Agricultural Systems 160 (2018) 11–20

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

The response of broadacre mixed crop-livestock farmers to agricultural greenhouse gas abatement incentives

Kai Tang[a,*], Atakelty Hailu[b], Marit E. Kragt[b,c], Chunbo Ma[b,d]

[a] School of Economics and Trade, Guangdong University of Foreign Studies, Guangzhou, Guangdong 510006, China
[b] School of Agricultural and Resource Economics, The University of Western Australia, Crawley, WA 6009, Australia
[c] Centre of Environmental Economics and Policy, The University of Western Australia, Crawley, WA 6009, Australia
[d] Department of Economics, China Centre for Economic Development and Innovation Strategy, College of Economics, Jinan University, Guangzhou 510632, China

ARTICLE INFO

Keywords:
Broadacre mixed crop-livestock agriculture
Agricultural carbon tax
Carbon farming
Farm profit
Whole-farm bio-economic modelling

ABSTRACT

Many countries have introduced incentives to encourage farmers' adoption of practices that can reduce greenhouse gas (GHG) emissions. In this study, we deliver a whole-farm bio-economic analysis to assess the changes in land-use patterns, farm practices and on-farm GHG emissions under varying levels of agricultural abatement incentives in the form of a carbon tax for a broadacre farming system in Western Australia's Great Southern Region. Our results consistently indicate that an increase in agricultural carbon tax rate reduces both farm profits and on-farm GHG emissions. Since livestock are the dominant emissions source, the optimised enterprises mix would shift further towards cropping to produce less emissions. Under a carbon tax, farmers also tend to include less canola-based rotations and more field-pea-based rotations in their optimal enterprise mix. The estimates show that broadacre farmers in Western Australia may abate their on-farm emissions to help meet the national goal (13% reduction), with marginal abatement costs not higher than \$20/ton CO_2 equivalent in 2015 Australian dollars. In general, the analysis implies that abating broadacre agricultural GHG emissions through changing land-use patterns and farm management practices is relatively a low-cost choice.

1. Introduction

Much solid scientific evidence supports that anthropogenic greenhouse gases (GHG) emissions must be mitigated for the propose of abating climate change's adverse effects (IPCC, 2015). Consequently, many countries have introduced policy incentives to encourage GHG mitigation and have announced GHG emission-reduction goals. For example, the Australian federal government has set its reduction goal as abating 13% emissions on the basis of 2005 levels by 2020 (Australian Government, 2015).

Agriculture has been identified as an important source of GHG such as CO_2, CH_4 and N_2O through, for instance, emissions from carbon lost caused by altering cultivation as well as emissions from fertiliser use or livestock. Globally, agriculture is responsible for > 13% of anthropogenic GHG emissions (WRI, 2014). Agriculture, ranked as the second largest emissions source, emitted around 16% of Australia's GHG emissions in 2013 (Western Australian Government, 2017). As such, agriculture may contribute to global and national efforts towards reducing GHG emissions.

Carbon farming has been thought as a critical approach to mitigate agricultural GHG emissions. Carbon farming refers to the land use and farm practices that can sequester carbon in natural sinks such as soil and vegetation, or mitigate emissions from agricultural production (Smith et al., 2008). Carbon farming practices such as conservation tillage, crop stubble management, conversion from annual to perennial crops or pastures, and grazing management could potentially enhance the amount of carbon stored in agricultural soils and reduce the amount of carbon released back into the atmosphere (Sanderman et al., 2010; Tang et al., 2016b). In addition, farmers could also mitigate non-CO_2 GHGs emissions through adopting carbon farming practices such as changing crop-pasture growing structure as well as optimising livestock management (Bosch et al., 2008; Bellarby et al., 2013).

Policies has been introduced in Australia to encourage farmers adopting carbon farming. The initial policy was the Carbon Farming Initiative (CFI); a voluntary GHG mitigation policy started in December 2011 (Parliament of the Commonwealth of Australia, 2011). Farmers could adopt carbon farming to provide carbon offsets that could be sold on a voluntary market. From July 2012 to July 2014, the CFI ran alongside a carbon price, which defined a value for GHG emissions mitigated or carbon sequestrated by farmers. The CFI was replaced by the Emissions Reduction Fund (ERF) in December 2014 (Parliament of the Commonwealth of Australia, 2014). Under the ERF, farmers can

* Corresponding author.
E-mail address: francistang1988@hotmail.com (K. Tang).

https://doi.org/10.1016/j.agsy.2017.11.001
Received 11 August 2017; Received in revised form 3 November 2017; Accepted 6 November 2017
0308-521X/

submit project bids stating the practices that they would adopt plus the required price per tonne of GHG emissions mitigation or sequestration to adopt the practice(s). The lowest cost projects will be purchased (Clean Energy Regulator, 2016).

Though the Australian government encourages carbon farming, there have been few studies that analyse what farmers would do if they are provided agricultural GHG abatement incentives. In this study, we conduct a whole-farm bio-economic study to assess the changes in land use patterns, farm practices and on-farm GHG emissions under varying levels of an agricultural abatement inventive in Australia. We focus on broadacre mixed crop-livestock farms, which represent a considerable part (about 30%) of agricultural sector in Australia (Dumbrell et al., 2016). We assess the marginal abatement costs of agricultural GHG emissions by analysing how farmers respond to agricultural GHG abatement incentives. In doing so, we hope to provide new insights to design more efficient agricultural carbon abatement incentives.

The paper is organised as follows. Section 2 provides a literature review. We then introduce the case study area, provide an outline of the farm modelling approach, and describe how the agricultural GHG abatement incentives are modelled in Section 3. This is followed by the results and discussions sections before the conclusions.

2. Background

Although the policy interest in encouraging the adoption of carbon farming practices by farmers is high, few studies have analysed how farm management and land use decisions change if farmers are provided agricultural GHG abatement incentives. Existing literature about carbon farming have mostly concentrated on estimating carbon sequestration strategies' costs. Studies has showed that conservation tillage (Grace et al., 2012), continuous cropping (Antle et al., 2001), rotational cropping (Tschakert, 2004; González-Estrada et al., 2008), crop stubble management (Kragt et al., 2012) and afforestation on agricultural land (Stavins, 1999; Hunt, 2008; Hoang et al., 2013) could achieve substantial carbon sequestration, but the costs of those strategies vary depending on the region of analysis, the farming system and the mitigation strategy focused. Overall, results show that in developed countries farm activities that enhance soil organic carbon levels are relatively low-cost carbon sequestration practices, while in developing countries afforestation is a potentially viable carbon farming strategy.

Investigating the marginal abatement costs (MAC) of GHG emissions in Australia's mixed crop-livestock agricultural sector is essential for evaluating mitigation policies' cost-effectiveness. Farmers will not abate GHG emissions in the case that the MAC are higher than the provided agricultural GHG abatement incentive (e.g. a carbon tax). The least-cost theorem of pollution control also suggests that sectors with low MAC can further abate emissions and bring their surplus quota to market to earn extra profits, while sectors with high MAC can cut down their total abatement cost by purchasing such quota. In doing so, the whole society can achieve Pareto optimality (Fan et al., 2016). Investigating the MAC is thus necessary to appraise mitigation choices' economic feasibility in crop-livestock farming system.

Few researchers have explored GHG emissions' MAC for broadacre mixed crop-livestock farming systems in Australia. Tang et al. (2016a) estimated the MAC for some Australian mixed cropping-livestock farms. They found that the average MAC for the 1998–2005 period was 29.3 Australian dollars (A$) per tonne of CO_2 equivalent (t^{-1} CO_2e). However, some studies have focused on the *average* abatement costs (AAC). Thamo et al. (2013) estimated the AAC for a mixed crop-livestock farm in the Whealtbelt region of Western Australia (WA). They suggested that the AAC would not be lower than A$50 t^{-1} CO_2e.

There is currently little research that incorporates how varying crop-pasture mixes influence the amount of agricultural GHG emitted. The majority of literature that explored the effects of carbon farming on GHG mitigation tend to focus on carbon sequestration from cropping only (e.g. Antle et al., 2001; Skidmore et al., 2014). However, livestock production has been identified as a major source of human-induced non-CO_2 GHG, contributing 3.1 gigatonnes CO_2e of CH_4 (44% of total anthropogenic CH_4 emissions) and 2 gigatonnes CO_2e of N_2O (53% of total anthropogenic N_2O emissions) per year (IPCC, 2007). In Australia, livestock production produces about 50% of total rural GHG emissions (Kragt et al., 2012). Therefore, it is necessary to consider not only carbon sequestration during crop production but also livestock's GHG emissions through enteric fermentation as well as manure. To the best of our knowledge, no one has analysed how changed crop-livestock mixes affect on-farm GHG emissions in the context of Australia dryland crop-livestock agriculture.

Overall, there is currently little research that analyses how farm management and land use decisions change if broadacre mixed crop-livestock farmers are provided agricultural GHG abatement incentives. This study attempts to fill the gaps in knowledge by analysing Australian broadacre crop-livestock farmers' response to an agricultural GHG abatement incentive using whole-farm bio-economic modelling.

3. Methods

3.1. Study area

We developed a bio-economic model to represent a typical farm in the Great Southern Region of WA. The region covers an area of approximately 39,000 km^2 on the south coast of WA, bordering 250 km of the Southern Ocean and extending 200 km inland.[1] It comprises 11 local government areas (Fig. 1).

In the Great Southern Region, the climate is influenced by the movement of a band of high pressure named the 'sub-tropical ridge'. In winter, the ridge moves northwards and drives a westerly flow of moist air over much of the southern Australia. In summer, this ridge moves southwards and drives an easterly flow of dry, warm air over much of the southern Australia. The winter-summer movement of the sub-tropical ridge results in the Great Southern Region experiencing a Mediterranean climate with wet, mild winters and dry, hot summers (Climate Kelpie, 2016). Annual average rainfall in the Great Southern Region is around 500 mm, decreases rapidly in a north-easterly direction from the southern coast. > 70% of the precipitation occurs from May to October.

The region is a typical broadacre agricultural region with the majority of local farmers running a mixture of cropping and livestock enterprises (Thamo et al., 2013). It is one of Australia's main agricultural zones. In the Great Southern Region, grain yields average about 2 $t{\cdot}ha^{-1}$ recently, compared to 1.4 $t{\cdot}ha^{-1}$ for WA and 1.3 $t{\cdot}ha^{-1}$for the whole Australia (Kragt et al., 2012). Many farms are crop-dominant, with more than half of their arable land allocated to cropping enterprises (Tang et al., 2016a).

Farm size in the Great Southern Region varies from 500 to 3000 ha (average about 1900 ha) comprising multiple soil types. Typically, about half of the land is used for cropping, with the rest for pasture to graze livestock (Tang et al., 2016a). The main agricultural products; cereals, live sheep, and wool, are mostly exported (Doole et al., 2009).

Since the late 20th century, improvements in technology and farm mechanisation have caused substantial increases in labour productivity and farm size in the region. Nowadays, farms in the region operate as a family-owned business. Some farms may also employ causal labour during shearing, seeding, and harvesting periods (Addai, 2013).

Generally, soils in the region have low fertility due to the long history of high weathering of the stable rock basement (Moore, 2001). Farmers in the region apply nitrogenous and phosphate fertilisers to improve crop yield. Other characteristics of the soils include widespread laterisation, coarse texture, and clay mineralogy (Singh, 1991). Shallow, sandy duplex soils, which may elsewhere be thought as non-

[1] http://www.gsdc.wa.gov.au/region/geography.