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Integrating ecosystem services into risk management decisions: Case study with Spanish citrus and the insecticide chlorpyrifos

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HIGHLIGHTS

- First initiative to apply ecosystem service analysis to pesticide authorisation.
- We examine chlorpyrifos use in Valencian citrus orchards using four scenarios.
- Conservation areas offset potential impacts on insects, whilst maintaining yield.
- Holistic assessment avoids unanticipated and unintended consequences for society.
- Shows conflict between European marketing standards and pesticide legislation.

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ABSTRACT

The European regulatory system for the approval of pesticides includes a thorough evaluation of risks to the environment and is designed to be protective of ecosystems. However, a decision to ban an agrochemical could also potentially have a negative impact on the value of ecosystem services, if resulting changes in crop management are damaging to ecosystems or result in negative socio-economic impacts. To support regulatory decision-making, consideration of ecosystem services to identify best environmental management options could be a way forward. There is generally a growing trend for the consideration of ecosystem services in decision making. Ecosystems provide the conditions for growing food, regulate water and provide wildlife habitats; these, amongst others, are known as ecosystem services.

The objectives of this case study were to bring a holistic approach to decision making by valuing the environmental, social and economic benefits derived from the use of chlorpyrifos in Valencian citrus production. Spanish growers harvest between 5 and 6 million t of citrus annually, worth an estimated €5 to 7 billion in food markets throughout Europe. The approach highlighted the potential for unintended negative consequences of regulatory decisions if the full context is not considered. In this study, rather than a regulatory restriction, the best option was the continued use of chlorpyrifos together with vegetated conservation patches as refuges for non-target insects. The conservation patches offset potential insecticidal impacts to insects whilst maintaining citrus production, farm income and the amenity value of the citrus landscape of Valencia. This was an initial proof-of-concept study and illustrates the importance of a wider perspective; other cases may have different outcomes depending on policies, the pesticide, crop scenarios, farm economics and the region.

1. Introduction

Ecosystems provide resources upon which health and well-being depend, including conditions for growing food, purify water, prevent soil erosion and maintain soil fertility, provide habitats for species and provide places for us to walk and play; these benefits are known as ecosystem services (ESs). The concept is defined in international initiatives, such as the Millennium Ecosystem Assessment (MEA, 2005) and more recently The Economics of Ecosystems and Biodiversity (TEEB, 2010).

In its opinion on agriculture and rural development, the European Parliament's Committee on the Environment, Public Health and Food Safety (2012) stated that over half of Europe's territory is managed by

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farmers, that farmland delivers important ecosystem services and that it has considerable socio-economic value. However, it also considers that the market currently fails to take into account the economic value of ecosystem services and reward those that properly manage the land to provide them. In particular, the opinion highlights permanent crops in Mediterranean countries, such as olive groves, vineyards and orchards as agricultural systems with high ecological and conservation value.

The EU regulatory system for the approval of pesticides (Regulation 1107/2009 EC) includes a thorough evaluation of risks to the environment and is designed to be protective of ecosystems (European Union, 2009). However, a decision to ban an agrochemical could also potentially have a negative impact on ecosystem services, if resulting changes in crop management are damaging to ecosystems or result in negative socio-economic impacts. To support regulatory decision making, consideration of ES to identify best environmental management options could provide a way forward (Defra, 2007; European Commission, 2011a; European Union, 2011b). There is generally a growing trend for the consideration of ES in decision making, though it has not yet been used in pesticide regulation. For example, the ES paradigm is embedded in the European Environmental Liability Directive (2004/35/EC) (COM, 2004) and socio-economic analysis is a decision-making tool in the European Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation 1907/2006 (European Commission, 2006).

Generally, ES studies globally have focused on natural ecosystems, such as wetlands, whereas managed or engineered systems such as farmland tend to be optimised for one service — the provision of food or fibre. Several studies have attempted to evaluate ecosystem services provided by agricultural landscapes, such as the UK National Ecosystem Assessment (2011), Power (2012), and Wratten et al. (2013). Whilst these studies provide contextual information to inform land use policies at a landscape, regional or national scale, they are not readily applicable to specific pesticide management.

The objectives of this case study were to bring a holistic approach to decision making by valuing the environmental, social and economic benefits derived from the use of chlorpyrifos in Valencian citrus production. This was an initial proof-of-concept to determine whether an ES approach could be integrated into pesticide regulation, specifically risk management decision making, by examining potential changes to ES before a decision is made to restrict a product, to ensure an optimum overall outcome for society. The case study was funded by chlorpyrifos manufacturers.

2. Context for the case study

Spain is the largest fresh citrus exporter in the European Union (EU), with the Valencia region accounting for 65% of Spain's production. Fresh fruit for sale (Classes 1 and 2) must be "practically free from pests" according to European Marketing Standards Regulation ((EU) No 543/2011) and consumer preference expects unblemished fruit. Valencian citrus fruit outside these classes is mostly used for juicing, for which the grower receives marginal income, if any, because the crop value is only sufficient to cover the cost of harvesting — in effect a crop failure. Hence, citrus cultivation is only profitable when fruit is free from pests and skin blemishes are reduced. Such standards and consumer preference for high quality fruit necessitate pest control with insecticidal sprays. Other regions of Spain cultivate citrus under different management regimes and grow varieties specifically for juicing.

A major insect pest responsible for damage to citrus fruit is the California red scale (*Aonidiella aurantii*). The insecticide chlorpyrifos has been the foundation of red scale management in Spain for several decades. This highly effective active ingredient is fast-acting, giving pest 'knock-down'. There is no alternative to chlorpyrifos with this activity profile and retaining this mode of action is also important for managing pest resistance. Typically, chlorpyrifos is applied together with the insect growth regulator pyriproxifen. The total citrus area in Spain is around 300,000 hectares (ha) and chlorpyrifos is applied to most of this area every year (FAOSTAT). Typically, Valencian citrus landscapes include areas of semi-natural vegetation, which for the purposes of this study are considered to be vegetated conservation patches ("conservation patches"), although currently these are not managed for wildlife. There are few natural enemies of the red scale in Spanish citrus orchards. Introduced biological controls, such as parasitism, have been trialled but further research is needed to understand environmental influences and commercial viability (IOBC, 2011).

Culturally and historically, citrus and Spain are inextricably linked. As a crop from East Asian tropical climates, drip irrigation is necessary for growing citrus in the dry Spanish climate. The trees die without irrigation, but profitability is a prerequisite for investment in watering systems. Competition from cheap imports from North Africa has pushed down citrus prices, with growers typically receiving around €0.22/kg for Classes 1 and 2 fruit compared with a retail sale price in the order of €2/kg. When prices drop below €0.17/kg, growers cannot cover expenses and rely on government subsidies (Lladro, 2010; MARM, 2009). Many growers have already gone out of business, irrigation has been switched off and orchards abandoned, with inevitable consequences for the orchard habitat.

Chlorpyrifos is registered under European Union (EU) pesticide legislation (91/414/EC (European Commission, 1991); now replaced by Regulation 1107/2009/EC). Being one of the few widely-used organophosphate insecticides, it attracts the attention of regulators and policy makers, yet growers rely on chlorpyrifos for producing saleable fruit. A key regulatory concern is the potential impact to non-target insects. Future decisions made by regulators on the use of this chemical, if negative, could impact availability of Spanish oranges for EU consumers, have consequences for Spain's citrus growers and agro-economy, and compromise Europe's ability to meet consumer demand for high quality citrus without increasingly turning to imports from outside the EU.

3. Methodology

The approach was consistent with existing frameworks and guidance, such as the Millennium Ecosystem Assessment (MEA, 2005), International Finance Corporation Performance Standard 6 (World Bank, 2012) and more recently The Economics of Ecosystems and Biodiversity (TEEB, 2010). Our approach was a step-wise process to prioritising ES, valuation of ES potentially affected by chlorpyrifos use and evaluation of management options; in this case, options that provide a net environmental benefit whilst managing risks and costs (Efroymson et al., 2004). The approach was an enhancement of the existing European Food Safety Authority framework for specific protection goals (EFSA, 2010). A suggested mechanism for the integration of ES analysis into pesticide regulation is provided in Fig. 1.

3.1. Net ecosystem service framework

A proof-of-concept framework (net ecosystem service analysis or NESA (Nicolette et al., 2013)) was developed to assess the priority services, which for valuation purposes were considered as follows:

- Regulating and provisioning ecosystem services represented by indicators for ground and surface water quality and water provision, soil formation and fertility, soil erosion prevention, and carbon sequestration.
- Habitat services represented by indicator species within and immediately surrounding the orchards.
- Food provision (citrus production) represented by farm income.
- Cultural services represented by landscape values.

These services were selected following an initial screening process adapted from the IFC Performance Standard 6 (World Bank, 2012). Screening criteria considered the presence of a service in the citrus