New Zealand Agricultural and Resource Economics Society (Inc.)

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Paper presented at the 2009 NZARES Conference
Tahuna Conference Centre – Nelson, New Zealand. August 27-28, 2009.

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Abstract

Agri-environmental indicators (AEIs) developed by the OECD have been used to assess the environmental performance of the agricultural sector in developed countries. The Agricultural Research Group on Sustainability (ARGOS) in New Zealand has investigated using these AEIs to assess the performance of individual kiwifruit orchards. ARGOS is following panels of orchards to investigate the impacts of organic and conventional management systems on economic, sociological, and environmental dimensions of farming. The environmental monitoring of these orchards has provided data for calculating AEIs. The paper discusses the performance of ARGOS orchards, the impact of management systems, and the implications for future research.

Keywords: agri-environmental indicators, kiwifruit, organic agriculture, sustainability

Introduction

The state of the natural environment is important for producers and consumers. For agricultural producers, degraded environments are by definition less able to produce output and are less resilient to negative shocks. Consumers are also demonstrating concern for the environment, for example, by buying organically grown food that they believe has been produced with less environmental harm. Furthermore, New Zealand depends on its natural environment for agriculture and tourism, which are key economic sectors.

It is possible to measure the state of the environment and changes to it. Environmental indicators describe the health of the natural environment and the impacts that economic activities like agriculture and tourism are having on it. The recent emphasis on the need for a more sustainable agriculture requires that agricultural practices minimise negative effects while maintaining positive contributions. Agri-Environmental Indicators (AEIs) have been developed to detect the risks and benefits resulting from agriculture and to improve the monitoring, evaluation and directing of agricultural programmes (Parris, 1999).

Two issues thus arise. The first concerns the accuracy of producer and consumer perceptions that they are helping the environment. For example, one cornerstone of the organic foods industry is its perceived lower environmental impact than the conventional food system. By using a standard set of indicators, it may be possible to

determine whether there is empirical evidence to support this perception. The second issue concerns the set of indicators to be used. Several sets have been developed, but their usefulness for describing on-farm or peri-farm environmental impacts is uncertain.

This paper addresses both issues. Using data from the Agricultural Research Group on Sustainability (ARGOS) and the OECD AEIs, this paper assesses both a sample of kiwifruit orchards and the indicators themselves. After a review of AEIs and brief description of ARGOS, data on the AEIs from the farms are summarised and analysed. The analysis then leads to a discussion and conclusion.

Review of AEIs

Indicators of the health of agri-environments have been developed in specific countries and internationally. These efforts are at various stages of completion. In New Zealand, environmental indicators have been development by a number of agencies. The Ministry for the Environment, for example, has an Environmental Performance Indicators programme. The programme has developed a set of national environmental indicators which are broader than AEIs but relevant to agriculture. Aspects of the environment measured include water quality, biodiversity, greenhouse gas emissions, and soil health, among others. The *Growing for Good* report (PCE, 2004) proposed a list of indicators that could be used to assess the state of New Zealand's natural environment and thus to evaluate the sustainability of the country's agriculture. Finally, New Zealand also reports on environmental farm plans (Manderson *et al.* 2007).

Internationally, one important set of AEIs has been developed by the OECD (2008). The basis of these AEIs is the OECD Driving Force-State-Response (DSR) Model (Parris, 1999), from which has been developed a number of AEIs (OECD, 2008). These indicators have then been used to assess countries' agri-environmental performance on a consistent set of criteria, which allows for international comparisons.

Method

ARGOS (Agriculture Research Group on Sustainability) is an unincorporated joint research programme of the AgriBusiness Group, Lincoln University and the University of Otago. It was formed in 2003 to undertake a six-year research programme examining the environmental, social and economic sustainability of different faming systems in several of New Zealand's agricultural sectors. One of the sectors investigated is the kiwifruit sector, which is the subject of this paper. In 2003, twelve clusters of three farms were selected on the basis of geographic proximity; farm size; willingness of farmers to participate in an intensive long-term study; and growers' involvement with market audit and certification schemes. The three panels of kiwifruit orchards were (1) certified green organic (Hayward); (2) integrated - GlobalGAP certified gold (Hort 16A); and (3) conventional - GlobalGAP certified green (Hayward).

The audit and certification schemes associated with organics, GlobalGAP, and ZESPRI dictate the farm management practices that kiwifruit orchard may and may not use. These practices may affect how well the orchards perform on environmental

measures. The ARGOS sample is thus appropriate for both objectives of this paper. First, a single set of indicators can be used to assess orchards' environmental performance. The panel structure of the data will allow robust comparison of orchard performance to test whether organically managed orchards performing differently from conventionally managed ones. Secondly, the ARGOS data can also be used to assess the AEIs. The environmental team has collected a large amount of environmental data on orchards, much more that is covered by the OECD AEIs. This data can provide a different perspective on orchards' environmental performance, which can be used to assess the usefulness of the AEIs themselves.

The programme used a longitudinal panel cluster design – assembling clusters of three orchards using different management systems. The project has since studied 36 kiwifruit orchards in 12 clusters of organic, integrated green, and integrated Gold. On these properties, ARGOS has measured many dimensions of farm performance, including: financial measures, productivity, energy, soil fertility, biodiversity, water quality, wellbeing, good farming, sense of place and breadth of view. A discussion of methods for collecting and analysing financial data can be found in Greer, et al. (2008); a discussion regarding environmental data can be found in Maegli, et al. (2007).

The ARGOS data were then transformed into orchard-level indicators that matched as closely as possible the AEIs developed by the OECD. These AEIs and their descriptions were taken from OECD (2008) and Parris (1999). A total of 36 indicators were investigated. Table 1 describes the specific indicators used, and groups them by the aspect of the environment (water, earth, air) and the characteristic of the aspect they are targeting.

Results

Table 2 provides a summary of results by indicator. The indicator numbers correspond to those in Table 1, with at least one row per indicator (some have two rows). Table 2 also contains comments on the indicators, as well as the average values for the indicators for the three panels of orchards and all orchards combined.

The results can be divided into three groups. The first group contains those indicators for which no data were collected. This exercise is concerned with taking environmental data gathered by a dedicated team of environmental scientists and mapping them to OECD AEIs. These scientists made conscious decisions to target aspects of the environment that were important to New Zealand and for which reliable data could be collected within the constraints of the ARGOS programme. Where no data were collected – such as with water quality and biodiversity indicators – either the data were too difficult to collect reliably or more important aspects of the environment took precedence.

The second group of indicators includes those that showed no variability across the panels. These indicators were generally either 'zero' or 'all' for all orchards in the panel. For example, there were no orchards that converted to other uses and all or nearly all orchards conduct soil testing. For some of the indicators, it is even possible to determine that they show no variability across New Zealand agriculture. For example, production agriculture will show very little variability in cultivated species across the country and methyl bromide use is nil for large parts of agriculture.

Table 1: Agri-environmental Indicators Measured

Environmental Aspect	Dimension measured	Indicator
Soil	Soil erosion	1. Area of agricultural land affected by water erosion
		2. Area of agricultural land affected by wind erosion
Water	Water use	3. Agricultural water use in total national water utilisation
		4. Agricultural groundwater use in total national groundwater utilisation
		5. Area of irrigated land in total agricultural land area
	Water quality	6. Nitrate and phosphate contamination derived from agriculture in surface water and coastal waters
		7. Monitoring sites that exceed recommended limits for nitrates in surface water and groundwater
		8. Monitoring sites that exceed recommended limits for pesticides
		9. Monitoring sites where one or more pesticides are present
Air	Ammonia emissions	10. Share of agricultural ammonia emissions in national total ammonia (NH3) emissions
	Methyl bromide use	11. Agricultural methyl bromide use in tonnes of ozone depletion potential
	Greenhouse gas emissions	12. Gross total agricultural greenhouse gas (GHG) emissions and their share in total (GHG) emissions
Biodiversity	Genetic diversity	13. Plant varieties registered for marketing for main crop categories
		14. Five dominant crop varieties in total marketed production for selected crops
		15. Area of land under transgenic crops in total agricultural land.
		16. Livestock breeds registered for marketing for the main livestock categories
		17. Three dominant livestock breeds in total livestock numbers for the main livestock categories
		18. Livestock in endangered and critical risk status categories and under conservation programmes.
		19. Status of plant and livestock genetic resources undernational conservation programmes.

Table 1 (cont): Agri-environmental Indicators Measured

Environmental Aspect	Dimension measured	Indicator
Biodiversity	Wild species diversity	20. Wild species that use agricultural land as primary habitat
		21. Populations of selected breeding bird species dependent on agricultural land
	Ecosystem diversity	22. Conversion of agricultural land area to (land exits) and from (land entries) other land uses
		23. Area of agricultural semi-natural habitats in the total agricultural land area
		24. Bird habitat areas where agriculture poses serious threat to ecological function
Farm management	Nutrient management	25. Farms under nutrient management plans
		26. Farms using soil nutrient testing
	Pest management	27. Arable and permanent crop area under integrated pest management
	Soil management	28. Arable land area under soil conservation practices
		29. Agricultural land area under vegetative cover all year
	Water management	30. Irrigated land area using different irrigation technology systems
	Biodiversity management	31. Agricultural land area under biodiversity management plans
	Organic management	32. Agricultural land area under certified organic farm management
Agricultural inputs	Nutrients	33. Gross balance between the quantities of nitrogen (N) inputs and outputs
		34. Gross balance between the quantities of phosphorus (P) inputs and outputs
	Pesticides	35. Pesticide use in terms of tonnes of active ingredients
		36. Risk of damage to terrestrial and aquatic environments, and human health from pesticides

Table 2: Average of Indicator Results by Management System

Dimension	Indicator	Comment	Years	Units	Averages			
					Conventional	Organic	Gold	Overall
Soil erosion	1	All zero	04-08	ha	0.00	0.00	0.00	0.00
	2	All zero	04-08	ha	0.00	0.00	0.00	0.00
Water use	3	For spraying only; other irrigation not quantified	08/09	m^3 / ha	10.92	14.28	11.91	12.37
	4	For spraying only; other irrigation not quantified	08/09	m^3 / ha	9.93	13.95	9.98	11.29
	5	Majority of orchards not irrigated	08/09	ha	0.98	0.63	0.59	0.74
Water quality	6	Not measured	-	-	-	-	-	-
	7	Not measured	-	-	-	-	-	-
	8	Not measured	-	-	-	-	-	-
	9	Not measured	-	-	-	-	-	-
Ammonia emissions	10	Estimated from Overseer	06/07	kg / ha	2.83	5.33	3.67	3.94
Methyl bromide use	11	All zero	All	tonnes	0.00	0.00	0.00	0.00
GHG emissions	12	In progress	04/05	tonnes	-	-	-	-
Genetic diversity	13	Kiwifruit varieties	08	number	1.08	1.00	1.67	1.25
	13	Other crop varieties	08	number	0.25	0.17	0.25	0.22
	14	All zero	04-09	number	0.00	0.00	0.00	0.00
	15	All zero	04-09	number	0.00	0.00	0.00	0.00
	16	All zero	04-09	number	0.00	0.00	0.00	0.00
	17	All zero	02-09	number	0.00	0.00	0.00	0.00
	18	All zero	02-09	number	0.00	0.00	0.00	0.00
	19	None	02-09	-	-	-	-	-

Table 2 (cont): Average of Indicator Results by Management System

Dimension	Indicator	Comment	Years	Units	Averages			
					Conventional	Organic	Gold	Overall
Wild species diversity	20	Mainly birds	04/05 06/07	number	birds	birds	birds	birds
	21	Density of all species	04/05	no. / ha	17.40	12.43	11.60	13.81
	21	Density of all species	06/07	no. / ha	27.62	26.37	28.91	27.63
Ecosystem diversity	22	No conversions to other uses	00-08	ha	0.00	0.00	0.00	0.00
	22	No conversions from other uses	00-08	ha	0.00	0.00	0.00	0.00
	23	No fallow land or woodlands	04-08	ha	0.00	0.00	0.00	0.00
	24	Not measured	-	-	-	-	-	-
Nutrient management	25	Unknown	-	-	-	-	-	-
	26	Nearly all orchards undertake soil testing	04-08	ha	All	All	All	All
Pest management	27	All NZ commercial kiwifruit IPM	04-08	ha	All	All	All	All
Soil management	28	Soil conservation not an issue	04-08	ha	All	All	All	All
	29	All land area covered with sward	04-08	ha	3.60	3.77	2.05	3.14
Water management	30	Definition unclear	04-08	ha	-	-	-	-
Biodiversity management	31	All organic orchards. Others unknown.	06/07	ha	-	3.77	-	-
Organic management	32	Kiwifruit canopy area in organic orchards	06/07	ha	-	3.77	-	-
Nutrients	33	N surpluses calculated by Overseer	06/07	kg N / ha	145.75	128.75	141.75	138.75
	34	P surpluses calculated by Overseer	06/07	kg P / ha	18.25	28.17	19.42	21.94
Pesticides	35	Total orchard	08/09	tonnes	0.15	0.27	0.09	0.17
	36	Active ingredient per effective area	08/09	tonnes	0.04	0.07	0.04	0.05

The third set of indicators contains those for which there is variability across farms and orchards in New Zealand and for which data was collected within ARGOS. This set contains 11 indicators, as shown in Table 3. For these indicators, data from the organic and conventional orchards were analysed with one-way ANOVAs to determine whether there were significant differences between these two panels of orchards. The results are provided in Table 3. Of the 11 indicators, only ammonia emissions had significantly different values between the organic and conventional orchards (organic orchards had more ammonia emissions). Another indicator, pesticide risk, approached significance. However, the ARGOS team was uncertain about the appropriate measure for this OECD indicator, so this result may be discounted. The other nine indicators showed no clear relationship between farm management practice an AEI values.

These 11 indicators were also used as the basis for a cluster analysis of the conventional and organic orchards. Two different approaches were used: a two-step cluster analysis and a K-means cluster analysis with number of clusters set to two. Both were undertaken in SPSS 17. Neither approach indicated that the results could be accurately grouped into more than one cluster. That is, the orchards appear to belong to a single group, cluster, or distribution.

Discussion

The results of the research permit two different assessments. The first is an assessment of the indicators themselves, while the second is an assessment of the sustainability of New Zealand kiwifruit orchards.

The results raise questions about the usefulness of OECD AEIs for investigating the sustainability of New Zealand kiwifruit orchards. There are two reasons for this. First, several of the indicators are difficult or expensive to collect. They are therefore unsuitable for on-farm assessment of sustainability, for which ease and accuracy are important considerations. In addition, some indicators are not applicable to New Zealand conditions, which is the reason that they are uninteresting for domestic environmental scientists. The second reason that the OECD AEIs are not useful is that many of them show little variation across New Zealand kiwifruit orchards. For example, the biodiversity is fairly homogenous across orchards, and the number of domestic species across orchards is fairly constant. Without variation, it is difficult to create rating or ranking of sustainability.

The results also provide some indication of the sustainability of New Zealand orchards. For two-thirds of the indicators, sustainability appears to be a function of the kiwifruit industry or the agricultural sector, not a function of practices that vary from farm to farm. Thus, sustainability in a general sense as measured by the OECD AEIs may not be a farm-level phenomenon. Sustainability may also not be related to the split between organic and conventional farms. This division is currently related to a market audit scheme that prescribes and proscribes specific inputs and practices. Adherence to the scheme allows an orchardist to claim organic status and receive a price premium through ZESPRI. For the 11 of the 36 indicators for which practices or values did vary by farm, only one showed a significant relationship to whether an orchard was organic. For the other indicators, whether farms did better or worse was not related to organic status. This result suggests that the ‘organic’ label does not provide an indication of sustainability that ties to the OECD AEIs.

Table 3. Results of one-way ANOVA, organic and conventional orchards

Indicator		Sum of Squares	df	Mean Square	F values	Sig.
3. Water use	Between Groups	67.67	1	67.67	1.508	.232
	Within Groups	987.22	22	44.87		
	Total	1054.89	23			
4. Groundwater use	Between Groups	96.80	1	96.80	1.791	.194
	Within Groups	1188.88	22	54.04		
	Total	1285.68	23			
5. Irrigated area	Between Groups	.74	1	.74	.367	.551
	Within Groups	44.06	22	2.00		
	Total	44.80	23			
10. Ammonia emissions	Between Groups	37.50	1	37.50	45.000	.000
	Within Groups	18.33	22	.83		
	Total	55.83	23			
13. Plant varieties	Between Groups	.04	1	.04	1.000	.328
	Within Groups	.92	22	.04		
	Total	.96	23			
21. Bird species	Between Groups	148.16	1	148.16	1.493	.235
	Within Groups	2183.67	22	99.26		
	Total	2331.83	23			
29. Permanent cover	Between Groups	.18	1	.18	.049	.826
	Within Groups	81.80	22	3.72		
	Total	81.98	23			
33. N balance	Between Groups	1734.00	1	1734.00	1.337	.260
	Within Groups	28528.50	22	1296.75		
	Total	30262.50	23			
34. P balance	Between Groups	590.04	1	590.04	.879	.359
	Within Groups	14759.92	22	670.91		
	Total	15349.96	23			
35. Pesticide active ingredient	Between Groups	.08	1	.08	2.608	.121
	Within Groups	.68	22	.03		
	Total	.76	23			
36. Pesticide risk	Between Groups	.00	1	.00	3.428	.078
	Within Groups	.02	22	.00		
	Total	.03	23			

The OECD indicators were designed to compare sustainability internationally. It may therefore be unfair to attempt to compare individual farms using them. However, the attempt to use these AEIs in the ARGOS programme suggests two lessons. First, sustainability may not be a function of considerations at the farm level, but rather may be a function of the industry or national initiatives. Secondly, farm-level

sustainability may not be adequately reflected in these AEIs; a different set of AEIs may be necessary to capture farm-level variation in sustainability.

Acknowledgements

Funding for the research was provided by the Foundation for Research, Science and Technology (FRST). Komie Kolandai provided research assistance for this paper.

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