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Plant & Food **RESEARCH**
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Estimating pesticide emissions for the product-related pesticide footprint of kiwifruits in New Zealand

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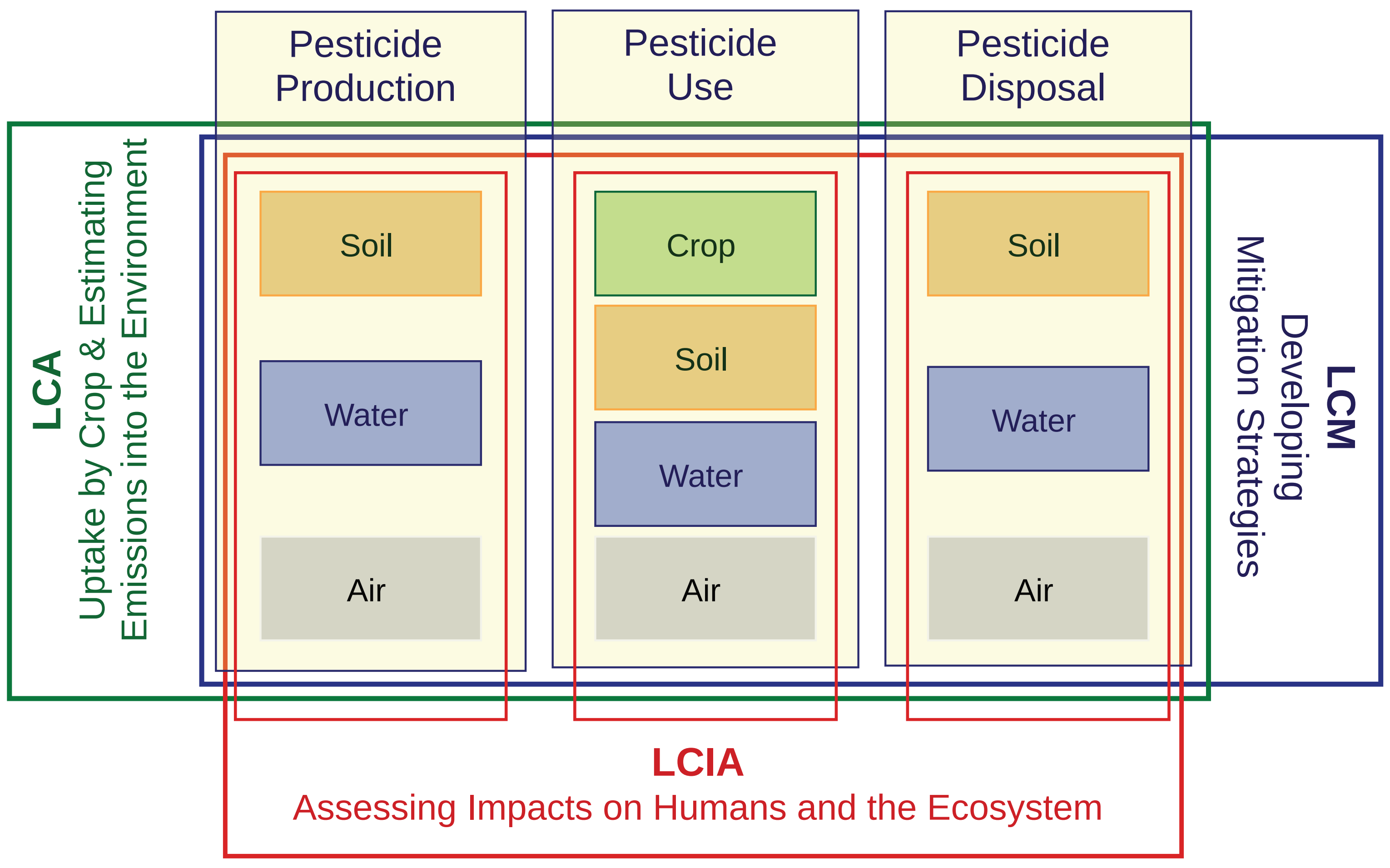
Background

Retailers and consumers demand scientifically rigorous verification of the environmental impact of products. For example, carbon and water footprints quantify the impact of products on climate change and water scarcity and quality. We have developed a new measure, the pesticide footprint (PFP).[1] The PFP is defined as the total loss of pesticides to the environment, and their respective impact on humans and ecosystems. PFP is associated with the pesticides used to produce a unit of a product, such as 1 kg of kiwifruit. The concept of the PFP comprises three stages (LCA, LCIA, LCM). Within each of the stages, the environmental compartments of soil, water and air are considered (Fig. 1).



Pesticide Production
Pesticide Use
Pesticide Disposal

LCA
Uptake by Crop & Estimating Emissions into the Environment

Soil
Water
Air

Crop
Soil
Water
Air

Soil
Water
Air

LCM
Developing Mitigation Strategies

LCIA
Assessing Impacts on Humans and the Ecosystem

Figure 1: Concept of the product-related pesticide footprint.

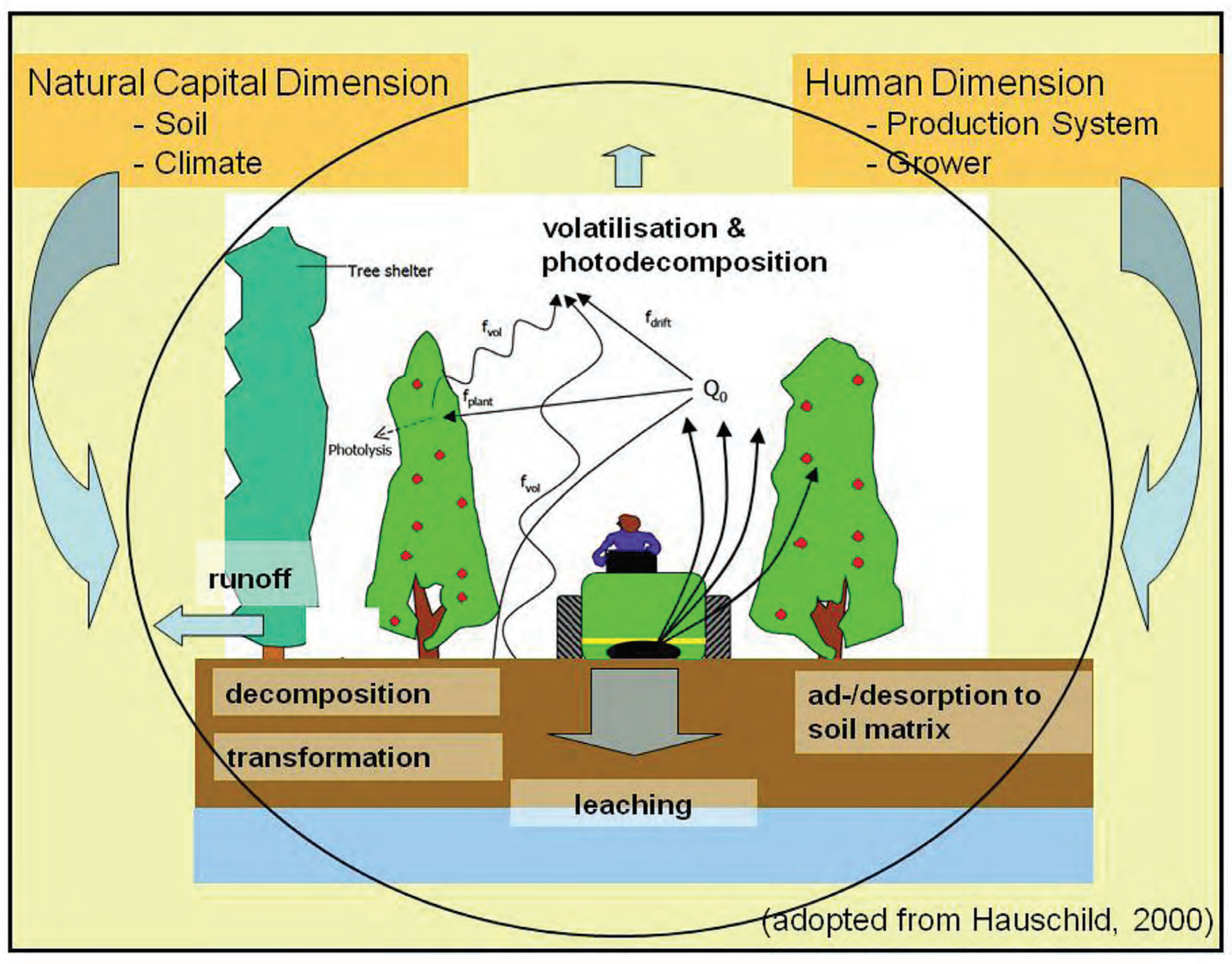
Objective

To calculate and illustrate the climate and soil specificity of pesticide losses to the different environmental compartments for the orchard phase of kiwifruit production in New Zealand (NZ). This is the first step of assessing the PFP for NZ kiwifruit.

Methods

We considered 39 kiwifruit orchards from the four regions in NZ that produced 85% of the national harvest in the 2009/10 season, and derived four region-specific spray plans. The losses of applied active ingredient to soil, water and air in each orchard were modelled with Plant & Food Research's Soil-Plant-Atmosphere-Model I (SPASMO).[2] The processes considered in SPASMO-modelling are summarised in Fig. 2. The modelling considered:

- Four pesticides covering a range of physico-chemical properties: iprodione (fungicide), glyphosate (herbicide), thiacloprid (insecticide), thiamethoxam (insecticide)
- Regional 38-year climate data records (Katikati, Te Puke, Tauranga, Waihi)
- Texture, soil organic carbon (SOC) contents and bulk density measured to 1 m depth in each of the orchards, combined with data from the soil series.



(adopted from Hauschild, 2000)

Figure 2: Processes considered for the modelling of pesticide emissions for the in-orchard LCA-stage of the pesticide footprint using SPASMO.

Results

Only a small fraction of the applied pesticides, ranging from 0 to 0.26%, was lost to the groundwater (i.e. leached below 1 m depth). The fungicide thiacloprid was not leached below 1 m at all, which can be explained by its low persistence in soils (DT50 = 18 d) and the low application rate of 19 g/ha. The fraction of pesticides resident in the soil profile down to 1 m depth ranged between 0.48 and 2.5% of the applied amounts. The highest fractions were observed for thiamethoxam, which has a half-life of 39 days. Between 0.2 and 12% of the applied pesticides was lost via runoff (Fig. 3).

- The variability in losses to groundwater, surface water and soil across the four regions was very high. Regional climate and soil properties were significant factors, and need to be considered for large-scale pesticide footprints.
- The losses of all four pesticides to groundwater, surface water and soil were significantly influenced by climate ($P < 0.05$).
- The clay and SOC contents to 1 m depth determined the fate of most pesticides in soil.
  - The clay and SOC contents explained 41 and 48% of the glyphosate degradation and runoff, respectively, and 34% of the thiamethoxam losses to groundwater (Fig. 4).
  - The average concentration (=50% probability of exceedance) of glyphosate in the soil at a depth of 1 m varied between 0.4 and 1.6 ng/kg among the regions.

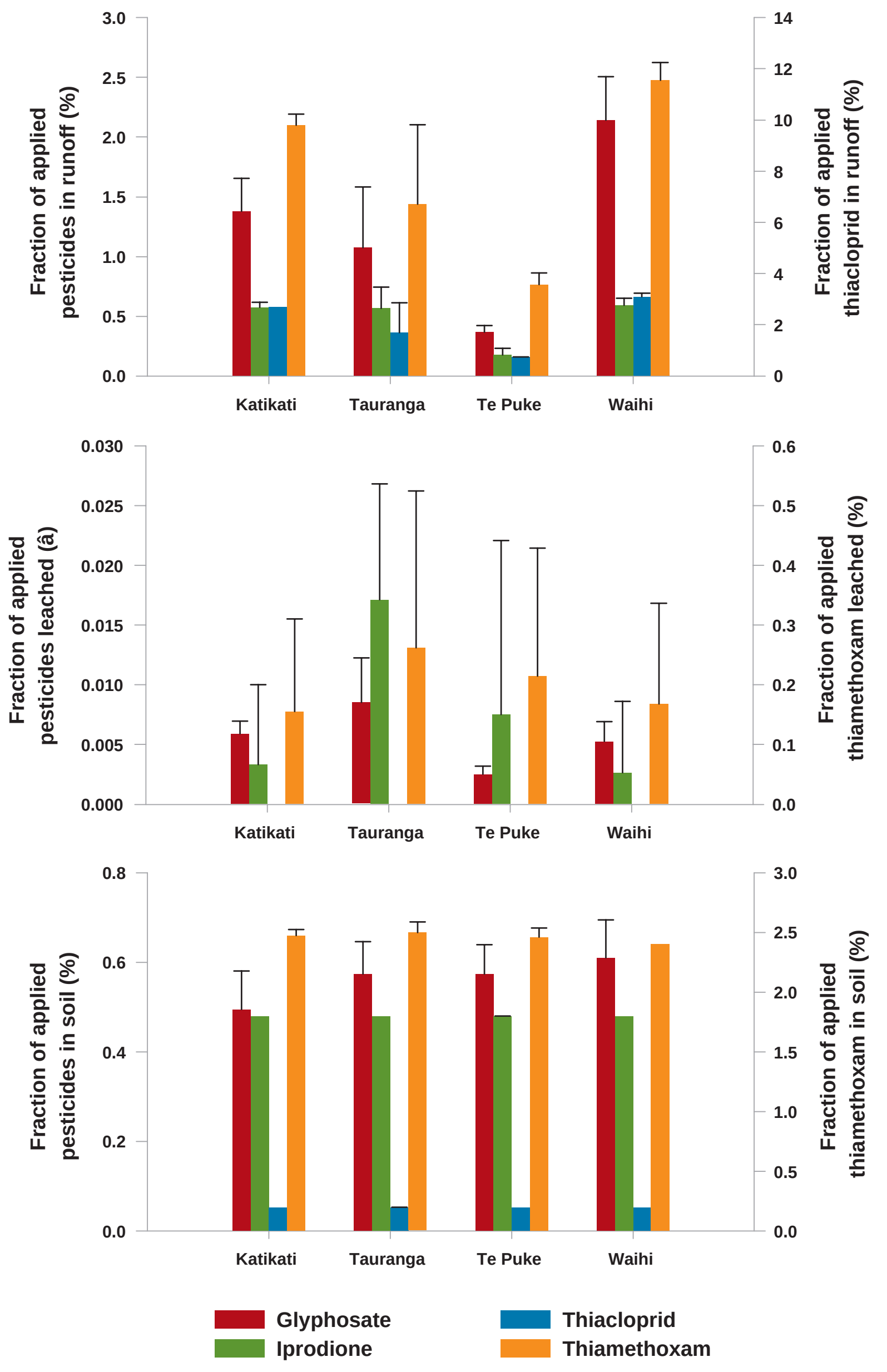


Figure 3: Fractions of the applied pesticides in (top) runoff (i.e. emissions to surface water), (middle) leachate below 1 m depth (i.e. emissions to groundwater), and (bottom) resident in the soil profile (0–1 m depth; i.e. emissions to soil) in the four kiwifruit growing regions.

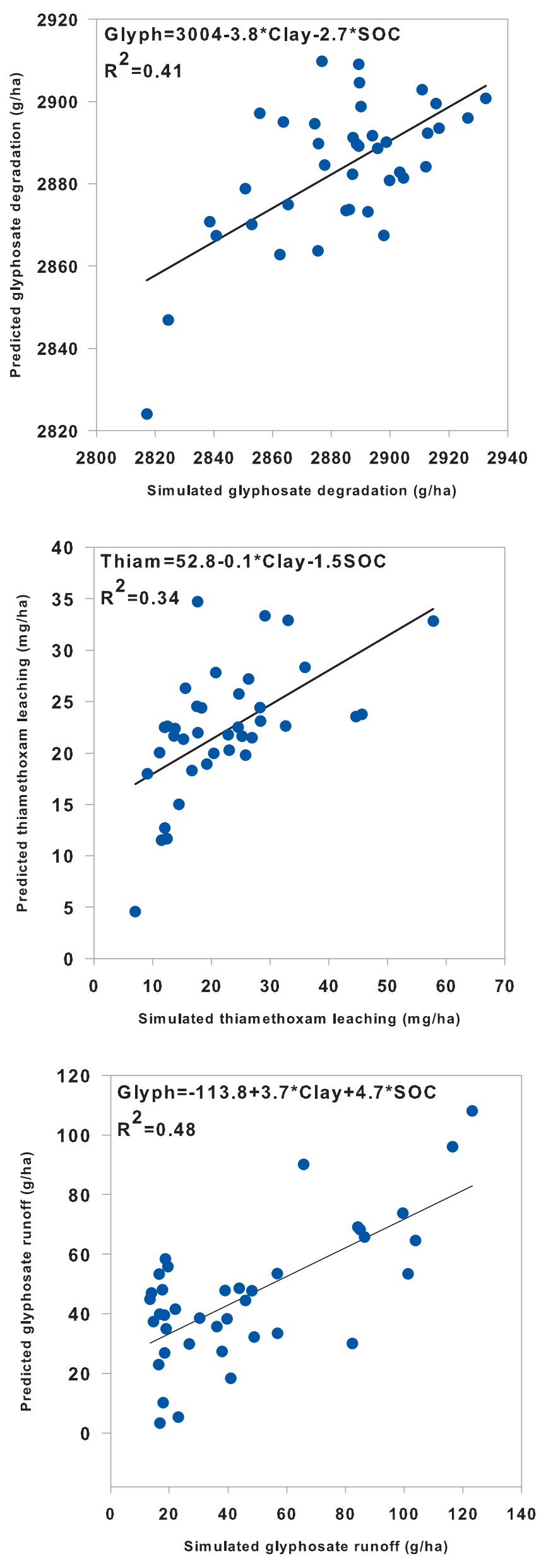


Figure 4: Comparison of simulated (mechanistic model SPASMO) and predicted (Multiple regression with only clay contents [%] and SOC stocks in 0-1 m [kg/m2] as explanatory variables) glyphosate degradation (left), thiamethoxam leaching (middle), and glyphosate runoff (right) for 39 kiwifruit orchards located in four regions.

Conclusions

- The results highlight the importance of using specific soil and climate data for pesticide fate modelling, which is not current practice in LCIA.
- SPASMO needs to be further modified to represent pesticide losses to air mechanistically.
- In the next step, the ecotoxicological impact of the losses will be interpreted using, for example, USEtox,[3] and then the impact will be related to a unit of kiwifruit product.

References

1. Müller K, Deurer M, Northcott G, Clothier BE 2010. Concept for assessing a product-related pesticide footprint. New Zealand Plant Protection 63: 39-46.
2. Sarmah AJ, Close ME, Pang L, Lee R, Green SR 2005. Field study of pesticide leching in a Himatangi sand (Manawatu) and a Kiripaka bouldery clay loam (Northland). 2. Simulation using LEACHM, HYDRUS-1D, GLEAMS, and SPASMO models. Australian Journal of Soil Research 43: 471-489.
3. Rosenbaum R, Bachmann T, Gold L, Huijbregts M, Jolliet O, Juraske R, Koehler A, Larsen H, MacLeod M, Margni M and others 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. The International Journal of Life Cycle Assessment 13(7): 532-546.