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Monetary Valuation of Natural Predators for Biological Pest Control in Pear Production

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ABSTRACT

In spite of global actions, biodiversity is declining at an alarming rate. Despite the need for objectively comparable monetary standards to include biodiversity arguments in policymaking, research on the relationship between species diversity and its valuation from a societal perspective is still scarce.

In this paper, a methodological framework for the valuation of natural predators based on their ecological role in the agroecosystem is introduced. The framework integrates a dynamic ecological model simulating interactions between species with an economic model, thereby quantifying the effect of reduced numbers of natural predators on the net farm income. The model attributes an objective monetary value to increased species diversity through the changes in the provisioning of a marketable good.

Results indicate that the loss of three predators could decrease net farm income with 88.86 € ha^{-1} to 2186.5 € ha^{-1}. For the pear production sector in Flanders in 2011, this constitutes to an indirect use value of 0,68 million € for one predator and 16.63 million € for the presence of three predators. The aim is to provide a justification for the argument for biodiversity conservation, based on the ecological function of species, through the delivery of comparable monetary standards.

1. Introduction

In spite of global actions, biodiversity is declining at an alarming rate (Butchart et al., 2010). The transformation of natural landscapes to agricultural systems, the abandonment of farmland with high natural values, and the intensification and changing scale of agricultural operations are the key processes driving low ecosystem quality and biodiversity losses in agro-ecosystems (Liu et al., 2013; Reidsma et al., 2006; Smith et al., 2013). Available evidence strongly indicates the importance of agro-ecosystem restoration for environmental benefits and acknowledges the potential to simultaneously minimize biodiversity harm at the local level and increase farm yields (Barral et al., 2015; Cunningham et al., 2013).

Although measurements of biodiversity have often been investigated, analyses at the farm scale and specific studies providing insights into factors driving agro-ecosystem community structure are scarce (Birrer et al., 2014; Farnsworth et al., 2015; Turtureanu et al., 2014). Furthermore, habitat and increased numbers of natural predators facilitate the provisioning of important ecosystem services such as maintaining agricultural pest control, and may increase efficiency in controlling pests. However, the relationship between natural predators and pest reduction potential is not well established (Chaplin-Kramer et al., 2013; Letourneau et al., 2015). More specifically, the control of pests and diseases by biological control agents contributes positively to the provisioning of agricultural products of a better quality or in higher quantities, however the relationship between the presence of natural predators and pear production in particular has not been investigated yet. Mathematical models for biological pest control have proposed the use of linear feedback control strategies to indicate how natural enemies should be introduced into the environment (Rafikov and de Holanda Limeira, 2011).

Farmers are in need of supporting evidence of biodiversity benefits outweighing the opportunity costs incurred in order to strengthen the argument for biodiversity conservation at the farm level. Moreover, without economic valuation of the environment, policy decisions that contradict economic rationality could be supported. In spite of the need for objectively comparable monetary standards, empirical literature investigating the relationship between species diversity and its valuation from a farmer's perspective is still scarce (Finger and Buchmann, 2015). The elicitation of values for biodiversity with the aid of stated

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preference methods suffers from the generally low level of awareness and understanding of what biodiversity means on the part of the general public (Bräuer, 2003; Christie et al., 2006). Furthermore, the willingness-to-pay (WTP) for species that are unfamiliar or undesired by the general public could yield extremely low values despite the fact that these species could be performing indispensable ecological services and thereby contribute indirectly to the farmers' income. This, combined with the complexity of biodiversity (Feest et al., 2010), might just overstretch the capacity of the usual stated preference valuation techniques for the valuation of biodiversity (Bartkowski et al., 2015). Revealed preference techniques have the advantage that they rely on the observation of peoples' actions in markets. However, the majority of species do not have a market price. Letourneau et al. (2015) value the changes in natural enemy diversity by studying changes in producer and consumer surplus. They estimate that losses in natural enemy species richness in squash and cucumber fields in Georgia and South Carolina could cost society between \$1.5 and \$12 million in social surplus every year.

In this paper we provide a complementary approach and overcome some of the limitations mentioned by Letourneau et al. (2015) by (i) including an ecological model that allows for spatial and temporal variation in the ecosystem service potential of natural enemies, their interactions with pests and the effect of those interactions on pest control cost savings, (ii) providing an alternative approach when the relationship between natural enemies and crop damage is not known, as is true for the majority of cases, (iii) confirming the results of Letourneau et al. (2015) that values are case specific and providing these values for a different crop in a different climatic zone, with a different pest insect and natural enemies and (iv) including the comparison of realistic alternative scenarios of species richness and measure economically meaningful data in a field setting that comes close to the conditions that prevail on actual farms.

This paper values the biological pest control provided by three natural predators of pear psylla (*Cacopsylla pyri* L.) (*Homoptera*: *Psyllidae*) in organic pear orchards in Flanders (Belgium). Three main research hypotheses are investigated:

H_1. A decrease in natural predators' species richness causes a decrease in pest suppression.

H_2. A reduction in species richness of natural predators reduces marketable agricultural production, thereby decreasing farm revenues.

H_3. An alternative valuation method for natural predators based on their ecological function in the ecosystem can be identified.

The first hypothesis is quantified through the development of an ecological simulation model; the second hypothesis is supported by the use of production functions and a direct market valuation technique and the third hypothesis integrates all three research tools: an ecological simulation model with a production function approach and a direct market valuation technique.

The approach results in a monetary value for marginal changes of biodiversity losses (here: reduced number of natural predators) whereby the functional role of the species in the ecosystem (here: pest control) is the key mechanism for affecting the provisioning of a marketable good (here: agricultural production). The aim is to provide support for the decision making process so that not only the costs of biodiversity conservation can be taken into account but also the monetary benefits.

2. Case Study Description: Biological Pest Control of Pear Psylla

Apple and pear production in Flanders accounted for 13,764 ha in 2011 and increased to 14,285 ha in 2013, comprising 3% of all farmland. Since 2005, pear production comprised just over half the hectarage with 7607 ha in 2011 and 7995 ha in 2013. The province of Limburg accounts for 85% of the total apple and pear production in Flanders. In 2011, an average farm possessed 12,0 ha of pear plantations and 14,4 ha in 2013. Organic production accounts for only a small fraction but production areas increased by 224% over the period 2002–2012 from 25,09 ha to 58,07 ha. Average yields were 36,031 kg per ha in 2011 and 38,681 kg per ha in 2013, with a maximum of 44,751 kg per ha in 2014 (Van der Straeten, 2016). Yearly sales volumes of pears amounted to almost 340 million kg in 2014. Annual sales revenues ranged between 15,133 € ha^{-1} in 2011 and 20,114 € ha^{-1} in 2013 (Van der Straeten, 2016). Yearly average selling prices for the period 2009–2013 were 0.57 € kg^{-1} for first-class pears, 0.39 € kg^{-1} for second-class pears and 0.88 € kg^{-1} for organic pears (personal communication Regional Auction Borgloon). Assuming that annual sales volumes would consist of second class pears only, 55.68% of gross revenues would be lost since if harvests consisted of only second class pears and gross revenues would amount to 11,736 € ha^{-1} as compared to 26,481 € ha^{-1} for harvests consisting of only first class pears (Van der Straeten, 2016). The sector is characterized by a decrease in the number of farms and an increase in the average size. Sales volumes and revenues remain extremely volatile due to changing environmental and market conditions (Platteau et al., 2014).

A major threat for the pear production industry is pear psylla (*Cacopsylla pyri*). The adults cause damage both directly by extracting nutrients from the meristem tissue, and indirectly by causing russet and roughness on pear skin. Pear psylla's status as a major pest is based on its damage potential and its ability to develop resistance to insecticides. Through the production of honeydew, the growth of black, sooty fungi, causing so-called “black pears” is facilitated. It russets the pear skin and causes the fruit to be downgraded, thereby decreasing its market value (Erler, 2004). Literature quantifying the relationship between pest insect density levels and the occurrence of fruit russet is however scarce (Brouwer, 2008). Research revealed the failure of conventional chemical control agents against the pear tree psyllid, stressing the need for alternative strategies such as enhancing natural arthropod enemies (Daugherty et al., 2007; Erler, 2004; Rieux et al., 1999). Pear psylla are commonly attacked by several different natural enemies (e.g. *Anthocoris nemoralis* (*Heteroptera*: *Anthocoridae*), *Allothrombidium fuliginosum* (*Acari*: *Trombidiidae*) and *Heterotoma planicornis* (*Hemiptera*: *Miridae*)), of which *A. nemoralis* is the most common predator. Data collection is comprised of two independently executed field tests. The first field test comprises field data collected on 7 plots in organic *Conférence* pear orchards in Hesbaye (Belgium) for two years from 2013 until 2014. Each field test sampled pear psylla eggs and nymphs on multiple days with an interval of 2–3 weeks (See Annex A.1 for data sampling method and pooled results). The second dataset was obtained from field tests performed every two weeks for the period 2010–2011 on 7 different organic plots in Hageland (Belgium) and Gelderland and Limburg (NL). The same techniques were used to assess mean egg numbers and larvae numbers (visual scouting and the beating tray method) (see Annex A.3).

Counts for the presence of beneficial insects were performed between February and October of 2013 and 2014 in organic *conférence* pear orchards (see Annex A.2 for data sampling methods and pooled counts).

3. Methodology

3.1. Ecological Model Construction

The ecological model simulates predator-prey dynamics between the pest insect and three of its main natural enemies to analyze the effect on pear psylla (Pp) abundance in case of a reduction in species diversity and abundance of natural predators. The main criterion for selection of the natural enemies is the importance of a species as main pear psylla antagonist and has been verified through expert opinion and literature review. With the use of STELLA 10.0.6 (Stella; available