ECOSYSTEM SERVICES IN PESTICIDE RISK MANAGEMENT: A PERSPECTIVE FOR DECISION MAKING

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INTRODUCTION

Over the last 40 years, farmers in the Valencia Region of Spain have relied on chlorpyrifos as an important component of pest control to limit the occurrence of blemishes on the surface of citrus fruit caused by red scale (*Aonidiella aurantii*), the prevalent pest in citrus orchards. Chlorpyrifos is an organophosphate insecticide that has proven effective, with a contribution from piriproxyfen (insect growth regulator), for controlling red scale in citrus orchards. Citrus are graded for sale based on their size, shape and lack of skin blemishes under the European Marketing Standards Regulations (EC/1221/2008); farmers only make a profit when unblemished fruit is sold in Europe.

Citrus fruit with red scale insects and skin blemishes

Spain is a leading producer and exporter of citrus with nearly 6.5 million tonnes produced by the European Union in 2007/08 (Guerrero *et al*, 2009), equivalent to approximately 23% of the world export market share (FAOSTAT, 2011). Commercial citrus farming is particularly important to Valencia, the largest citrus producing region in Spain, producing up to 65% of annual production.

Ecosystem services (ESS) principles and cost-benefit analysis are strictly governed by European legislation such as the Environmental Liability Directive (2004/35/EC) with valuation methods developed for more than 20 years in the United States to deal with legacy contamination. These methods have informed recent European initiatives on environmental liability, biodiversity offsetting, strategic planning and product registration. The European Food Safety Authority (EFSA) has now decided to use ESS principles when setting protection goals of ecological risk assessments for plant protection products (EFSA, 2010). Picking up on this trend, ENVIRON conducted an analysis of the effects on ESS (including socio-economics) of using chlorpyrifos in citrus orchards in order to identify risk management actions and understand the consequences of a hypothetical situation of the discontinued use of chlorpyrifos. The study brings a holistic approach to environmental decision making and demonstrates policy options to the regulators responsible for product registration.

METHODOLOGY

A quantitative approach was advanced in this study for evaluating changes in ESS associated with the use of chlorpyrifos in citrus production. Initially a proof of concept framework net ecosystem services analysis (NESA), was developed to conceptualise the range of potential ESS uses, management actions and habitat types typically found in Valencian commercial citrus orchards. Based on a field ecology study of birds (Wolf *et al*, 2010) and a field visit, three orchards were chosen as a representative sample for the region with varying topography, a range of surrounding land uses and a wide variety of species including 53 bird species. The NESA framework was applied to the representative combined orchards, with a total combined area of 26ha, to evaluate the potential effects on ESS in the context of two scenarios.

Case Study Scenarios

Scenario 1 (baseline condition) represents the present day conditions and management of the orchards. Sub scenarios considered potential impacts on ESS if mineral oil replaced chlorpyrifos in the farmer's pest control strategy (1A) or vegetated conservation areas were used (1B) to offset the potential influence of chlorpyrifos (which is mainly on arthropods). Vegetated areas provide refuges for arthropods, seeds and other food items, shelter, foraging and nesting habitats.

Scenario 2 is hypothetical and assesses the potential ESS changes should chlorpyrifos become unavailable to growers. This includes partial abandonment of orchards due to operations becoming economically unviable. Using publicly available economic data 30% of commercial orchards is conservatively estimated to be abandoned over a 50 year period (assuming a constant 1.4% decrease in available orchards over 25 years and remaining constant thereafter). It is assumed that irrigation and other management activities will cease, the citrus trees will die within a season and the land initially returns to a ruderal (weedy) habitat with succession to native Mediterranean scrub over the 50 year time span.

Scenario 1 (Baseline)	Scenario 1A	Scenario 1B	Scenario 2
Current agricultural practicesand orchard extent; chlorpyrifos is used in pest control	Current agricultural practicesand orchard extent; except mineral oil used instead of chlorpyrifos	Current agricultural practices and orchard extent; chlorpyrifos is used in pest control, plus10m vegetated conservation buffer	Hypothetical scenario. Chlorpyrifos is no longer available to growers; 30% abandonment of orchard extent

The results provided by comparisons of these scenarios are extrapolated over time to assess time accumulated service flows over a 50 year period and supported through biological modelling.

NESA Framework

An overview of the NESA approach is provided in Figure 1 below.

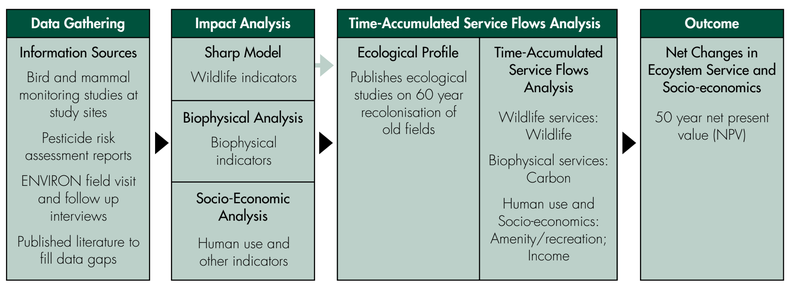


Figure 1. Overview of the NESA approach

The approach required the collection of environmental data describing land cover, spatial coverage, species presence, life history profiles, soil and water conditions and the management practices of farmers at citrus orchards. The framework allows the user to integrate, organise, analyse and communicate wildlife, biophysical and socio-economic data in transparent manner; a summary of indicators studied is provided below (Figure 2):

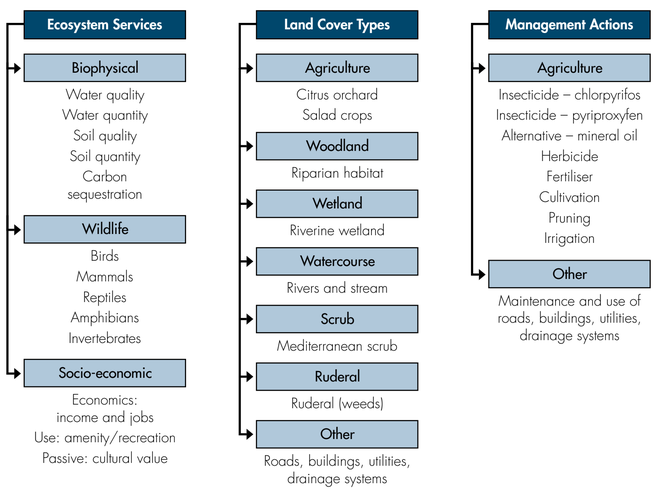


Figure 2: Overview of the three main data categories and sub-categories required for this first NESA approach

Photo taken during the field visit showing recreational use of the citrus orchards

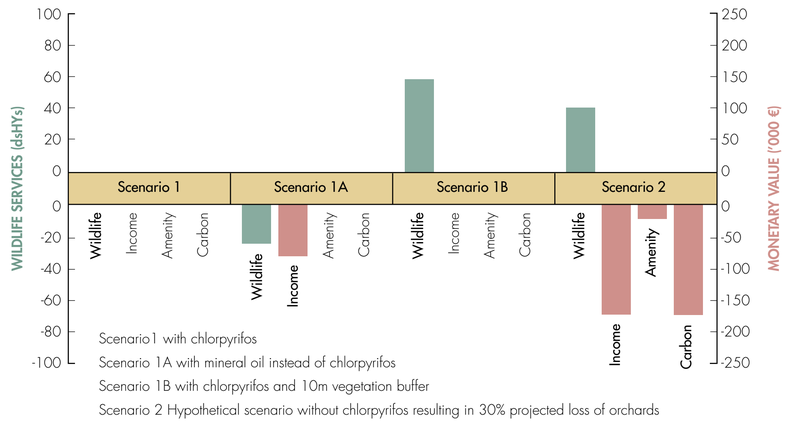


Figure 7: Summary of net changes in ESS associated with the use and hypothetical discontinuation of chlorpyrifos in citrus production in the Valencia Region, Spain

RESULTS

Biophysical Indicators

Losses or gains in the biophysical environment occur when a proportion of the citrus orchards are abandoned under scenario 2 due to commercial pressure on growers following the hypothetical discontinued use of chlorpyrifos. The greatest change is to carbon sequestration when citrus trees die due to the cessation of irrigation in the abandoned orchards; the formerly high above ground biomass of citrus trees reverts to ruderal vegetation (low sequestration potential) following the abandonment of 30% of citrus orchards (Figure 3).

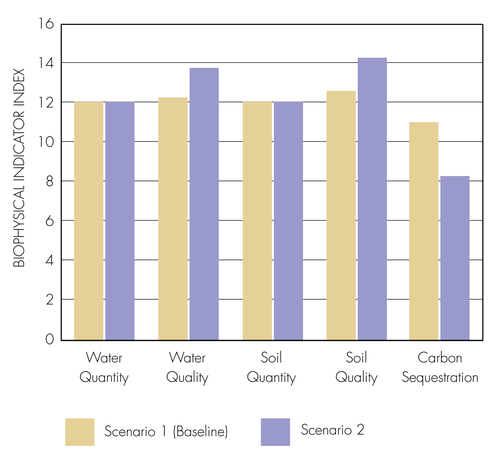


Figure 3. Biophysical indicators comparing relative contribution to ESS between Scenario 1 (chlorpyrifos use) and Scenario 2 (hypothetical discontinued use of chlorpyrifos)

Wildlife Indicators

Following the change in habitat under scenario 2 when 30% of orchards are abandoned due to commercial pressure small changes are seen in the potentially suitable habitat (PSH) for birds and mammals. Invertebrates and, to a lesser extent, insectivores such as the reptile, benefit from the change in orchard habitat to ruderal vegetation and the corresponding reduction in management. Figure 4 provides a comparison of PSH for scenarios 1 and 2 by focal species, life stages and land cover (habitat).

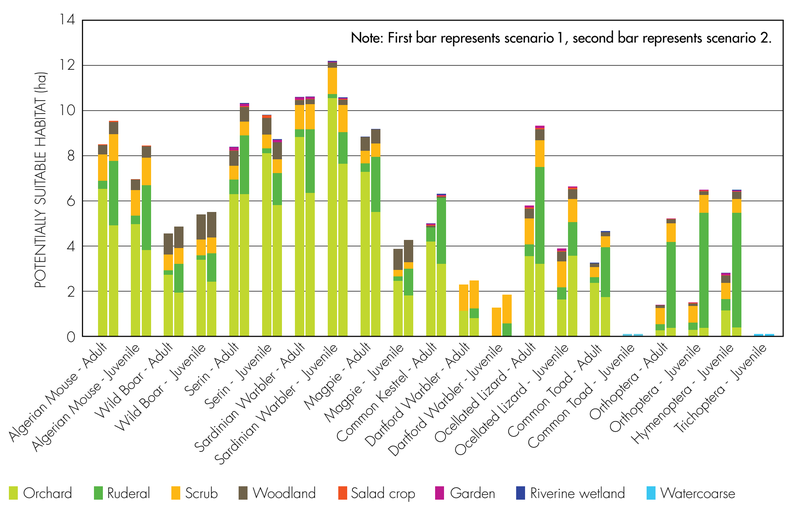
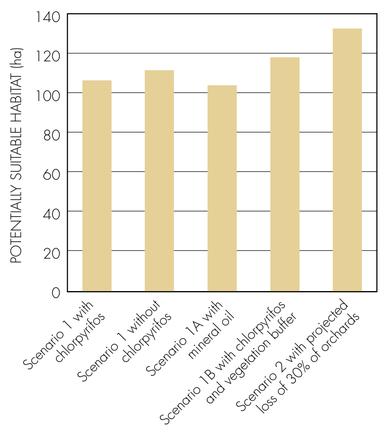


Figure 4. The gain or potentially suitable habitat (PSH), by species, habitat and scenario

Figure 5 provides an insight into policy options for decision makers when only wildlife indicators are considered under present day conditions (scenario 1). The equivalent of up to 5% of combined potentially suitable habitat is influenced by chlorpyrifos under scenario 1 (Figure 5; comparison of 1st and 2nd bars). If chlorpyrifos is unavailable to growers and a less efficacious insecticide such as mineral oil, is used then there is little change in combined PSH (scenario 1A). When a vegetated conservation area is applied to present day conditions there is an increase in combined PSH for the wildlife indicators (scenario 1B). For the purposes of this proof-of-concept study, the vegetated conservation area was wrapped around each orchard, but it may also be located in crop or may be fragmented. Under the hypothetical scenario 2, the PSH is greatest due to the change in land use and cessation of agricultural management in the abandoned orchards.



Note: The second bar is not a scenario *per se* because it is unviable not to control red scale insects; the bar illustrates the influence of chlorpyrifos on combined PSH.

Figure 5. Total species and life stages combined PSH values, for all scenarios

Socio-Economic Indicators

Based on economic forecasts using published literature, income, amenity value and jobs all decrease under scenario 2 at the combined representative orchard.

Time Accumulated Service Flows

The results were extended to provide a temporal profile of changes in wildlife, carbon, amenity and income over a 50 year period to provide decision makers with potential policy options for future generations. A habitat equivalency analysis was undertaken to estimate time accumulated service flows in line with US valuation guidance (such as NOAA, DOI). A comparison of the valuation over 50 years with a 3% discount rate is provided in Figure 7.

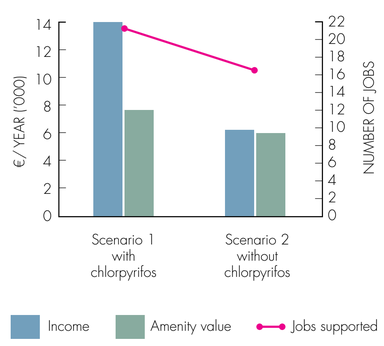


Figure 6. Socio-economic indicator results for the representative orchard

KEY FINDINGS

The key findings from the ESS study indicated that:

- Chlorpyrifos appears to have a slightly negative influence on combined wildlife services of between 1 and 5% (mainly attributable to effects on insects). Field studies suggest there are no observable direct long-term effects to vertebrate wildlife from chlorpyrifos (Wolf et al, 2010).
- The use of mineral oil results in a larger potential loss of wildlife services than chlorpyrifos use and may result in significant loss of income (scenario 1A).
- The gain in wildlife services associated with risk mitigation activities such as an area of vegetated conservation buffer has the capacity to more than outweigh any potential effects of chlorpyrifos (scenario 1B). As an example, an area equivalent to a 5m buffer or less is likely to more than offset any potential chlorpyrifos effects.
- The vegetated buffer is an area of Mediterranean plants (eg Maquis habitat) managed for conservation purposes. The benefits are its proximity to the crop to provide a refuge for arthropods, food sources for seed-eating birds and mammals and as a habitat for foraging, shelter and nesting (especially for the Sardinian warbler which prefers bushes for nesting).
- If chlorpyrifos was to become unavailable to Spanish citrus farmers the magnitude of potential socio-economic service losses appear to be extremely significant with a marginal potential wildlife service gain when compared to current baseline conditions.
- Based on this study the continued use of chlorpyrifos with changes to orchard management provides the greatest net benefits when compared to other alternatives.

FUTURE DIRECTIONS

- **Scaling to regional level:** Scaling tools are publicly available, allowing for site-specific results to be scaled to regional level.
- **Building on these foundations:** The ESS concept is relatively new and the underpinning science, methods and integration into regulations, policies and technical guidance is still evolving. There is value in further evaluating the synergies with approaches in other legislative spheres such as damage assessment.
- **Communicating results to stakeholders:** This first analysis of ESS and socio-economics of chlorpyrifos in commercial citrus orchards provides a basis for discussion with national regulatory agencies, European Commission, growers associations and other stakeholders.
- **Supporting decision-making on risk mitigation:** The case study provides a basis for making evidence based decisions on multiple stressors and taking a holistic perspective of influences on the environment, social values and economics. It could be used to engage in open dialogue on how valuation should and could be incorporated more formally into pesticide risk assessment and management decisions.
- **Applying framework to new pesticide/crop combinations:** This is a first analysis of one pesticide/crop combination and its foundations can be built upon to address other crop/pesticide combinations.

Photos taken during the field visit displaying a commercial citrus orchard (left) and an abandoned orchard (right)

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