Potential damage costs of Diabrotica virgifera virgifera infestation in Europe – the "no control" Scenario

Wesseler, Justus and Fall, El Hadji
Wageningen University

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Short- title: Potential Damage Costs of Dvv. in Europe

Justus Wesseler,

Corresponding author, Environmental Economics and Natural Resources Group, Wageningen University, The Netherlands, e-mail: justus.wesseler@wur.nl

El Hadji Fall

Technical Adviser, The Pole-Development Strategies & Public Finance, UNDP Africa Sub-Regional Office I, Dakar – Senegal, e-mail: el.hadji.fall@undp.org

Abstract

The Western Corn Rootworm (WCR or *Dvv.*, Diabrotica virgifera virgifera Le Conte) was first detected in Europe in the early nineties in Serbia. Since then the beetle has spread to more than 15 European countries. We assess the potential damage costs of the invasive species *Diabrotica virgifera virgifera* LeConte (Dvv.) in Europe under a "no control" scenario. While previous studies considered benefits and costs at country level, this study explicitly investigates the external benefits of control in one country for other countries. The assessment considers the spatial and temporal aspects of invasion considering a number of scenarios developed together with experts. The results indicate enormous economic benefits can be gained by controlling further spread of Dvv. The economic benefits of control range between 143 million Euro in the best case and 1739 million Euro in the worst case scenario. The most likely scenario results in average annual economic benefits of 472 million Euro. Even in countries that do not face high damage costs control can be justified as this will reduce the speed of spread of the WCR and generate a positive externality for other regions with higher damage costs.

Keywords: invasive species, damage costs, spatial model

IWGO conference contribution

1. Introduction

The Western Corn Rootworm (WCR or *Dvv.*, Diabrotica virgifera virgifera Le Conte) was first detected in Europe in the early nineties in Serbia. Since then the beetle has spread to more than 15 European countries. Isolated populations have been detected in Belgium, England, France, and The Netherlands (Ciosi et al, 2008). The WCR and the northern corn rootworm (*D. barberi* Smith and Lawrence) cause extensive economic damage to maize in the United States. Annual yield losses and control costs are estimated to be around $1 billion (Metcalf, 1986).

It is reasonable to expect economic damages to be severe in Europe as well, although studies at country level provide mixed results. MacLeod et al. (2004) conclude in their study for Great Britain that potential damage costs do not justify implementing the statutory campaign against the WCR in England and Wales. Likewise, Janssens et al. (2005) in their study for The Netherlands assess the potential damages to be too low to justify intensive control measures, while Baufeld and Enzian (2005) and Kehlenbeck and Bokelmann (forthcoming) in their study for Germany report relatively high damages justifying control measures. Dillen et al. (forthcoming) illustrate the difficulties of linking pest pressure and damage costs resulting in difficulties in identifying the best control strategy.

The objective of this study is to investigate potential damage costs for Europe under a “no control scenario”. The study is spatially and temporally explicit by considering intensity and profitability of maize production among European countries as well as the speed of spread of the pest over time. A scenario approach has been chosen to identify a possible range of damage costs. While previous studies considered benefits and costs at country level, this study explicitly investigates the benefits of control in one country for other countries. The model for assessing the damage costs has been kept fairly simple in view of the fact that information on the economics of WCR control in Europe is severely lacking. Hence, the model can be seen as a first step assessing the benefits and costs of Dvv. control at EU level and be improved and modified with the availability of additional information. Nevertheless, the results indicate damage costs can be substantial and warrant control measures. Even in countries that do not face high damage costs control can be justified as this can reduce the speed of spread of the WCR and generate a positive externality for other regions with higher damage costs.

The paper is structured as follows. Firstly, the main assumptions of the “no control scenario” are described followed by the data sources, the method of assessment and the results. Finally, the results are discussed in the light of the EU policies for the control of the WCR.

2 Assumptions of “no control” scenarios

2.1 Maize area susceptible to be infested

The area of maize susceptible to be infested by the WCR depends on climatic conditions, the density of maize in the area and on the spreading rate of the pest over time and space. Baufeld (2003) analyzed the rate of spread of the WCR in Europe and assumes the rate of spread to range from 60 to 100 km/year if there are no containment measures. MacLeod et al. (2004) assume the same range for the maximum and the minimum rates and a typical rate at 80km/year for the purpose of their analysis. Experts at the Wageningen workshop on the WCR (2007) agreed on a consensus for modeling WCR spreading at a rate of 20 km/year in areas where the proportion of maize is less than 50% and 60 km/year in areas where the proportion of maize is higher than 50%. To simplify the analysis we only consider the area allocated for continuous maize as susceptible for infestation, as damages during the first year of infestation are almost zero (Dun et al, 2009) and crop rotation is an effective WCR control method. Further, for calculating the additional damage costs only areas not yet infested will be considered.

2.2 Yield losses

There are large disparities on yield losses reported by scientists. Chiang et al. (1980) reported yield losses ranging from 2 to 50% in artificially infested field plots of maize with WCR eggs at the time of sowing. Other reports of yield losses are in the range of 10-40% or in extreme cases even 90% (McBride, 1972; Spike & Tollefson, 1991). Apple *et al*, (1977) and Petty *et al*, (1968) found yield losses of 10% to 13% whilst Calvin *et al.* (2001) estimated yield losses for untreated fields in the north-eastern part of the USA to be 6.5 %. We assume maximum yield losses of 10% to 30% in line with European studies (Schaafsma et al., 1999; Baufeld and Enzian, 2005; MacLeod et al., 2004).

A consensus exists on the fact that there is a time lag of approximately five years between the first finding of WCR and reports of severe economic damage in an infested zone. We assume maximum economic damage will be reached five years after the first infestation with WCR The increase in damage over the first five years is assumed to be linear (see also MacLeod et al., 2004).

2.3 Economic losses

The annual yield losses are valued by the average price for grain maize and green maize. We discount the annual yield losses using as a discount rate opportunity costs of capital[1] of 5% and present the average annual damage costs. Assuming the same and constant interest rates for borrowing and lending this can simply be done by multiplying the damage costs in present value with the discount rate in decimal form. We further hold prices and quantities of inputs constant and assume for each scenario producers face a perfectly elastic demand curve to keep the model simple. The implications of the assumptions made are discussed in more detail in the following section.

[1] This is close to the average long-term interest rate of 4.85% in the EU over the past nine years 2000-2008 using data provided by the European Central Bank (2009).

3. Data, Results and Discussion

Eighteen of the 27 EU member states have been considered for the analysis. They include the EU countries Austria, Belgium, Bulgaria, Czech Republic, France, Greece, Germany, Hungary, Italy, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, the United Kingdom, and Croatia along with Switzerland. The potential area susceptible for infestation depends among others on the climatic conditions. The southern part of Italy, for example, is not susceptible to the pest because of the warm climate. The same applies for Greece, Spain, and Portugal, while Scotland as part of the United Kingdom will be too cold. The susceptible continuous maize area has been adjusted accordingly as reported under the column "country area susceptible" in table 1. The respective percentages have been identified by country experts at the Wageningen workshop on WCR in 2007.

Data on the percentage of continuous maize area and the total area allocated to maize have been collected from experts at the Wageningen workshop, except for Germany, Italy, Austria and Belgium for which we apply percentages from Baufeld and Enzian (2005). For Portugal, Greece and Spain, we do not have data on the proportion of continuous growing maize area. For these countries we apply the average proportion of continuous maize growing area in our panel of countries. For Romania and Bulgaria the Hungarian proportion of continuous maize area has been applied. Price, yield and area data have been collected from EUROSTAT for the year 2005.

3.1 Area Susceptible for Infestation

Table 1 provides information on the country size and area susceptible for WCR infestation. The countries considered have a total size of about 3.26 million sq km. Some areas are not susceptible. This reduces the total area susceptible to WCR to about 2.82 million sq km. Some areas are already infested with WCR. This is about 265 thousand sq km or 9.5% of the area susceptible to WCR. The total area not yet infested but considered a potential area for infestation is about 2.55 million sq km or about 78% of the total area or about 91% of the susceptible area. This is the area we have used for calculating the additional damage costs for the "no control" scenario.

3.2 The Speed of Spread

An important factor driving the damage costs of WCR infestation is the speed of spread of the pest. Depending on the average annual speed the infested area will differ substantially. The annually infested area per country has been calculated according to the following equation:

$$IA_{t,i} = \begin{cases} (\upsilon \cdot t)^2 \cdot \pi & if \quad IA_{t,i} < CAS_i \\ CAS_i & if \quad IA_{t,i} \geq CAS_i \end{cases} \tag{1}$$

and $i = 1,\ldots,n.$

IA is the infested area per year in sq km, υ is the speed of spread in km per year, π the mathematical constant, *t* the number of years, CAS the country area susceptible to WCR, *i* is the country indicator and *n* the number of countries considered. The total infested area has been calculated according to equation 2:

$$TIA_t^A = \sum_{i=1}^{i=n} IA_{t,i} \ , \tag{2}$$

with TIA_t^A as the total infested area in sq km.

Calculating the annual infested area according to equation 1 assumes that WCR enters each country at the same point in time at its geographical center and spreads in the form of a circle with no control methods applied. The results by country underestimate the speed of spread for larger countries such as France or Germany as encroachment from neighboring countries is not considered. The same applies for the calculation of the speed of spread for the total area. For elongated countries such as Portugal or the UK the speed of spread is overestimated as all countries are reduced to a circle.

The results in table 2 indicate that smaller countries can be infested within a short period of time such as Slovenia, Slovakia, and Switzerland. Using the country specific data to calculate the numbers of years till total infestation results in the number of years presented in row Total A.

If we consider WCR will be introduced in all countries considered at the same point in time with $CAS = \sum_{i=1}^{n} CAS_i$ the total area infested, TIA_t^B, can be calculated:

$$TIA_t^B = \begin{cases} n(\upsilon \cdot t)^2 \pi & if \quad n(\upsilon \cdot t)^2 \pi < CAS \\ CAS & if \quad n(\upsilon \cdot t)^2 \pi \geq CAS \end{cases} \tag{3}$$

The number of years till total infestation under this scenario is presented in the last row of table 2 (Total B).

Figure 1 shows the link between the number of years till total infestation and the speed of spread. The results show that a reduction of the speed of spread at initial low speed can reduce the number of years until total infestation considerably, whereas in the case of an initially high speed of spread the same absolute reduction has a much less pronounced effect. Reducing the speed of spread by 20 km per year from 100 km to 80 km per year reduces the time till total infestation by about one year whereas a reduction from 40 km to 20 km per year reduces the time till total infestation by about ten years. If we consider that national borders are not a barrier to spread of WCR in the “no control” case the number of years until the total area of 2.82 million sq km is infested decreases as shown in figure 1.

Please note that the years reported for TIA_t^B are based only on countries and country areas not yet infested (2.55 million sq km). For the following we continue using equation 3 as the basis for calculating the damage costs as this simplifies the computations significantly. The reader may expect an overestimation of the damage costs, but the use of average numbers reduces the total damage costs as large countries with relatively high maize revenues such as France, Germany and Italy get less weight (see also country specific results presented in table 6).

3.3 The Maize Area Damaged and Damage Costs

Table 3 presents the area allocated by country to green and grain maize and the area allocated to continuous maize. The area allocated to continuous maize indicates the number of hectares that can be damaged per year. In table 3 also the yield per hectare and the price per ton of green and grain maize are reported. The average revenue per ha is about 756€/ha for grain maize and about 1204€/ha for green maize and about 939€/ha on average for maize. The percentage of continuous maize has been treated the same for grain and green maize. The results show prices and yields differ considerably between countries. This indicates that the economic importance of the pest on a per hectare level will differ by country and damage costs will be regionally specific. The revenue per ha ranges between 336€/ha for green maize in Bulgaria to up to 2303€/ha for green maize in Belgium.

The information about the continuous maize area and the average revenue for maize in combination with the speed of spread and the relative damage can be used to calculate the potential damage costs. A number of scenarios have been specified for the calculation of the damage costs. Three damage levels have been considered, 10%, 20%, and 30%. Three different revenue levels have been considered: the average revenue of 939€/ha, the mid-range revenue of 1443€/ha and the upper-quartile range value of 1997€. An average level of 1.26% of continuous maize on total land (Table 3) has been considered. Additional scenarios including higher speed of spread and an increase of the continuous maize area have also been calculated and are available upon request from the authors.

The damage costs in present value, PVD, for each scenario have been calculated according to equation 4:

$$PVD = \sum_{t=1}^{\infty} TIA_t^B \cdot R \cdot D_t \cdot q^{-t} \ , \qquad (4)$$

with R as the annual revenue in €/ha, q^{-t} the discount factor, and D_t the annual percentage loss in revenue R. The annual values for D_t have been calculated according to equation 5:

$$D_t = \begin{cases} D & if \quad t \geq 5 \\ D \cdot \frac{t}{5} & if \quad t < 5 \end{cases}, \tag{5}$$

with *D* as the total proportional damage.

The average annual damage, AAD, has been calculated by multiplying the damage costs in present value by the 5% discount rate *i* in decimal form (the factor for converting a present value into an infinite annuity):

$$AAD = PVD \cdot i\,. \tag{6}$$

Table 4 illustrates the calculations for the scenario of 1.26% continuous maize, maize revenue of 1443€/ha and 20% damage and speed of spread of 40km per year. Table 5 lists the different scenarios computed and the results and figure 2 visualizes them.

The results presented in table 5 and figure 2 show damage costs will be substantial. Even in the best case scenario we calculate annual average damage costs of about 143 million Euro per year. In the worst case the average annual costs are about 1739 million Euro per year. Both results, the worst and best case are not very likely. Scenario 2 with 40km spread per year and average annual costs of 472 million Euro presents the Wageningen workshop scenario and can be seen as the most-likely scenario based on expert assessment. Assuming a mid-range maize revenue, medium relative damage of about 20% and a current continuous maize area of about 1.26% on total land area results in average annual damage costs of 1004 million Euro.

It should be noted that our results are in line with the potential level of damage estimated by Baufeld and Enzian (2005). They calculated a pecuniary yield loss of 147 million Euro for a group of eight countries (Austria, Belgium, France, Germany, Italy, Luxemburg, The Netherlands and Switzerland) for one year assuming a damage level of 10%. The countries the authors consider account for about 50% of the area considered. If we take the results presented for the first scenario in table 5 (10% damage), we observe all values taken at 50 per cent are below the value calculated by Baufeld and Enzian while most of the values of scenario 4 (10% damage) at 50 per cent are above their damage costs but not considerably.

The results by country as presented in table 6 indicate substantial differences between countries. By and large the damage costs in Eastern European countries are relatively small, which can be explained by low maize revenues as discussed earlier. While the damage costs for some countries such as

Luxemburg appear to be small, we also have to consider that control of the WCR has a positive impact on neighbouring countries such as France or Germany.

The main benefit from controlling the spread of WCR is delaying the time of infestation. A successful eradication programme may even be able to stop further infestation. EU member states invest considerable amounts of money to monitor and control the movement of WCR. From the implementing agencies' point of view it is important to know whether or not the amount of taxpayer's money being spent for controlling WCR is being well spent. The results presented in tables 5 and 6 provide some information for answering such questions.

The total benefit of a successful control programme that stops damages from the WCR can be justified if the costs are below total damages of about 472 million Euro per year as under scenario 2 and a speed of spread of 40km per year. A WCR control programme should not cost more than this on average per year. However, the numbers by country differ significantly. By and large France can expect the highest benefits from a successful control programme of about 124 million Euro per year as reported in table 6.

The numbers presented include Belgium, The Netherlands and the United Kingdom but are in line with the damage costs reported by Janssens (2005) and MacLeod et al. (2004). Whether the WCR will be as damaging as presented is questionable because of the climatic conditions. The average annual costs decrease by only about 7% if those countries are excluded and this does not have important implications for our conclusions.

WCR populations are already established in some of the countries listed such as Croatia, Czech Republic, Hungary, Slovenia, and Slovakia and present in Poland and Romania. The numbers presented provide some indications for the value of eradication programmes within the countries. Take, for example, the case of Hungary which can be considered 100% infested. A successful eradication programme should not cost more than about 55 million Euro per year as reported in table 6.

In the long run total eradication and stopping the spread of the WCR might not be an option. Under those circumstances reducing the spread of the WCR becomes an important alternative. Monitoring and eradicating populations immediately delays the pest damage. Again, the average annual damage costs inform us about the benefits of reducing the speed of spread of the pest. Reducing the speed of spread under scenario 2 from about 40km per year to 20km per year provides 74 million Euro per year of avoided damages.

If we only take the countries where the pest is not present but considered to be of economic importance such as Austria, France, Germany, and Italy, monitoring and eradication of the WCR can be justified if it does not cost more than about 273 million € a year for the same scenario.

It is interesting to note that in countries such as Belgium and The Netherlands where the damage might be much lower than calculated and therefore monitoring and eradication would not be economical at the country level, controlling WCR can provide economic benefits to neighboring countries such as France and Germany by reducing or even stopping the movement of the pest.

While the results highlight the importance of WCR control, readers should note that the assessment has been made using simplified assumptions. The model assumes an even move of the pest, while geographic differences can increase or reduce the speed of spread. Minimum speed of spread of 20km per year has been reported. Results under that scenario provide a lower boundary. Another assumption of the no control scenario was the introduction of the pest at the geographical center of each country at the same point in time. This is not unreasonable considering reports of WCR detection in the EU; some countries have even reported several entry points within a given year. Assuming a simultaneous increase from all entry points in circular form as shown under scenario B reduces the time until full infestation as overlapping areas are counted twice and may result in an overestimation of the damage costs. We expect this effect to be minimal based on visual assessment using the map of Europe. The damage costs have been calculated using the country weighted average maize revenues. Revenues not only between countries but also between regions within countries differ. As only damages on areas under continuous maize have been considered the damages can be expected to be on the lower side. Farms growing continuous maize can be expected, for many reasons, to depend on maize either as an important input for livestock production or as for direct income in the case of grain maize. Yield damages on their farms can be expected to have wider consequences than for farms not growing maize on a continuous basis. The severe, even violent complaints, by farmers in continuous maize areas against the implementation of crop rotation under the EU regulations support this argument. The calculations have been done in a comparative static way. Farmer responses to the pest have not been included while there certainly would be responses such as changing crops and other farming practices (Wesseler et al., 2007). Calculations for the Netherlands by Janssens et al. (2005) and for different EU member states by Fall and Wesseler (2007) show crop rotation would only become a viable option if damages are 20% and more among continuous maize growers. The invasion of the pest may also result in higher prices for maize increasing incentives for producing maize in non continuous or non maize areas. The effect of an increase in maize production due to an increase in biofuel production has not been considered and may further increase the damage costs. Taking all this together the scenario with a low speed of spread and low damage costs is on the lower side and can be considered the minimum costs of no control. Future research on the damage costs of the WCR over time and space should take farmers response and geographic differences into account. The model being presented includes the most important features, time and space, and can serve for developing models that do take geography and farmer response more explicitly into account.

4. Conclusion

The economic benefits of WCR control in Europe are substantial. The most likely scenario results in economic gains of complete WCR control of about 472 million Euro per year. The economic benefits of control and the control costs are unevenly distributed among EU member states. This uneven distribution may result in incentives undermining a successful control strategy. Indeed, some countries will benefit from the actions taken by others countries to avoid the WCR expanding throughout Europe. For example, Germany is now benefitting from the actions taken by Austria. This externality effect should be valued at EU level to improve the implementation of EU wide management programs.

The analysis of WCR damage costs assessment provides a global idea of the economic benefits of control. This does not provide an answer for the control costs and optimal control strategies. While control costs have to a certain extent been investigated (Dillen et al., forthcoming; Fall and Wesseler, 2007) those studies including monitoring and administrative costs come to the conclusion the economic benefits do not justify the costs (Janssens, 2005; MacLeod, 2004). Those studies have been carried out for countries with relatively low damage costs. The picture will change for countries with higher damage and lower control costs. Whether the economic benefits of control cover not only the costs at farm level but also the administrative costs is still an open question. The model presented provides a first step to investigate this in more detail.

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