Red Palm Weevil Eradication Project

Methodological Tool

Socioeconomic Impact Assessment of the Red Palm Weevil in NENA Countries (The Case of Egypt and Saudi Arabia)

Ex-post impact assessment (impact evaluation of the proposed interventions)

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1 Background

Date palms are trees of high importance across the NENA region due to their economic and cultural importance, and also for their importance as a renewable natural resource and as a provider of other ecosystem services. Since its arrival in the NENA region, a main date palm production region, RPW is causing widespread damage to date palm and affecting date palm production, which is having a significant impact on the livelihoods of farmers as well as the environment.

Literature review on the topic reveals the limited research dealing with the environmental and socio-economic impact of RPW on date palms in the world and particularly in the NENA region. This is mostly due to the fact that reliable estimates of environmental impacts and other financial costs of biological invasions are important to assess. However, these estimates remain critical for developing credible management, trade and regulatory policies in addition to effective decision making for potential remediation investments.

Two types of understanding the financial losses caused by the RPW can be identified. Firstly, direct costs can be attributed to the value of the destroyed palms and the progressive production loss. These are also related to the implementation of RPW management programs including expenses incurred for the elimination and disposal of infested palms. Secondly, indirect costs are substantial and are mostly related to the import restrictions of trees, especially their offshoots. These restrictions result in drastic cuts in trade not only among countries but also between different regions (i.e, GCC countries) that has also curtailed the expansion of new plantations. Additional indirect costs are related to the adverse impact of this biological invasion on the environment and landscape as a result of chemical treatments (purchase and application), expenses related to medical treatments for people affected by the application of these chemicals, damage caused by environmental contamination, and removal of the infested palms, respectively. According to FAO (2017), in the Middle East, RPW has been the most destructive insect pest to date palm and is a Category-1 pest. The estimated annual loss during 2009 in the Gulf region of the Middle East, due to removal of severely infested palms, ranged from 1.74 to 8.69 million USD caused by a 1-5% infestation, respectively. However, this figure remains significantly underestimated if we further consider many of the environmental costs (including ecosystem services among others) which have not been included in these estimates. However, considering such environmental costs remains challenging especially from the conceptual point of view. In fact, the damage caused by this pest depends on a number of factors related to environmental conditions, the plant variety and the species being cultivated, the socio-economic conditions of farmers, and the level of the production technology and the technology to control the biological invasion used. In addition, not all NENA governments have solid programs to monitor and systematically evaluate the losses occurred in date palm farming activities due to RPW.

The damage caused by the RPW depends on a number of factors related to environmental conditions, farming system, socio-economic context of farmers, level of technology employed and level of enforcement of quarantine measures. In Egypt the RPW is now recorded in 25 governorates with infestation ranging from 2% to 35 %. The estimated total cost on RPW control per year is about $ 20 million (Abbas, 2018). The annual loss in the Gulf countries due to eradication of severely infested palms has been estimated to range from US$ 5.18 to 25.92 million at 1 and 5% infestation levels, respectively (El-Sabea et al., 2009). In Southern Europe RPW has killed thousands of palms, significantly impacting many tourist resorts. The direct cost for removing and replacing dead palms has been estimated at more than €500 million. Ferry (2010) reported that in Italy, Spain and France, the combined cost of pest management, eradication and replacement of infested palms, and loss of benefits were forecasted to increase to €200 million by 2023 if a rigorous containment program is not in place.

There is a need for cooperation and coordination of efforts at the national, regional and international levels for development and implementation of a successful integrated and sustainable RPW-control strategies to protect against RPW threats, to reduce its devastating effects and alleviate the socio-economic impact on rural communities. It is important that such a strategy to focus on promising technologies/innovations to control RPW and with due consideration to the socio-economic aspects and participatory approaches to enhance farmer and other stakeholder participation in the management programs.

2 Rationale

Despite these conceptual challenges, economic assessments of the impacts of RPW are needed to provide credible information to policy makers and to justify costs associated with management efforts. Decisions must often be made in the absence of complete data, but it is important to explicitly identify and address the uncertainty inherent in the data through different scenarios and sensitivity analysis.

This part of assessment concerns with the socio-economic and environmental impacts of control and eradication interventions at all levels of control and prevention and will be conducted through application of rigorous assessment methods to estimate the impact of RPW control or eradication and the associated costs and benefits for different farming systems and farm size. The focus will be on situation analysis from farm to market to produce necessary information on financial, economic, social and environmental impact of the RPW control interventions implemented by partners focusing more on ex-post analysis with different analytical techniques at farm level. These will include the cost-benefit and welfare analysis of the introduced control methods and other alternative methods for different farming systems and farm size in two countries such as Egypt and Saudi Arabi. We expect that Ex-post assessment results will inform stakeholders (palm growers, communities, development agencies and decision makers) in the region at large about the efficiency and the effectiveness of the introduced control methods and the feasibilities of other available alternative methods. Focus of the analysis will be on the impacts on date palm production and yield, date qualities, growers' income, the national supply of dates and impact on trade.

The proposed work suggests the following objectives:

- Assess the socio-economic and if it is possible social and environmental impacts of the control methods applied in the indicated two countries.
- Identify the economic efficiency and effectiveness of the applied control methods and their suitability across farming systems and farm size.
- Assess the economic impacts of the methods on farm production level.

3 Methodological Framework

3.1. Sampling design

Selecting a truly representative sample for analysis is the backbone of every survey. Given the objective of this study is the socio-economic assessment of the impact of control and eradication interventions at all levels of control and prevention, an end line survey will be implemented with the same farmers interviewed during the ex-ante impact assessment study. The ex-post assessment is planned to be conducted through application of rigorous assessment methods to estimate the impact of RPW control or eradication and the associated costs and benefits for different farming systems and farm size in the two target countries.

To have a scientific valid result, the sampling frame is in synergy with the one established by the Arab Organisation for Agricultural development (AOAD) team who are engaged in conduction the ex-post impact assessment study. As it was suggested and implemented by AOAD, this sampling frame is based on:

- The territorial distribution of date palms within each one of the two selected countries (i.e., KSA and Egypt).
- The associated incidence of RPW infestation (i.e., Governorate Selection/country) and on the variations in farming systems, as follows:
  - Traditional (Scattered); are irregularly spaced date palm farming systems based on flood irrigation.
  - Traditional (Organized); are well-spaced date palm farming systems based on flood irrigation.
  - Modernized; are date palm farming systems based on localized irrigation (drip, bubblers, etc.)

3.2. Selection of the respondents

As outline above, the selection of the respondents has been identified by the AOAD team. It was based and guided by the analytical techniques proposed for the socio-economic impact assessment (SEIA) of RPW spread. As per what has been reported by the AOAD conceptual framework, the selection process was as follows:

1. A quantitative analysis was based on pecuniary information collected through Focus Groups Discussion (FGD's), managed by the AOAD study team. The number of FGDs (6 -8 persons in each group) per farming system and region within each country are provided below:

Table 1. Selection process of the interviewed farmers

Country	**Region**	**Farming System**			
		Traditional (Scattered)	Traditional (Organized)	Modernized	Total
Egypt	Lower Egypt (As Sharqiyah)	2	2	2	6
	Upper Egypt (Aswan)	2	2	2	6

	Oases (Al Wahat Al Bahriyah)	3	2	2	7
	Sub-total	**7**	**6**	**6**	**19**
Saudi Arabia	Riyadh	2	2	3	7
	Qassim	2	2	2	6
	Al Ahsa	3	2	2	7
	Al Madinah	2	2		4
	Sub-total	**9**	**8**	**7**	**24**
TOTAL		**16**	**14**	**13**	**43**

Source: AOAD progress report (2022).

2. A qualitative analysis is to be based on information collected through interviewing individual respondents randomly selected from within each of the selected Governorates displayed above.
   - In Egypt: Will interview the 120 respondents who were randomly selected from 3 localities within each of the selected 3 Governorate (total 360 respondents)
   - In Saudi Arabia: Will interview the 120 respondents who were randomly selected from 3 localities within each of the 4 Regions (total of 480 respondents)

In conclusion, the ex-post impact assessment study will target a total of 840 respondents identified by during the ex-ante impact assessment study process (with 360 respondents in Egypt and 480 respondents in Saudi Arabia).

3.3. Implementation of the ex-post impact assessment survey

Data Collection Activities

The data collection activities will follow the same process established during the implementation of the ex-ante impact assessment study. We plan this activity will be carried out in the following chronological order:

- ***Pre-survey activities***
  - Identification of the Nomination of National Coordinators with FAO support. To have the implementation of the data collection activity efficient and given their skills on the RPW subject in their respective countries, ICARDA suggest having the same government officials involved in the ex-ante impact assessment study to coordinate the filed activities.
  - These two resource persons are identified by AOAD based on its contact with the Ministries for Agriculture and Land Reclamation (MALR) in Egypt and for Environment, Water and Agriculture (MEWA) in Saudi Arabia:
    - **Egypt**: Dr. Mohamed Kamal Abbas
    - **Saudi Arabia**: Dr. Yousuf Ahmed Al Fihaid

- ***Survey activities***

    - The national coordinators will take the freedom the select the field assistants and numerators/data collectors and implement all activities related to the survey activities (training of enumerators, data collection, data entry, data cleaning, and data processing)

3.4. Data collection instruments

As previously noted, structured questionnaire targeting the same farmers interviewed by the AOAD team will be designed for this household survey. This questionnaire is employed to gather information on general information of the questionnaire and the type respondent, the socio-demographic characteristics of the HH, the awareness of RPW problems, the assessment of RPW control methods, the adoption of RPW control methods, the land ownership and use and the productions, inputs, and treatments undertaken at the farm level (cost and revenue). The generic questionnaire is in the Appendix.

3.4.1. Components of the structured Questionnaire

The questionnaire is divided on seven sections:

- **Section A : General information**

This part includes general information for the questionnaire (number, date of interview, location, etc.) and for the respondent (Name, type).

- **Section B: Socio-economic characteristics of the sampled farmers**

This section part includes 23 questions regarding household composition, education, sex, age, occupation, farm activities, income, farming experience, training participation, government support, etc.).

- **Section C: Awareness of RPW problems**

This part includes farmer's awareness on infestation by RPW in his area and his farm; major causes, location of infestation, Records of date palm infestation in his farm, the impact of infestation on tree productivity, how infestation was detected, importance of RPW inspection for RPW control, What control methods are most effective in controlling RPW, What date palm varieties are better in tolerating RPW, etc.

- **Section D: Knowledge and qualitative assessment of RPW control methods**

In this part, the respondent farmers asked about the methods of RPW control (Pheromone traps, Trunk injection, drenching with pesticides, chemical fumigation, manual scraping and cleaning, motorized spraying, aluminum oxide fumigation, others) they know and use, their qualitative assessment for the RPW control methods (Efficiency, Easy to use, Cost-effective) and if they have skills to apply these methods.

- **Section E: Quantitative assessment of RPW control methods**

This section includes a quantitative assessment (based on qualitative scale) of RPW control methods through eleven criteria which take into account performance and usage constraints:

1. *Magnitude of the effectiveness of a curative treatment*: ability of the method to destroy a population of RPW when applied to an infested palm.

2. *Magnitude of effectiveness of a preventive treatment*: ability of the method to prevent a healthy palm tree from being infested by RPW.
3. *Persistence of the effect of a curative treatment*: duration during which the one-off application of the method (= 1 treatment operation) retains its curative effectiveness. Quantitative rating estimated in number of days.
4. *Persistence of the effect of a preventive treatment*: duration during which the one-off application of the method (= 1 treatment operation) retains its preventive effectiveness. Quantitative rating estimated in number of days.
5. *Sustainability of the effectiveness of the method*: Risk that the intrinsic effectiveness of the method significantly over time.
6. *Operationality of a treatment*: the degree of applicability of the method given its stage of development.
7. *Practicality of implementing a treatment*: Level of technical and logistical difficulty associated with carrying out the treatment.
8. *Annual cost of a treatment*: cost of implementing the treatment of a single palm tree. To take account of the nature and methods of implementation of the method, this cost is estimated for a single treatment ("individual" rate) or for grouped treatments ("average" rate, with economies of scale).
9. *Safety of a treatment for the environment*: potential impact of a treatment on the environment (biodiversity, water quality, etc.) when carried out in accordance with regulations and good practice.
10. *Safety of a treatment for the operator*: potential impact of a treatment on the health of an applicator - professional or private - when it is carried out in compliance with the regulations and good practices, taking into account, however, the fact that its repetitive nature may lead to an increase in risk linked in particular to a reduction in vigilance.
11. *Safety of a treatment for the palm tree*: Potential impact of a treatment on the physiological condition of a palm tree and its life expectancy compared to a palm tree not infested or not threatened by RPW and which would not have been treated.

- **Section F: Consciousness of RPW control methods and its assimilation (acceptance and adoption)**

This part includes acceptance and adoption of RPW control methods (preventive, legislative, cultural, mechanical and chemical methods); heard of these methods, main source of information on these methods, number of years for the use of these methods, etc.

- **Section G: Land ownership and use**

This section includes information on the size of land, status of land (owned, rented, other), how did acquire land, the nature of palm cultivation on the farm, the type of production system, number of date palm trees (fruitful, unfruitful), varieties of dates on the farm, etc.

- **Section H: Productions, inputs, and treatments**

In this part, the farmer's asked on the productions, inputs and treatments of the palm trees cultivation at the farm level (date fruit, offshoots, byproducts). All costs and revenues associated to palm trees cultivation will be collected.

3.5. Quantitative economic techniques

In the literature, several conceptual modelling frameworks have been proposed, and the choice of an approach depends largely on the objective of the model and the availability of data. In this proposal, the applied methodological framework will be based on the following process:

In the literature, three techniques for quantitative economic assessment: partial budgeting, partial equilibrium analysis and computable general equilibrium analysis. Partial budgeting is a method that addresses the additional costs and lost revenues that are incurred at the producer level when a pest invades. This method takes into account the area attacked by the pest, the loss per unit area, and the price of the product, but it does not include relationships between production volume and prices, or interlinkages between markets. Partial equilibrium modelling does take into account the price effects of changes in production volume in addition to those factors already taken into account by partial budgeting. Partial equilibrium modelling techniques also address linkages to other agricultural markets, e.g., due to substitution of one product by another. Computable general equilibrium modelling techniques are the most comprehensive and complex tools to look at effects of pest invasion on the whole economy. The techniques thus differ markedly in scope, i.e., the extent to which the impacts for the economy at wide are addressed. As a result, they differ in data requirements, the level of expertise needed to conduct the analysis, and the time investment required to complete an analysis. Partial budgeting is the easiest and fastest to conduct, and computable general equilibrium modelling the most difficult and time consuming. No guidance is given in International Standards on Phytosanitary Measures (ISPM) No.11 as to the pros and cons of different techniques for conducting economic impact assessment.

The limited use of quantitative economic techniques, and advanced economic techniques in particular, may be due to limited familiarity with these techniques in the professional field of regulatory plant protection. More generally, it is not clear whether the greater scope of more advanced techniques justifies the extra effort required in terms of data collection and human resources (Vose, 2001; Sansford, 2002). Also, it is felt that advanced techniques may require data that are impossible to obtain or characterize with sufficient certainty. It is felt that the more comprehensive techniques may introduce more uncertainty in the results than is justified by the extra insights they may provide (Vose, 2001; Sansford, 2002). The key question is: what added value does an advanced quantitative method for assessing economic impacts bring to the pest risk analysis (PRA), and does this extra value justify the costs in terms of data and resources? In this section we review the main quantitative methods that may be used for estimating the economic impact of pest invasions. We evaluate characteristics of these methods in terms of goals, founding principles, scope, and data requirements, and provide criteria that may be used in selecting the most appropriate technique for conducting a pest risk analysis.

3.5.1. Partial Budgeting (PB)

PB is a basic method designed to evaluate the economic consequences of minor adjustments in a farming business. The method is based on the principle that a small change in the organization of a farm business will reduce some costs and revenues, but at the same time add others. The net economic effect of a change will be the sum of the positive economic effects minus the sum of the negative effects (Table 2.1). Due to the marginal approach, PB is not designed to show the profit or the loss of a farm as a whole, but the net increase or decrease in farm income.

Table 2.1. Partial budgeting layout.

Partial budget: Comparison current plan (no pest) versus alternate plan (pest invasion)	
Costs	**Benefits**
A) Additional costs: costs under the alternate plan that are notrequired under the current plan	**C)** Additional returns: returns under the alternate plan that arenot received under the current plan
B) Reduced returns: returns under the current plan that will not be received under the alternate plan	**D)** Reduced costs: costs under the current plan that will beavoided under the alternate plan
Total costs: A+B	**Total benefits: C+D**
Net change in profit: C+D-A-B	

With respect to plant production, various PB applications are known, primarily assessing the profitability of management options such as irrigation, pesticide use and fertilizer use (e.g., Arpaia et al., 1996; Donovan et al., 1999; Pemsl et al., 2004). Partial budgeting is also a suitable tool for assessing the economic impact of pests (Macleod et al., 2003; FAO, 2004). The strength of PB in conducting a pest risk assessment is its simplicity and transparency. PB has a low complexity level with respect to resource needs as it requires a limited amount of data, skills, and time investment (Holland, 2007). Although the method is designed to evaluate the direct impact at the producer level, PB can also be used at the national or continental level by scaling up the budgetary impacts of the individual farms (Rich et al., 2005). Macleod et al. (2003) and Breukers et al. (2008) used PB to assess economic consequences of invasion of a quarantine pest or disease at the national level. However, PB is not suited to measure long-term effects or impacts in other sectors of the economy due to its reliance on fixed budgets with predetermined coefficients (i.e., price) to describe an isolated activity. Any change in production caused by a pest invasion could have a long-term effect on total market supply and prices, thereby affecting other producers and other sectors of the economy such as transport and the processing industry (Macleod et al., 2003). Aggregation of PB results from a representative farm to reflect costs at a higher scale will therefore only be representative if price effects and interlinkages with other sectors are weak. These shortcomings of PB can be counterbalanced by a complementary use of techniques that are described below.

3.5.2. Partial Equilibrium Modelling (PE)

PE is a powerful tool to evaluate the welfare effects on participants in a market which is affected by a shock like a policy intervention or an introduction of a pest. The approach is based on defining functional relationships for supply and demand for the commodity of interest to determine the market equilibrium or, in other words, the combination of prices and quantities that maximizes social welfare (Mas-Colell, 1995). Maximum social welfare is realized when consumers and producers - in aggregated terms - maximize their utilities and profits as illustrated in Figure 1A.

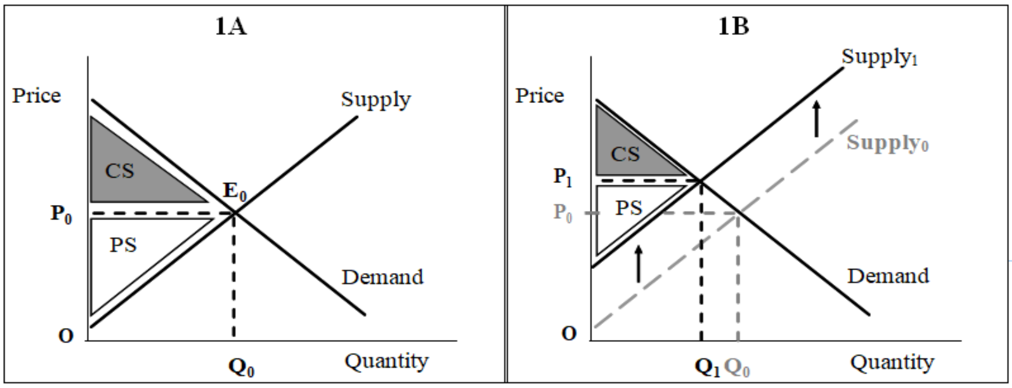

Figure 1. Impact of shock on market equilibrium.

This figure shows a downward-sloping demand curve, reflecting diminishing marginal utility as consumption increases, and an upward-sloping supply curve, reflecting increasing marginal costs of production. The market equilibrium (E0), where quantity supplied equals quantity demanded, occurs at an equilibrium price of P0 and quantity Q0. The difference between P0 and the demand curve represents how much consumers benefit by being able to purchase the product for a price that is less (P0) than they would be willing to pay. This total benefit derived by the consumers, or consumer surplus, is represented by the triangle labeled CS. Since the supply curve represents the marginal variable cost of production, the area below the curve equals the total variable costs. The revenues from sales are equal to price (P0) times quantity (Q0), which is the area enclosed between the dashed lines. Hence the producer surplus, defined as the difference between total revenue and total variable costs is reflected by the triangle PS. Social welfare is defined as the sum of consumer surplus and producer surplus.

By PE analysis, the aggregated impact of a shock is determined by measuring the differences in equilibrium price and quantity, and change in welfare before and after the shock. A shock, like a pest invasion, may lead to a loss in yield and an increase in production costs, resulting in an upward shift in the supply curve (Figure 1). This shift in the supply curve alters the equilibrium point (Figure 1B), implying a decrease in quantity supplied (from Q0 to Q1) and an increase in market price (from P0 to P1). Producer losses, or the reduction in producer welfare, that result from the new equilibrium point can be calculated by comparing PS before and after invasion. In the same way, changes in consumer welfare can be calculated. The change in social welfare is determined by the aggregated impact of the changes in producer welfare and consumer welfare (Just et al., 1982). For the purpose of illustration, the demand curve in Fig.1B is assumed to be unaffected by the shock. In reality, demand can also be affected; for instance, the presence of a pest might affect consumer preferences, thereby shifting the demand curve down, resulting a lower price and quantity at equilibrium.

Partial equilibrium modelling has been widely applied to the analysis of agricultural policy, international trade, and environmental issues (e.g., Qaim and Traxler, 2005; Elobeld and Beghin, 2006; Cook, 2008; Kaye-Blake et al., 2008; Schmitz et al., 2008). Examples of recent applications on pest risk assessment are the analyses performed by Arthur (2006), Breukers et al (2008) and Surkov et al (2009). Arthur (2006) used PE to evaluate the impact on net social welfare of liberalizing the Australian apple market for imports from New Zealand, accounting for the risk of entry of fire blight disease in Australia. The benefits were presented in terms of consumer welfare gain, resulting from lower apple prices due to an increased supply from abroad, while the costs were derived from the reduction in producer welfare as a consequence of losses in production and expenditures to control the pest. Measuring the change in net social welfare, Arthur concluded that Australia would be better off by $90 million even if fire blight became established across all areas. Breukers et al. (2008) modelled the impacts of repeated brown rot outbreaks on supply and (national and export) demand of seed potatoes. They found that the indirect effects as a consequence of reduced export demand are far bigger than the direct effects (yield losses). Surkov et al. (2009) determined the optimal phytosanitary inspection policy in the Netherlands given the estimated costs of introduction of pests through trade pathways. In this study the PE approach was used to account for the potential price effects due to a pest introduction.

The use of PE within a pest risk assessment is appropriate when the pest impacts are expected to change prices or social welfare significantly. PE analyses can be conducted with respect to one sector (single-sector model) or multiple sectors (multi-market model). Multimarket models link related markets and are, therefore, able to capture spillover effects between main markets as, for example, the impact of a pest affecting wheat supply on supply and demand of potential substitute crops like corn. The calculation of producer and consumer surplus in multiple markets involves sequentially computing the effects in each of the affected markets. Within each PE model main assumptions needs to be made to define the structure of the affected market(s) (e.g., perfect competition), the level of homogeneity for products from exogenous markets and the influence of domestic producers on the world market. Data requirements can be substantial (Mas-Colell, 1995; Rich et al., 2005; Backer et al., 2009) as data are needed to reflect the affected markets, including data on prices, quantities, and price elasticities of both supply and demand. Despite its suitability for the evaluation of effects on markets of agricultural commodities, PE is limited in its ability to account for economy-wide effects. PRA by PE is, therefore, only appropriate when the indirect impact of the pest is not expected to significantly affect other non-agricultural markets or to generate measurable macroeconomic changes (e.g., changes in income and employment). For applications that require an economy-wide scope Input-Output analyses or Computable General Equilibrium modelling approaches may be needed.

3.5.3 Input – Output Analysis (I-O)

The technique of I-O analysis focuses on the interdependencies of sectors in an economy (regional or national), making it suitable to predict an economy-wide impact of changes within a particular sector (Leontief, 1986). Central to an I-O analysis is the specification of an I-O table to describe the monetary flows of inputs and outputs among the productive sectors of an economy (Miller and Blair, 1985). In an I-O table, economic sectors are aggregated into representative groups. Each sector-group is represented by a row and a column. The rows of the table specify the distribution of total output of a specific sector sold to other sectors (i.e., to intermediate demand) or to final demand (e.g. to final consumption, investments and exports). The columns refer to the production side of a given sector, by denoting the value of inputs of each sector required to produce output. Table 2.2 represents a hypothetical I-O table with 3 productive sectors, viz. agriculture, industry and transport. In this example, the agricultural sector sells a value of 80 of output within agriculture, 300 of output to industry and 30 of output to transport, whereas a value of 60 is intended for the final demand. As denoted by the column accounts, the industrial sector purchases for its production a value of 300 in intermediate products from the agricultural sector, 500 of input within industry and 200 of input from transport, leading to a value added of 120. The value-added cell includes payments to employees, holders of capital, and governments (e.g. wages and salaries, interest, dividends, and taxes) and represents the value that a sector adds to the inputs it uses to produce output. The value-added row measures each sector's contribution to wealth accumulation.

Any change in final demand for the products of a sector generates direct as well as indirect effects on the economy as a whole. Changes create large primary "ripples" by causing a direct change in the purchasing patterns of the affected sector. The suppliers of the affected sector must alter their purchasing patterns to meet the demands placed upon them by the sector originally affected by the change in final demand, thereby creating a smaller secondary "ripple". In turn, those who meet the needs of the suppliers must change their purchasing patterns to meet the demands placed upon them by the suppliers of the original sector, and so on. The relationship between the initial change and the total effects generated by the change is known as the multiplier effect of the sector, or the impact of the sector on the economy. To compute this multiplier effect, I-O tables are mathematically converted into matrices of multipliers that reflect the amount by which production, employment and income would alter as a result of one-unit change in final demand (Miller and Blair, 1985).

Based on I-O analysis, the impact of a pest invasion on an economy can be evaluated by adjusting the final demand in the affected agricultural sector according to the expected shock to demand (e.g., reduction in exports), multiplied by the multiplier matrix. Examples of recent applications to pest risk assessment are the analyses performed by Elliston et al. (2005) and Julia et al. (2007). Elliston et al. (2005) used I-O analysis to investigate the regional economic impact of a potential incursion of Karnal bunt in wheat in Queensland. As Karnal bunt is considered a quarantine disease in Australia's most important wheat export markets, an incursion in Australia would lead to a significant loss of export markets. In the scenario of a widespread incursion the direct effect in the wheat and other grains industries was estimated as an $89 million decline in output over a fifteen-year planning horizon and a loss of 400 full time jobs. The indirect effects of the incursion in all other industries were estimated as a decline of $38 million in output and a decline in employment of 200 full time jobs. Another example of I-O analysis is the analysis of the total costs of the invasive weed Yellow starthistle in the rangelands of Idaho (Julia el al., 2007). In this analysis, direct and indirect economic effects of the weed were determined in relation to its interference with agricultural and non-agricultural benefits (e.g., wildlife recreation expenditure and water winning). Agricultural related economic impacts accounted for 79% of the total impact on the rangeland-economy, and non-agricultural impacts for the remaining 21%. The strength of the I-O approach is its ability to capture spillover effects between economic sectors. The accuracy of this 'capture' depends on the level of sector aggregation in the I-O tables. If the level of aggregation is too high, indirect impacts of a shock will be overestimated. Lower levels of aggregation are, however, associated with substantial increases in data requirements. In addition to its high data requirement, the potential use of I-O analysis is restricted by two fundamental assumptions. First, I-O models only account for changes in the economy due to shifts in demand; supply is assumed to be perfectly elastic. Since supply constraints are often present in agriculture, I-O models may miss important effects of a pest introduction. Second, due to the use of fixed coefficients, I-O models cannot account for changes in prices or for changes in the structure of a sector over time. This means that I-O models assume fixed prices, no substitution between inputs, and constant returns to scale. However, this static assumption can be justified if the I-O technique is used to analyze only short-term impacts. To conclude, the I-O approach provides the opportunity to measure short-term, spillover impacts across broad sectors of the economy given plant health incidents that affect the demand side only. For applications that require the economy-wide scope of I-O models as well as the economic realism of PE models, a Computable General Equilibrium Modelling approach would be more appropriate.

3.5.4 Computable General Equilibrium Modelling (CGE)

The CGE approach combines the strengths of I-O analyses and PE models to answer a wide range of questions. It uses I-O tables to represent the entire economy with the inclusion of functional relationships between actors in this economy as in a PE model. The basic structure of a CGE model can be described in terms of "blocks" of equations that specify demand relationships, production technologies, relationships between domestic and imported goods, prices, household income and numerous equilibrium conditions. Such a framework enables CGE models to address questions concerning impacts across sectors and employment groups as well as price changes and longer-run impacts. This capacity, however, makes CGE models highly complex, imposing high costs in the development of such a model as well as in the interpretation of its results (Sadoulet and de Janvry, 1995; Dixon and Parmenter, 1996).

By nature, CGE models are highly aggregated, making it difficult to analyze a change in a sub sector of the economy. Many CGE models are disaggregated into only two agricultural sub-sectors, such as tradable and non-tradable crops, or food crops and cash crops (Bourguignon and Pereira da Silva, 2003). Applications of CGE models are, therefore, only appropriate to address large-scale problems which are most likely to generate measurable macroeconomic impacts. Pest invasion problems rarely generate such major effects as changes in aggregate employment, income or inflation rate. As a consequence, there are few applications of CGE applications in pest risk assessments. Recent applications are those of Wittwer et al. (2005, 2006). In Wittwer et al. (2005) a CGE model was used in order to quantify the impact of a hypothetical outbreak of the Tilletia indica fungus (the causal agent of Karnal bunt) on the wheat crop in west Australia. In their analysis, the effects on output, income, employment, wages, capital stocks and exports were estimated. In a second paper, Wittwer et al. (2006) investigated by the use of CGE the economic consequences of introducing Pierce's disease of grapevine in South Australia. Special attention was given to the adjustment in the labour market as a result of the disease outbreak.

3.5.6. Decomposition model

Numerous models can be used to analyze the economic performance of Integrated Crop Management Farmer Field School Program (ICM-FFS) including the decomposition model. This model is a mathematical technique to break down something that is aggregated into its components, so it is possible to allocate the difference in the dependent variable to each independent variable (Catelo, 1984). This model had been used to analyze the contribution of each independent variable on income differences, production, and productivity in several studies. Catelo, (1984), for example, used this to analyze the impact of the communal irrigation system on rice production. Kiresur et al. (1995) conducted a study of technological change in the production of sorghum to decompose productivity differences between new and traditional varieties into labor, seeds, fertilizer, and capital. Narayanan et al. (2002) analyzed the impact of shelterbelts on the decomposition of peanut production in the rilands, South India. On the other hand, Simatupang et al. (2004) applied this technique to examine the sources of growth in upland rice production in Indonesia. Feder et al. (2004) used decomposition analysis to assess the impact of the implementation of the Integrated Pest Management Farmer Field School (IPM-FFS) on rice productivity and pesticide use. Thank and Singh (2004) also decomposed changes in crop acreage into production and productivity, as well as the interaction between the two components. Meanwhile, Mehta (2009) examined the contribution of each component to the growth of crops in various regions in India.

3.5.7. Multi criteria decision making techniques

Decision making in controlling harmful plant diseases is a complex process involving a large range of stakeholders with different and often conflicting interests. Their views may represent the interests of the farming community, other sectors of the economy, the consumer or the environment. This may create a situation of conflicting interests, as economic motives may prevail in the views of some, while landscape, environmental or human-welfare motives may be prominent in the view of others. Multi-Criteria Decision Making (MCDM) could support policy makers in choosing the control strategy that best meets all of these conflicting interests. MCDM techniques deal with complex problems that are characterized by any mixture of quantitative and qualitative objectives. It establishes preferences between alternatives to an explicit set of objectives and measurable criteria (Mourits and Oude Lansink, 2006).

Multi-Criteria Decision Making is by now a well-established paradigm in decision sciences. The key characteristic of this paradigm is that a decision maker does not optimize a single defined objective but aims for the achievement of satisfying levels in the goals or seeks an optimal compromise between several, often conflicting objectives (Romero and Rehman 2003). The general purpose of MCDM is to serve as an aid to thinking and decision making, but not to take the decision. MCDM techniques are capable of dealing with complex problems that are characterized by any mixture of quantitative and qualitative objectives. This is done by breaking the problems into more manageable pieces to allow data and judgments to be brought on the pieces. Next, the techniques reassemble the pieces to present a coherent overall picture to decision makers (Voogd 1982).

The applied Multi-Criteria Analysis (MCA) involves eight steps: (1) Establish the decision context, (2) Identify the alternatives to be appraised, (3) Identify objectives and criteria, (4) Scoring, (5) Weighting, (6) Calculate overall value, (7) Examine the results and (8) Sensitivity analysis.

Decision making in quarantine plant diseases is also complex and conflicting, due to the involvement of various epidemiological, economic and social-ethical value judgments. Control measures as the use of a particular pesticide may limit the spread of the infectious disease (= epidemiological value), but could also affect the subsistence of harmless organisms (= social-ethical value), result in residues in potential food products (= economic and social-ethical value) or even influence the existence of a whole ecosystem (= social-ethical value). Controlling the disease by a measure as complete destruction of plants and plant products may be very efficient from an epidemiological point of view but could have serious economic consequences for the affected producers and – depending on the magnitude of the outbreak – even affect the world food supply, resulting in a global social-ethical distress (Mourits and Oude Lansink, 2006).

4 References

Arpaia, M.L.U, Stottlemyer, D.E., Witney, G.W., 1996. Economic Analysis of Irrigation and Fertilization Management of Avocados. Hortscience, 31 (1), 156-159 .

Arthur, M., 2006. An economic analysis of quarantine: The economics of Australian’s ban on New Zealand apple imports. 2006 Conference, New Zealand Agricultural and Resource Economics Society, 31959, Nelson, New Zealand.

Baker, R.H.A, Battisti, A., Bremmer, J., Kenis, M., Mumford, J., Pette,r F., Schrader, G., Bacher, S., De Barro, P., Hulme, P.E., Karadjova, O., Oude Lansink, A., Pruvost, O., Pysek, P., Roques, A., Baranchikov, Y., Sun, J-H., 2009. PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union. EPPO Bulletin 39, 87-93.

Bourguignon, F., Pereira da Silva, L., 2003. The impact of economic policies on poverty and income distribution, evaluation techniques and tools. Washington, D.C., The World Bank and Oxford University Press.

Breukers, A., Mourits, M. , van der Werf, W. , Oude Lansink A., 2008. Costs and benefits of controlling quarantine diseases: a bio-economic modeling approach. Agricultural Economics 38, 137 – 149.

Catelo, S.P. 1984. Decomposition analysis of the effect of communal irrigation system on rice production in cagayan region, philippines', Master's Thesis, University of the Philippines Los Baños, 1984.

Cook, D. C., 2008. Benefit cost analysis of an import access request. Food Policy, 33 (3), 277-285

Dixon, P.B., Parmenter, B.R., 1996. Computable general equilibrium modeling for policy analysis and forecasting. In: Amman, H.M., Kendrick, D.A., Rust, J. (Eds.), Handbook of computational economics, Vol- I, Elsevier science B.V.

Donovan, C., Wopereis, M.C.S., Guindo, D., Nebié, B., 1999. Soil fertility management in irrigated rice systems in the Sahel and Savanna regions of West Africa: Part II. Profitability and risk analysis. Field Crops Research. 61 (2), 147-162.

Elliston, L., Hinde R., Yainshet A., 2005. Plant Disease Incursion Management. Lecture Notes in Computer Science, 3415, 225-235.

Elobeld, A., Beghin, J.,2006. Multilateral trade and agricultural policy reforms in sugar markets. Journal of Agricultural Economics, 57 (1), 23-48.

FAO, 2004. Pest risk analysis for quarantine pests including analysis of environmental risks. International Standards for Phytosanitary Measures. Publication No. 11. Rev. 1. FAO, Rome (IT).

Feder, G. Murgai, R and Quizon, J.B. 2004. Sending farmers back to school: the impact of farmer field school in Indonesia. Review of Agricultural Economics, vol. 26, no.1, pp. 45– 62.

Holland, J., 2007. Tools for Institutional, Political, and Social Analysis of Policy Reform. A source book for Development practitioners. Washington, D.C., The World Bank and Oxford University Press.

Juliá, R., Holland, D.W., Guenthner, J., 2007. Assessing the economic impact of invasive species: The case of yellow starthistle (Centaurea solsitialis L.) in the rangelands of Idaho, USA. Journal of Environmental Management. 85, 876-882.

Just, R.E., Hueth, D.L., Schmitz, A., 1982. Applied Welfare Economics and Public Policy. Englewood Cliffs: Prentice-Hall, Inc.

Kaye-Blake, W.H., Saunders, C.M., Cagatay, S.,2008. Genetic Modification Technology and Producer Returns: The Impacts of Productivity, Preferences, and Technology Uptake. Review of Agricultural Economics, 30 (4), 692-710.

Kiresur, V. Pandey, R.K. and Mruthyunjaya. 1995. Technological change in sorghum production: an econometric study of dharwad farms in Karnataka. Indian Journal of Agricultural Economics, vol. 50, no. 2, pp. 185–192.

Leontief, W., 1986. Input-Output Economics, Oxford University Press, New York.

Mourits, MCM and Oude Lansink, AGJM 2006, Multi-criteria decision making to evaluate quarantine disease control strategies. in AGJM Oude Lansink (ed.), New approaches to the economics of plant health. Frontis, Wageningen, pp. 131-144.

Macleod, A., Head, J., Gaunt, A., 2003. The assessment of the potential economic impact of Thrips palmi on horticulture in England and the significance of a successful eradication campaign. Crop Protection 23, 601– 610.

Mas-Colell, A., Whinston, M.D., Green, J.R., 1995. Microeconomic Theory. New York, Oxford University Press.

Mehta, P. K. 2009. Role of crop diversification in output growth in india: a state-level analysis',IUP Journal of Agricultural Economics, vol. 6, no. 2, pp. 24–42.

Miller, R., Blair, P., 1985. Input Output Analysis: Foundations and Extensions. Prentice-Hall, Englewood Cliffs, N.J.

Narayanan, V.V. and Maynard, L. J. 2002. Impact of shelterbelts on groundnut production in therilands: a decomposition analysis. Paper presented at the Annual Meeting of the Agricultural and Applied Economics Association, Long Beach, California, July 28– 31.

P. Simatupang, I. W. Rusastra, and M. Maulana. 2004. How to solve supply bottleneck in agricultural sector. Agricultural Policy Analysis, vol. 2, no. 4, pp. 369–392.

Pemsl, D., Waibel, H., Orphal J., 2004. A methodology to assess the profitability of Bt-cotton: case study results fro the state of Karnataka, India. Crop Protection 23 (12), 1249-1257.

Qaim. M., Traxler, G.,2005. Roundup Ready soybeans in Argentina: farm level and aggregate welfare effects. Agricultural Economics, 32 (1), 73-86.

Rich, K.M., Miller, G.Y., Winter-Nilson, A., 2005. A review of economic tools for the assessment of animal disease outbreaks. Scientific and Technical Review of the Office International des Epizooties., 24, 833-845.

Romero, C. and Rehman, T., 2003. Multiple criteria analysis for agricultural decisions. 2nd edn. Elsevier, Amsterdam. Developments in Agricultural Economics no. 11.

Sadoulet, E., de Janvry, A., 1995. Computable general equilibrium models. In: Quantitative development policy analysis. The Johns Hopkins University Press, Baltimore, pp. 341-372.

Sansford, C. 2002. Quantitative versus Qualitative: Pest Risk Analysis in the UK and Europe including the European and Mediterranean Plant Protection (EPPO) system. NAPPO International Symposium on Pest Risk Analysis Puerto Vallarta, Mexico, 2002.

Schmitz, T.G., Giese, C.R., Shultz, C.J., 2008. Welfare Implications of EU Enlargement under the CAP. Canadian Journal of Agricultural Economics, 56(4), 555-562.

Surkov, I.V., Oude Lansink, A.G.J.M., van der Werf, W., 2009. The optimal amount and allocation of sampling effort for plant health inspection. European Review of Agricultural Economics, 36, 295-320.

Thanh, C. H. and Singh, B. 2006; Trend in rice production and export in vietnam, Omonrice 14, pp. 111–123.

Voogd, J.H., 1982. Multicriteria evaluation for urban and regional planning. PhD Thesis. TU Eindhoven. [http://alexandria.tue.nl/extra1/PRF4A/8203510.pdf]

Vose, 2001. Risk analysis: A Quantitative Guide. Second edition (Wiley & Sons), UK.

Wittwer G., McKirdy S., Wilson R., 2006. Analyzing a hypothetical Pierce's disease outbreak in South Australia using a dynamic CGE approch. Working Papers G-162, Monash University, Centre of Policy Studies/IMPACT Centre.

Wittwer, G., McKirdy, S., Wilson, R., 2005. Regional economic impacts of a plant disease incursion using a general equilibrium approach. Australian Journal of Agricultural Resource Economics 49, 75–89.