Dynamic ecological-economic modeling to quantify the market value losses attributed to the absence of natural predators in Belgian pear production

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Biodiversity plays a key role in ecological processes and the delivery of ecosystem services and its importance has been widely recognized (MA, 2005). However, many uncertainties over the effect of biodiversity decline on the provisioning of ecosystem services remain (Balvanera et al., 2014; Schroter et al., 2014). Furthermore, an important challenge remains in the quantification of the economic consequences of the loss of biodiversity (De Meester et al., 2011). The aim of this paper is twofold and consists of (i) contributing to the quantification of the link between the loss of species and the provisioning of the ecosystem service biological pest control and (ii) quantifying the market value losses which can be attributed to the loss of those species.

An integral part of agricultural intensification at the plot level is the deliberate reduction of biodiversity (Bianchi et al., 2013; Swift et al., 2004). Biodiversity provides however a wide variety of ecological services and disservices in agro-ecosystems (Tschjarntke et al., 2005, De Meester et al., 2011, Kragt et al., 2014). The control of pests by their natural enemies represents an important ecosystem service that maintains the stability of agro-ecosystems and has the potential to mitigate pest control costs both to private producers and to society (Zhang and Swinton, 2006). In this research, the indirect use value of the presence of natural enemies for the biological pest control of pear psylla (*Cacopsylla pyri*) is analyzed for two pear orchard agro-ecosystems in Belgium, being: (i) organic production and (ii) Integrated Pest Management (IPM).

In a first part, a dynamic predator-prey model is built in which the functional role of natural predators in suppressing the outbreak of pear psylla is simulated for the reference scenario (organic production) and the alternative scenario (IPM). The model describes predator-prey dynamics between the pest insect pear psylla (*Cacopsylla pyri*) and three of its main natural enemies *Anthocoris nemoralis*, *Allothrombidium fuliginosum* and *Heterotoma planicornis*. Species-specific data on phenology and feeding behavior were employed to simulate species interaction, predation and reproductive behavior. After calibration and determination of equilibrium conditions, field data on timing (y^{-1}), concentration of active ingredient (gl^{-1}), quantities of insecticides applied ($kgha^{-1}$) and ecological toxicity data of the effect of consecutive insecticide applications on pear psylla and natural enemies (% death rate) are incorporated in the alternative scenario. The biodiversity loss function is defined as the difference in abundance of species for both scenarios. Finally, the change in biological pest control potential of natural enemies is defined as the amount of pear psylla predation which is lost due to the use, concentration and timing of consecutive insecticide applications.

Preliminary results reveal that when population dynamics and timing of applications are taken into account the effect of consecutive insecticides application, which are generally considered as safe (<25% death fraction of natural enemies) could result in significantly higher natural enemy death rates and therefore account for potential higher losses of biological pest control.

The second part determines the indirect use value of natural predators by investigating the Economic Injury Level (EIL). The EIL is defined as the relationship between pear psylla densities (#individualsha^{-1}) and market value losses (€ha^{-1}) due to sooty mold damages caused by pear psylla activity. In order to determine the EIL, first average management costs, (e.g. labour (FTE), yields ($kgha^{-1}$), input factor costs (€ha^{-1})) and market values of agricultural production (€kg^{-1}) are analyzed for both scenarios. Next, by deriving the relationship between pear psylla densities and sooty mold damages based on data from a small scale field experiment in 2004, the loss in market value due to pear psylla activity is estimated for both scenarios. Finally, the results of the ecological model in which the contribution of natural predators to the biological pest control of pear psylla is quantified, is integrated with the loss in market value of agricultural production. In doing so, an indirect use value for the presence of natural predators, based on their functional role as biological control agents for pear psylla, is determined based on changes in market values due to pear psylla activity. A sensitivity analysis is performed to account for the uncertainty of ecological (e.g. predation rates and net growth rates) and economic (e.g. market value prices and input factor costs) model parameters.

The use of this approach allowed the researchers to address two pressing research needs: (i) to quantify the link between the loss of species and the provisioning of the ecosystem service biological pest control and (ii) to quantify the market value losses which can be attributed to the loss of those species. With this research, the aim is to contribute to the rising awareness on the importance of including the functional role of species when attempting to value non-marketable species and stress the need for the integration of full ecological and economic models in biodiversity conservation policy making.

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