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Eco-efficiency as a sustainability measure for kiwifruit production in New Zealand

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ABSTRACT

Assessing the sustainability of orchards focuses on quantifying environmental impacts and resource consumption. Sustainable orchards also have to be profitable and socially responsible. We aimed to identify sustainable kiwifruit production in the Bay of Plenty, New Zealand, by considering orchards' environmental and economic performance. We conducted a survey of 40 orchards with different cultivars (*Actinidia deliciosa* 'Hayward' (green) v. *Actinidia chinensis* 'Hort16A' (gold)) and management (integrated v. BioGro certified organic). Assessment of environmental performance was restricted to greenhouse gas emissions (carbon footprint of the orchard phase). We defined eco-efficiency on an area basis as NZD net profit per kg greenhouse gas emissions (1 NZD = 0.83 USD, 31/10/2013). Carbon footprints for the cultivars and management systems were comparable. The choice of functional unit, namely land area and 1 kg of produce, did not affect the result. Our analysis revealed fertilizer use and the N-associated emissions as hot spots for greenhouse gas emissions. Opportunities to reduce greenhouse gas emissions arise in the background system of fertilizer production, packaging, storage and transport, and the optimization of nutrient-use efficiency in the orchard. The integrated system had insignificantly higher greenhouse gas emissions than the organic system. Taking into account the profitability of the orchards, the eco-efficiency of organic orchards was significantly higher than that of integrated orchards. We demonstrated that the metric of eco-efficiency can enhance product differentiation for customers and can also assist orchardists to find the most sustainable management system. However, the volatility of commodity markets and changing consumer preferences remain challenges.

1. Introduction

Assessing the sustainability of orchard systems generally focuses on quantifying environmental impacts such as nutrient, pesticide, and sediment losses to aquatic ecosystems, greenhouse gas emissions to the atmosphere, resource consumption including water and energy use, and fertilizer input. The recent evaluation of the water footprint of New Zealand kiwifruit production (Deurer et al., 2011), or the life cycle assessment of New Zealand apple production (Mila i Canals et al., 2006) are examples. However, sustainability evaluations of orchards need to be extended beyond simply environmental impacts. Sustainable orchards also have to be profitable and socially responsible in the longer term.

Eco-efficiency is an improved measure of sustainability because it links environmental impacts directly with some kind of economic performance. The concept of eco-efficiency was first introduced by Schaltegger and Sturm (1989). It encompasses the idea of 'creating more value with less impact' (Lehni, 2000). Other authors reversed the ratio, and reported the economic value-added per unit of environmental impact as eco-efficiency (e.g., Meul et al., 2007a). There are no agreed-upon methods and tools for calculating eco-efficiency (Huppes and Ishikawa, 2005). This implies that eco-efficiency claims for products and services need to be critically assessed (Ehrenfeld, 2005). Environmental impacts for eco-efficiency calculations usually include energy use, resource use, water use, greenhouse gas (GHG) emissions and ozone-depleting emissions (Verfaillie and Bidwell, 2000). The concept of eco-efficiency has so far been mainly used by industrial businesses to support economic decisions such as assessing acquisitions and

Abbreviations: GHG, greenhouse gas.

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changes in product lines, as well as to create new market opportunities by demonstrating stewardship for natural resources (Saling et al., 2002). It can also be applied to decision-making problems in agriculture, for example, in relation to irrigation and crop protection management decisions (de Jonge, 2004; Meul et al., 2007a, 2007b; Wießner et al., 2010). Applications, challenges and opportunities of the general concept to agricultural production systems have recently been reviewed by Keating et al. (2010).

Kiwifruit is the fruit of a perennial woody vine and is of considerable importance for New Zealand's economy. New Zealand developed the first commercially viable kiwifruit in 1937, and nowadays the country is amongst the leading kiwifruit producing countries worldwide. Kiwifruit production totalled about 1,412,351 MT in 2012 with Italy and New Zealand producing together about 54% of this total (http://faostat.fao.org/site/339/default.aspx). Kiwifruit is one of New Zealand's highest earning horticultural exports. Export earnings for New Zealand grown kiwifruit were $1.122 billion over the 2011-12 year. The largest population of kiwifruit worldwide is the *Actinidia deliciosa* cultivar Hayward, a green-fleshed fruit. In New Zealand, 9336 ha of *A. deliciosa* Hayward is under integrated management, and 576 ha grown according to BIO-GRO organic standards. For *Actinidia chinensis* Hort16A, a gold-fleshed fruit, the areas total 2590 ha (Zespri Group Limited Annual Review, 2012; http://www.zespri.com/about-zespri/zespri-investors/investor-publications.html).

Management practices designed for carbon storage in kiwifruit orchards, and other perennial tree crops, are potential tools for New Zealand growers to mitigate and adapt to the consequences of climate change. In particular, growers in existing growing regions will need to be more resilient to climate related impacts associated with warmer temperatures, scarcer water resources and a greater risk of extreme storm events. National and international initiatives to reduce rising atmospheric concentrations of greenhouse gases include encouraging growers and other value chain stakeholders to reduce the GHG emissions associated with the production of their products and services. Changes in management methods could enable growers to meet eco-verification market demands for products with a low carbon footprint, and potentially exploit the emerging business opportunity in carbon storage.

The objectives of our study were threefold: (1) to compare the environmental impacts in the form of GHG emissions arising from organic and integrated kiwifruit production and to identify management operations which have the highest impact in the systems studied, namely hot spots for GHG emissions; (2) to compare the environmental performances of different kiwifruit cultivars, and; (3) to combine the results of the environmental assessments with profitability data and calculate eco-efficiencies for the different kiwifruit production systems. In our study, the eco-efficiency ratio answers the question of how much net value is added to the grower per kg of GHG emitted to the atmosphere.

2. Material and methods

2.1. Survey of kiwifruit orchards

In New Zealand, 77% of the total canopy area of kiwifruit (12,825 ha; http://www.freshfacts.co.nz/file/fresh-facts-2011.pdf) is located in the Bay of Plenty region of the North Island (http://www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/

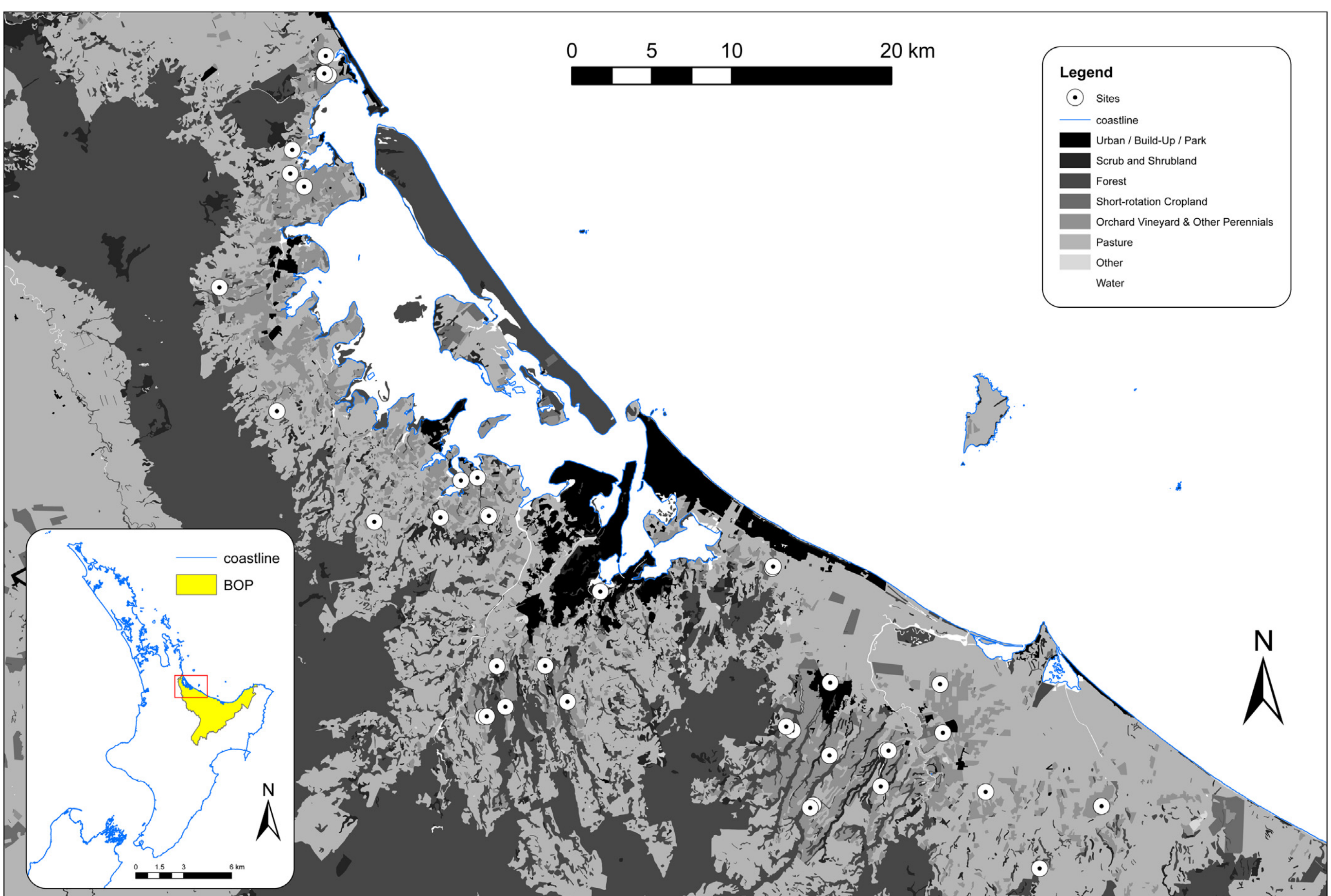

Fig. 1. Location of the 40 kiwifruit orchards in the Bay of Plenty (BOP) region, New Zealand that participated in the one-year survey on orchard practices.