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Are private and social goals aligned in pasture-based dairy production?

Craig Galloway [a,*], Beatrice Conradie [b], Heidi Prozesky [c,d], Karen Esler [a,e]

[a] Department of Conservation Ecology and Entomology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[b] School of Economics and Centre for Social Science Research, University of Cape Town, Private Bag X1, Rhodes Gift 7703, South Africa
[c] Centre for Research on Evaluation, Science and Technology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[d] DST-NRF Centre of Excellence in Scientometrics and STI Policy, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa
[e] Centre for Invasion Biology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa

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A B S T R A C T

To become more sustainable, dairy farms should aim to maximise productivity at a minimum cost to the environment. Standard environmental impact measures were combined with non-parametric total factor productivity analysis to investigate if this is possible in a pasture-based production system. Stocking density and energy-corrected milk production per hectare correlated with overall farm efficiency. More effective use of concentrates and farm-produced hay make these operations more productive and at the same time lower their carbon footprint and make them more nutrient-use efficient. Therefore the pursuit of greater sustainability is well aligned with the objective of profit maximization in this relatively clean form of dairy production.

1. Introduction

In a finite resource world, agriculture will have to become more sustainable if it is to cope with ongoing income and population growth. However, the complexity of the biophysical system that needs to be made more sustainable has thus far prevented meaningful measurement of progress (Mayberry et al., 2005; Ernst and Wallace, 2008; McGuire et al., 2013). There is some consensus that it is desirable to look at multiple dimensions of sustainability at the same time (Rigby et al., 2001; Van Calker et al., 2005; Bezlepkina et al., 2011; Salazar-Ordonez et al., 2013). For dairy farming, the sustainable production problem can be formulated as minimising the environmental impact of a given level of milk production or maximising the output associated with a given level of environmental impact. This paper takes the second approach and uses total factor productivity (TFP) analysis as its main theoretical frame. In this approach, the technical efficiency with which all inputs are converted into all outputs are considered. The two main environmental impacts considered are nutrient and greenhouse gas emissions.

TFP analysis can be approached parametrically or non-parametrically. On the parametric side, a stochastic frontier with inefficiency effects has been the standard formulation in the field since Battese and Coelli (1995) and models of this kind have been applied to dairy production many times (e.g. Hadley, 2006; Mkhabela, 2006; Reinhard et al., 1999). See Coelli et al. (2005) for a technical description of how these models work. This class of model involves establishing best practice to measure firm-level inefficiencies and then explaining those inefficiencies with observable data. In early applications, separate models were run in which the distributional assumptions needed to predict inefficiencies contradicted those needed to explain them. In the Battese and Coelli (1995) formulation this problem is avoided by fitting both sets of parameters simultaneously.

A nitrogen surplus as possible explanation of deviations in farm-level efficiency first appeared in the translog production function put forward by Reinhard et al. (1999). Later a phosphate surplus and total energy use were added to the model, which was used to calculate environmental efficiency using both stochastic frontier analysis and data envelopment analysis (Reinhard et al., 2000). Unlike stochastic frontier analysis, data envelopment analysis (DEA), the standard non-parametric approach, accommodates multiple outputs of which one is often formulated as an environmental “bad”. Ramilian et al. (2011) incorporated nitrogen discharge as an undesirable by-product of milk production, Iribarren et al. (2011) included waste water and air pollutants and

* Corresponding author.
E-mail address: craig@traceandsave.com (C. Galloway).

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Toma et al. (2013) considered the effect of greenhouse gas emissions, nitrogen surplus and phosphorous surplus on dairy production.

Our study asks if high levels of technical efficiency in dairy production are associated with high or low levels of nutrient and carbon emissions. Like Reinhard et al. (2000) and Toma et al. (2013) we examine both greenhouse gas emissions and nitrogen and phosphorus surpluses. The argument goes as follows: if an increasing productivity (or economic efficiency) is associated with increasing levels of CO_2 or nutrient emissions, a trade-off between economic and environmental objectives will be confirmed; but if productivity and emission levels are negatively associated, emission reductions will be a by-product of profit maximisation.

2. Material and methods

2.1. Dataset

The dataset used in this analysis was obtained from Woodlands Dairy's Sustainability Project. Woodlands Dairy is a private milk processor and manufacturer of dairy products based in Humansdorp in the Eastern Cape Province of South Africa. The Sustainability Project runs the *Trace & Save Programme* which is aimed at cost effectiveness and limiting environmental impact. The program monitors milk, feed and fertilizer data as well as the soil and water data needed for carbon footprint and nutrient budget analyses and offers a field advisory service to producers. Producers receive a monthly feed use efficiency report and each farm's environmental impact is updated annually, which results in an unusually rich and accurate source of both management and environmental impact data.

Woodlands Dairy draws milk from the southern portion of the Sarah Baartman District Municipality, the area between the Storms River in the west and the Great Fish River in the east (Fig. 1). On the coast, forage production is mainly rain-fed with occasional irrigation from ground and surface water. Further inland, along the Great Fish River, it is fully irrigated. In both areas dairy production is pasture based, with purchased concentrates and some supplementary purchased roughage. The main dairy breeds are Holstein Friesians and Jerseys or cross breed herds of these two types. The typical farm is family owned and operated, with an average of 793 cows in milk and an annual milk turnover of ZAR 24.4 million. Feed costs account for 70% of farm expenses. The coefficients of variation in Table 1 indicate that most farms in the group are close to best practice on cow nutrition and less so on hay production. Profit margins have been under pressure for a while, resulting in many business failures in recent times, with the number of dairy farms reducing from 407 in January 2008 to 256 in August 2015 (MPO, 2015).

The dataset contains 80 observations collected from 43 farms in the period since January 2012, the inception date of the Sustainability Project. These data represent all participants in this voluntary programme that raise heifers on the milking farm. Biased towards the behaviour of first movers, the results presented here

Fig. 1. Location of the study area.