Parametric insurance as a tool to optimise crop management and reduce environmental impacts of cropping on the Great Barrier Reef

Thorburn PJ[1*], Biggs JS[1], Webster AJ[2], McMillan L[1], Mehmet R[3]
[1] CSIRO Agriculture and Food, 306 Carmody Rd, St Lucia, Qld, 4067. Peter.Thorburn@csiro.au
[2] CSIRO Agriculture and Food, James Cook University, McGregor Rd, Smithfield Qld 4878
[3] Willis Towers Watson, 123 Eagle Street, Brisbane, Qld, 4000

Abstract

There are benefits from minimising the environmental footprint of cropping. One example is reducing the impact of sugarcane cropping on the Great Barrier Reef (GBR) through optimising N fertiliser applications. For sugarcane farmers, managing N fertiliser is an exercise in risk management: applying sufficient N to minimise the risk that N deficiency will limit yields. As an alternative approach, we have developed a novel parametric insurance concept where farmers receive a payout in years where yields are impacted by reduced N fertiliser applications. The risk of yield loss is simulated at the field scale for conventional and reduced N rates specified by the farmer. To determine the appetite amongst sugarcane farmers for such a concept, we developed a prototype commercial product and had sugarcane farmers in the Wet Tropics (North Qld) "buy" mock insurance. Feedback from the farmers about the concept was positive. Water quality and financial outcomes of these "purchases" were evaluated over 70 years. Farmers were financially better off because payouts from the mock policies combined with savings in fertiliser costs were on average more than $8/ha greater than insurance premiums. If an insurance product like this was implemented over 40% of the Wet Tropics region there would be approximately 100 t/year less N discharged to the GBR at no cost to the public. Achieving that outcome from publicly funded grants and incentives to farmers would cost ~$20M /yr. This innovative insurance concept can provide a win-win for farmers and the GBR. The use of cropping systems modelling in insurance is not common and it could have benefits if applied to other cropping risks.

Keywords

Nitrogen use efficiency, environmental nitrogen losses, sugarcane, APSIM

Introduction

There are benefits from minimising the environmental footprint of cropping, ranging from improving access to markets to reducing impacts on ecosystems. In Australia, an example of the latter is the impact of dissolved inorganic N (DIN) lost from sugarcane crops on the health of Great Barrier Reef (GBR) ecosystems. DIN losses are correlated with N fertiliser applications so an important pathway to reducing DIN impacts on the GBR is to have sugarcane farmers reduce N fertiliser application rates to their crops. How will that reduction come about? Since 2008 there have been both regulations and substantial (~$1B) investment in voluntary approaches for ensuring farmers don't over-apply N (Kroon et al. 2016). However, many farmers still apply above regulated N rates. Further, regulations represent a "minimum standard", and rates will need to be reduced below those to meet targets for GBR ecosystems protection.

In seeking to change sugarcane farmers' N fertiliser management practices it is important to understand the factors that determine their current practices. The optimum rate of N in sugarcane production is highly variable (Thorburn et al. 2024) and can be considerably different from regulated rates. Thus, farmers can't predict in what years the optimum N rate will be high, so applying high rates of N is a "rational" response by these farmers to minimise the risk of yield being limited by N availability. Insurance is an instrument commonly used to mitigate risk, and we asked: Could an insurance product be developed to help farmers manage the risk of reduced yields from reduced N? If so, would sugarcane farmers be interested in buying it, and would it be potentially commercially viable?

In this paper we describe a prototype parametric product for insurance against risk associated with reduced N applications to ratoon sugarcane crops. With parametric insurance, the payout is assessed from some "parameter" rather than an actual verified loss. In this study the parameter was based on simulated sugarcane yields. We then describe the feedback we obtained from farmers on the prototype, which provided insights into their attitudes on the concept and possible financial and water quality benefits if it became commercial.

Methods

Structure of N insurance concept

The basis of this concept was using the APSIM-Sugar model to quantify the (1) historical risk of yield loss, which is one input to the price of the insurance, and (2) magnitude of yield loss for an insured crop, which determines the payout (as described by Thorburn et al. 2020). Yield loss was calculated as the difference in yields between two N rates. The N response of ratoon crops depends on soil type, climate and the time within the harvest season the crop starts (i.e. when the previous crop is harvested) (Biggs et al. 2021). Simulations were run for all combinations of N rate, soil type, climate zone, and crop start dates in the target region. The target region was the ~64,000 ha of sugarcane production in the Wet Tropics region of North Qld. The simulations were based on those of Biggs et al. (2021). The main change was that all soils identified in local soil surveys were parameterised (following Biggs et al. 2021) and simulated, compared with a small number of "representative" soils in a region. For the historical risk, simulations were run from 1950 to 2020 at a range of N rates (110 to 180 kg/ha in increments of 10 kg/ha) for ratoon sugarcane crops.

To define an insurance policy for a field, a farmer selects the location of the field (which determines the climate zone and soil type), the original and new N rates (e.g. their conventional rate and the reduced rate they will apply), the crop start, the value of cane and the area of the field. For simplicity, crop start was limited to three options, early (15 July), mid (15 Sept) and late (15 Nov) starts, a range which adequately captures the variation in N response (Biggs et al. 2021). Sugarcane farmers use various forward pricing mechanisms, so we decided they should specify the value of the insured crop. The "technical price" (T, \$/ha) was based on the average yield loss (ΔY, t/ha) between the two N rates across years, the standard deviation of the annual loss (S, t/ha) and the cane value (V, \$/t): Here $T = (\Delta Y + 0.2S)V$. ΔYV is the long-term expected loss of a policy and $0.2SV$ is a loading for operating costs and profits. The premium (P) paid by farmers would include brokerage (assumed 17.6 % of T), GST and stamp duty. These three costs equate to 41 % of T. The payout (\$/ha) was ΔY for the insured crop by the cane value and area insured. Higher yields at the reduced N rate compared with the conventional were excluded from the payouts.

Farmer feedback

To obtain feedback from farmers, we developed a web portal to be facsimile of a potential commercial product (Figure 1). That, together with the overall concept was presented to 22 farmers and 6 advisors across 6 workshops attended by 22 farmers and 9 advisors. Participants were surveyed about their opinions of the concept at the end of the workshops. Quantitative data, described below, was also collected from the portal.

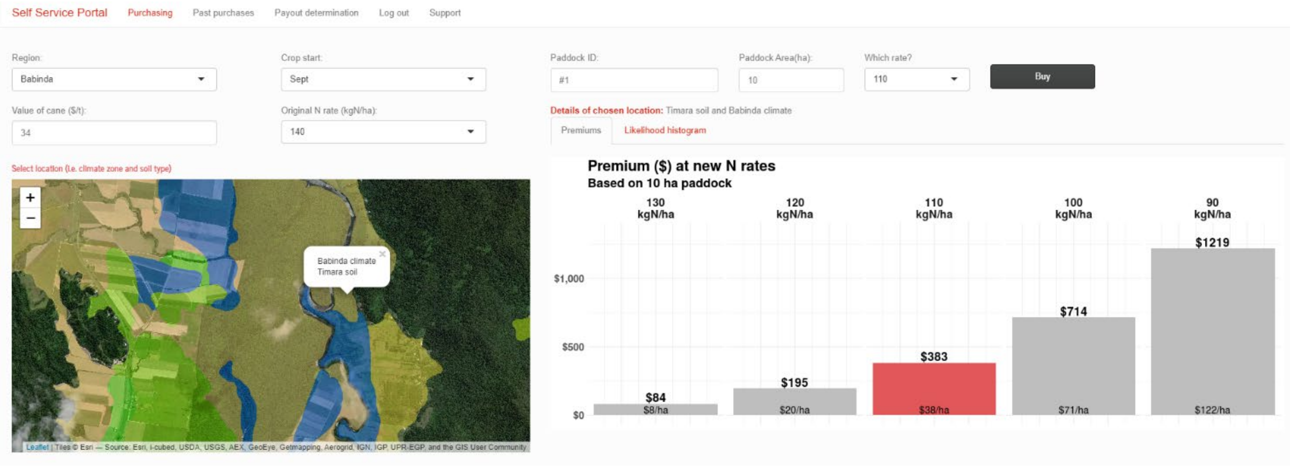
Region: Babinda
Crop start: Sept
Paddock ID: #1
Paddock Area(ha): 10
Which rate?: 110
Value of cane ($/t): 34
Original N rate (kgN/ha): 140
Details of chosen location: Timara soil and Babinda climate

Figure 1. Screen shot of the Self-Service Portal. Different premiums are displayed for five rates of N reduced from the original rate. The premiums for the new (i.e. lower) N rate a farmer selected are shown in the red bar.

The web portal was based around a map interface that allowed farmers to specify the field to be insured, which then determined the climate and soil type. Based on other parameters specified, the premiums (both as \$/ha and \$ for the field) were displayed for five potential N rate reductions from the original (i.e. higher) N rate. The farmer then selected the new rate to be insured. A mock policy could then be "bought". The details of all "purchased' policies were stored to allow both the calculation of the hypothetical outcomes of the policy if it had been "bought" in each of the previous 70 years and to assess N rates, soil types and crop starts selected. These data potentially influence both the commercial potential of a product (e.g. defining systemic risk, Roberts et al. 2023) and the water quality benefit from reduced N applications. For the latter, we assumed that the ratio of N fertiliser applied to DIN discharged from a region was 0.2 (Thorburn et al. 2013).

Results

Mock "policies"

There were 100 mock insurance policies "purchased". Policies were reasonably evenly distributed across crops starts (early, 26 %, mid 43 %, late 31 %) and soil types. The mean N rate reduction across the policies was 19 kg/ha. For 80 % of "insured" fields, the original N rate was greater than our estimate of the regulated maximum N rate in the field although the difference was only 10 kg/ha in 39 % of the fields.

Across the mock policies, premiums ranged from $2.66 /ha to $241.11 /ha with a mean of $48.82 /ha (Table 1), with the distribution of premiums skewed towards lower premiums (data not shown). The mean N rate reduction (19 kg/ha) equated to a fertiliser cost saving of $28.28 /ha (Table 1) using the cost of N fertiliser ($1.50 /kg) at the time of the workshops. Offsetting the fertiliser cost savings against the premiums, the net cost of insurance (or net premium) was $20.54 /ha. In more than 50% of mock policies the premium was less than the fertiliser savings (data not shown) and the minimum net was -$37.24 /ha.

Table 1. Mean values of the 100 mock N risk insurance policies "purchased" by farmers. The net premium is the premium "paid" by farmers less the fertiliser cost saving. The revenue retained (by insurance companies) is the difference between the technical price and payouts.

Premium ($/ha)	Fertiliser cost saving ($/ha)	Net premium ($/ha)	Payout ($/ha)	Net benefit ($/ha)	Brokerage ($/ha)	Technical Price ($/ha)	Revenue retained ($/ha)
48.82	28.28	20.54	28.79	8.25	$6.09	34.61	5.82

If these 100 mock policies had been "purchased" in all of the historical years, the mean payout (across policies and years) would have been $28.79 /ha (Table 1). The mean net benefit to farmers considering the cost of premiums, N cost savings and payouts received was $8.25 /ha, although there was a considerable variation in net benefit across policies and years. The mean technical price was $34.61/ ha (Table 1), which is the revenue received by the insurance company. After accounting for payouts across policies and years, the revenue retained by the insurance company was $5.82 /ha (Table 2). The mean brokerage was $6.09 /ha.

Regional benefits

If these outcomes occurred annually in 40 % of the target region (or equivalent area), the total net benefit to farmers would be $211,200 /yr. Similarly, revenues retained by insurance companies would be $148,992 /yr and the total brokerage $155,900 /yr. The reduction in DIN discharged to the GBR would be ~100 t/yr.

Feedback on the concept

The overall sentiment about the concept was positive. Comments from farmers and advisors included:

> *"This insurance thing could help going forward. This is really innovative, we've gotta keep moving and keep trying new things. If you don't participate in these new things, we all end up losing." [Farmer]*
>
> *"I reckon it has legs, the conversations around the table in [the region] were good and people were pretty positive about how useful this could be. It's pretty complex, so takes a bit to get farmers to understand it. I guess we'd have to see how it goes in a real trial to see what people think; and also for those who made purchases to check in after harvest." [Advisor]*

The feedback also revealed two broad strategies for "purchasing" policies: One being to only buy when the premium was less than fertiliser cost savings and the second based on farmers assessing the value of the potential yield loss and price they would be prepared to pay to protect that loss. In the workshops this second strategy was commonly discussed and is exemplified by the comment:

> *I wanted to reduce N on a block... I'm worried I could lose 10 t/ha, which is worth about $300/ha, so I'd be prepared to spend $150/ha or more to protect that.*

However, more than 50 % of mock policies "purchased" had premiums less than fertiliser cost savings suggesting the first was somewhat more influential in purchasing decisions.

Discussion

New approaches are needed to facilitate farmers reducing N fertiliser applications to, and thus DIN lost from sugarcane crops in the GBR catchments. We hypothesised that insurance could be a tool to help farmers manage the potential risk of yield reductions if N rates are reduced and developed an original parametric insurance concept for that purpose. The combinations of soil type, climate and crop start mean that the concept operates at the field scale in contrast to other parametric approaches (e.g. rainfall index insurance) that operate on scales of at least 25 km^2. We also know that farmers are acutely aware of field-to-field variability and the concept complements that outlook and may help make it attractive to farmers.

Historically, there has been a poor uptake of crop insurance in Australia (Roberts et al. 2023) which raises the question about the potential uptake of this N insurance concept. There are two factors that may help its success. One is that the N fertiliser cost savings are an implicit subsidy of the premium. As we have seen a common strategy was for farmers to only insure crops when the premiums were less that cost savings. The second is the public pressure to reduce N applications. This pressure is reflected in N applications to sugarcane crops being regulated and many of the policies “bought” had original N rates greater than regulated rates. So, this concept may help farmers comply with regulations.

Our results also suggest that, if taken up at scale, the concept could (1) be commercially viable for insurance companies and brokers, and therefore (2) provide an ongoing means of supporting lower N fertiliser applications to sugarcane crops at no cost to the public. This would be a good outcome given that substantial investment in publicly funded grants and incentives to farmers has resulted in meagre success. For example, reducing DIN discharges by ~100 t/yr through grants and incentives costs ~$20M /yr, representing the possible savings of public funding from a commercial insurance program operating at scale.

What is the broader relevance of this work? Firstly, the concept could be applied to other crops where there are pressures to reduce inputs, such as N applications, irrigation, etc. More broadly, while the specific concept developed here is, to our knowledge, unique, the use of comprehensive cropping systems models like APSIM in crop insurance is rare. The representation of soil, climate and management at the field scale may provide advantages for model-based crop insurance compared with more spatially uniform products such as rainfall index insurance. Thus, there is opportunity for further innovation in this area.

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