Extended Abstract
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Paper/Poster Title	**Optimization of apple production intensity in Flemish orchards for income, production and insect biodiversity under different agri-environmental policy scenarios in the land sharing versus land sparing continuum**

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Abstract	***200 words max***
Agri-environmental policies aspire to enhance biodiversity and ecosystem service provisioning, without compromising food production and income of those who manage the land. Whether this can be achieved by land sparing (intensive farming and conservation of natural areas), land sharing (extensive agriculture across the entire landscape), or an intermediate solution is subject to intense debate. In this study, policy scenarios encompassing different combinations of land sharing and sparing are evaluated on their potential to increase production, income and biodiversity in apple orchards for a Flemish study area with intensive agriculture and low environmental quality. Trade-off functions, based on sampling of bees, Heteroptera and estimation of yields in orchards and semi-natural grasslands, were applied to maximization models of production, income, number of species with population sizes at 90% of the maximum, inverse Simpson diversity and Shannon diversity. Results suggest that scenarios that include the Biodiversity Strategy target of 30% nature in the landscape have the highest potential to increase biodiversity indices, while at the same time achieving income gains in an optimal configuration of intensity in the set of orchards. Incorporating the Farm to Fork objective of 25% organic farming did not result in substantial gains in either economic or ecological indicators.	

Keywords	Land sharing versus land sparing; Trade-offs; Policy evaluation; Farm to Fork; Biodiversity Strategy; Apple orchards
JEL Code	Land Ownership and Tenure; Land Reform; Land Use; Irrigation; Agriculture and Environment Q15 Ecological Economics: Ecosystem Services; Biodiversity Conservation; Bioeconomics; Industrial Ecology Q57 Environmental Economics – Government Policy Q58 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***
Agriculture has been recognized as a driver of biodiversity loss for a long time. However, there is still a lively debate going on regarding how to solve the dilemma of producing enough food of high quality, generating a viable income for farmers and at the same time ensuring resilient ecosystems with high levels of biodiversity and	

ecosystem service provisioning. A key factor in this debate is the configuration of production intensities in the landscape, ranging between the two extremes of land sparing (i.e. concentrating production in a small area and conserving large stretches of natural areas) and land sharing (cultivating the entire landscape at low intensities). In many empirical assessments, land sparing is favoured over land sharing due to the specific convex trade-off functions of many species between production intensity (yields) and population density.

Recently, attention is shifting to more intermediate solutions between the two extremes, as not all species react similarly to yield increases. Some species do show concave trade-offs, favouring land sharing, but also more complex trade-offs are possible, requiring more nuanced solutions. The three-compartment model can be such a solution, with high, low and zero intensity of production in different areas of the landscape or more gradual plot-level intensity differences. This paper investigates the optimal distribution of production intensities in apple orchards of an intensively managed study area in Flanders. Additionally, we evaluated the impact of different policy scenarios on this distribution and subsequently on the potential to maximize biodiversity, production quantity and income generation.

Methodology	***100 – 250 words***

Flemish fruit production is concentrated in the study area, Hageland-Haspengouw, with intensive agriculture and low environmental quality. Bee and Heteroptera species and yields were sampled for 10 organic and 12 conventional apple orchards and 8 semi-natural grasslands. Average density (individuals/ha) was calculated for each species. Yield was approximated as apples/tree x average weight/apple x tree density (trees/ha) in the orchard. Species-specific best fitting trade-off curves were estimated, using the methodology of Simons and Weisser (2017), comparing model fit of linear, convex-concave, polynomial and hump-shaped functions. Species found in less than 4 parcels, without significant parameters or resulting in unlikely predictions were removed from the dataset.

Production intensity (yields) over all apple orchards (3917 orchards, 5632.24 ha) in the study area was optimized using the NSGA-II algorithm (*mco*-package, v.1.15.6) in R (v.4.1.0). Nine scenarios of hypothetical and official policies were applied to maximization models of five criteria: production, income, number of species at 90% of maximum population size, inverse Simpson diversity and Shannon diversity. Economic maximizations were constrained by obtaining at least estimated population sizes at current overall productivity (accounting for proportions of conventional and organic fruit farming) for each species. Ecological maximizations were constrained by the current overall income, based on proportional areas, fixed and variable costs, selling prices, subsidies for organic production and average yields for organic and conventional fruit farming. Optimal configurations were evaluated on production and income gains and Simpson and Shannon biodiversity indices. Lorenz curves and Gini indices indicate the degree of sparing or sharing.

Results	100 – 250 words

Out of a total of 94 bee species and 60 Heteroptera species, respectively 42 and 20 were found in more than 3 parcels. Good model fits were obtained for 35 bee species and 12 Heteroptera species. Yields ranged between 19.91 and 50.92 tonnes/ha for organic orchards and between 27.32 and 69.71 tonnes/ha in conventional orchards, which are values consistent with general productivity data.

Only the “100% conventional”, “Current (4.89% organic, 95.11% conventional)” and “Farm to Fork (25% organic, 75% conventional)” scenarios resulted in production gains, together with substantial income gains, but only when maximized for productivity or income. Biodiversity indices are lowest for these scenarios for all maximizations. All other scenarios (apart from the “Free allocation”) are unable to achieve current production levels. For all criteria maximizations, income gains are most substantial for the “100% organic” scenario, but under the strong and unrealistic assumption that prices for organic produce would remain high, although most other scenarios can also exceed current estimated income levels. Regardless of the maximization criterion, the scenarios that incorporate the Biodiversity Strategy target of 30% nature (=conversion of 34% of farmland in the case of Flanders) achieve highest values for the diversity indices, approaching current productivity when maximization occurs for Simpson and Shannon diversity and exceeding current income levels for all criteria maximizations. Land sharing scenarios, i.e. the “Farm to Fork” and “100% organic” (and in addition the “Current” and “100% conventional” scenarios) perform worst for both diversity indices in all criteria maximizations.

Discussion and Conclusion	100 – 250 words

Environmental quality needs to be improved in many intensive agricultural landscapes, but without compromising the production of food or the income of those that manage the land. Applying the sharing versus sparing framework on bee/Heteroptera – intensity trade-offs, optimal configurations of production intensity (using yield as a proxy) for maximization of economic (production and income) and ecological (richness and diversity indices) criteria were evaluated for nine scenarios of hypothetical and established policies.

Diversity indices were lowest for sharing and highest for sparing scenarios, regardless of maximization criterion. Combining the Biodiversity Strategy (sparing) with the Farm to Fork objective of 25% organic farming (sharing) did not generate substantial improvements for any indicator, apart from income (under the unrealistic assumption of stable and high prices for organic farming). When intensities can freely vary between zero and max production, optimal configurations show intensities across this entire range, although it tends to favour land sparing over land sharing, especially for larger parcels. For biodiversity indices, this scenario performs worse than land sparing scenarios, but better than land sharing configurations. Overall, the Biodiversity Strategy, resembling land sparing, has most potential for enhancing biodiversity, without compromising production and income in optimal configurations, whereas the Farm to Fork organic farming objective (25%) did not generate substantial benefits.

The analysis is based on a limited number of parcels and species, which can affect the findings. Another drawback is the neglect of the effects of surrounding habitats and spatial configuration, i.e. proximity and connectivity of intensive and extensive parcels.