Developing an evidence base for assessing natural capital risks and dependencies in lending to Australian wheat farms

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Abstract:

Farmers are highly dependent on stocks of natural capital, and lenders are in turn exposed to natural capital through their loans to farmers. However, the traditional process for assessing a farmer's credit risk relies primarily on historical financial data. Banks' consideration of environmental factors tends to be limited to major risks such as contaminated land liabilities, and to large project and corporate finance, as opposed to the smaller loans typical of the Australian agricultural sector. The relevant risks and dependencies for agriculture vary by sub-sector and geography, and there is a lack of standardized methodologies and evidence to support risk assessment. We provide an evidence base to support natural capital risk assessment for a single sub-sector of Australian agriculture – wheat farming. We show that such an assessment is possible, with a combination of quantitative and qualitative inputs, but the complexity and interconnectedness of natural capital processes is a challenge, particularly for soil health.

Key Words:

Acknowledgements:

1   Introduction

Agriculture is a small but important part of the Australian economy, accounting for 7% (by value) of total exports in 2014-15 (ABS 2016a), and contributing as much as 12% of Australia's GDP, when including the value of associated pre- and post-farm production activities (NFF 2012). Farmers own or manage 61% of Australia's land (NFF 2012) and therefore play a key role in managing Australia's stocks of natural capital, or "those elements of nature which either directly provide benefits or underpin human wellbeing" (Natural Capital Committee 2013, 11).

Farmers all over the world are highly dependent on environmental factors such as rainfall, temperature and climate, as well as natural capital stocks such as energy, mineral and water resources, productive soils and ecosystems. Australia's aridity (70% of mainland Australia receives less than 500mm of rain per year – Geoscience Australia 2016) and generally poor soils means that Australian agriculture is particularly vulnerable to variability and extreme conditions. For example, widespread drought in 2002-03 led to a 41% reduction in agricultural income, reducing Australia's GDP by around 1% in that year (Lu and Hedley 2004).

99% of the 134,000 farm businesses operating in Australia in 2012 were family owned (NFF 2012), with on average 85% of business equity being held by the operator and close relatives or business partners (ABARES 2016). The remaining 15% takes the form of debt, including short-term unsecured debt such as credit cards; equipment supplier finance; and formal secured loans, usually from one of the small number of Australian banks with extensive rural networks. Through these loans, which are typically used either to fund land or machinery purchases, or to provide working capital to bridge temporary income-cost mismatches, these banks are exposed to a range of natural capital and environmental risks and dependencies. The traditional process for assessing a farmer's credit risk, however, relies primary on historical financial data, which only indirectly and incompletely reflects these risks and dependencies.

In 2012, around 40 international financial institutions signed the Natural Capital Declaration (NCD), committing to integrate natural capital considerations into their financial products, and their accounting and reporting frameworks, by 2020.[1] A pilot study (Cojoianu et al. 2015) found that 42% of financial institutions claim to be already integrating natural capital risks in credit risk assessments. However, the evidence to date suggests that this is limited to large (over US$10 million) project finance deals and even larger corporate loans, and is virtually non-existent for smaller secured loans typical of the Australian agricultural sector. A key challenge for agriculture is the fact that the relevant risks and dependencies vary by sub-sector and in some cases by individual crop or animal production system, as well as by geography. Other difficulties include lack of awareness around natural capital issues, the vagueness of regulatory requirements

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[1] http://www.naturalcapitalfinancealliance.org/about-the-natural-capital-declaration/ (accessed 26 October 2016).

around natural capital issues, the challenge of relating long-term issues to short-term materiality, and most importantly, lack of standardized industry- and geography-specific methodologies and robust information for the quantification of natural capital risks (Cojoianu et al. 2015). Our paper therefore aims to help address these challenges by developing an evidence base to support natural capital credit risk assessment for a single sub-sector of Australian agriculture – wheat farming, which contributed over A$7 billion or 13% of Australia's total value of agricultural production in 2015, second only to cattle grazing (ABS 2016b).

The paper is structured as follows. In section 2, we review the literature on environmental credit risk assessment. Section 3 outlines our methodology for identifying key environmental and natural capital risks and dependencies, and section 4 sets out our findings for the Australian wheat sector, explaining why each risk is material, how it can be mitigated, and how a bank could assess and monitor the risk. Finally, section 5 discusses the overall findings that emerged from this analysis.

2   Environmental credit risk assessment

The literature on sustainability in the banking sector can be divided into two broad groups (Zeidan et al., 2015): one dealing with external practices (which include banks' communications with shareholders and stakeholders around sustainability issues) and the other with internal practices (which include how sustainability issues are incorporated into risk management models and lending or investment decisions). Our paper contributes to the latter.

Within this strand of the literature there are two main areas of focus. The first considers how environmental performance influences the perceived credit risk and cost of debt of companies, with most studies finding that firms with better sustainability performance ratings experience a lower cost of debt, and vice versa (Bauer & Hann 2010; Nandy & Lodh 2012). Most studies focus on public companies in developed countries (although Weber, Hoque, and Ayub Islam (2015) provide evidence linking sustainability criteria to loan default probability in a developing country, while noting that sustainability criteria are not yet being used by lenders there), and on major risks such as hazardous chemicals, substantial emissions and climate change (Schneider 2011; Chava 2014). Most papers also focus on large-scale corporate loans and bond finance, rather than smaller loans to privately held companies and SMEs, where data on sustainability as well as financial issues is much scarcer and opaque (Berger and Udell 1998). There is, to the best of our knowledge, no peer-reviewed research demonstrating a clear link between environmental performance at this smaller scale, and the availability, terms or cost of bank loans. Nevertheless, from our discussions with Australian banking officials it appears that at least some banks are operating on the assumption that there is such a link:

"I guess, you know, there's an assumption that we've made, that seems to be validated by numerous case studies, that our more productive agribusiness customers are those who manage their environmental resources better, and they seem to be one and the same thing." (Environmental finance professional, August 6, 2015).

The second area concerns the extent to which banks incorporate sustainability criteria in their lending decision-making. It is generally agreed that banks have been incorporating *some* environmental risks into their credit assessment processes, since the early 1990s (Weber, Fenchel, & Scholz 2008). This was originally driven by legislation, such as the Comprehensive Environmental Response, Compensation and Liability Act 1980 in the United States, which imposed remediation liabilities on the owners of contaminated sites. As a result, early environmental credit risk assessments tended to focus only on such specific liabilities, rather than providing a comprehensive framework for the assessment of all potentially material environmental (and social) risks, dependencies and opportunities. In the mid-2000s, Weber, Fenchel, & Scholz (2008) identified only four classes of environmental risk being considered by banks: contamination liabilities; impacts of mandatory environmental regulations; changes in buyer/consumer attitudes; and reputational risk due to being associated with projects seen as environmentally or socially damaging by stakeholders. Furthermore, they found that most attention was given to environmental issues in the rating (or risk identification) phase of the credit management process, least in the costing (or risk evaluation) phase and an intermediate level in the monitoring (or risk controlling) phases.

A recent survey of 36 financial institutions and 26 financial research providers undertaken for the NCD (Cojoianu et al. 2015) found that although 42% of respondents claim to consider natural capital risks in their credit risk assessment, there is no evidence that this is done systematically. Lenders cited numerous difficulties in assessing natural capital risks including the lack of suitable contextual methodologies, data, budgets and capacity. Currently, only project finance transactions and related services can be benchmarked to an international standard of environmental and social due diligence: the Equator Principles, which are applied only to projects over US$10 million, or US$100 million for corporate loans.

The aforementioned body of research on sustainability performance and perceived credit risk of borrowers goes some way toward explaining why banks might seek to incorporate environmental risks and dependencies in their credit assessment processes. As Weber, Hoque, and Ayub Islam (2015, 3) observe, "The rationale for using sustainability indicators for predicting credit risks is based on the idea that good sustainability performance mitigates risks arising through environmental and social impacts as well as through and stakeholder pressure and regulation." However, while high-level sustainability indicators may be available for larger companies, usually based on research providers' analysis of annual and sustainability reports, they are typically not applicable to smaller-scale loans such as those typical in the Australian agricultural sector.

Very little research has been published on the incorporation of environmental risks and dependencies into credit assessment for smaller-scale loans in any sector, or for any scale of loans in agriculture in particular. A search across all academic databases subscribed to by the University of Oxford using the keywords 'environmental', 'credit', 'risk' and 'agriculture' yielded only 80 results, only a few of which were found to be relevant. For example, Georgopoulou et al. (2015) develop a framework to assess the risk of climate change to lending across several Greek industries, including wheat farming, using the loan portfolio of a Greek bank as a case study. The authors use climate and agronomic modelling to make the case for materiality of climate change to the agriculture sector, and conclude that the physical risks from climate change to Greek crop farms are between 7.4-12.4% of their annual turnover. However, they do not provide an evidence base for the assessment of more granular risk factors (e.g. rainfall availability), but rather rely on a generic crop yield simulation model. The emphasis is on calculation of portfolio-level exposure to systemic risks, as opposed to individual loan assessment. Similarly, Do et al. (2016) find evidence that banks are considering drought risk at a systemic level, increasing loan interest rates to large agricultural enterprises by up to 6 basis points for every step increase in regional drought level in the 12 months prior to loan origination. Zeidan et al. (2015) propose a sustainability credit score system for the sugar industry in Brazil, based on six dimensions: economic growth, environmental protection, social progress, socio-economic development, eco-efficiency and socio-environmental development. Whilst taking a higher-level sustainability focus, this study is the most complementary to our own in terms providing a basis for the evaluation of such risks for a specific sector and country.

In summary, there is an almost complete absence in the literature of detailed assessments of how environmental and natural capital risks can be identified and included in the credit risk assessment process for smaller-scale (e.g. US$0.5-2 million) bank loans. This is true across industries, and for agriculture in particular. Our paper complements the top-down approach taken by Zeidan et al. (2015) by developing a bottom-up, robust evidence base on why and how different natural capital risks and dependencies are likely to affect the financial performance of wheat farms in Australia, how these risks can be managed, and how the resultant managed risk can be assessed by a lender.

3   Methodology

We followed a multi-stage approach to identifying, prioritizing and researching the natural capital risks and dependencies applicable to Australian wheat farm lending, from a lender's perspective. First, we searched the publicly available environmental risk methodologies of 66 financial research providers and consultants identified by Cojoianu et al. (2015) for environmental risk factors specifically relevant to the agricultural sector. As we found that coverage of agriculture was limited to just nine research providers, we also conducted a desk review of 34 publications

from financial institutions related to environmental risks, published between 2006 and 2016, to identify high level environmental risk factors which were considered to be material across a broad range of industries. Those most applicable to agriculture are listed in Table 1 below.

The next step was to determine which of these risks were of most importance for wheat farming, in the Australian context in particular. To do this we triangulated evidence from three different sources: a review of 39 relevant academic papers shortlisted from a set of 974 papers containing the keywords 'wheat', 'Australia' and 'yield' in the Scopus database; a review of online publications from Australian industry-specific bodies (such as the Grains Research and Development Corporation, GRDC) and relevant government agencies; and a set of four interviews with Australian agribusiness professionals, credit managers and environmental finance professionals. Typically, industry body publications proved the most useful in demonstrating the materiality of specific environmental risks to the wheat industry, given their focus and access to information specific to the Australian context.

A risk was considered material if it was clearly capable of being a significant determinant of either yields, prices or costs, either in the short- or long-term. It was not practicable to set quantitative thresholds for significance, but where possible we have provided quantitative evidence in support of our judgment. We consider historical average conditions to be the baseline: a risk is therefore only significant if it results in a deviation (in a negative direction) from this baseline, either in the short- or long-term. It should be noted that risk is the product of the probability of occurrence and the magnitude of impact, and it is therefore appropriate to include some factors which are low impact but high probability, and vice versa. In addition, some factors have been included on the basis of externalities which are currently not fully priced, but which may become more appropriately priced in the medium to long term.

Finally, to keep this paper concise, we excluded weather, climate, energy and air emissions risks, as these are already relatively well understood. The results of these steps are summarized in Table 1 below. Factors relevant to wheat farming are highlighted in gray, with light gray indicating the factors that are considered material, but not included in the following discussion.

Table 1: Agriculture – Environmental and Natural Capital Risk Factors

Thematic Area	Risk Factor	Sub-Risk Factor
Water	Water Availability	Growing Season Average Rainfall (Lower Quantity or Increased Variability
		Excessive Rainfall
	Water Use Efficiency	Crop Water Use Efficiency
		Pasture Water Use Efficiency
		Animal Stock Watering Efficiency
		Farm Water Use Efficiency
	Water Rights	Quantity
		Price

Category	Subcategory	Sub-subcategory
	Irrigation Technology Failure	
	Water Quality	Salinity Management
		Water Contamination
		Water Acidity
Weather and Climate	Heat Stress	
	Frost Damage	
	Extreme Weather Events	
Land Use and Pollution	Fertiliser Use	Quantity
		Price
		Run-Off
		Appropriate Application
	Soil Organic Carbon	
	Soil Erosion	Water Erosion
		Wind Erosion
	Soil Acidification	
	Soil Salinity	
	Soil Compaction	
	Organic Contaminants	
	Heavy Metals	
	Waste Management	
Biodiversity and Ecosystems	GMO Contamination	
	Pests and Diseases	
	Weeds	
	Biodiversity	
	Livestock Health/Animal Welfare	
	Pasture Cover and Composition	
Energy Use	On-Farm Energy Use	
	Fertiliser Production and Transport Energy Use	
Air Emissions	Carbon Dioxide	Energy Use Emissions
		Fertiliser Production and Transport Energy Emissions
		Direct Land Use Change Emissions
	Methane	Enteric Fermentation Emissions
		Manure Management Emissions
	Nitrous Oxide	Fertiliser Application Emissions
	F-gases (Hydrofluorocarbons, Perfluorocarbons and Sulfur Hexafluoride)	

The same sources of evidence were then used to explore each of these risks in further detail. In the following section, for each key risk, we discuss why it is material, what mitigation options are available, and what information a lender would require to assess and monitor these risks, either quantitatively or qualitatively. The key risks identified for wheat can, for ease of discussion, be grouped into the following headings: water; fertiliser use; soil health; pests, diseases and weeds, and biodiversity.

Hoepner et al. (2014) point out that banks can adopt two different approaches to assess the credit-worthiness of a borrower. The first is the traditional approach to credit risk assessments or 'transaction-based banking', which is based on quantitative and easily verifiable information, predominantly financial metrics. The second is 'relationship banking', in which lending decisions are based on intangible factors which are harder to quantify, often collected manually and difficult to verify (e.g. managerial competence). The authors highlight a growing body of literature showing that the use of intangible information in tandem with financial metrics can lead to better credit risk assessments than those based only on financial factors. Hence we have considered both quantitative and qualitative information that could contribute to assessing each risk.

4 Natural capital risks and dependencies in Australian wheat farming

Most of Australia's grain production is located on a narrow belt of land (in the east, south east and south west of the country), known as the Wheatbelt or Grainbelt, which benefits from a temperate climate, sufficient rainfall (on average 300-600mm/year) and relatively fertile soils (Land Commodities 2012). At 46 million hectares, the Wheatbelt comprises 6% of Australia's total land area (Land Commodities 2012). Despite the name, farmers in the Wheatbelt also raise livestock and grow other crops in addition to wheat. In 2014-15, wheat was grown on about 57% (13.8 million ha) of total Wheatbelt farmland (24.3 million ha) (Farrell 2015).

The majority of Australia's grain, including around 90% of wheat, is grown in a single winter growing season, with precise sowing and harvesting periods varying by region (Land Commodities 2012). There is minimal water available for irrigation across the Wheatbelt, hence almost all grain in Australia is produced under a dryland cropping system (i.e. crops are rain-fed, not irrigated). Rainwater availability and efficiency of use is therefore a key natural capital risk/dependency for Australian wheat farming.

4.1 Water

4.1.1 Overview

The level of rainfall is the biggest predictor of agricultural productivity in a given year, and long-term averages are a key determinant of land prices (Land Commodities 2012). Rainwater availability for any crop is a function of four inter-related dimensions (Land Commodities 2012):

- **Quantity** (total annual average rainfall);

- **Timing** (in particular, the amount received during the growing season, and the amount received in excessive downpours which can cause damage during the growing season or at harvest time);

- **Reliability** (the variability of both quantity and timing from year to year); and

- **Water use efficiency** (the proportion of rainfall which becomes available to the crop itself, which itself is a function of various factors including soil characteristics, drainage, topography, timing of rainfall events, climatic conditions after rainfall, nitrogen supply, weed cover and crop characteristics).

In a relatively small study (based on rainfall data from six weather stations in New South Wales over six years) CelsiusPro AG (2010) found a linear relationship between wheat yields and cumulative rainfall during the late growing season (1st August to 31st September), with rainfall over this period explaining 90% of the annual variation in wheat yield. This suggests that every millimeter less rainfall in the late growing season would result in a decrease in yield of 0.0188 t/ha (compared with average yields of around 1.5 t/ha). Assuming an average farm-gate price of A\$250-300/t, this would translate into a decrease in earnings of A\$4.70-5.64/ha/mm. This is significant in the context of typical profit margins of 10-20% or roughly A\$37.50-90.00/ha based on the same yield and price assumptions.[2] While further work is required to establish whether these implications hold for other regions and time periods, it does suggest that the **quantity of rainfall during the late growing season** is a critical component of water risk for wheat.

4.1.2   Risk mitigation

Farmers can mitigate the impacts of rainfall variability in several ways. Huda (1994) concludes that yields can be protected by reducing the area sown when rainfall is low (less than 40mm) in the early growing season (1st April -15th June) and increasing the area sown when rainfall is high (greater than 100mm). Timing is also important: farmers should decrease planting when the opening of the rainy season is delayed, and increase planting when the opening is early. Choosing to grow a longer-duration wheat cultivar in early rainfall years, or increasing sheep stocking as an alternative to wheat during low rainfall years is another option given accurate and early forecasting capabilities of growing season rainfall. A variety of actions can be taken to improve crop water use efficiency, for example by increasing the depth of rooting (Turner 2004). However, this strategy is most effective on sandy soils in high-rainfall zones where nitrogen may leach into the root zone, with neutral and sometimes even negative effects in clay soils which experience limited wetting to root depth (Smith and Harris 1981).

4.1.3   Lender information requirements

In the short term, lenders providing finance to wheat farmers can assess likely rainfall quantity, timing and variability according to location, by comparison with historical rainfall data. In Australia, Bureau of Meteorology data is likely to be sufficient, but could be supplemented with farm-specific rainfall data, particularly for remote areas. In addition, lenders could qualitatively determine whether the farmer has the necessary knowledge and track record to deal with variable rainfall patterns and to employ appropriate risk mitigation measures as described above

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[2] Own analysis. Indicative prices and profit margins from personal communication, Agribusiness finance manager, August 12, 2016.

and in Table 2. In the longer term, shifting rainfall patterns could change the risk profile of wheat farms. Assessing this risk requires inputs from state-of-the-art climatic models producing decadal and regional projections.

Table 2: Water risks, information needs and data sources

Risk Factor	Timeframe	Scale	Information Need	Data Sources
Growing Season Rainfall	Short term	Region to farm	Region- or farm-specific critical growing season dates	Bureau of Meteorology or farm-specific rainfall datasets combined with regional- or farm-specific yield records
	Short term	Region to farm	Region-specific historical average growing season rainfall and variability (e.g. over 10 years)	Bureau of Meteorology or farm-specific rainfall datasets
	Short term	Farm	Farmer's ability to predict and deal with variability	Farmer questionnaire
	Long term	Region	Projected changes in growing season rainfall patterns	Regional outputs from long-term climatic models
Harvesting Season Excessive Rainfall	Short term	Region to farm	Farm exposure to excessive rainfall during growing season or harvesting season	Farmer questionnaire on historical crop damage in growing or harvesting season. Bureau of Meteorology or farm-specific rainfall datasets.
Crop Water Use Efficiency	Short term	Farm	Recent historical average water use efficiency, compared with the same data for similar farms	Farmer yield data and Bureau of Meteorology or farm-specific rainfall datasets
	Short term	Farm	Farmer's ability to improve water use efficiency	Farmer questionnaire

4.2 Fertiliser use

4.2.1 Overview

Fertiliser use has significant environmental impacts in several ways: it represents consumption of various input natural resources and energy; it results in GHG emissions in both production and consumption; and it has the potential to both positively and negatively impact other natural

resources, notably soil, water and biodiversity. It is also economically very important for farmers: fertiliser use is estimated to add $12.7 billion in increased productivity to the Australian agriculture sector (Ryan 2010). The purchase of fertiliser is generally the largest single variable cost for grain producers, typically amounting to 15-20% of annual cash costs (IPNI 2013). Thus nutrient use efficiency for nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) is an indicator of more general resource use efficiency (IPNI 2014a).

Having the right amount of nutrients in the soil when the crop needs it most is crucial for both yield optimisation and long-term soil health. While fertiliser is a major contributor to crop yield and health, mismanaging its application can result in significant risks for both the financial wellbeing of the farm and the environment. Key fertiliser related risks include:

- Rising fertiliser input quantity and cost;

- Energy use and associated GHG emissions across the supply chain;

- Crop over- or under-fertilisation resulting in soil degradation; and

- Off-field run-off into adjacent watercourses, water tables or land.

Farmers have an incentive to manage fertiliser efficiently to reduce costs, but there may be trade-offs between up-front costs of efficiency investments (such as smarter fertiliser application systems) and the longer-term benefits of efficiency improvements, as well as between positive short-term yield improvements and negative longer-term soil, water or GHG impacts.

Two complementary indicators are particularly relevant for nutrient use efficiency. These are (IPNI 2014b):

- Partial Nutrient Balance (PNB) which is measured as kg nutrient removed from soil / kg applied and can provide an insight into whether soil is under- or over-fertilised; and

- Partial Factor Productivity (PFP), or the crop yield per unit of fertiliser applied (kg yield / kg nutrient applied).

Benchmarks are available for these indicators: for example, IPNI (2016) recommend that, for cereal crops harvested for grain, PNB (nitrogen) should be in the range of 0.1-0.9 kg/kg with a PNB >1.0 kg/kg implying that the soil is being 'mined' for short-term productivity gain at the expense of longer-term degradation, while PFP (nitrogen) should be 40-80 kg/kg. Similar benchmarks can be established for phosphorus, potassium and sulphur, and a lender could establish their own benchmarks across a portfolio of similar farms. However, differences in soil type, crop variety, micro-climate and other factors may make it difficult to distinguish between best and worst performers: for example, Mahjourimajd et al. (2016) find that different wheat genotypes have a significantly different PFP in low rainfall environments in Australia.

4.2.2 Risk mitigation

While rising fertiliser input costs, production energy use and associated GHG emissions are outside the control of the farmer, fertiliser application rates, timing and location can all be influenced, thereby affecting the total cost of fertiliser to the farmer, consumption-phase GHG emissions, and impacts on soil and water.

4.2.3 Lender information requirements

Lending institutions can monitor both the risk factors which are outside the farmer's control (fertiliser costs, fertiliser production energy use and GHG emissions) and those which are within the farmer's influence such as soil nutrient balance, fertiliser productivity, timing and placement.

Table 3: Fertiliser use risks, information needs and data sources

Risk Factor	Timeframe	Scale	Information Need	Data Sources
Fertiliser quantity and cost	Short term	Farm	Fertiliser quantity (absolute or kg/ha) and percentage of total annual farm cash costs. Farmer's ability to balance fertiliser purchasing decisions with weather dependent fertiliser requirements	Farmer questionnaire
	Long term	National	Predicted fertiliser price trends	Market analysts
Fertiliser production and transport energy use and GHG emissions	Short and long term	National	Energy and GHG emissions per kg fertiliser	Life-cycle assessment studies, fertiliser manufacturer disclosure and/or farmer questionnaire
Appropriate application of fertiliser	Short term	Farm	Farmer's ability to optimise fertiliser application	Farmer and peer questionnaire (peer with similar rainfall profile)
	Long term	Farm	Impact of fertiliser application on soil quality (e.g. monitoring PNB)	Soil samples (for nutrient removal rate); farmer questionnaire (for fertiliser applied)
Fertiliser run-off	Short and long term	Farm and surrounding area	Adjacent water and soil contamination from fertiliser run-off	Farmer questionnaire; environmental regulator data

4.3 Soil health

4.3.1 Overview

Agricultural activity relies heavily on the underlying health of the soil. However, agricultural activity itself can undermine soil health through changes in nutrient balance and alkalinity, or

through increased exposure to water and wind erosion, for example as a result of tillage, loss of soil surface cover and removal of crop residues. Soil health related risks translate directly into decreased agricultural productivity, long-term natural capital degradation and depreciation in land value.

Sbrocchi et al. (2015, 37) argue that soil condition indicators would ideally be a comprehensive "measure of the soil's capacity to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation". The multi-dimensional nature of soil health means that, in an ideal world, at least seven different indicators would be monitored: acidification, soil organic carbon, water erosion, wind erosion, salinity, nutrients, physical condition and biological condition. Physical and biological condition is very difficult to monitor at the extensive scales relevant to Australian wheat farming, and is therefore not considered further. In the remainder of this section we discuss the first five indicators, with nutrient balance being already considered in the section on fertiliser use.

Soil acidification is a slowly-occurring natural process which is accelerated by agriculture, mainly due to excessive use of ammonium-based fertilisers, and partly because the product removed (e.g. grains or other crops) is alkaline. Nitrogen in ammonium-based fertilisers is readily converted to nitrate and hydrogen ions in the soil. If the nitrate is in excess of what can be taken up by the plants it can leach away, causing a build-up of hydrogen ions, or acidity, resulting in poor root growth and restricted access to water and nutrients.

It is estimated that more than 70% of surface soils and half of subsurface soils across the Wheatbelt are affected by soil acidity (Wheatbelt NRM 2013), which results in up to A\$500m/year in lost production.[3] The optimal pH range for wheat is around or above pH 5.5 in the topsoil and 4.8 in the subsurface – key thresholds below which root growth is impaired (Gazey & Andrew 2009).

Soil organic carbon (SOC), and the ability of soil to store it, is regarded as an important basis for soil fertility, and consequently, crop yields. It is also an important component of the global carbon cycle, with potential to provide either substantial additions or removals to atmospheric CO_2 levels, depending on how it is managed. Across Australia, the total stock of organic carbon in the top 30 cm of soil is estimated to be 19-32 GtC (Viscarra Rossel et al. 2014). In Western Australian soils under broadacre grain production, SOC is typically 0.8-2% of soil mass in surface soils (the top 10cm), or the equivalent of 8-20 tC/ha (Hoyle 2016).

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[3] https://www.agric.wa.gov.au/news/media-releases/world-soil-day-wa-soil-acidity-research-boosts-yields-and-profitability (Accessed 27 October 2016)

Increased soil carbon levels can benefit crop growth through processes such as improved nitrogen and water supply to crops. However, this is the case only at low fertiliser application rates (0-50kg N/ha), when the crop relies on mineral nitrogen from soil organic matter rather than nitrogen supplied by farmers (Palmer et al. 2015). At higher rates of fertiliser application, which is more typical of current farming practices, there was little or no productivity benefit from increased SOC.

Dryland **salinity** occurs when the concentration of soluble salts near the soil surface is sufficient to reduce plant growth. Dryland salinity develops when a supply of water and a store of salt in the soil meets the ground surface, mainly due to clearing for agriculture and the replacement of deep-rooted perennial vegetation with shallower rooted annual crops. Up to 17 million hectares of mostly agricultural land in Australia is thought to be at risk of developing salinity problems by 2050 unless effective action is taken to mitigate this risk (ABS 2013). Salinity is also thought to have caused a 50% decrease in the numbers of wetland bird species, and is threatening 450 plant species with extinction (ABS 2013).

Water and wind erosion can impact wheat yields by removing fine fractions of soil which include clay, organic matter and soil nutrients, resulting in reduced capacity of the soil to retain water and nutrients. If the top 10 mm of soil are subjected to erosion, crop yields can be reduced by 25% (DAFWA 2013).

4.3.2 Risk mitigation
Soil acidification risk can be mitigated by using acid-tolerant cultivars of wheat, in conjunction with liming to recover soil pH to target levels (Gazey and Davies 2009). SOC loss can be slowed, or even reversed, by optimizing agricultural management through stubble retention, fertilisation and conservation tillage (Wang et al. 2013). The four major strategies available to address salinity are the planting of more salt-tolerant crops, the planting of trees, the fencing of land from grazing and the construction of earthworks such as drains (ABS 2003). Finally, water erosion can be minimized through stubble retention and the construction of earthworks to reduce the velocity and volume of peak flows,[4] and wind erosion can be controlled by reducing wind-speed at ground level (e.g. by planting windbreaks) and minimising soil disturbance. Around 50-75% ground cover is required to minimise erosion, depending on soil type (DAFWA 2013).

4.3.3 Lender information requirements
Lending institutions would be primarily interested in the farmer's ability to manage soil health issues, and in monitoring long-term trends in the above indicators for evidence of soil health degradation.

Table 4: Soil health risks, information needs and data sources

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[4] https://www.agric.wa.gov.au/water-erosion/water-erosion-introduction (Accessed 1 December 2016)

Risk Factor	Timeframe	Scale	Information Need	Data Sources
Soil acidification	Short term	Farm	Farmer's ability to monitor and manage soil acidification	Farmer questionnaire
	Long term	Farm	Change in soil pH over time	Soil samples
Soil organic carbon	Short term	Farm	Farmer's ability to monitor and manage SOC	Farmer questionnaire
	Long term	Farm	Change in SOC over time and estimated carbon dioxide equivalent emissions or removals	Soil samples plus published conversion factors
Soil salinity	Short term	Farm	Farmer's ability to monitor and manage salinity	Farmer questionnaire
	Long term	Farm	Change in salinity over time	APSoil database (baseline) plus on-going soil samples or electromagnetic mapping
Water and wind erosion	Short term	Farm	Farmer's ability to monitor and manage erosion	Farmer questionnaire
	Long term	Farm	Soil loss over time	Farmer observations (e.g. photos); erosion maps

4.4 Pests, diseases and weeds

4.4.1 Overview

Pests, diseases and weeds can be seen as ecosystem interactions that result in reduced crop health and yields if farmers do not take appropriate action to mitigate their impacts. They can also have significant impacts on other forms of natural capital such as biodiversity, soil or water quality. The economic losses associated with pests, diseases and weeds in the Wheatbelt are summarized in Table 5.

Table 5: Yearly economic loss related to pests, diseases and weeds in agriculture. Data sources: GRDC (2013) and Australian Government (2016)

	Pests	Diseases	Weeds

Economic loss	A$789m/year or A$60/ha	A$913m/year or A$76.64/ha	A$1.5bn/year (weed control) + A$2.5bn/year (lost agricultural production)

The risks to wheat crops from pests, diseases and weeds are material to not only short- and long-term crop health, but also to the surrounding environment and its ecosystems.

4.4.2 Risk mitigation

Management of pests and diseases is achieved by the use of resistant cultivars, paddock preparation and management, and application of pesticides (Murray and Brennan 2009). Weed control relies on effective monitoring plus interventions such as winter cleaning of pastures or chemical fallowing.

4.4.3 Lender information requirements

Lenders would be interested in the historical frequency and severity of pests, diseases and weeds affecting a particular region or farm, the farmer's ability to monitor and mitigate those risks and projected changes in risk incidence over time.

Table 6: Pests, diseases and weeds risks, information needs and data sources

Risk factor	Timeframe	Scale	Information Need	Data Sources
Pests and diseases	Short term	Farm to region	Frequency and severity of pests and diseases outbreaks, and farmer's ability to monitor and manage	Grain Research and Development Corporation (GRDC) reports and datasets and farmer questionnaire
	Long term	Farm to region and national	Projected changes in frequency of occurrence of pests and diseases outbreaks	GRDC reports and datasets
Weeds	Short term	Farm to region	Time and resources spent on weed management and farmer's ability to monitor and manage	Farmer questionnaire
	Long term	Farm to region and national	Projected changes in distribution of weeds	GRDC reports and datasets

4.5 Biodiversity

4.5.1 Overview

Australia's biodiversity is in decline, with more than 1,700 species and ecological communities known to be at risk.[5] The key threats to biodiversity include agricultural practices which lead to loss, degradation or fragmentation of habitats, changes to water flows and quality, altered fire regimes and the introduction of invasive pests, diseases and weeds.

Biodiversity has many different values. These include regulation of bee pollination, recreational/amenity values, and cultural/spiritual values among others. However, only some of these values are currently priced in some way (e.g. Australia's commercial fisheries are valued at $2.2 billion) (ABS 2010). Threatened species and ecological communities are protected in Australia under the Environment Protection and Biodiversity Conservation Act 1999, which controls actions likely to cause significant impacts.

4.5.2 Risk mitigation

A variety of actions can be taken to avoid negative impacts and/or to positively enhance biodiversity. These include: mapping, conserving and regenerating remnant patches of native vegetation; creating buffers and setting land aside for biodiversity; creating corridors between areas of relatively undisturbed habitat; and controlling invasive species.

4.5.3 Lender information requirements

Lenders would be interested in understanding the baseline condition of biodiversity on the farm, the projected long-term trend for biodiversity in the area, and the farmer's ability to monitor and manage biodiversity. Whether the farm is in a biodiversity hotspot or close to the range of a threatened species could be indicators of high quality risk.

Table 7: Biodiversity risk - information needs and data sources

Risk factor	Timeframe	Scale	Information Need	Data Sources
Biodiversity	Short term	Farm	Extent of remnant native vegetation (ha)	Farmer questionnaire
	Short term	Region	Quality of biodiversity	Biodiversity hotspots map; Atlas of Living Australia; region-specific studies
	Long term	Region	Projected changes in biodiversity	CSIRO and other research on climate change and other long-

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[5] http://www.environment.gov.au/biodiversity/threatened/species (accessed 23 March 2017).

			term impacts on biodiversity
Short term	Farm	Farmer's ability to monitor and manage biodiversity	Farmer questionnaire

5 Conclusions

Developing a detailed, context-specific understanding of potential environmental risks and dependencies applicable to smaller-scale borrowers could not only help overcome the inevitable information asymmetry between borrower and lender (Akerlof 1970), but also help identify and price risks that the borrower themselves may not be aware of. A bank's ability to demand information from its customers (Goss & Roberts 2011) and to analyse this across a portfolio in combination with other sources of information has the potential to detect systemic opportunities or risks in any area of business, and may be particularly applicable to sustainability risks, which are often long-term, large-scale processes, where systemic understanding is still emergent.

There is a trade-off, however, between the cost of obtaining and analysing information, and the associated benefit. It is no surprise that the principal environmental risks which research providers currently analyse are those which can be relatively easily measured through the use of publicly available datasets: greenhouse gas (GHG) and other air pollutant emissions, water and climate risks, with only a few research providers offering services related to agricultural or natural resource depletion risks. One reason for this may be that understanding such risks requires the ability to analyse large volumes of spatial data, for example using Geographical Information Systems (GIS), which traditional research providers typically do not use (Cojoianu et al. 2015).

We have demonstrated that it is possible to derive a suitable evidence base to support a comprehensive, industry- and geography-specific assessment of natural capital risks for smaller-scale loans in agriculture, using wheat farming in Australia as a case study. In principle, this suggests that the same generic approach could be followed to develop similar frameworks suitable for other sub-sectors and geographies.

However, the exercise has not been without challenges. Natural processes are often characterised by complexity and interconnectedness. While it is relatively easy to identify high-level natural capital risk categories, we discovered that most of these are in fact multi-dimensional: for example, rainwater availability is a function of quantity, timing, reliability and water use efficiency, each of which can be associated with distinct risks. These sub-factors can combine in various ways, each entailing different risks: for example, the risk of insufficient water availability during the critical growing stages involves a different combination of quantity and

timing issues to the risk of excessive rainfall at harvest. The multi-dimensionality of environmental risks can be observed at multiple levels and often involves cross-linkages with other environmental risks: for example, water use efficiency is itself a function of various factors including soil characteristics, nitrogen supply, weed cover and so forth. An assessment framework based on dissection of multi-dimensional risks in order to evaluate individual risks may overlook some systemic cross-linked issues.

A related challenge has been to bridge the gap between the financial sector's desire for an unambiguous answer to what seems a simple question – is this loan an acceptable risk? – and the complexity, uncertainty and heterogeneity of the reality on the ground. We have had to use our own judgement in some cases to distil what seem to be the key risk factors from a mass of detailed, sometimes contradictory, scientific and industry statements. Our presentation of any given risk may well be regarded as a gross over-simplification by an expert in that particular area. Whilst the evidence base we have presented can undoubtedly be refined and improved, a balance must be struck between exactitude and practicality. No metric will ever perfectly capture any given risk – to be useful, it need only perform better than the current alternative, which for many of these factors is no assessment whatsoever.

Some risks are less challenging to evaluate than others. For example, energy use and GHG emissions are relatively easy to monitor and to price with a shadow cost of carbon, and therefore we have not discussed these risks further in this paper. Soil health risk factors are at the other end of the spectrum, being highly complex, interconnected, and long-term issues.

Finally, we have shown that many sources of useful quantitative data to assess natural capital risk factors exist – at least in a developed country such as Australia – but also that qualitative data will almost always also be required to obtain a view of how able the borrower is to manage a particular risk. The 'managed risk' situation is what is most relevant to the lender, as opposed to only the underlying physical risk on its own. Furthermore, the fact that most risks can be managed proactively suggests that there is a role for natural capital risk assessment in ongoing monitoring and farmer engagement, and not only at the initial credit assessment stage.

We have only been able to infer financial materiality at the level of the farmer from evidence of the magnitude of physical risks and generic financial evidence such as sector-level costs. Further research to evaluate the impact on farm financial performance of any individual risk factor, or ideally all of them in combination, would be extremely useful.

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