Drought and climate adaptation program

DCAP3

CREATING ALTERNATE INCOME STREAMS TO INCREASE FARM PROFITABILITY AND BENEFIT THE ENVIRONMENT (UNISQ)

Milestone Report 6a

Preliminary cost/benefit analysis of the different options identified and how they relate to climate risk.

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Summary

The Milestone 6 report is focused on conducting preliminary cost-benefit analyses of various income diversification (incremental and transformational) options available in Queensland's crop production regions, particularly in relation to identified climate risks.

We assumed that an environmental scheme has generated surplus income, and a farmer is looking to reinvest the extra profit to enhance the resilience of their cropping enterprise through suitable incremental and transformational adaptation options. To facilitate improved decision-making, we have analysed the cost-benefit of several selected options (see Table 1). These options include:

- Translocation: New location – either the same or a new production system
- New irrigation system (e.g., drip irrigation): Investment in enhancing irrigation systems, particularly for cotton production, to efficiently utilize water, especially during droughts.
- Biochar addition as a drought risk management strategy

Cotton relocation options, including expanding part of current operations to a new location, could be a key strategy when planning comprehensive climate risk management strategies. It would be more effective if the risks between the Burdekin and Central Highlands and the Maranoa regions were not correlated. For example, during drought years, a healthy return in the Burdekin could offset lower returns in the Balonne, Central Highlands, and Maranoa regions, providing sustainability to diversified farming systems. The relocation strategy could be more appealing if suitable plant varieties were available that match northern Queensland's climate. Better varieties will allow for higher yields and maximize income opportunities. Moreover, supporting infrastructure will encourage much more significant and quicker expansion of relocation opportunities.

Investing in modern irrigation systems, like sprinkler and drip irrigation, is a widely recommended adaptation option that can significantly improve water use efficiency and reduce agricultural water consumption, helping to mitigate the impact of drought. We investigated the feasibility of investing in highly efficient irrigation systems, especially in the context of surplus income generated by cotton producers through environmental plantations. Our findings suggest that adopting these technologies is an economically viable option with strong economic returns, especially in the face of more frequent drought conditions.

Biochar has been praised for its potential to enhance drought tolerance and soil fertility and reduce land degradation, ultimately leading to increased agricultural productivity. Our study evaluated the economic implications of integrating biochar into dryland wheat farming in the Maranoa region. Our economic evaluation shows that a modest increase in yield alone does not make using biochar economically viable. However, considering both the increase in yield and the cost savings on fertilisers, we find that using biochar is marginally feasible. Our sensitivity analysis shows that yield and biochar costs are important factors in determining economic feasibility. We did not consider the environmental benefits, but accounting for them may also improve the economic feasibility of biochar application.

This report

Building on our earlier analyses and reports (Kath et al., 2023; Reardon-Smith et al., 2023; Thorpe et al., 2023; Kath et al., 2024; Kath & Thorpe, 2024, Kath et al., 2024, and Reardon-Smith and Mushtaq, 2024), this current Milestone 6 (MS6) report aims to conduct preliminary cost-benefit analyses of a selection of different income diversification options currently available, and specifically in relation to climate risk identified across Queensland's crop production regions.

This relates to Step 4 in the overall 'logic' that informs this project (Figure 1).

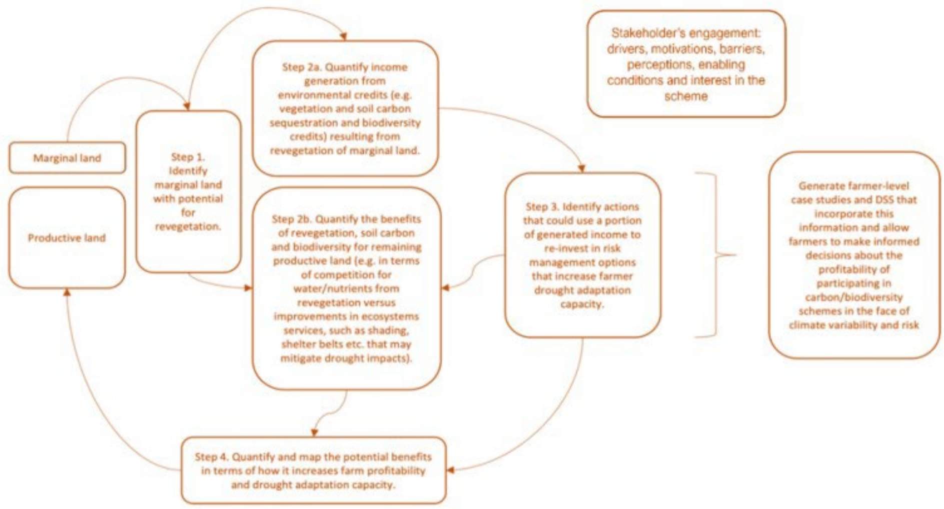

Figure 1. Schematic outlining the approaches and activities that are being undertaken in this project

The value of diversified farming systems: recap

In our MS4 report (Kath & Thorpe, 2024), we estimated that investments in environmental benefit or 'natural capital' schemes, such as agroforestry or shelter belt plantings, are expected to improve the financial gross margin outcomes for farming enterprises in Queensland's climatically marginal cropping areas (Kath et al., 2023). This is particularly true when considering the ecosystem services provided by such investments.

In our recent analysis (see MS 4 report), we have determined several key thresholds at which it would make economic sense for farmers to shift from production (cotton and broadacre cropping) focused systems to environmental benefit projects or mixed systems that also incorporate such projects. Our research, particularly in the Balonne, Central Highlands, and Maranoa regions, has revealed the following modelled thresholds (see Figure 2):

1. where long-term average cropping gross margins fall below $57 ha/year, without factoring in ecosystem services, farmers should be looking at diversification opportunities that provide them with additional income sources. In such instances, environmental (natural capital) credit schemes may provide potential opportunities.

2. if we assume an overall 10% positive impact of ecosystem benefits due to the natural capital scheme on a production system, the average gross margin at which the farmer should be looking at environmental benefit scheme investment opportunities increases to $101 ha/year. At gross margins greater than this threshold level, there are opportunity costs involved in entering into such schemes (i.e., the farmer is better off continuing to crop).

3. if we assume an overall 10% negative impact on production (i.e., trade-offs that detrimentally impact the cropping system), threshold crop production gross margin values

fall to $13 ha/year, at which point the farmer is better off investing in environmental benefit scheme rather than cropping.

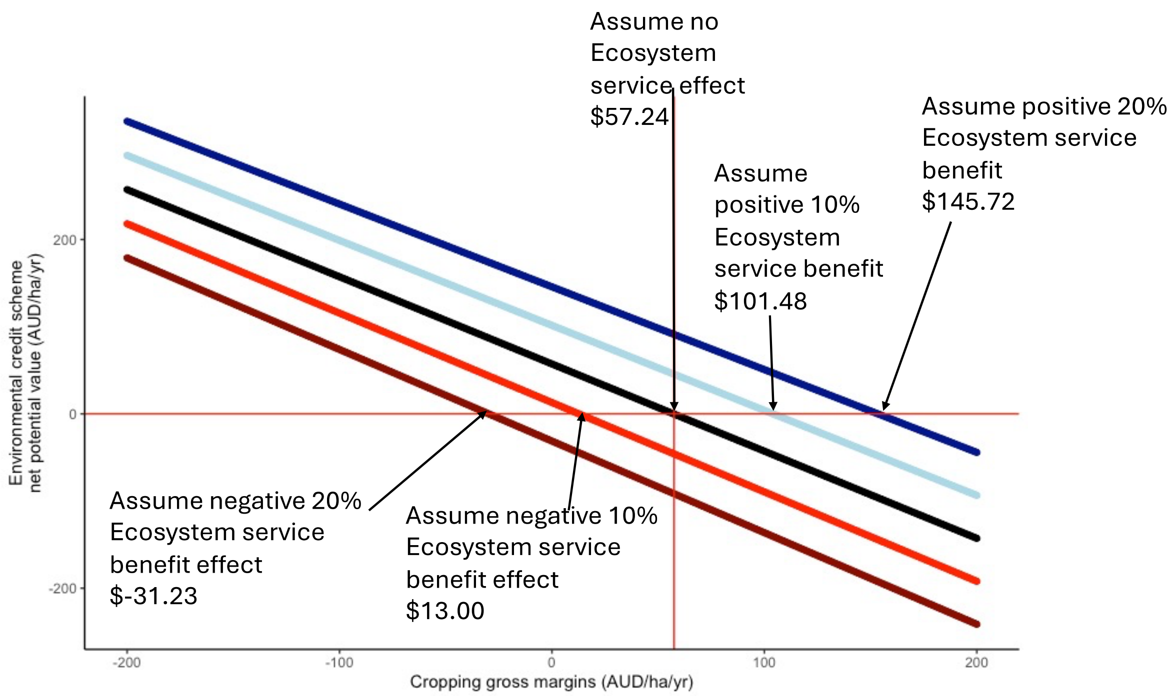

Figure 2. The average estimated transition point between agricultural gross margins and potential environmental credit schemes under a range of ecosystem benefit scenarios. The different coloured lines represent the five-ecosystem service disbenefit/benefit (-20%, -10%, 0%, 10%, 20%) scenarios that were tested and reported in Kath & Thorpe (2024). The dollar values shown correspond to the average cropping gross margins below which farmers could start considering environmental credit schemes when ecosystem services are considered. Note that, of the 82 studies included in this study, only one indicated disbenefit (reproduced from Kath & Thorpe, 2024, Figure 11).

Identifying suitable adaptation options for reducing drought risk and increasing adaptive capacity

Once a decision has been made to take part in a project aimed at promoting carbon or biodiversity benefits, it is expected that producers or land managers will benefit from a positive income stream because of biodiversity schemes. This surplus income is important as it can help stabilise revenue during periods of low agricultural productivity. Additionally, it can be utilised to develop suitable adaptation options during productive years. These adaptation options may include utilising innovative technologies, enhancing skills, and obtaining crop insurance, among other strategies, to enhance the resilience of a farming enterprise to potential future challenges such as droughts and floods. These specific strategies were detailed in our MS5 report and are recapped in Table 1 and Figure 3.

It is important to remember that if the average gross margins for the enterprise continue to decline and approach certain values, it may be necessary to consider additional investment in adaptation, risk transfer, transformation, or income diversification due to the potential for ongoing deterioration in climatic conditions. As highlighted by Sánchez et al. (2020), diversified systems, when utilised as a risk management approach, are particularly advantageous in protecting farm incomes. This is especially pertinent considering the escalating challenges stemming from fluctuating climatic patterns and the dynamics of a globalised market.

Table 1. Details of potential investment options available for Australian crop production systems (Reardon-Smith and Mushtaq, 2024; MS 5)

Investment option	Detail	References
Farm Management Deposit (FMD) Scheme	FMD accounts allow primary producers to make tax deductible deposits during years of good cash flow and withdraw them during bad years → income smoothing.	Australian Tax Office, 2022; e.g., West et al., 2021
Climate risk adaptation options	Include skills, practices, technology, equipment, drought preparation … doing things 'better'	e.g., Cradock-Henry et al., 2020; Hughes et al., 2022; McKenzie et al., 2024
Crop insurance – drought, extreme rainfall, hail, frost, and excessive heat insurance	Climate risk transfer to insurance sector	e.g., Mushtaq et al., 2020, 2022;
Environmental (carbon, biodiversity) credit projects	Income diversification projects based on environmental markets & payment for delivery of (additional) environmental benefit according to prescribed methodologies.	Clean Energy Regulator, 2024; Queensland Government, 2024a, 2024b; Thorpe et al., 2023.
New irrigation system (e.g., drip irrigation)	Investment in enhancing irrigation systems, particularly for cotton production, to efficiently utilize water, especially during droughts.	Maraseni et al. (2014); Mushtaq et al. (2014)
Expansion of current production system	Smaller farms tend to have lower profit margins than larger farms due to economies of scale	e.g., Jackson et al. 2020; Hughes et al., 2022
Adjust a proportion of different production systems	e.g., in mixed farming (cropping-grazing; wheat-sheep) systems	e.g., Ghahramani & Bowran, 2018; Ghahramani et al., 2020.
Transformation	New production system (same location) … doing things 'differently'	e.g., Mushtaq, 2018; McKenzie et al., 2024
Translocation	New location – either the same or a new production system	e.g., Mushtaq, 2018; van Leeuwen et al., 2024;

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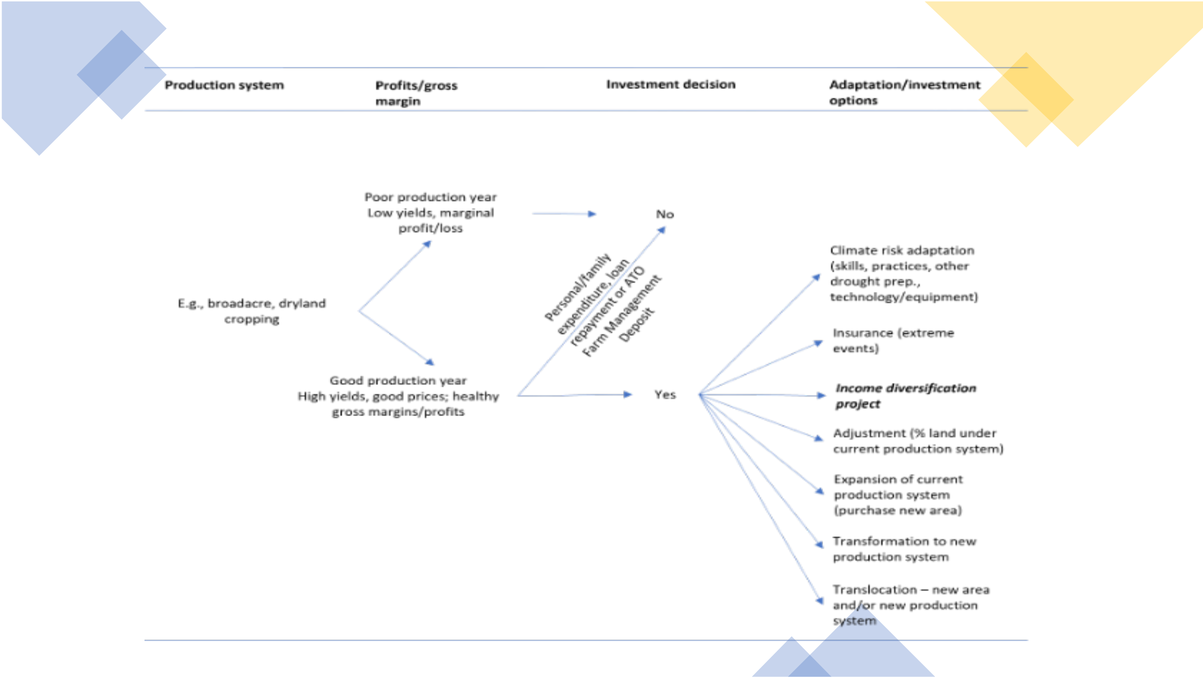

Figure 3. Potential investment options available for Australian crop production systems to further improve the resilience of the production systems, especially during drought years (details in Table 1)

Preliminary cost-benefit analysis of selected options

In this section we assume the environmental scheme has generated surplus income, and the farmer is eager to reinvest the additional profit to further increase the resilience of his farm. He is currently exploring suitable risk management options for investment. To help with improved decision-making, we have analysed the cost-benefit of a few selected options (refer to Table 1).

- Translocation: Expanding part of the current operation with additional lands in a new location – either the same or a new production system.
- New irrigation system (e.g., drip irrigation): Investment in enhancing irrigation systems, particularly for cotton production, to efficiently utilize water, especially during droughts.
- Biochar addition as a drought risk management strategy.

Translocation: Managing climate risks through the expansion of part of the current production system to a new location

Climate change is changing rainfall patterns in Australia, leading to variations in rainfall distribution and crop productivity across different regions (Kevin et al., 2017; Smith et al., 2013; Sprigg et al., 2014). Some of Queensland's cropping regions are expected to become drier. Our Milestone 3 report confirms a growing marginality of cotton and broadacre production systems in the Balonne, Central Highlands, and Maranoa regions, posing significant challenges to maintaining productive capacity and economic viability.

Conversely, there is potential for increased rainfall, as well as more frequent and intense extreme weather events in the northern regions (Potgieter et al., 2013; CSIRO and Australian Bureau of Meteorology, 2014). Northern Australia presents an opportunity to consider relocating a portion of the production system from increasingly marginal southern cropping areas as a risk management strategy (Mushtaq, 2018; van Leeuwen et al., 2024). This could involve taking advantage of the potentially more conducive climate conditions in the north to safeguard against declining productivity in southern cropping regions.

The strategic transformation of production systems involves the relocation of operations to climatic zones that are better suited to mitigating risks. This approach is becoming increasingly common as a means of diversifying risk. Importantly, the relocation of certain aspects of production systems to different climate zones, where the risks between the zones are uncorrelated, has been identified as an effective strategy for managing climate risk (Sánchez et al., 2020). However, it is imperative that if such a relocation strategy to manage climate risk is to work, it should generate considerable economic returns, especially during those years when the economic returns in the southern regions are low.

In this section, we examine the strategy of investing surplus income in relocating a portion of a cotton production system to northern Australia, where the long-term climate outlook is more favourable. This strategy aims to mitigate the impact of drought and other climate-related risks, resulting in more resilient and economically viable farming systems.

Following Mushtaq et al. (2014), we have identified Burdekin as a potential area for relocation. Mushtaq et al. (2014) elaborated the rationale behind this decision. Key factors influencing our choice include assessing additional irrigation infrastructure costs, considering the availability of reliable irrigation water supply (e.g., Burdekin Falls Dam) and its proximity to major cities like Townsville and ports.

We used a gross margin analysis method to evaluate the net margins of the cotton crop. The net margins were calculated by subtracting the variable costs from the gross income. Variable costs included expenses directly associated with wheat production, such as cultivation, sowing, fertilizers, herbicides, and contract harvesting. It's important to note that our analysis focused solely on the direct variable costs linked to crop production and did not factor in any fixed charges or overheads. Additionally, we assumed that there are no agricultural or infrastructure limitations.

The cotton crop models, such as APSIM cotton and DSSAT models, are not sufficient, mainly due to a lack of suitable cultivars and a different environment for simulating cotton yield in northern Australia (Mushtaq et al. 2014). Therefore, we relied on experimental yield and published yield estimates. Based on the CSIRO trials in Burdekin, the cotton yield varied between 3.5 bales/ha to 9.5 bales/ha, with an average of 6.5 bales/ha (Grundy & Yeates, 2009).

The net margin calculated in this analysis was primarily derived from 'CottonInfo' estimates specific to the northern cotton industry. However, it was also adjusted to account for experimental yield data. We chose Burdekin as a potential area for relocation and used the furrow-irrigated cotton crop for our analysis. For a detail, please visit:

https://www.cottoninfo.com.au/publications/australian-cotton-industry-gross-margin-budgets

Table 2 shows the gross margin analysis of cotton irrigated with furrow, based on the average yield of 7.5 bales/ha from the literature review. According to Table 2, cotton farmers can anticipate earning $1720/ha, which is slightly lower than cotton grown in the Central Highlands, Maranoa regions, and other parts of Australia (Mushtaq et al. 2014, CottonInfo, 2024). This is mainly due to the higher yield of up to 12 bales/ha that could be achieved in those regions.

Table 2. Gross margin analysis for furrow irrigated cotton in Burdekin.

Items		Yield (bale/ha)	Price ($/bale)	Total
Income	Cotton lint	7.5	$600	$3,900
	Cotton seed		$90	$585
	Total gross margin			**$4,485**
Cost	**Ground preparation**			**$65**
	Nutrition			$750
	Planting			$120
	Irrigation (6 ML applied)			$120
	Crop protection			$650
	Defoliation			$125
	Picking, cartage & ginning			$1,500
	Farming: Post-crop			$125
	Total variable costs			**$3,445**
Net Margin				**$1,720**

The profitability of agriculture is mainly influenced by crop yield and prices. When considering relocating cotton production to reduce the impact of climate-related risks, it is important to focus on achieving higher yields to increase income. Assuming drought is uncorrelated and does not impact Burdekin, Central Highlands, and Maranoa regions simultaneously, a strong return in Burdekin will likely offset lower returns in the Balonne, Central Highlands, and Maranoa regions, and therefore provide sustainability to the diversified farming systems.

To account for yield and price variability, we conducted a sensitivity analysis. As shown in Figures 4a and 4b, relocating cotton production to the Burdekin region is not economically feasible at lower yields and prices, even with more affordable irrigation costs. The estimated break-even yield is 5 bales per hectare (4a). Conversely, with average yield, cotton prices need to be $370 per bale or higher for farmers to make a profit (4b).

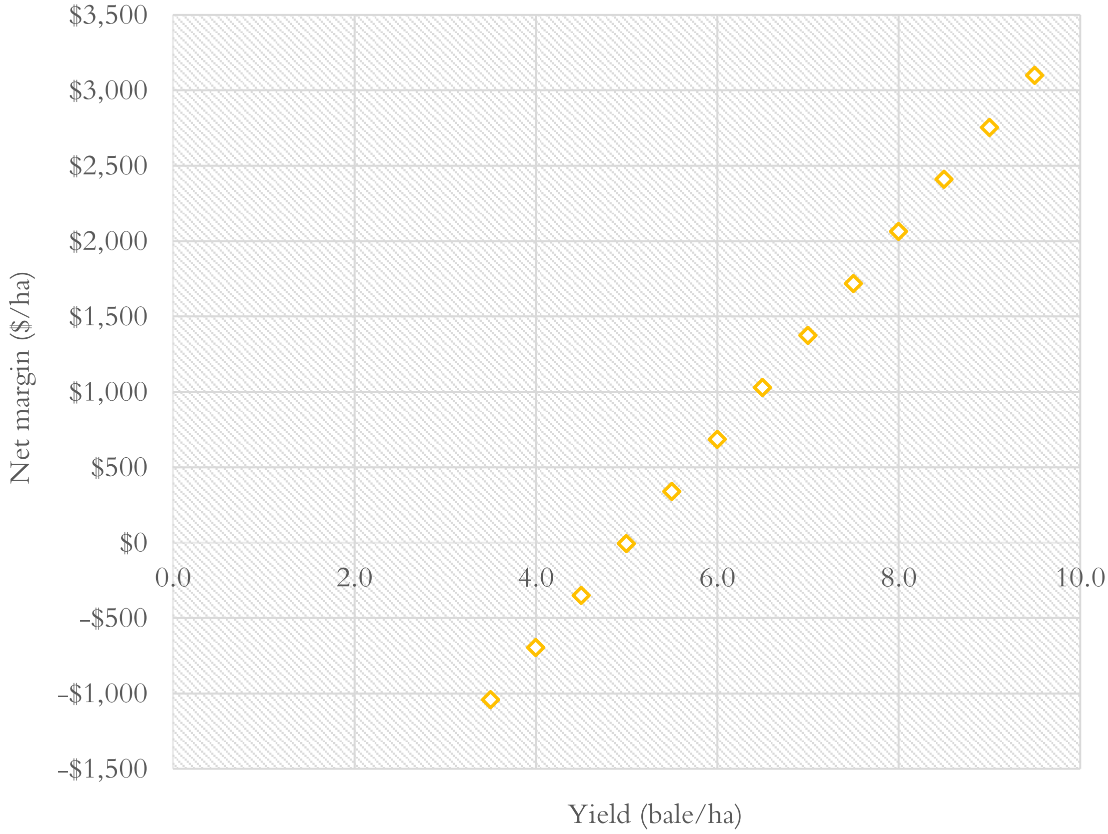

Figure 4a: Sensitivity analysis of net margins under various levels of cotton yield.

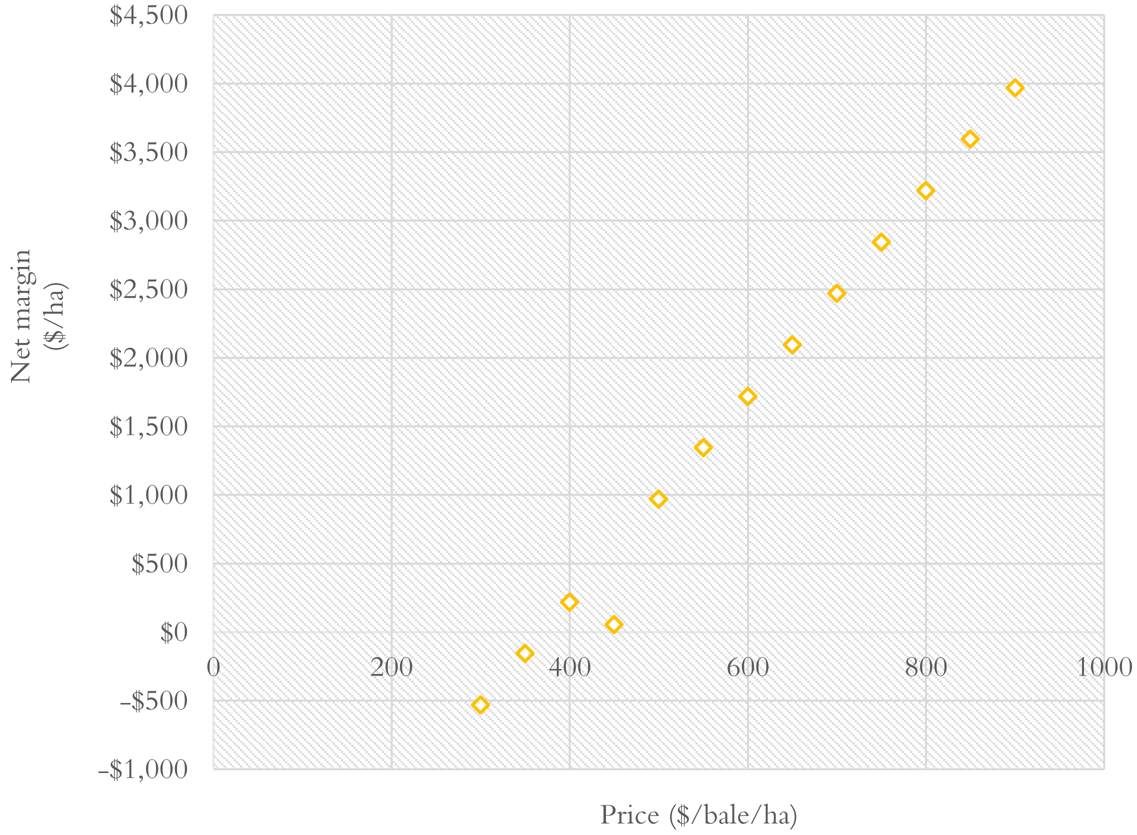

Figure 4b: Sensitivity analysis of net margins under various levels of cotton lint seed prices, with average yield.

Key conclusion: Cotton relocation, expansion of part of the current operation to a new location, and options could be key strategies when planning comprehensive climate risk management strategies. It would be effective if the risks between the Burdekin and Central Highlands and the Maranoa regions were not correlated. For example, during drought years, a healthy return in the Burdekin could offset lower returns in the Balonne, Central Highlands, and Maranoa regions, providing sustainability to diversified farming systems. It is important to note that the analysis is only based on gross margin analysis. We did not attempt to estimate regional and social benefits.

The relocation strategy could be more appealing if suitable plant varieties were available that match northern Queensland's climate. Better varieties will allow for higher yields and maximize income opportunities. Moreover, supporting infrastructure will encourage much more significant and quicker expansion of relocation opportunities.

Modern irrigation system (e.g., drip irrigation): Investment in enhancing water use efficiencies

Cotton growers face a major risk from drought. A significant drought can reduce crop yields and cause farmers to decrease production areas. Our project has conducted a detailed analysis of the impact of climate marginality on cotton production in the regions of Balonne, Central Highlands, and Maranoa. Our findings indicate that these sub-regions are at considerable risk in terms of production, primarily due to adverse trends in soil moisture, declining rainfall, and increasing night-time temperatures (MS 3 report; Kath et al., 2023).

Drought not only directly impacts cotton yield, but also affects water availability. Often, water allocation during drought years is significantly lower than in normal years. Prolonged drought generally results in large reductions in water availability, which affects decisions about cotton production including how much to plant, which varieties to plant, and the best row configuration to use (Mushtaq et al., 2014).

Cotton producers face several critical decisions in their efforts to mitigate the impacts of drought. These decisions may involve determining the optimal production levels, adopting deficit irrigation practices, and considering alternative row configurations (Power et al., 2011; Mushtaq et al., 2014). Investment in irrigation efficiency may also help reduce the impact of drought. High-efficiency irrigation technologies, such as sprinkler and drip irrigation systems, offer promising solutions by enhancing water use efficiencies and reducing agricultural water consumption (Maraseni et al., 2014).

In this section, as outlined in Table 1, we examine the feasibility of investing in highly efficient irrigation systems if the cotton producers achieve surplus income through environmental plantations. This strategy aims to not only mitigate the adverse effects of drought and, therefore, low water availability but also to increase the overall resilience of the cotton production system.

To assess the economic viability of modern irrigation systems like drip and sprinkler (lateral move or central pivot), we utilised metadata from five cotton case studies conducted in similar regions (see Maraseni et al., 2014; Mushtaq et al., 2014 for details). We then revised the economic projections to ensure their relevance today.

We employed four commonly used economic indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback Period (in years) to thoroughly evaluate the economic feasibility and effectiveness of drip and sprinkler (lateral move and central pivot) systems.

In the five case studies, as provided on the case studies, several significant assumptions were made:

- Water saving: It was assumed that cotton sprinkler irrigation would save between 0.5-2ML of water per hectare, while drip irrigation would save between 1.7 to 3ML, depending on the soil.
- The benefits from these systems continue over the life of the system, usually 15–25 years, depending on the type of system.
- Labour savings: A labour savings of around 5.0 hours per hectare was used
- Additionally, an interest rate of 5% is assumed

We also conducted a sensitivity analysis to validate the economic analysis based on water availability (or drought) scenarios. This involved systematically changing the values of key benefit parameters, with the results mainly discussed using NPV as the evaluation criterion.

The economic feasibility of high-efficiency irrigation systems, such as drip and sprinkler irrigation, from five case studies, is summarised in Table 3. Depending on the farming characteristics, level of water and labour savings, the adoption of modern irrigation technologies – drip and sprinkler irrigations – are a viable option. There was not much difference in terms of NPV between the drip and sprinkler irrigation. This is due to high initial capital and maintenance costs.

Table 3 Economics of highly efficient irrigation systems to manage drought risks based on five case studies

Assessment criteria	Unit	Sprinkler irrigation system (lateral move)	Sprinkler irrigation system (centre-pivot sprinkler)	Sprinkler irrigation system	Average for sprinkler irrigation system	Drip irrigation system	Drip irrigation system	Average for drip irrigation system
Net present value (NPV)	$	$19,366	$16,090	$2,803	$12,753	$3,145	$2,699	$2,922
Benefit–cost ratio		3.7	1.4	1.4	2.2	1.3	1.2	1.3
Internal rate of return	%	51.5	12.6	10.7	24.9	10.2	8.8	9.5
Payback period	Years	3.1	10.6	12.4	8.7	13.0	15.1	14.1

The initial analysis was carried out based on average water availability conditions. However, it's important to note that the profitability of highly efficient irrigation systems could be significantly higher under drought or low water availability conditions.

Therefore, a separate sensitivity analysis was conducted, considering the drought or low water availability scenarios. In this sensitive analysis, temporary water market prices, which are indicative of the supply and demand of water, were utilised as a proxy for the actual value of water ($/ML). This signifies that in times of sufficiently high volume of water availability (or wet conditions), water trading prices tend to be low, and conversely, in times of low water availability, water trading prices tend to be higher (Mai et al., 2019; Nguyen-ky et al., 2018; Khan et al., 2010).

For example, during the 2007-08 drought season when growers received less than 10% water allocation, temporary water prices were above $1100 per ML. Conversely, water prices were only $35 per ML during times of high volume of water availability when growers received 100% water allocation (Murray Irrigation, 2024)

Based on the methodology of MS 4 (refer to Kath et al., 2023) for characterising drought outlook, we have established three water availability scenarios as follows:

- High water availability: Drought is experienced in 2 out of 10 years.
- Medium water availability: Drought is experienced in 4 out of 10 years.
- Low water availability: Drought is experienced in 6 out of 10 years.

Assuming other parameters remain the same, sensitivity analysis indicates that both drip and sprinkler irrigation systems remain economically viable under different water availability scenarios (see Figure 5). It is important to note that while the drip and sprinkler irrigation systems show weaker economic viability overall, they demonstrate considerably higher value during drought conditions. This underscores the crucial role of modern irrigation systems in mitigating the impacts of drought.

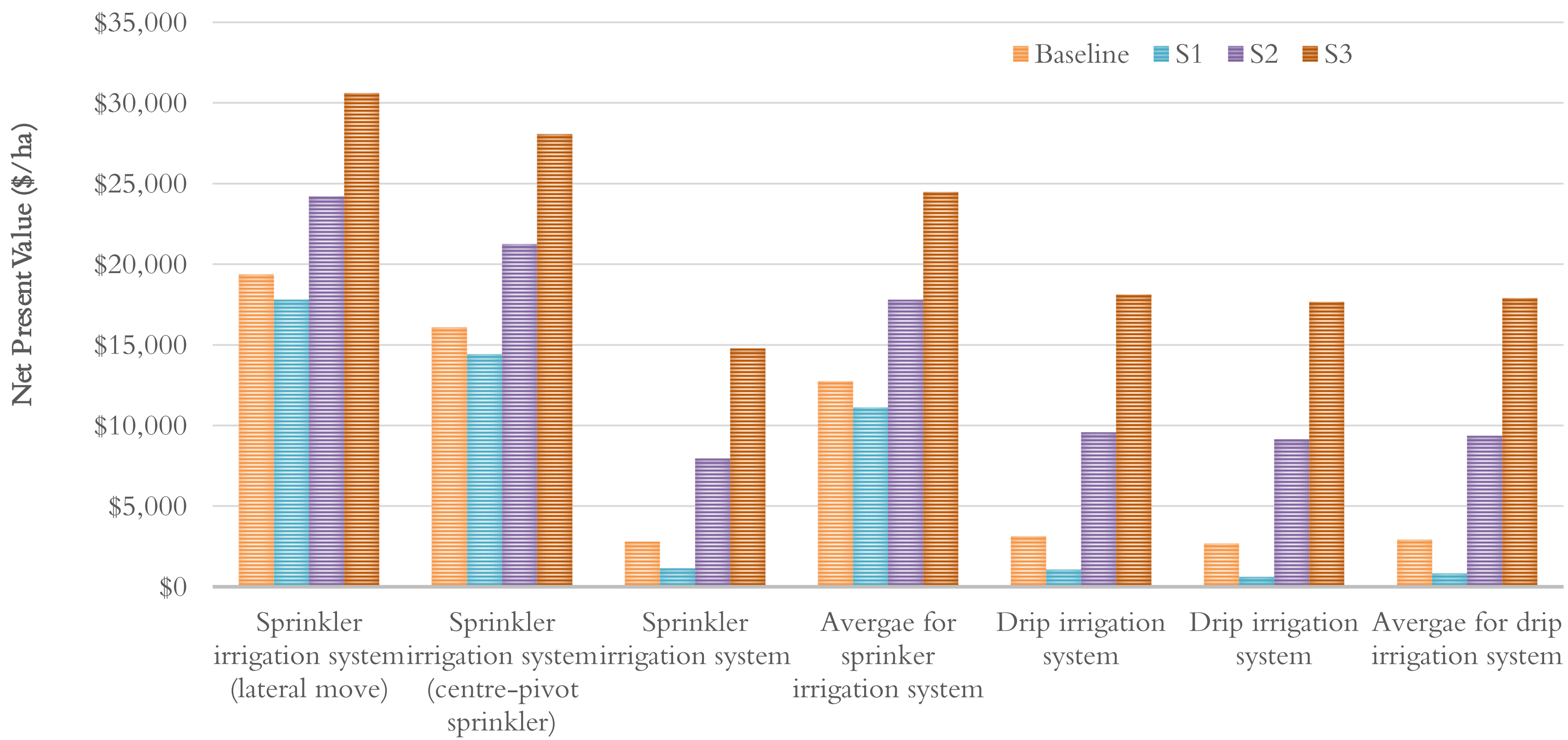

Figure 5. Sensitivity analysis of highly efficient irrigation technologies (sprinkler and drip irrigation systems) in various water availability scenarios

- S1: High water availability: Drought is experienced in 2 out of 10 years.
- S2: Medium water availability: Drought is experienced in 4 out of 10 years.
- S3: Low water availability: Drought is experienced in 6 out of 10 years.

Key conclusion: Investing in modern irrigation systems, such as sprinkler and drip irrigation, has the potential to significantly improve water use efficiency and reduce agricultural water consumption, helping to mitigate drought impact. We examine the feasibility of investing in highly efficient irrigation systems, particularly in the context of surplus income generated by cotton producers through environmental plantations. Our findings suggest that adopting modern irrigation technologies, especially drip and sprinkler irrigation, is an economically viable option based on farming characteristics, water and labour savings, and prevailing conditions. Importantly, we have found that drip and sprinkler irrigation systems offer stronger economic returns, especially in the face of more frequent drought conditions, highlighting their crucial role in mitigating the adverse effects of drought.

Biochar addition as a drought risk management strategy

Biochar, a form of charcoal produced from biomass, has been proposed as a valuable adaptation strategy to enhance drought tolerance and soil fertility, reverse land degradation in agricultural systems, and increase overall agricultural productivity (Blackwell et al., 2010; AECOM, 2019; Robb et al., 2020). One of the key benefits of biochar is its ability to improve soil water retention, which allows for better colonisation of soil microbes and enhanced air circulation. This, in turn, facilitates improved access to essential soil nutrients for plant growth and increase yield (Blackwell et al., 2010; Robb et al., 2020)

The impact of biochar application on dryland wheat production and fertiliser use was studied in a long-term experiment (1997-2008) in Western Australia and South Australia. The findings suggest that biochar has the potential to decrease the overall need for fertilisers while maintaining or increasing crop productivity. Adding biochar to the soil has been shown to boost crop yields even with lower fertilizer rates, indicating its potential to optimise agricultural practices and resource utilisation. A biochar application rate (1 t/ha) may significantly improve yield and reduce fertiliser requirements by enhancing crop nutrient and water uptake (Blackwell et al., 2010). Several studies, including Robb et al. (2020), Steiner et al. (2018), and Kumar et al. (2018), have also reported an increase in yield and cost-saving aspects of fertilizers due to biochar application.

In this section, as outlined in Table 1, we investigate the economic impact of biochar application in a dryland wheat cropping system in the Maranoa region. This strategy aims not only to mitigate the adverse effects of drought by retaining soil moisture for a more extended period but also to increase yield. Eventually, this approach has the potential to enhance the overall resilience of the dryland wheat production system.

As indicated earlier, we employed four commonly used economic indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Payback

Period (in years) to thoroughly evaluate the economic feasibility of biochar application in dryland wheat crop in the Maranao region.

As there are limited studies available on the cost-benefit application of biochar, the study leaned heavily on Blackwell et al. (2010) and Robb et al. (2020) to extract data for the economic assessment. The following parameters and assumptions were considered:

Benefits assumptions:

- While the data obtained through the research experiment shows a yield gain between +40% to -5%, an average 10% increase in wheat yield was observed, depending on the rate of biochar used, climate and soil conditions. In this study, we considered a 10% increase in dryland wheat yield by applying 1 tonne per hectare of biochar.
- The benefits of applying biochar are expected to last for a long time after its application. It is anticipated that these benefits could either remain constant or decline over time. An experiment conducted in Western Australia analysed both constant and declining benefits over a 12-year period during an economic assessment. However, for the purpose of this analysis, we will assume that the benefits will remain constant over a period of 10 years.
- Biochar is not a replacement for fertilizer and should not be considered a fertilizer on its own. Therefore, completely stopping the use of fertilizers is not recommended. While biochar can reduce fertiliser use, it is best to use a combination of biochar and fertiliser to maximise benefits. In this study, we assume that fertiliser use will be halved, resulting in a 50% cost savings on fertiliser.
- Average gross margin data for dryland wheat in Maranoa between 2016 and 2021 was utilised. The gross margins were sourced from AgMargins (https://agmargins.net.au/Reports/Index#) and provided in Annex 2.

- Prices play a crucial role in estimating economic outcomes. To account for price variability, we used wheat prices from the last five years (2016-2021) from AgMargins (https://agmargins.net.au/Reports/Index#).

Cost assumption:

- We model variable costs in our economic assessment, which include expenses directly associated with wheat production, such as cultivation, sowing, fertilisers, herbicides, and contract harvesting. It's important to note that our analysis focused solely on the direct variable costs linked to crop production and did not factor in any fixed charges or overheads. The variable costs data for the period between 2016-2021 was obtained from AgMargins (https://agmargins.net.au/Reports/Index#) and provided in Annex 1.

- Biochar can be produced from various sources, including wood, piggery waste, and other types of organic waste (AECOM, 2019). As a result, the cost of biochar depends on the material used to produce it. In this study, we utilised blended biochar at a rate of 1 tonne per hectare. The price of the biochar is $750 per ton, which was obtained from Green Man Char (https://greenmanchar.com.au/products/blended-biochar)

Other assumptions related to simulations:

- The biochar economic assessment model was run for a duration of 10 years, with an assumed interest rate of 5% for the economic evaluation.

- While there are potentially substantial environmental benefits associated with biochar application, these benefits are not factored into the assessment due to challenges in accurately quantifying and monetising them.

Scenario assessment:

To account for yield and biochar price variability, we conducted two types of sensitivity analysis:

- Change in wheat yield from 0% to 30% - Increase wheat yield by 5%, 10%, 20%, and 30%.
- Changes in biochar prices from $100 to $1000 per tonne.
- There could be other possible scenarios, such as variations in interest rates, the duration of biochar benefits, and fluctuations in wheat prices, but we did not consider them in this study.

The gross margin analysis for dryland wheat in the Maranao region, with and without biochar, is presented in Table 4. When considering only the yield benefits (10% increase) from applying biochar, the results indicate a 24% increase in net return (or $66 per hectare). However, when considering both the yield benefits (10% increase) and the benefits from reduced fertilizer costs (50%), the overall benefits increased by 34% (or $94 per hectare), which represents a significant increase in net margin (Table 4).

Table 4. Gross margin for dryland wheat for Maranao region with and without biochar.

Item	Without biochar	With biochar (10% increase in yield)	With biochar (10 % increase in yield and 50% reduction in fertiliser cost)
Income	$658	$724	$724
Cost			
Fallow Management	$29	$29	$29
Planting	$61	$61	$61
Nutrition	$177	$177	$177
Crop Protection	$58	$58	$29
Harvesting	$32	$32	$32
Post-Harvest	$3	$3	$3
Others	$22	$22	$22
Total variable cost	$381	$381	$353
Net Margin	$277	$343	$371

The economic implications of using biochar in dryland wheat production are presented in Table 5. The economic assessments consider yield benefits alone and yield and fertiliser benefits. The results in Table 5 show that when considering only yield benefits, the economic efficiency of applying biochar is questionable. This is indicated by the negative NPV of -$206, a relatively low IRR of 3%, and a BCR of 0.71, which is below the threshold of 1. The primary reason for this inefficiency is attributed to the significant costs associated with biochar production.

Furthermore, when expanding the analysis to encompass both yield and fertiliser cost-saving benefits, the economic viability of using biochar remains tenuous. Across all economic parameters, including NPV, IRR, and BCR, the outcomes merely meet the minimum economic assessment criteria, indicating a marginal level of economic viability.

Table 5. Economics of biochar to manage drought risks for dryland wheat for Maranao region, Queensland.

Assessment Criteria	Units	With biochar (10% increase in yield)	With biochar (10 % increase in yield and 50% reduction in fertiliser cost)
NPV	$	-$206	$14
IRR	%	-3%	6%
BCR		0.71	1.02
Payback period	Year	>10 years	8

A separate sensitivity analysis was conducted based on yield benefits and reported in terms of NPV to account for yield increase and biochar price variability. It is important to note that the sensitivity analysis did not consider fertiliser cost saving benefits. As shown in Figures 6a and 6b, biochar application becomes economically feasible strategy when the yield increase is greater than 15% or when the biochar price becomes lower than $550 per tonne. The estimated breakeven increase in yield is 15% per hectare (Figure 6a). Similarly, the breakeven biochar price is $530 per tonne (Figure 6b).

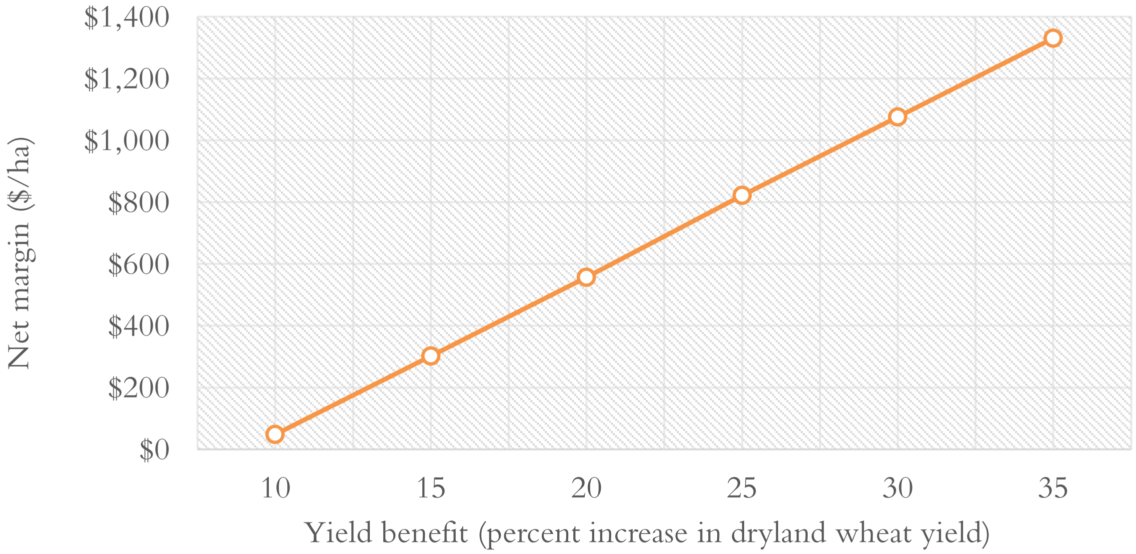

Figure 6a Sensitivity analysis of net margins under various levels of yield increase resulting from biochar application (1 tonne/ha) in dryland wheat for the Maranao region.

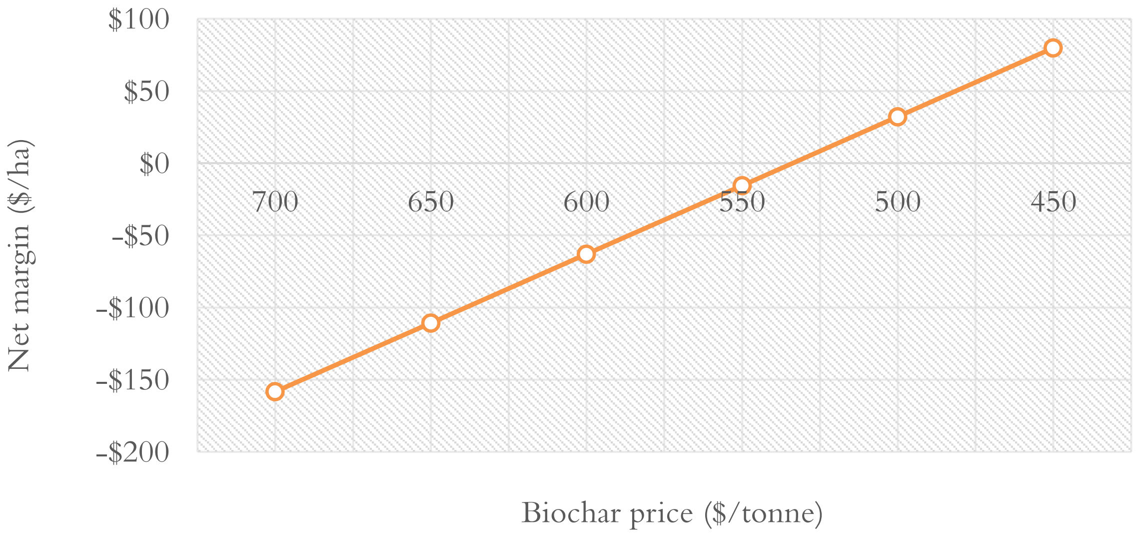

Figure 6b Sensitivity analysis of net margins under various levels of biochar prices ($/tonne) with a 10% increase in dryland wheat for the Maranao region.

Key conclusion: Biochar has been praised for its potential to enhance drought tolerance and soil fertility and reduce land degradation, ultimately leading to increased agricultural productivity. Our study evaluated the economic implications of integrating biochar into dryland wheat farming in the Maranoa region. Our economic evaluation shows that a modest increase in yield alone does not make using biochar economically viable. However, considering both the increase in yield and the cost savings on fertilisers, we find that using biochar is marginally feasible. Our sensitivity analysis shows that yield and biochar are important factors in determining economic feasibility. We did not consider the environmental benefits (i.e., ecosystem service benefits), but accounting for them may also improve the economic feasibility of biochar application.

Summary

The Milestone 6 report focuses on analysing a number of income diversification options in Queensland's crop production regions in relation to climate risks. It includes cost-benefit analyses of options such as translocation, new irrigation systems, and biochar addition for enhanced drought risk management. These strategies aim to enhance farm resilience and mitigate the impact of drought. The summary of the results include:

- The translocation relocation strategy is an attractive option but could be more appealing if suitable plant varieties that match northern Queensland's climate were available. Moreover, supporting infrastructure will encourage much more significant and quicker expansion of relocation opportunities.

- Investing in modern irrigation systems is a widely recommended adaptation option that can significantly improve water use efficiency and reduce agricultural water consumption, helping to mitigate the impact of drought. Our findings suggest that adopting these technologies is an economically viable option with strong economic returns, especially in the face of more frequent drought conditions.

- Biochar has received praise for its potential to improve drought tolerance, soil fertility, and reduce land degradation, ultimately leading to increased agricultural productivity. Our economic evaluation indicates that a modest increase in yield alone does not make using biochar economically viable. However, when considering both the increase in yield and the cost savings on fertilizers, we find that using biochar is marginally feasible. We did not account for the environmental benefits (or of possible environmental credit scheme payments) but factoring them in may also improve the economic feasibility of biochar application.

Next steps

- Discuss the implications of the results with a range of stakeholders and consolidate the preliminary economic assessment with additional data and locations.
- Based on the preferences and data availability (Table 1), consider additional incremental and transformational options, and conduct additional cost-benefit analysis.

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Annex

Annex Table 1: Historical annual water sale and prices data from Murray Irrigation Area (https://www.murrayirrigation.com.au/historical-water-data)

Season	Sales	ML Sold	Total Cost of Sales	Ave Price/ML	Low Price/ML	High Price/ML
1999-00	814	34503	$1,416,952	$43	$21	$99
2000-01	1252	71568	$1,121,847	$16	$8	$32
2001-02	1133	77287	$2,845,838	$39	$0	$75
2002-03	1590	60418	$12,636,209	$228	$100	$350
2003-04	1349	79287	$5,720,953	$70	$50	$150
2004-05	1155	66729	$4,968,153	$73	$44	$200
2005-06	1258	95068	$4,214,487	$45	$34	$140
2006-07	1403	58936	$12,276,748	$300	$70	$800
2007-08	902	11537	$7,845,601	$747	$200	$1,100
2008-09	1834	54948	$16,384,774	$308	$225	$600
2009-10	1142	61498	$9,094,910	$165	$25	$500
2010-11	390	60328	$1,535,847	$33	$1	$97
2011-12	903	135979	$2,155,038	$15	$2	$35
2012-13	2495	214430	$9,901,211	$54	$0	$85
2013-14	2036	219814	$14,564,843	$66	$0	$118
2014-15	2335	175321	$20,700,864	$120	$27	$210
2015-16	1885	111703	$25,832,496	$234	$119	$294
2016-17	1801	202146	$9,754,917	$50	$5	$195
2017-18	2458	201395	$25,833,367	$131	$80	$220
2018-19	1986	99599	$42,124,867	$438	$168	$650
2019-20	1014	34895	$17,966,046	$539	$140	$695
2020-21	2122	126604	$15,374,398	$122	$70	$270
2021-22	1655	196135	$10,269,312	$55	$0	$136
2022-23	934	142483	$2,617,871	$17	$0	$63

Annex Table 2. Gross margin reports for the period 2016-2021 for dryland wheat for Maranoa region.

Industry Any | Commodity Wheat | Year Any | Region Maranoa | Irrig/Rain Rainfed | Sort By Modified | Reset Filters

	2017 Wheat Rainfed	2018 Wheat Rainfed	2021 Wheat Rainfed	2019 Wheat Rainfed	2020 Wheat Rainfed	2016 Wheat Rainfed
Region	Maranoa	Maranoa	Maranoa	Maranoa	Maranoa	Maranoa
Income (per ha)						
Grain	$462	$462	$714	$840	$840	
Wheat						$632
Total Income	$462/ha	$462/ha	$714/ha	$840/ha	$840/ha	$632/ha
Variable Costs (per ha)						
Fallow Management	$26	$27	$26	$27	$27	$38
Planting	$59	$59	$59	$59	$59	$71
Nutrition	$181	$177	$174	$177	$177	$176
Crop Protection	$38	$77	$38	$77	$77	$38
Harvesting	$26	$26	$24	$43	$43	$32
Post-Harvest	$1	$1	$0	$0	$0	$16
Other	$18	$18	$23	$26	$26	$21
Total Costs	$346/ha	$381/ha	$345/ha	$408/ha	$408/ha	$392/ha
Gross margin	$116/ha	$81/ha	$369/ha	$432/ha	$432/ha	$240/ha
Updated	17/07/18	17/07/18	16/02/22	17/02/22	17/02/22	23/02/24

Source: AgMargins, 2024 (https://agmargins.net.au/Reports/Index#)