates to a description of methods and illustrative specific cases presented in Section III and more specific information presented in the respective appendices. Section IV provides references for additional information on impact assessment.

SECTION II: METHODOLOGICAL STEPS FOR EVALUATING IPM IMPACTS: FLOW DIAGRAMS

This section presents flow diagrams to guide you through the evaluation of different types of impact in an IPM program by means of a series of questions for you to answer.

Diagram 1 asks about the stage of the IPM program you wish to evaluate, and has three possible answers (when the program is in the experimental stage; when activities with farmers are being started; or when activities with farmers are well underway). Accordingly, each of these lead to an answer related to the type of impact evaluation that can be done, which is presented in the diagrams that follow.

Once the stage of the program you wish to evaluate has been selected, pass to Diagram 2, where the main question regards the type of impact you wish to measure. The diagram provides four alternatives, which relate to evaluation of impact on human capital (changes in knowledge, attitudes and capacities), on social capital (changes in organization, social networks, access to information, etc.) on economic aspects (net benefits and rate of return) and on environmental aspects, specifically referring to changes in the use of pesticides (changes in level of environmental contamination and health risk to workers and consumers using the environmental impact quotient or EIQ method).

Diagrams 3, 4, 5 and 6 guide you through a number of questions and alternatives related to measuring impact on human capital, social capital, and economic and environmental aspects, respectively. These questions and alternatives are complemented by the appendices, where more detailed information is given on specific methods that can be used.

Highlighted notes in the Diagrams indicate points to which you should pay special attention.

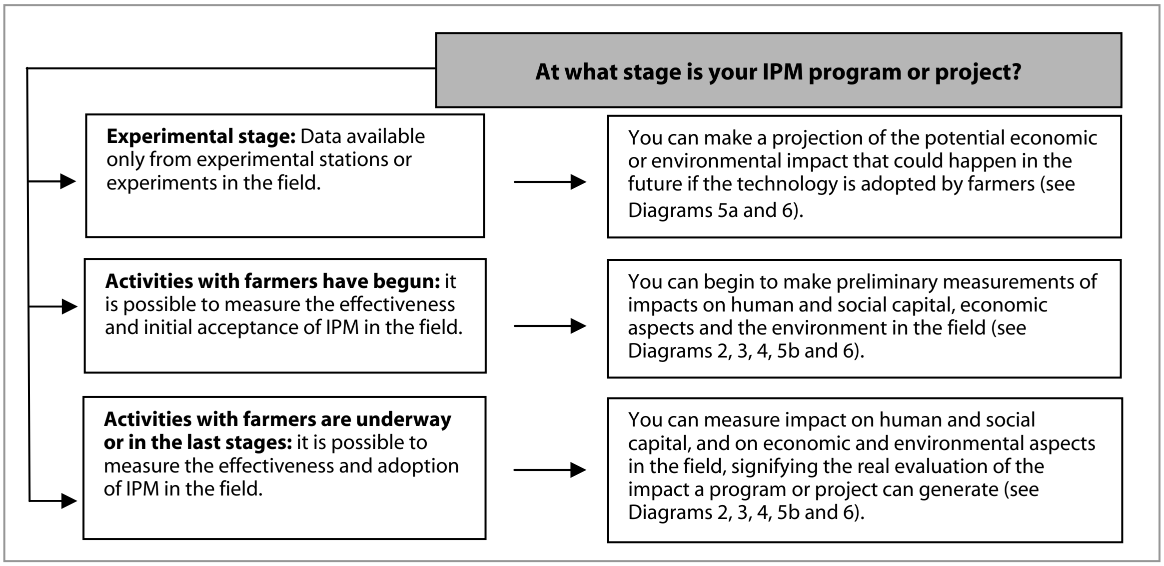
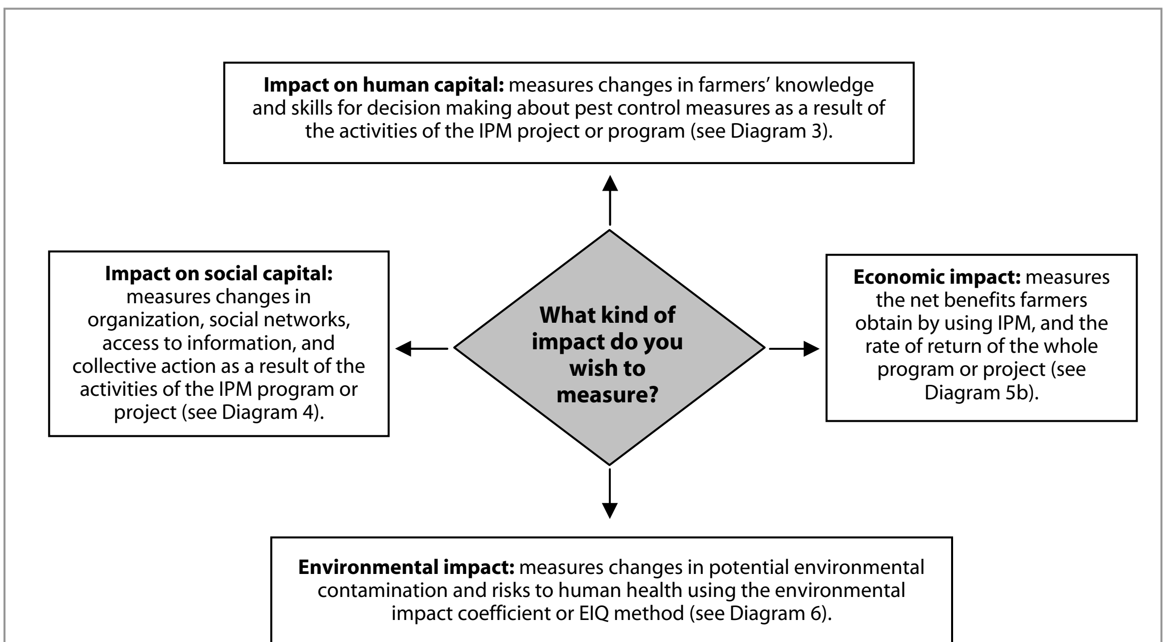


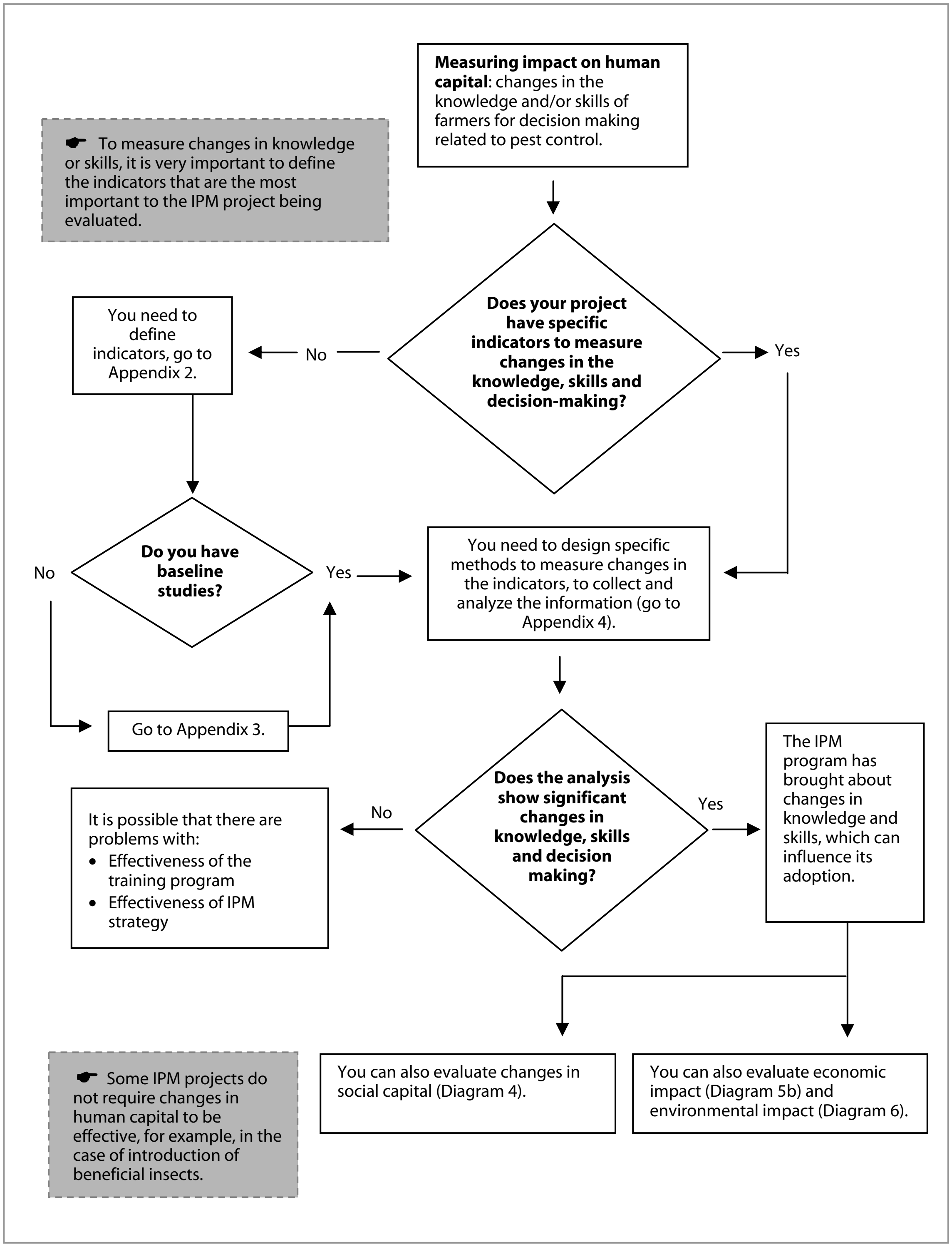
Diagram 1. Selecting the current stage of your IPM program



☛ Depending on availability of resources and type of project, integral impact evaluations, including changes in human and social capital, and economic and environmental aspects, are recommended to better explain the effects. However, when the project is at the experimental stage, only projections of economic and environmental impact can be made, as changes in human and social capital cannot yet be measured. If you would like to know more about the basic concepts concerning impact evaluation, go to Appendix 1.

Diagram 2. Defining the type of impact you would like to measure

Diagram 3. Measuring impact on human capital



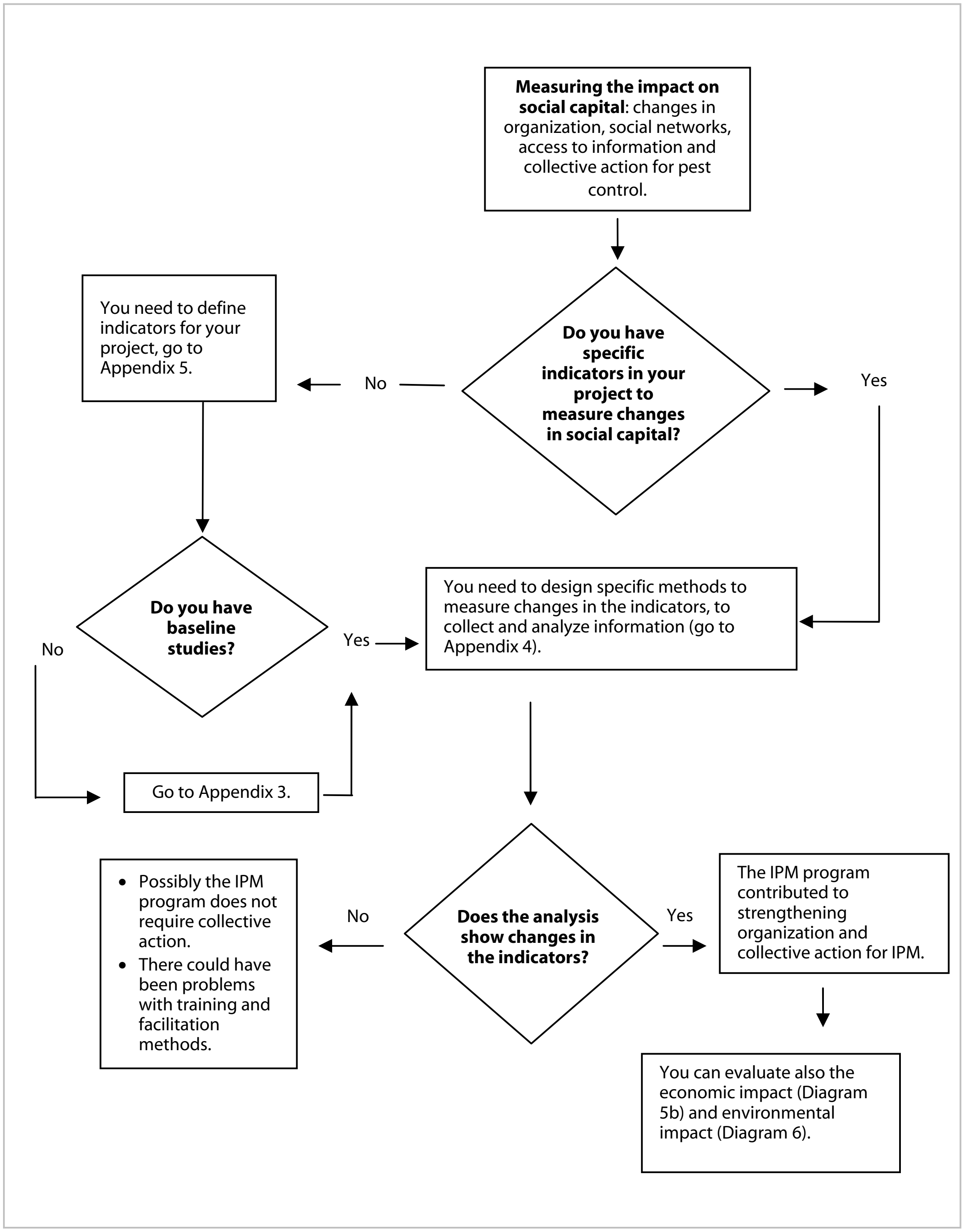
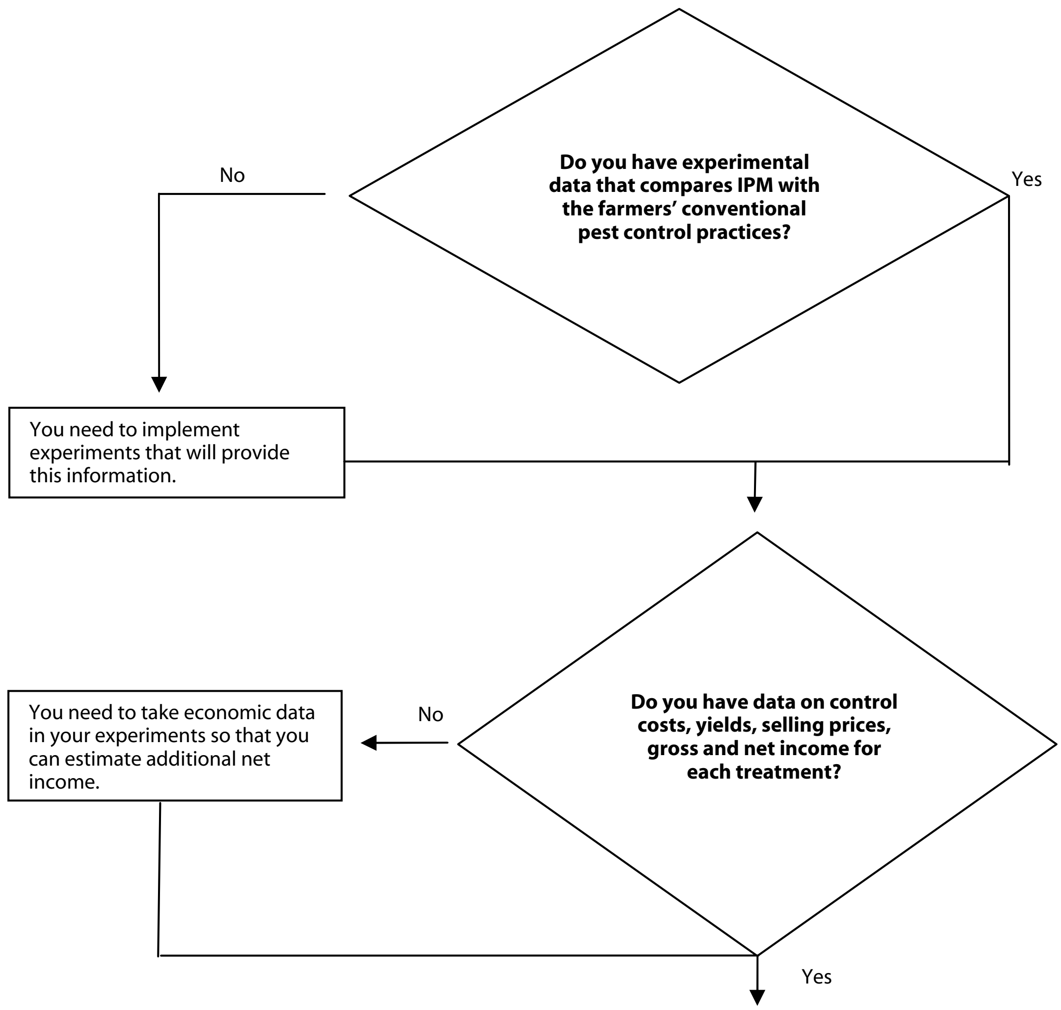


Diagram 4: Measuring impact on social capital

Diagram 5a:
Projecting economic impact on the basis of experimental data



☛ With the additional income from each treatment, you should extrapolate your data to hectares to calculate the potential additional income per hectare (ha) that the IPM program would produce, using partial budget analysis principles (Appendix 6). For example, you can estimate that farmers will earn US$ 100/ha by using IPM, then you can multiply this amount by the number of ha on which IPM could be adopted in the future. To do this, you can use the total number of ha where the crop is grown, and then assume conservative adoption, for example, 10% or 15% of the area in a certain region. With this data, you can use the project costs to estimate IRR (internal rate of return) and NPV (net present value) (Appendix 9). This data can be used to see if sufficient profitability from the IPM project can be expected in the future.

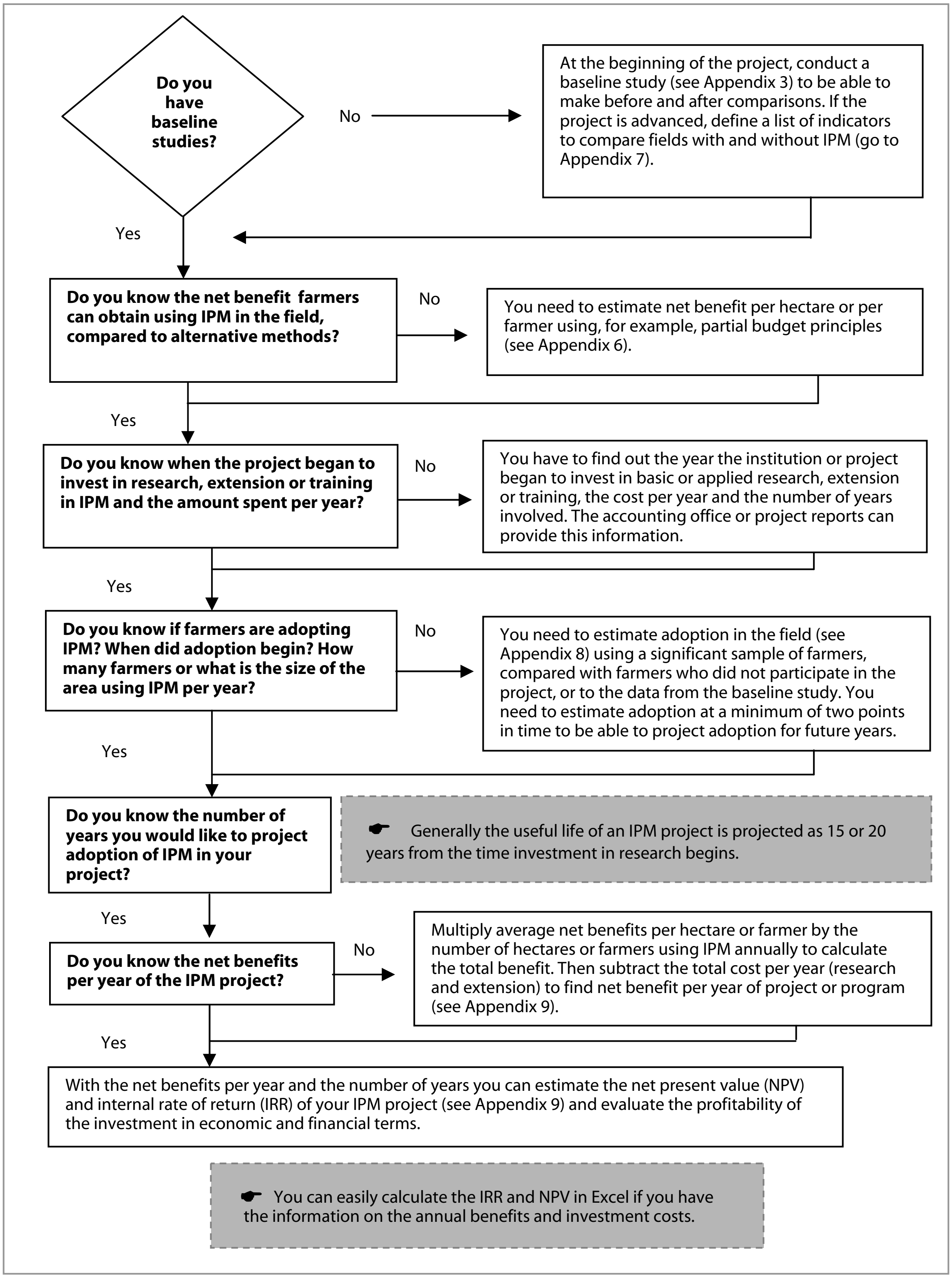
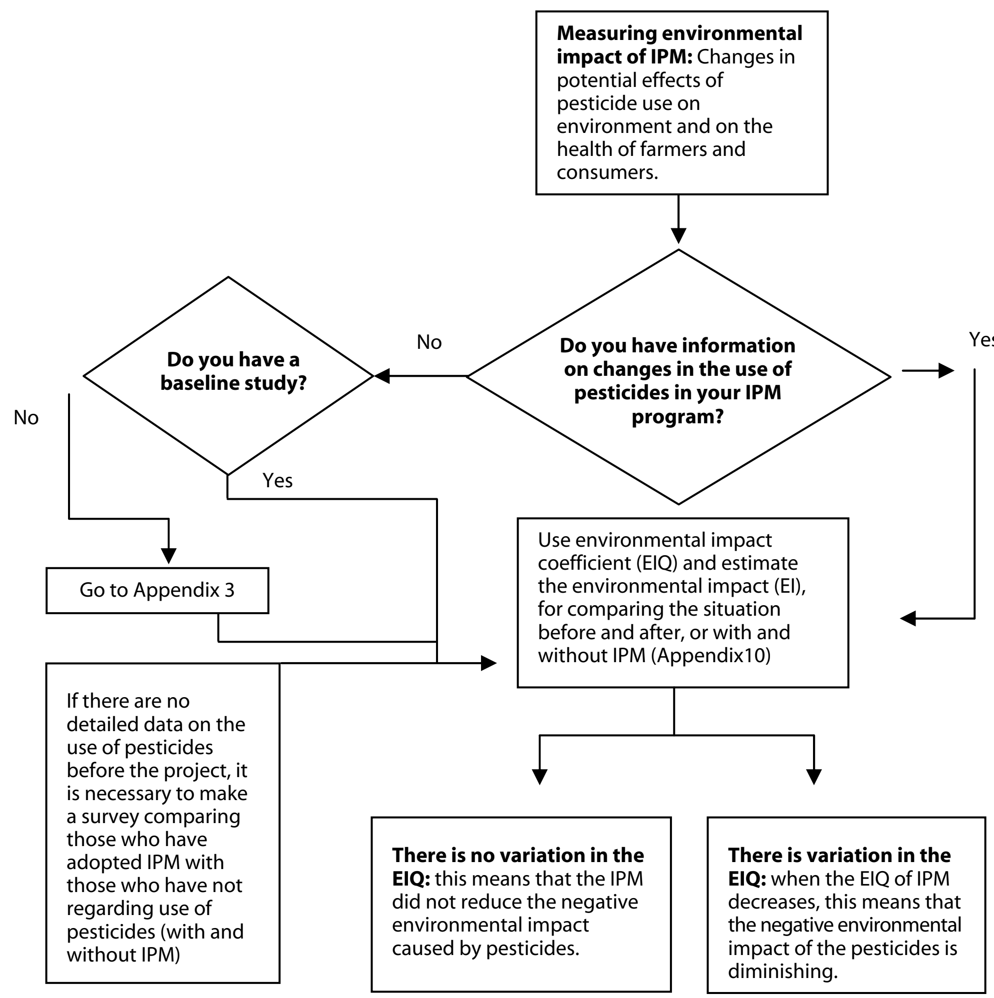


Diagram 5b:
Measuring economic impact of IPM in the field

Diagram 6: Measuring environmental impact



☛ This type of impact can also be evaluated based on experimental data, for which is needed the type of pesticide, number of applications and dose conventionally used by farmers as well as the same information using IPM technology. In this way the potential environmental impact of each technology can be estimated and compared. It is expected that the potential environmental impact of IPM will be significantly less.

SECCION III: EXAMPLES OF IMPACT EVALUATION OF IPM

In this section we present four case studies of IPM impact evaluation. The results are presented as diagrams that sum up impact evaluation on human and social capital, and on economic and environmental aspects: these results have been extracted from completed and published studies, which are listed below.

1. **Maza, N., A. Morales, O. Ortiz, P. Winters, J. Alcazar, y G. Scott**. 2000. *Impacto del manejo integrado del tetuán del boniato (Cylas formicarius) en Cuba [Impact of integrated control of the sweetpotato weevil (Cylas formicarius) in Cuba].* Centro Internacional de la Papa (CIP). Lima, Perú. 52p.
2. **Züger, R.** 2004. *Impact Assessment of Farmer Field Schools in Cajamarca, Peru: An economic evaluation*. Social Sciences Working Paper No. 2004-1. International Potato Center, Lima, Peru. ISSN 0256-8748
3. **CENTA.** 2008*. Estudio de Impacto Socioeconómico de Microtúneles para la Producción de Hortalizas [Study on the Socioeconomic Impact of Microtunnels for the Production of Vegetable Crops].* Unidad De Biometría y Socioeconomía [Biological Statistics and Socioeconomic Unit], Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA; National Center of Agriculture and Forestry Technology), El Salvador.
4. **Deleón, A.** 2008. *Estudio de Impacto de la Adopción de la Variedad de Frijol CENTA San Andrés en El Salvador [Study on the Impact of Adopting Bean Variety CENTA San Andrés in El Salvador].* Unidad De Biometría y Socioeconomía [Biological Statistics and Socioeconomic Unit], Centro Nacional de Tecnología Agropecuaria y Forestal (CENTA, National Center of Agriculture and Forestry Technology), El Salvador.

Diagram of impact of integrated management of the sweetpotato weevil (*Cylas formicarius*) in Cuba (Maza et al., 2000)

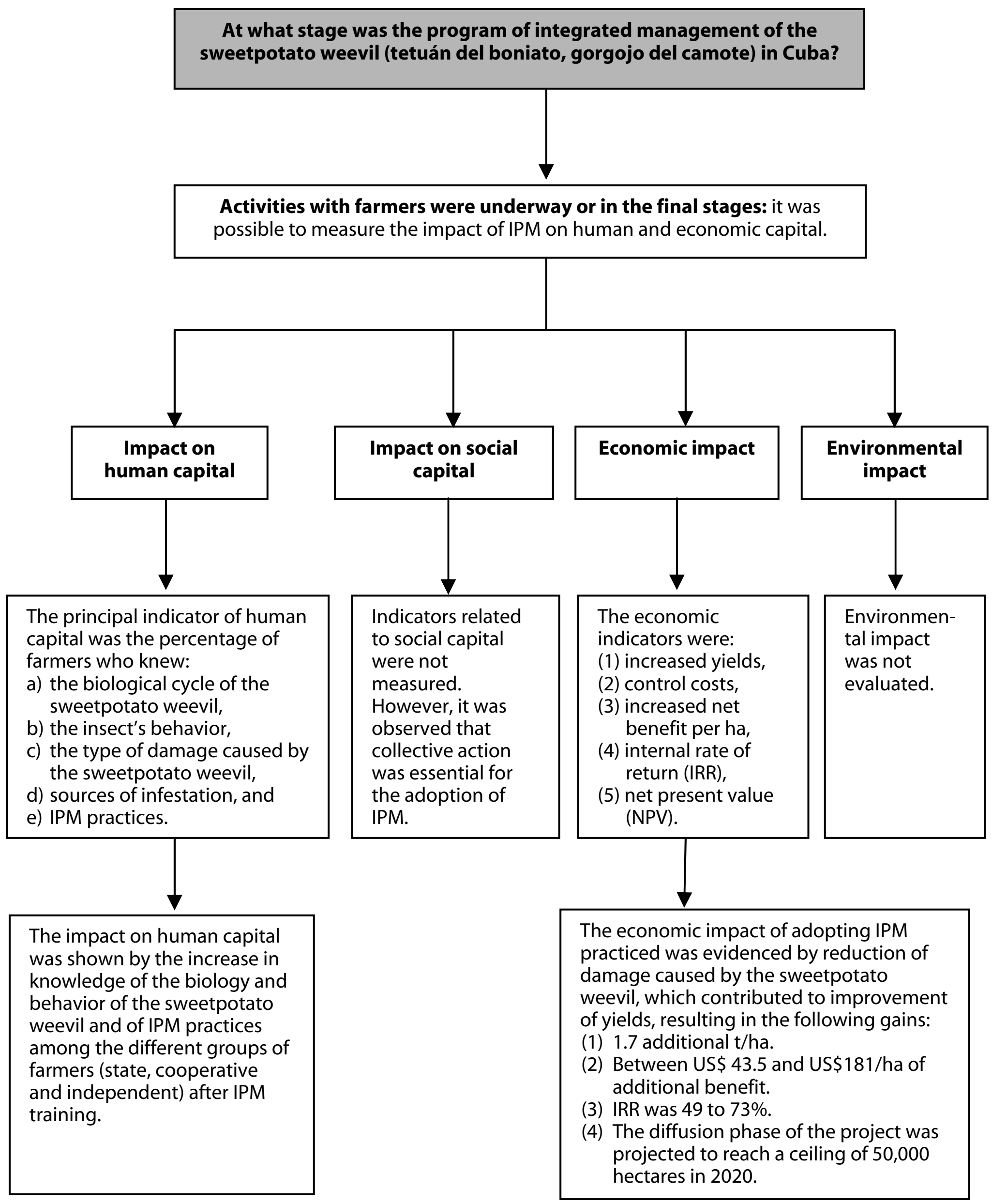


Diagram of impact assessment of Farmer Field Schools in Cajamarca, Peru: An economic evaluation (Züger, 2004)

At what stage was the Farmer Field Schools program for potato late blight management in Cajamarca, Peru?

↓

The activities with the farmers were in the last stages, IPM practices had been adopted in the field: it was possible to measure impacts on human and social capital, and on economic and environmental aspects.

Impact on human capital

The indicators of human capital were the percentage of farmers who knew the origin and dissemination of potato late blight and the Andean potato weevil, and the percentage of farmers who knew the different control practices.

↓

There was significant impact on human capital: the correlation analysis demonstrated that FFS participants obtained better results in knowledge evaluations than non-participants

Impact on social capital

The study by Züger did not evaluate impact on social capital; but complementary studies showed changes in the level of organizational abilities of the farmers who participated in FFS and the formation of an association of farmer facilitators for FFS, which indicated positive changes in social capital.

Economic impact

The economic indicators were:
(1) adoption of IPM practices,
(2) yield increases,
(3) increased net benefit per ha,
(4) cost of FFS,
(5) internal rate of return (IRR).

↓

There was positive economic impact:

The results showed that better knowledge influenced:

(1) Adoption of some components of crop management.
(2) Increase in yield of 2.7 t/ha/year.
(3) Increase in net benefit of US$ 236/ha/year.
(4) Cost of the Farmer Field Schools per farmer: US$70/year
(5) IRR of 28%.

The economic impact was influenced by the size of the potato plots.

Environmental impact

The indicators of environmental impact were:
(1) reduction in the use of pesticides and
(2) reduction in the application of highly toxic pesticides.

↓

There was limited environmental impact, with a reduction of 0.8 pesticide applications per ha. No significant differences were found between participants and non-participants regarding to the type and quantity of pesticides used, which suggests that the farmers used the same number of fungicide sprays on the susceptible varieties of potato and those resistant to late blight introduced by the project.

Diagram of the study on the socioeconomic impact of microtunnels for the production of vegetable crops (CENTA, 2008)

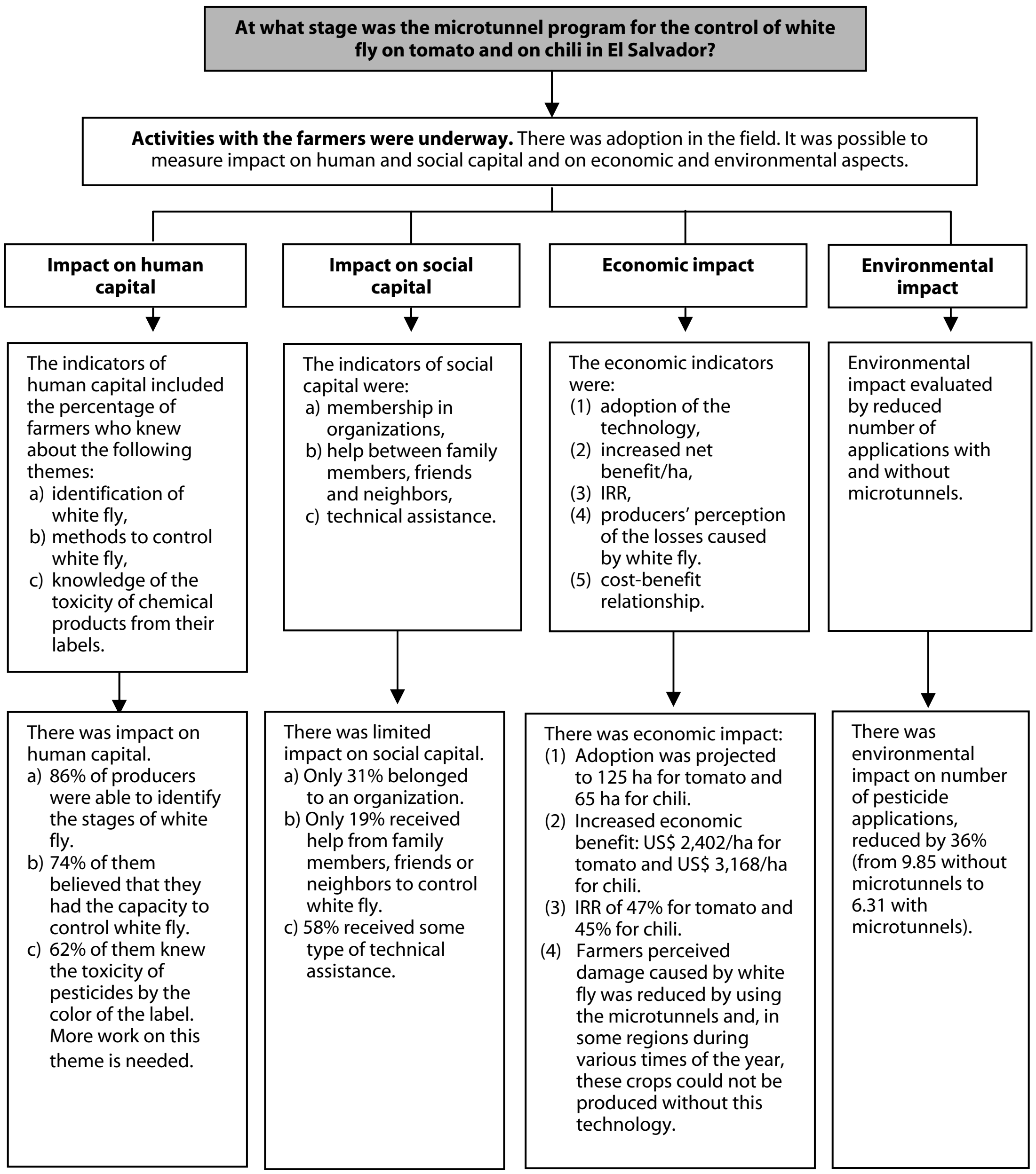


Diagram of the study on the impact of adoption of bean variety CENTA San Andrés (resistant to bean golden mosaic virus transmitted by white fly) in El Salvador (Deleón, 2008).

At what stage was the project for introduction and diffusion of bean variety CENTA San Andrés in El Salvador?

The activities with the farmers were well underway and adoption had begun. The impact on human and social capital and on economic and environmental aspects could be evaluated.

Impact on human capital

The indicators of human capital included the percentage of farmers who knew the following:
a) tolerance of the variety San Andrés to bean golden mosaic virus,
b) methods to control white fly
c) the relationship between white fly and bean golden mosaic virus,
d) the need to use less pesticides in the resistant variety.

There was partial impact on human capital:
a) 87% knew about the tolerance of the variety San Andrés.
b) 77% believed that they had the capacity to control white fly.
c) 68% knew the relationship between the white fly and bean golden mosaic virus.
d) Only 21% applied less pesticide on the resistant variety. More work on this theme is needed.

Impact on social capital

The indicators of social capital were:
a) membership in organizations,
b) participation of organizations in white fly control.

There was limited impact on social capital
a) Only 39% belonged to an organization.
b) 69% of these thought that their organization helped to control white fly.
The project for introducing the variety did not promote the producers' organization which would have been appropriate.

Economic impact

The economic indicators were:
(1) adoption of the variety,
(2) increased yields,
(3) increased net benefit,
(4) IRR.

Extra direct benefits from the use of the variety San Andrés:
(1) The adoption has been projected to 1300 ha.
(2) Additional yield is estimated at 1.05 t/ha.
(3) Increased net benefit was US$ 428/ha.
(4) IRR was 42%.

Environmental impact

There was no significant change in the utilization of pesticides with the use of the variety CENTA San Andrés.

SECCION IV: SOME USEFUL REFERENCES RELATED TO IMPACT EVALUATION

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Fleischer, G., F. Jungbluth, H. Waibel, J.C. Zadocks. 1999. *A field practitioner's guide to economic evaluation of IPM.* Pesticide Policy Project Publication Series No 9. University of Hannover. (http://www.ifgb.uni-hannover.de/fileadmin/EUE_files/PPP_Publicat/Series/PPP09.pdf)

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Norton, G., J. Mullen. 1996. *A primer on economic assessment of integrated pest Management.* In. Proceedings of the Third National IPM Symposium/Workshop. S. Linch, C. Greene y C. Kramer-LeBlanc (Eds.). pp. 76-92. US Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. Miscellaneous Publication No 1542 (http://www.ers.usda.gov/publications/mp1542/MP1542.PDF#page=82)

Ortiz, O., J. Alcázar, W. Catalán, W. Villano, V. Cerna, H. Fano y T.S. Walker. 1996. *Impacto económico de las prácticas de MIP para el gorgojo de los Andes en el Perú [Economic impact of IPM practices for the Andean potato weevil in Peru]. En: Estudios de Casos de Impacto Económico de las Tecnologías Relacionadas con el CIP en el Perú [Case Studies of Economic Impact of*

Technologies Related to CIP in Peru]. Thomas S. Walker y Charles Crissman (Eds.). Lima, Perú: Centro Internacional de la Papa (CIP) 32 p.

Unda, J., V. Barrera, y P. Gallegos. 1999. *Estudio de adaptación e impacto económico del manejo integrado del gusano blanco (Premnotryper vorax) en comunidades campesinas de la provincia de Chimborazo [Study of the adoption and economic impact of integrated control of the Andean Potato weevil (Premnotrypes vorax) in farmer communties in the province of Chimborazo].* En: Estudio de caso del impacto económico de la tecnología generada por el INIAP en el rubro papa [Case study of the economic impacto of the technology generated by INIAP for potato]. V. Barrera y C.C. Crissman (eds.) pp 33-71 (http://www.redepapa.org/unda.pdf)

Walker, T., C. Crissman, (Eds.). 1996. *Case studies of the economic impact of CIP-related technologies.* Lima, Perú. Centro Internacional de la Papa.

Züger, R. 2004. *Impact Assessment of Farmer Field Schools in Cajamarca,* Peru: An economic evaluation. Social Sciences Working Paper No. 2004-1. International Potato Center, Lima, Peru. ISSN0256-8748
(http://www.prgaprogram.org/External%20Review%20Web/Other%20Publications/CIP/Zuger_2004.pdf)

Appendix 1: Important concepts related to impact evaluation

Definition of impact: Impact is the change produced at farmer level as a result of research, training and adoption of new technologies. Changes depend on project objectives. If a project intends to introduce a new variety of maize, it is assumed that the changes should be in proportion of the areas planted with the new and the old varieties, and the economic and social effects of such changes. In the specific case of IPM, impact refers to changes in pest control practices and in costs and benefits generated for the farmers. Immediate impacts, such as improvement in crop profitability, generate medium and long term consequences, such as improvement in the sustainability of agricultural production.

Types of impact: Generally, traditional impact evaluations have focused on economic impact, for farmers (improvement of profitability) as well as for consumers (price reduction): however, currently, it is about trying to measure impact on the farmers' livelihood in a more integral way. The impact can be on the different kinds of capital farmers have, such as human capital (their knowledge), social capital (their social networks), natural capital (the land, biodiversity and environment managed by them) and financial capital (the capacity to convert the other kinds of capital into money).

An IPM project usually plans to train farmers and to improve their knowledge of the biology of the insect and control practices. For this reason an impact on human capital can be expected. In other cases, the IPM project uses methodologies that hope to improve the organizational capacity of farmers, thus improving social capital. Reducing the use of toxic pesticides is a goal in the majority of IPM projects in which the farmers' environment and their natural capital is improved. However, the main impact that IPM should generate is economic benefits for the farmers.

Impact evaluation is defined as evaluation of the degree to which the program or project causes changes in the desired direction in a particular population. That is, the degree to which an IPM program or project has changed the knowledge, organization, practices of pest control and farmers' profitability. Generally, positive impacts bringing improvements to farmers are expected.

However, sometimes there are negative impacts and the evaluation process should be ready to identify them.

Types of comparisons to evaluate impact:

- **Before and after:** The situation of the same community of farmers before and after intervention is analyzed in this comparison. That is, the situation before IPM (baseline) and after using IPM. For example, if the Andean potato weevil caused damage to an average of 50% of potato tubers before the project and after the project the damage is 15%, then it can be said that the IPM project had a positive effect. This type of comparison has advantages and disadvantages:
  - **Advantages:** dealing with people from the same community is an advantage because there are no significant differences between farmers in socioeconomic and agro-ecological terms.
  - **Disadvantages:** in many cases the presence of pests is greatly influenced by weather conditions, and it is possible that favorable or unfavorable weather existed in the "before" situation that is compared to the "after", which can bias the evaluation. For example, in the case of potato late blight, if in the "before" situation the damage to the foliage reached an average of 60% under very rainy weather conditions and in the "after" situation reached an average of 15% damage under dry weather conditions, it would be impossible to conclude that the difference in damage was due to the IPM project: it could be due to the effects of weather.
- **With and without:** With this comparison, two different communities are analyzed at the same time, one that will or has participated in the IPM project. If in the same year community A has an average damage level of 40% and community B has an average damage level of 20%, it is possible to say that the project had a positive effect. This comparison also has advantages and disadvantages:
  - **Advantages:** The communities are compared in the same year and under the same weather conditions (since they are located in the same agro-ecological zone), for which reason it is hoped that the climate will not generate effects that would bias the comparison.
  - **Disadvantages:** It is difficult to select two communities sufficiently similar in agro-ecological and socioeconomic terms. Consequently, differences in damage could be influenced by other factors, like greater or less access to information and economic

resources between the two communities. It could be that that the communities that do not participate have greater or less previous knowledge of the pest, which affects the control measures they use. It is necessary to make an effort to demonstrate that the communities are comparable in socioeconomic and ecological terms and, especially, with respect to the level of knowledge in the "before" stage previous to initiating the IPM project.

- **Comparison "with" and "without" combined with "before" and "after":** The best way to reduce bias due to weather or external factors in the evaluations is to compare communities that have participated in the IPM project with communities that have not participated in the projects at two points in time (before and after) That is, it is necessary to include the two types of communities in the baseline study and to be sure they are sufficiently similar. When the "after" evaluation is made, the very same communities with and without the IPM project must be included. This improves the possibility of correctly attributing the changes observed in pest control to the IPM project.
- **Sample size for impact evaluation:** There are defined statistical methods based on principles of random sampling to determine the size of a significant sample. Calculations of sample size for complex surveys, like the case of surveys for IPM impact, can be done the following way:

1. Calculate sample size where the population (N) is infinite using the following formula:

$$n_0 = \frac{Z_{\alpha/2}^2 * P(1-P)}{e^2}$$

Where:
n_0= sample size;
Z = Confidence level selected, this is determined by the value of α . For a confidence level of 95% (α = 0.05), which is commonly used, this value is 1.96;
P= expected proportion of answers to the questions. When you do not have previous knowledge of this information and the survey has various questions, a 50% probability of reply is normally used;
e = error or maximum tolerance level of the sample (it is the approximation to the real values you would like, given the limits of time and budget). Generally, a maximum error of 5% to 10% is expected.

The tolerance level that you are willing to accept is what varies, because the values of Z and P (Z = 1.96; P = 0.5) have been predetermined to simplify the calculation of sample size since you do not know the characteristics of your population:

With a tolerance level of 5%:

$$n_0 = \frac{Z_{\alpha/2}^2 * P(1-P)}{e^2} = \frac{1.96^2 * 0.5 * 0.5}{0.05^2} = \frac{0.9604}{0.0025} = 384.16 \approx 384$$

With a tolerance level of 10%

$$n_0 = \frac{Z_{\alpha/2}^2 * P(1-P)}{e^2} = \frac{1.96^2 * 0.5 * 0.5}{0.10^2} = \frac{0.9604}{0.01} = 96.04 \approx 96$$

2. Prove this result:

$$N > n_0(n_0 - 1)$$

Where N is the size of the population.

If this proves to be correct, the process ends here, and n_0 is equal the size of the sample that should be taken.

If this does **NOT** prove to be correct, we pass to a third phase:

3. Calculate the sample size using the following formula:

$$n = \frac{n_0}{1 + \frac{n_0}{N}}$$

To simplify the calculation, let us suppose that we have three populations of farmers that we would like to survey, with 300, 1000 and 10,000 inhabitants, respectively (see table below).

Population	**Tolerance or maximum error**	**n_0**	**Did condition 2 prove to be correct?**	**Total number to be sampled**
300	5%	384	no	168
300	10%	96	no	73
1000	5%	384	no	277
1000	10%	96	no	88
10000	5%	384	no	370
10000	10%	96	yes	96

Although it is advisable to work with significant samples, in many cases sample size is determined by the amount of financial and human resources available to make the impact study. Consequently, it is not always possible to follow statistical procedures rigorously. Samples of 60 to 100 farmers, who adopted IPM and a similar number of farmers who did not, have been found to be sufficient to estimate impacts.

Appendix 2. Defining indicators for measuring changes in human capital: knowledge, skills and decision making

Some principles for defining indicators of human capital

- The indicators related to knowledge, skills and decision making are specifically defined for each IPM program developed, taking into account the knowledge of the pest in question and the methods for controlling it.
- In the baseline study (see Appendix 3) local knowledge of the pest problem is analyzed and some indicators can be defined. For example, if the farmer mentions that "the weevil comes from hail", then an indicator like "knowledge of the origin of the insect-pest" should be defined.
- The importance of indicators related to knowledge depends on the pest and the contents of the training program on IPM to be carried out. There are practices of pest control that should be applied at a specific time, therefore the farmer has to know the different stages of development of the insect pest. An example of this is stirring soil to destroy pupae. This is the case of the Andean potato weevil, which has a life cycle almost a year long related to the cropping cycle. In this case, it is important to recognize the insect's developmental stages to define the control practices to be used. On the contrary, in the cases of other insects with very short life cycles (leafminer fly or white fly), it is not essential for farmers to know or identify the different stages of the life cycle in order to apply IPM practices. However, it is necessary for farmers to know that there are adults and larvae and also to know the causes for increases in pest populations.
- In general, you can include the following indicators related to knowledge in the baseline study.
    - Knowledge of the origin, biology and behavior of the pest.
    - Knowledge of the means of dissemination (ways in which the pest arrives to field or storage).
    - Knowledge of control practices.
    - Knowledge of the principles of control practices, that is, if farmers know the reasons for which a specific practice should be implemented at a certain time and place. For

example, the elimination of field residues to reduce the possibility of the insect's continuing to reproduce there.

- Indicators related to skills can be used to measure the changes in the way farmers implement control measures. You can have indicators related to:
    - Skills to diagnose. This relates to the ways the farmer can identify the presence and severity of an insect or a specific disease that is attacking the crop, this refers to how to monitor the development of the pest.
    - Skills to carry out a specific practice. For example, it would be expected that farmers increase their capacities to monitor the presence of pests with pheromone traps, which implies skills for installing traps and monitoring them.
- The indicators related to decision making are more difficult to establish and they refer to the way farmers make decisions to select practices or strategies to control pests. These indicators relate to the reasons given by farmers for implementing a practice. For example, if they explain that they remove the soil in the infestation sources to cut the life cycle of the insect, this can indicate that they have improved their decision-making capacity.

Examples of indicators related to human capital:

Here we present examples to illustrate indicators and also types of questions that can be used to obtain answers on farmers' knowledge, skills and decision- making for controlling pests.

Example: IPM program for the Andean potato weevil (*Premnotrypes spp*).
Note: Some of these indicators and questions may not be relevant for other pests.

- Indicators related to knowledge:
    - Knowledge of the origin, biology and behavior:
        - Question: What is the origin of the insect?
          Indicator: % of farmers who know the origin of the insect, that is, that insects reproduce and do not appear spontaneously.
        - Question: Where do the larvae (worms) come from?
          Indicator: % of farmers who know that the adult lays eggs and the larvae come from these eggs.
        - Question: How does the insect arrive in your field?

Indicator: % of farmers who know that the insect arrives by walking from other fields or sources of infestation.

- Question: Where does the insect that arrives to your field come from?
  Indicator: % of farmers who know where the insect came from (source of infestation).

- Knowledge of control practices and their principles.
  - Question: What practices do you use to control the Andean potato weevil?
    Indicator: % of farmers who know specific IPM practices (those introduced by the program); for example, % of farmers who know about the use of plant barriers.
  - Question: Why do you use plant barriers?
    Indicator: % of farmers who explain that the plant barriers are used to prevent entry of adult Andean potato weevils into potato fields.
  - Question: Do you know why one pesticide has a red label and another has a green one?
    Indicator: % of farmers who can tell differences in pesticides according to the color of the labels (which indicate the toxicity level).

- Indicators related to skills:
  - Skills to diagnose:
    - Question: How do you know that there are weevils attacking your potato plants?
      Indicator: % of farmers who recognize the presence of the weevil in the field by identifying half-moon shaped bites on the edges of potato leaves.

  - Skills to implement practices:
    - Question: How did you use the plant barriers? (this question usually requires verification in the field).
      Indicator: % of farmers who correctly use plant barriers (correct species, planting time and suitable density) around the potato fields.
    - Question: How do you use ground sheets (blankets, sheets, etc.) at harvest time?

Indicator: % of farmers who used ground sheets appropriately to pile potatoes on at harvest time to capture and eliminate larvae.

- Indicators related to decision-making: although generally related to indicators of knowledge and capacity, these refer to specific reasons for which farmers decide to use specific practices.
  - Decision-making to implement IPM practices:
    - Question: Why did you use plant barriers around the potato fields?
      Indicator: % of farmers who explain that they use plant barriers around their fields to prevent entry of adult insects from other fields or infestation sources.
    - Question: Why did you use sheets or blankets to pile the potatoes upon at harvest time?
      Indicator: % of farmers who explain correctly that they use sheets or blankets to capture the larvae and keep them from going back into the soil to complete their lifecycle.

Appendix 3: How to establish a baseline for the evaluation of IPM impacts

As was explained in Appendix 1, baseline studies should be made, both in the communities that are going to participate in the IPM project and those communities that are not (control group), and these communities should be sufficiently similar so that the situation of pest control after the IPM program can be evaluated.

The baseline is a description of the presently existing state of an environment or a situation in function of variables defined for a specific project. In this particular case, the baseline is the situation of damage caused by a pest and the knowledge and control methods used by farmers. Variables referring to human and social capital and economic and environmental (use of pesticides) aspects can be considered for the baseline study before the project begins. Some examples are farming systems, productivity, pest damage, farmer knowledge, types of technologies used to control pests, etc. Afterwards, the results of the baseline study will be compared with the survey results and with the evaluation after the project has ended to analyze whether the IPM project has generated significant change in the indicators.

The baseline study is the initial measurement of the variables, using the indicators, that are expected to be modified by the IPM project. The indicators depend on the pest to be controlled. For this reason, it is essential to define indicators that can be measured in the baseline study and afterwards. The principle indicators related to human capital are those related to farmers' knowledge of the specific pest, its biology and behavior, and of control practices (see more details in Appendix 2.). The principle indicators related to social capital are the existence of organizations or farmers' groups, or collective action for pest control (see more details in Appendix 5). Regarding economic indicators, it is necessary to record data on control costs, levels of damage caused by the pest, economic losses and net income of the crops where IPM will be implemented (see more details in Appendix 7). Similarly, indicators related to environmental aspects, such as the pesticides used (active ingredients), the number of applications, the dose and number of farmers who use such pesticides should be recorded (see more details in Appendix 10).

It is recommendable to pay special attention to the recording of weather variables like temperature, humidity and precipitation, during the baseline study, especially for those pests that can be influenced by climate, like white fly or potato late blight. By the same token, when the final evaluations are carried out, the weather situation should be compared to detect possible bias in the evaluation “before” and “after”. Also, it is recommendable to take samples of insect populations to be able to compare the situation after the project.

To obtain data in a baseline study, secondary information from previous studies, technical reports of IPM projects, or other available sources of information can be used. However, the principle activity of a baseline study is to collect initial information related to the indicators. This can be done through focal groups, structured surveys, semi-structured surveys, direct evaluations or field monitoring and experimental results on the effects of the practices of pest control (see description of methods in Appendix 4).

The baseline study should establish some institutional variables that should be registered over time, thus facilitating subsequent impact evaluation. An example is registering the costs of research and training related to the IPM program in the first year of the project and establishing a system to register such costs annually.

In those cases where the evaluation is to be made of an IPM program that did not carry out a baseline study, it is only possible to estimate the differences by carrying out a comparison “with” and “without” IPM after the project.

Appendix 4. Methods for measuring changes in indicators related to human and social capital and economic and environmental aspects

Main methods of data collection and analysis according to areas of impact and indicators.

Table 1. Examples of indicators, types of comparison and methods for the collection and analysis of data.

Areas of impact and indicators	Types of comparison	Methods of collection and analysis of data
Changes in human and social capital		
Improving knowledge of biophysical principles of pest control	Before and after With and without	Focal groups, questionnaires, observations, case studies, box test.
Improving knowledge of IPM practices	Before and after With and without	Focal groups, questionnaires, observations, case studies, box test.
Improving access to information sources (social networks supportive of IPM)	Before and after With and without	Focal groups, questionnaires, participative workshops.
Improving skills to use IPM practices	Before and after With and without	Focal groups, semi-structured interviews, plots for monitoring, direct observations in the field.
Changes in economic and environmental aspects		
Changes in the use (adoption) of IPM practices	Before and after With and without	Focal groups, questionnaires, plots for monitoring, case studies, box test.
Changes in income	Before and after With and without	Focal groups, semi-structured or structured interviews, plot for monitoring.
Cost-benefit analysis of interventions	Before and after	Focal groups, semi-structured or structured interviews, workshops, plots for monitoring.

Types of comparisons Two types of comparisons can be made for the evaluation of impact indicators: “with” vs. “without” and “before” vs. “after” (see Appendix 1).

Description of the methods used Qualitative and quantitative methods can be used to collect and analyze information related to the indicators. The use of more than one method to triangulate (compare, verify) evidence and improve validating the evaluation process is recommended. For example, use a semi-structured interview and focal groups with the same groups of farmers and with similar questions.

Qualitative methods

Focus groups[1]**:** Groups of approximately ten people (farmers, facilitators or researchers) and a moderator, who discuss specific questions according to the areas of impact and indicators. Participants use cards, matrices and/or ranking techniques according to the theme that they are going to discuss. The moderator records the conclusions of the discussion. The farmers' focus groups are organized with the participants of the IPM program and with those who have not participated in the project from the same community or similar communities. These groups should be organized at the beginning of the project and, if possible, annual assessments should take place to monitor changes over time.

Participatory workshops**:** Meetings with groups of 20 to 30 farmers at the beginning and the end of the growing season (at least twice a year), involving representatives of farmers who are participating in the project and of farmers who are not. The purpose of these workshops is to discuss the progress of project activities and changes in indicators, and to make suggestions and adjustments for the next cropping season. With the farmers who are not participating in the project the idea is to analyze changes in the system related to pest control, for example, the introduction of new pesticides.

Participant observation[2]***:*** Facilitators and researchers involved in the process are responsible for observing research and training activities and what happens in the farmers' fields, which is recorded on specific file cards. A lot of information can be obtained by visiting farmers' fields, observing practices used and through informal conversations.

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1 There are various books on focus groups, also useful information on the Internet. We suggest consulting: http://www.unu.edu/unupress/food2/UIN03E/UIN03E00.HTM At this Web site there is a manual on the theme, which, though applied to medical research, contains general and applied concepts on the focus group method.

2 More information on participant observation can be found at this Web site, though related to research in public health: http://www.fhi.org/NR/rdonlyres/ed2ruznpftevg34lxuftzjiho65asz7betpqigbbyorggs6tetjic367v44baysyomnbdjkdtbsium/participantobservation1.pdf

Case studies: Individuals or groups of participants and non-participants are monitored to obtain detailed information on pest control and changes in knowledge, skills, decision-making, organization, costs and benefits related to IPM. The information collected in the case studies helps to interpret the data from other methods, like surveys.

Box test: This is a specific test designed to evaluate changes in knowledge and attitudes about pest control. It consists of approximately 20 questions, each with three possible answers. Preferably, the boxes are situated in the field using live or other types of samples (plants, leaves, insects, pesticides, photos, etc.). The farmer participants are asked to respond to each question by picking the answer they consider to be correct. The test lasts approximately 30 minutes and the results are analyzed and presented to the group immediately. This test is useful for evaluating knowledge before and after the intervention, and also for comparing knowledge between participants and non-participants.

Semi-structured interviews: Interviews with open-ended questions used to record knowledge and pest control practices used by participants and non-participants in the IPM project and evaluate possible differences.

Quantitative methods

Questionnaires to evaluate knowledge: The farmers are asked questions about the topics dealt with in the training sessions and the answers are recorded and graded correct or incorrect. In some cases, a hypothetical problematic situation can be presented so that the farmer can identify what should be done and make a decision. Questionnaires are used with participants and non-participants. Each question has a number of points, depending on whether the answer is correct or incorrect. Afterwards, the total number of points per farmer can be used to compare with the baseline. Also, the average score obtained by the group who participated in the IPM project can be compared with the average score of the group who did not. This type of results allows for comparisons using nonparametric statistics.

Monitoring plots: These are farmers' plots selected for the purpose of recording and evaluating specific variables related to pest control. The evaluation is conducted directly in the field based on random samples. For example, the severity of a disease or insect infestation during different stages of crop development, doses of insecticides used, costs of applications, and yield at harvest can be evaluated. Monitoring plots can be part of or can complement the semi-structured questionnaire, with the difference that the interviewer observes or takes samples directly in the field. If a sufficient number of plots belong to farmers who are participating in the IPM project and farmers who are not, the differences can be evaluated.

Structured interviews: Extensive questionnaires that include socioeconomic characteristics of participants and non-participants, and closed-ended questions about indicators of change in human and social capital and economic and environmental aspects. These questionnaires can be used to make more detailed statistical analyses to explain associations between different variables. For example, if adopters of IPM are the ones who have smaller pieces of land, or if less use of insecticides is associated with participation in IPM training activities. If the the questionnaire is administered before and after the project (or in sites with and without the project), the differences can be analyzed in statistical terms.

Appendix 5: Defining indicators to measure changes in social capital

Some principles to define indicators of social capital:

- Social capital related to IPM can be defined as the means by which people interact among themselves to resolve pest problems. Therefore indicators related to social capital refer to possible changes in forms of access to information, organization, collective action or institutionalization that could have originated in the IPM project.
- Because IPM projects are located in places with specific socioeconomic characteristics, the indicators relating to social capital are specific to the place and project.
- The most common indicators of changes in social capital are related to organization, collective action, social networks and exchange of information. These indicators should be measured starting from the baseline study.

Examples of indicators for IPM related to social capital

- Examples of indicators related to changes in farmers' organizational capacities as a result of IPM intervention:
  - Formation of farmers' organizations to deal with pest problems.
    Indicator: Number of farmers' organizations formed specifically to support pest control.
  - Strengthening of existing organizations to deal with pest problems.
    Indicator: Existence of agreements between organizations to support pest control, farmers' membership in an organization.
  - Formation of working groups within organizations or communities to deal with pest problems.
    Number of working groups functioning.

- Examples of indicators related to collective action.
  - The existence of organizational or communal action to implement specific IPM practices.

Indicators: number of communal actions to eliminate sources of infestation, existence of communal regulations regarding practices and use of pesticides.

- Examples of indicators related to interactions and information exchange:
  - Promotion or strengthening of interactions to exchange information about pest control. **Indicator:** Number of interactions (meetings, personal contacts, visits, etc.) to access information on pest control, percentage of farmers who have had access to training.
  - Number of sources of information about pest control. **Indicator:** Number and type of sources of information from which information on pest control can be obtained.

Appendix 6. Principles for partial budget analysis

Partial budget analysis is a method for comparing the costs and benefits of changing a method of pest control[3]. For example, to change from the pesticides to using IPM. The aim is to estimate the changes in income or losses from farmers' plots due to changes in control practices. Partial budgets do not calculate the income or total expenses for plots with or without IPM. It is assumed that only the costs of pest control change and other costs remain the same.
In the following formula: NI is the net income from the sale of agricultural products or, expressed in another way, the amount of money obtained when total costs (TC) are subtracted from total benefit (TB):

NI = TB – TC (1)

Total costs include the costs of all inputs, such as seed, fertilizers, etc., but for the partial budget it is not necessary to estimate total costs, just the costs that vary due to the change in technology. In this case, these are the costs that vary in changing the pest control method. It is assumed that the rest of the costs are the same. When deciding whether or not to adopt IPM, a farmer wants to know if his or her income will increase. The net income (NI) is the difference between total benefits (TB) and control costs (either of IPM or traditional control). The difference in net income using IPM (NI-IPM) compared to net income using the traditional method (NI-traditional) will be the additional income the farmer obtains by using IPM.

NI-IPM = TB (IPM) – C (IPM)
NI-traditional = TB (traditional) – C (traditional)
Increase in income = NI (IPM) – NI (traditional)

Three criteria should be taken into account for making recommendations: first: if net income remains the same or decreases, the new technology should not be recommended because it is not more profitable that the technology being used by the farmer; second: if income increases and costs of control remain the same or decrease, the new technology should be recommended because it is clearly more profitable than the farmer's old technology; and three: if both net income and the control costs increase, the marginal return (gains) should be analyzed to try to find out how much money is earned for each unit of money that increases the cost of control.

To evaluate economic impact, it is necessary to estimate the additional benefit per hectare generated by IPM to calculate profitability using IRR or NPV. For example, in the case of the Andean potato weevil, it has been estimated that by using IPM there was an additional benefit of US$100/ha, which, multiplied by the number of hectares adopted annually, generated the accumulated additional benefit per year for the project.

[3] Perrin, F. K.; Winkelmann, D. L.; Moscardi, E. R.; Anderson, J. R. 1976. Formulación de recomendaciones a partir de datos agronómicos: Un manual metodológico de evaluación económica [Making recommendations based on agronomic data: A methodological manual of economic evaluation]. CIMMYT México, D. F. 54 p.

Appendix 7. Defining indicators to measure changes in economic aspects

Some principles to define economic indicators:

- Indicators of changes in economic aspects are usually defined as profits or losses caused by pests and pest control. For example, how much did the farmer spend to control pests with insecticides or with IPM and how much did he/she earn with each alternative.
- Because IPM projects are located in places with specific socioeconomic characteristics, the economic indicators are specific to the place, the crop and the project.
- The most common indicators of changes related to economic aspects include yield per hectare, level of damage caused by the pest (which in some cases influences the quality of the product and therefore its price), costs of control, selling price of the products and net profit. These indicators should be measured starting from the baseline study so that they can be used as a point of comparison. If there is no baseline study, it is necessary to compare groups of participants in the IPM project with non-participants.
- Examples of economic indicators related to IPM at farmer level:
    - Total yield per hectare in the fields of farmers who have used IPM and of farmers who did not use IPM. Note: There are problems in estimating yields because this indicator is influenced by many other factors (soil fertility, crop management, etc.) besides pest control. For this reason, the groups of farmers and fields to be compared should be as homogeneous as possible.
    - Damage level of the harvested product, especially from pests that affect the final product, like Andean potato weevils or potato tuber moths, which damage potato tubers.
    - Commercial yield, which is the part of the harvest that can be sold in the marketplace. With higher commercial yield, the harvest has more value. In some cases, the damage caused by insects reduces the value and proportion of the harvest to be sent to market. For example fly-damaged fruit has less value than healthy fruit.
    - Damage level of the foliage, used in the case of pests that affect the crop in the field like potato late blight, leafminer fly and white fly. It is important to determine the level of damage in the field because this damage influences the yield of the potato.

- **Pest control costs:**

  Costs of using pesticides. This is calculated by asking about the product used, its price, dosage, labor costs and number of applications.

  Costs of IPM practices. This is calculated by asking about the materials used (for example, yellow traps), the price and labor costs.
- Selling price of the harvest according to commercial categories of the product at harvest time. This is the price the farmer gets by selling his crop in his/her field. Note: This is not the price that the consumer pays in the market.
- Economic losses caused by pests. Having data on damage levels, yields and selling prices, losses caused by pests are estimated with present methods of control (for example, pesticides), which will be compared with the losses at the end of the project when the farmers are using IPM. Losses are expected to decrease.
- Note: The part of the harvest that is not sold and used for seed or family food should also be given a value. Generally, this value is less than the commercial value.
- Gross benefit, which is the value of the whole harvest.
- Net benefit, which is the gross value less the cost of production. For the partial budget method, the only costs that vary are those costs related to pest control.
- Marginal utility, which is the farmer's gain or loss when he or she uses IPM as compared to using pesticides or other control methods.

- Examples of economic indicators related to IPM estimated at the project or institutional level:
  - The annual cost of the IPM research and training project. Ideally, this cost should be recorded from the time the research on a particular pest begins and should be registered annually. In some cases, the specific cost related to research and training for a given pest must be estimated because the accounting departments record global costs, which include various pests.
  - The net present worth (NPW) or net present value (NPV) is a procedure to calculate the present value of the costs and benefits of an IPM research and/or extension program in a given period. The method also discounts a certain rate or type of interest which is the same over the time period under consideration. NPW or NPV is calculated from the difference between the additional annual benefits generated by IPM among farmers who adopt this technology (obtained by multiplying the additional benefit per hectare by the number of

hectares where IPM is expected to be adopted), and the annual costs of the IPM research and training project for a given period (usually 5 or 10 years), bringing all past or future values into the present. Obtaining the NPV is an essential tool for assessing the profitability of IPM projects. IPM projects are expected to have an NPV greater than zero to make them profitable. See more details in Appendix 9.

- The internal rate of return or internal rate of return (IRR) of IPM projects is defined as the interest rate where the NPW or NPV is equal to zero. The value of IRR is compared with the required minimum rate of return (opportunity cost) acceptable to the donor or the institution financing a given project, and is accepted if it is above that minimum rate. In the absence of a project with which it can be compared, comparison can be made with a bank interest rate between 10% and 12%. That is, the maximum interest that a project can pay for the resources used when the project recovers its investment. See more details in Appendix 9.

Appendix 8: Estimating adoption in the field

Adoption is the intermediate step by which economic impact is achieved. That is to say, without adoption of IPM there will be no impact. For the evaluation of adoption rates for IPM technologies, it is necessary to measure the adoption of IPM practices at farmer level. The best known method for measuring adoption is based on surveys conducted on a random sample of farmers (see ways of estimating sample size in Appendix 1), to estimate the number of farmers who have adopted the technology and the number of hectares where IPM is being used. Surveys are conducted in zones where the project has worked as well as in zones where it has not. It is also advisable to make a survey on pest control practices before and after the project for comparison.

In the case of IPM, access to information and knowledge on pests and pest control (improvement in human and social capital) facilitates adoption of the technology. Usually IPM programs present various control practices, therefore the adoption of each practice must be estimated. There are cases where the IPM project is based on the introduction of a pest-resistant or disease-resistant variety. Therefore adoption is measured by the number of farmers and hectares using this variety. In other cases it is a question of cultural practices, so adoption is measured by the number of hectares where, for example, nocturnal manual collection is being used to control the Andean potato weevil. When IPM programs include more than ten practices, specialists should define the essential practices to control the pest so as to determine how many farmers and on how many hectares is the minimum number of practices being used, in order to be considered IPM.

The adoption rate per year for the life of the project is essential information for evaluating economic impact. The number of hectares or farmers who use the technology every year, multiplied by the average benefit per ha or farmer who has adopted the technology, will give us an idea of the economic benefit the IPM project can generate per year.

Usually, it is assumed that adoption follows a logarithmic curve in the form of an S; that is it begins slowly, then accelerates and finally the adoption decreases until it stabilizes. Afterwards, the initiation of a process to replace this technology with another is to be expected.

Ideally, adoption data for two or three points in time should be available to be able to make a projection of future adoption. It is equally important to define the number of years for which adoption of IPM technology is being projected. Generally, projections are made for the next 15 to 20 years.

Appendix 9: Analysis of return on investment in IPM

The analysis of investment in IPM projects evaluates whether the money invested in the development, evaluation and dissemination of the technology has generated sufficient accumulated profit at the farmer level within a given time. The assessment is carried out to determine if the accumulated benefits cover accumulated costs and generate profit.

This investment analysis also takes income and costs for future years into consideration on the assumption that the technology will continue being adopted. For income and costs of past and future years to be comparable, the assumption is made that all income and all costs are taking place in present time. Income and costs are brought to their present value by means of a discount or interest rate (generally between 10% to 12% yearly).

Accumulated income and costs are the sum of all the income and costs generated by IPM during the years it is projected that the technology will continue to be used in the field. The annual income is the additional benefit per hectare – or per family – generated by the IPM multiplied by the number of hectares – or families – that adopted the technology in a certain year. The annual cost is the sum of the costs of developing, evaluating and disseminating the technology in a certain year. Generally, these are values recorded by the accounting department of the institutions implementing the projects.

With the annual income and costs during the life of a project, you can calculate the net present value (NPV) of the IPM project. If the NPV is less than zero, that means that the project lost money and if the NPV is greater than zero, then it is profitable. Total income and total costs data from the initial investment in the project are used for the calculation of NPV. Two basic elements are needed for this analysis: the initial investment required to start up the project and the annual income and costs during the life of the project. The years of life of the IPM project is the period from which research was begun in a country or determined zone projected for up to 15 or 20 years. The assumption is that the IPM technology developed will be replaced with another technology after that period.

Following is an example of the data required and the formula that is used to calculate NPV.

$$NPV = \Sigma_{i=1\ldots n} NB_i / (1+r)^i$$

Where:

NPV: Net Present Value

NBi: Net Benefit of Year i

r: Interest rate

As previously indicated, the Excel program can make these calculations automatically.

The internal rate of return (IRR) is another financial parameter for measuring the profitability of investment projects in general, and it is also applied to IPM projects. The IRR gives us a percentage value that indicates the profitability of the project. This value can be compared to other investments.

Table 2 from the study of Ortiz et al. (1996) demonstrates the calculations made to estimate IRR. In this table the costs of the project and the area under adoption are included. An increase in income of US$154 per hectare per year was assumed for the calculation of total benefits.

Table 2. Returns to the investment in research and extension for management of Andean potato weevil in key areas selected by NGOs in Peru at 1993 prices.

Year	Costs ($)	Area (ha)	Total benefits (area x $154)	Net benefits ($)
1988	63,272		0	(63,272)
1989	62,936		0	(62,936)
1990	59,070		0	(59,070)
1991	103,883		0	(103,883)
1992	100,400	500	77,308	(23,092)
1993	100,400	750	115,500	15,500
1994	400,000	1,250	192,500	(207,500)
1995	400,000	2,250	346,500	(53,500)
1996	400,000	3,750	577,500	177,500
1997	0	3,750	577,500	577,500
1998	0	3,750	577,500	577,500
1999	0	3,750	577,500	577,500
2000	0	3,750	577,500	577,500
2001	0	3,750	577,500	577,500
2002	0	3,750	577,500	577,500
2003	0	3,750	577,500	577,500
2004	0	3,750	577,500	577,500
2005	0	3,750	577,500	577,500
2006	0	3,750	577,500	577,500
2007	0	3,750	577,500	577,500
2008	0	3,750	577,500	577,500
2009	0	3,750	577,500	577,500
2010	0	3,750	577,500	577,500
2011	0	3,750	577,500	577,500
2012	0	3,750	577,500	577,500
2013	0	3,750	577,500	577,500
2014	0	3,750	577,500	577,500
2015	0	3,750	577,500	577,500
2016	0	3,750	577,500	577,500
2017	0	3,750	577,500	577,500
2018	0	3,750	577,500	577,500
		TIR=0.30		

The value of IRR is a way to compare between other similar options of investment. In the example, a rate of 30% is profitable and attractive compared with other agricultural research and development projects. In principle, any IRR that is higher than the opportunity cost of investment in the project (the interest that another type of project to improve the conditions of these farmers would have generated, or if there is no interest, the amount corrected for inflation that the money would have generated in the bank, generally between 10% to 12%) is adequate because it means that the project has a positive impact. As this difference increases, the investment becomes more attractive.

The IRR in the examples mentioned in Section III fluctuate range 28% in the case of the FFS in Peru (Züger, 2004), to around 40% and 50% for the cases of white fly IPM (CENTA, 2008; Deleón, 2008) in El Salvador, and IPM of the sweetpotato weevil in Cuba (Maza et al., 2000), respectively, with the later reaching 73% in the most optimistic cases. There are other examples of analysis of investment of IPM using IRR in other Latin American countries like the integrated pest management and agroforestry project of CATIE in Nicaragua, which had a IRR of 19.1% (Garming and Waibel, 2005) and a project of integrated management of Andean potato weevil in Ecuador that had an IRR of 33% (Unda et al., 1999).

The IRR of IPM programs depends on the cost of the project. In general, projects that require less initial investment can generate higher profitability. The value of IRR also depends on the additional benefit per hectare and on the adoption rate. If adoption is reduced, profitability can also be reduced. What is desirable is that IPM programs are not extremely expensive and that they generate benefits per hectare that are attractive so that the farmers will adopt the technology on a sufficient number of hectares.

Appendix 10: Environmental impact quotient *(EIQ) and environmental impact (EI)*

This methodology was developed by Cornell University (Kovach et al., 2004). Environmental impact *(EI)* is an indicator used to assess the potential risk caused by use of pesticides. This indicator assesses the impact of pesticides on the farmers who apply them, on consumers and on ecological components (for example beneficial fauna). It is a relatively simple methodology requiring easily obtained data, such as the type of pesticide, number of applications, number of farmers using it and doses used. In this case, the *EI* before the IPM project can be compared with the general situation created after the project. Also, the *EI* in the zone with IPM can be compared with the *EI* where IPM technology is not used. It is expected that IPM programs will reduce the use of highly toxic pesticides by farmers.

There are environmental impact quotient *(EIQ)* values for many pesticides (See Tables 3 and 4), but not for all. When a specific pesticide does not have an *EIQ* value, this value should be estimated using the average *EIQ* value, according to the class of pesticide in question. Also, the classification of pesticides by the danger they present, recommended by the World Health Organization, can be used to help estimate the *EIQ* of those pesticides not evaluated by Kovach[4, 5].

The calculation of *EIQ* is based on a method of weighing environmental and health risks of an application scheme of a particular pesticide. The *EIQ* model uses toxicological data and information about chemical parameters to calculate the risk to farmers, consumers and organisms in the environment, to generate the environmental impact coefficient for each pesticide being compared. The *EIQs* for many pesticides have been calculated. The first step is to look in Tables 3 and 4 for the pesticides to be used.

The equation to calculate the environmental impact coefficient for each pesticide indicated in Table 3 is:

$$EIQ = \{ C [(DT \times 5) + (DT \times P)] + [(C \times ((S + P) / 2) \times SY) + (L)] + [(F \times R) + (D \times ((S + P) / 2) \times 3) + (Z \times P \times 3) + (B \times P \times 5)]\} / 3$$

[4] For more information about EIQs visit the web page of the Integrated Crop Management Program of New York state: http://nysipm.cornell.edu/publications/eiq/default.asp

Where:

C	= chronic toxicity	DT	= dermal toxicity
P	= plant surface half-life		
S	= Half-life of residues in the soil		
SY	= Systematicity	L	= leaching potential
F	= fish toxicity	R	= surface loss potential
D	= bird toxicity	Z	= bee toxicity
B	= beneficial arthropod toxicity		

The values in the equation are determined by toxicological information from various databases, including Extension Toxicology Network (EXTOXNET), CHEM-NEWS, SELCTV, information sheets of the chemical manufacturers and sources of public data available from the US Environmental Protection Agency. The information on chronic toxicity values (C) included in the human health portion of the equation comes from data from studies of genetic mutations in animals, and the teratogenic, reproductive and oncological effects of these chemicals. These values are presented in Tables 3 and 4.

In case the pesticide to be used in the calculation is not found on the list, it is necessary to estimate its impact according to the active component it contains and the concentration of this active component. If the active component is not found on the lists, the family of pesticides to which it belongs should be established and the average *EIQ* of the pesticides belonging to this family which are on the lists should be calculated.

After the *EIQ* values for the active ingredients of each pesticide have been established, the proportion used in the field is calculated to obtain the value of environmental impact in the field *(EI),* which is to say the *EIQ* is multiplied by the dose, the percentage of active ingredients and the number of applications of each pesticide. The higher the value of *EI*, the greater the potential of negative environmental impact becomes. These field values are useful to make comparisons between pesticides or between different programs of pest management.

Table 3. Values of the environmental impact quotient (*EIQ*) for common insecticides (Kovach et al., 1992[5], with *EIQ* values updated in 2007)

N°	Common name	Trade name	*EIQ*	N°	Common name	Trade name	*EIQ*
1	abamectin	Agri-mek	38.0	54	fluvalinate	Mavrick	46.4
2	acephate	Orthene	23.4	55	fonofos	Dyfonate	44.6
3	acibenzolar S-methyl	Actigard	22.6	56	formetanate	Carzol	21.5
4	aldicarb	Temik	38.67	57	furathiocarb	Promet	35.33
5	allethrin	Pynamin	36.1	58	halofenozide	Mach II	26.18
6	avermectin	Agri-mek	22.7	59	hexakis	Vendex	12.8
7	azadirachtin	Turplex, Aza-direct	12.8	60	hexythiazox	Savey, Hexygon	33
8	azinphos-methyl	Guthion	44.9	61	imidacloprid	Admire	34.9
9	Bacillus thuringiensis (kustaki)	Xentari, Dipel	7.9	62	indoxacarb	Avaunt	43
10	bendiocarb	Dycarb	25.7	63	isazofos	Triumph	30.7
11	bifenazate	Floramite	14.8	64	isofenphos	Oftanol	103.5
12	bifenthrin	Brigade, Talstar, Capture	87.8	65	lindane	Lindane	69.2
13	carbaryl	Sevin	21.7	66	malathion	Cythion	23.83
14	carbofuran	Chlordane, Furadan	50.67	67	methamidophos	Monitor	36.8
15	chlordane	Chlordane	63.6	68	methidathion	Supracide	69.3
16	chlordimeform	Bermat	32.6	69	methomyl	Lannate	30.7
17	chlorethoxyfos	Fortress	37.3	70	methoxychlor	Marlate	53.7
18	chlorfenapyr	Pirate, Alert, Pylon	84.5	71	methoxyfenozide	Intrepid	33.4
19	chlorfenvinphos	CFV	43.9	72	methyl parathion	Penncap-M	35.2
20	chloropicrin	Larvacide	36.4	73	mevinphos	Phosdrin	28.2
21	chlorpyrifos	Lorsban	43.5	74	naled	Dibrom	37.7
22	cinnamaldehyde	Cinnamite	9.2	75	oil	Oil	27.5
23	clofentizine	Apollo	26.3	76	oxamyl	Vydate	22.9
24	clothianidin	Poncho	31.78	77	oxydemeton-methyl	Metasytox-R	75.03

(Continue)

[5] J. Kovach, Petzoldt C., Degni J., and Tette J. 1992. A Method to Measure the Environmental Impact of Pesticides. IPM Program, Cornell University, New York State Agricultural Experiment Station, Geneva, New York 14456.

N°	Common name	Trade name	*EIQ*	N°	Common name	Trade name	*EIQ*
25	Cryolite	Kryocide	21.4	78	oxythioquinox	Morestan	44.4
26	Cyfluthrin	Baythroid	39.6	79	parathion	Niran, Phoskil	104.4
27	cyhalothrin, lambda	Warrior, Schimitar	43.5	80	pentacholorophenol	PCP	59.4
28	Cyhexatin	Cyhexatin	32.8	81	permethrin	Ambush	88.7
29	cypermethrin	Cymbush	27.3	82	phorate	Thimet	68.2
30	cyromazine	Trigard	24.18	83	phosalone	Zolone	24.4
31	deltamethrin	Deltagard, Decis	25.7	84	phosmet	Imidan	23.9
32	Demeton	Systox	85.5	85	phosphamidon	Swat	26.3
33	Diazinon	Diazinon	43.4	86	piperonyl butoxide	Butacide	20.8
34	Dichlorvos	Vapona	40.6	87	pirimicarb	Pirimor	16.7
35	Dicofol	Kelthane	29.9	88	propargite	Omite	42.7
36	dienochlor	Pentac	15.1	89	propoxur	Baygon	87.3
37	diflubenzuron	Dimilin	25.33	90	pymetrozine	Fulfill, Sterling	17.1
38	dimethoate	Cygon	74	91	pyrethrin	Pyronone	18
39	Dinocap	Karathane	21.02	92	pyridaben	Pyramite, Posieden	25.8
40	Disulfoton	Di-Syston	104.5	93	resmethrin	Resmethrin	33.6
41	emamectin benzoate	Proclaim	26.3	94	rotenone	Chem Fish	33
42	Endosulfan	Thiodan	42.1	95	ryania	Ryania	55.3
43	esfenvalerate	Asana	39.6	96	sabadilla	Red Devil	35.6
44	Ethion	Ethion	41	97	soap	M-Pede	19.5
45	Ethoprop	Mocap	58.8	98	spinosad	SpinTor,Tracer	17.7
46	Etoxazole	Terasan 5 WDG	13.42	99	tebufenozide	Confirm	17.8
47	fenamiphos	Nemacur	71.33	100	tefluthrin	Force	25.3
48	fenoxycarb	Comply, Precision	13	101	terbufos	Counter	66
49	fenpropathrin	Tame, Danitrol	25.3	102	thiacloprid	Calypso	31.33
50	fenpyroximate	Akari	19.33	103	thiamethoxam	Actara	33.3
51	fensulfothion	Dasanit	66.9	104	thiodicarb	Larvin	23.3
52	fenvalerate	Pydrin	49.6	105	tralomethrin	Saga	26.7
53	Fipronil	Regent	90.92	106	trichlorfon	Dylox	14.8

Table 4. Environmental impact quotient (*EIQ*) values for common fungicides (Kovach et al., 1992[5], with values of *EIQ* updated in 2007

N°	Common name	Trade name	*EIQ*	N°	Common name	Trade name	*EIQ*
1	anilazine	Dyrene	26.7	36	kresoxim-methyl	Sovran	11.7
2	azoxystrobin	Quadris, Abound, Heritage	15.2	37	mancozeb	Manzate	14.6
3	bacillus licheniformis Strain SB3086	Ecogard	6.67	38	maneb	maneb	21.4
4	benomyl	Benlate	52.6	39	maneb + dinocap	Dikar	46.5
5	boscalid	Endura, Pristine	43.67	40	mefanoxam (metalaxyl-M)	Ridomil, Apron	29.40
6	captafol	Captafol	17.3	41	metiram	Polyram	40.0
7	captan	Captan	15.8	42	mono-potassium phosphite	Phosguard	7.33
8	carbendazim		56.17	43	myclobutanil	Nova	33.0
9	carboxin	Vitavax	20.0	44	PCNB, quintozine	Terraclor, Blocker	35.0
10	chlorothalonil	Bravo	40.1	45	pencycuron	Monceren	22.78
11	copper hydroxide	Kocide	33.3	46	polyoxin-D, polyoxorim	Stopit, Endorse	9.33
12	copper sulfate	copper	47.8	47	potassium bicarbonate	Armicarb, Kaligreen	8.0
13	copper sulfate+lime	Bordeaux	67.7	48	potassium bromide		8.0
14	cymoxanil	Curzate	8.7	49	propamocarb hydrochloride	Previcur,Tatoo	21.5
15	cyproconazole	Sentinel, Alto	36.63	50	propiconazole	Orbit, Tilt	27.51
16	cyprodinil	Vanguard, Switch	21.9	51	pyraclostrobin	Cabrio, Headline	31.45
17	di-potassium phosphite	Phosguard	7.33	52	pyrimethanil	Scala	14.33
18	dichloran	Botran	35.9	53	quinoxyfen	Quintec	32.00
19	difenoconazole	Dividend, Score	48.67	54	sulfur	Sulfur	45.5
20	dimethomorph	Acrobat	24.0	55	tebuconazole	Folicur	40.3
21	dodine	Syllit	22.00	56	oxytetracycline	Mycoshield	22.2
22	ethylenethiourea		15.43	57	thiabendazole	Thiabendazole, Mertect	35.5
23	etridiazole	Terrazole	32.8	58	thiophanate methyl	Topsin-M	22.42
24	famoxadone	Famoxate	11.77	59	thiram	Thiram	32.5
25	fenarimol	Rubigan	22.4	60	tolylfluanid	Eurapen-M, Elvaron	19.50
26	fenhexamid	Elevate	11.7	61	triadimefon	Bayleton	30.7

(Continue)

N°	Common name	Trade name	*EIQ*	N°	Common name	Trade name	*EIQ*
27	ferbam	Carbamate	28.8	62	trifloxystrobin	Flint	30.9
28	fluazinam	Omega	23.3	63	triflumizole	Procure	22.2
29	fludioxonil	Maxim	26.12	64	triforine	Funginex	41.2
30	flusilazol	Nustar	32.9	65	triphenyltin hydroxide	Fentin hydroxide, Super tin	70.1
31	flutolanil	Prostar, Moncoet	24.4	66	triticonazole	Real, Premis	13.17
32	folpet	Phaltan	22.2	67	vinclozolin	Ronilan	13.33
33	fosetyl-Al	Aliette	11.3	68	zineb	Dithane Z	44.0
34	imazalil	Deccozil	26.0	69	ziram	Ziram	25.8
35	iprodione	Rovral, Chipco	11.0	70	zoxamide	Gavel, Zoxium	14.7

An example of analysis of the potential impact of pesticides in potato and tomato crops using *EI* has been done using data from the project of integrated management of white fly carried out by PROINPA Foundation of Bolivia.

Table 5. Calculation of environmental impact (*EI*) on farmers' fields with tomato and potato crops using IPM technology compared with the traditional technology in Comarapa, Bolivia. Growing season 2007-2008.

Tecnology	Insecticide	Active Ingredient	Concentration	Quantity / ha	Applications (Nº)	*EIQ*	*EI*/ha
Case 1: tomato							
IPM	Impacto	Imidacloprid (%)	70%	0.1	2	34.9	4.89
	Engeo	Tiametoxam (kr/l)	0.141	0.25	1	33.3	1.17
		Lambdacyalotrina (kr/l)	0.106	0.25	1	43.5	1.15
	TOTAL						7.21
Farmer	Impacto	Imidacloprid (%)	70%	0.1	6	34.9	14.66
	Curacron	Profenofos	50%	1	2	26	26.00
	Sunfire	Clorfenapir (%)	50%	0.25	2	84.5	21.13
	Engeo	Tiametoxam (kr/l)	0.141	0.25	2	33.3	2.35
		Lambdacyalotrina (kr/l)	0.106	0.25	2	43.5	2.31
	Hook	Buprofezin (%)	25%	0.5	2	27.63	6.91
	TOTAL						73.34

(Continue)

Tecnology	Insecticide	Active ingredient	Concentration	Quantity / ha	Applications (Nº)	*EIQ*	*EI*/ha
Case 2: potato							
IPM	Impacto	Imidacloprid	70%	0.1	1	34.9	2.44
	TOTAL						2.44
Farmer	Espartaco	Cartap (%)	50%	1	3	26	39.00
	Rambo	Metomil (%)	20%	0.9	1	30.7	5.53
	Impacto	Imidacloprid (%)	70%	0.1	4	34.9	9.77
	Hook	Buprofezin (%)	25%	0.5	1	27.63	3.45
	TOTAL						57.75

Note: The *EI* value is obtained by multiplying the concentration by the quantity/ha and the *EIQ* value (taken from Table 3) for the insecticides used in the production of potato and tomato, 2007-2008.

The results of the *EI* analysis demonstrate a significant reduction in environmental impact with the technology proposed by IPM, which consists of applying insecticides only when there is a determined population level of white flies (the technology is known as application thresholds). In the case of tomato, the IPM technology can reduce environmental impact from 73.4 to 7.21, and in the case of potato from 57.75 to 2.44, which represents a substantial reduction in the risks to people and to the environment caused by pesticides.

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International Potato Center
Apartado 1558 Lima 12, Perú • Tel 51 1 349 6017 • Fax 51 1 349 5326 • correo-e cip@cgiar.org