Assessing the suitability of central Queensland mining region for growing Pongamia trees as a source of biofuel

Mandana Shaygan[1], Monia Anzooman[1], Neil McIntyre[1], Peter deVoil[2], Joe Lane[3], Daniel Rodriguez[2]

[1] Centre for Water in the Minerals Industry, The University of Queensland, St Lucia, QLD, Australia
[2] Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, St Lucia, QLD, Australia
[3] UQ Gas & Energy Transition Research Centre, The University of Queensland, St Lucia, QLD, Australia

INTRODUCTION

Pongamia, a leguminous tree with seeds containing ~40% oil, has potential for biofuel production. Seed yields range from 9–90 kg/tree annually, influenced by plant, soil, and climate interactions. While Pongamia thrives in diverse conditions, its yield consistency in Central Queensland's variable environment is unknown.

Research Aim: To evaluate the suitability of Pongamia for biofuel production in Central Queensland's mining region.

Objectives:

- Assess Pongamia's establishment potential based on local soils, climate, and topography.
- Develop an APSIM model to predict Pongamia growth, seed, and oil yield under varied conditions.
- Create an agro-economic model to quantify revenue, costs, net present value, and internal rate of return for Pongamia plantations.

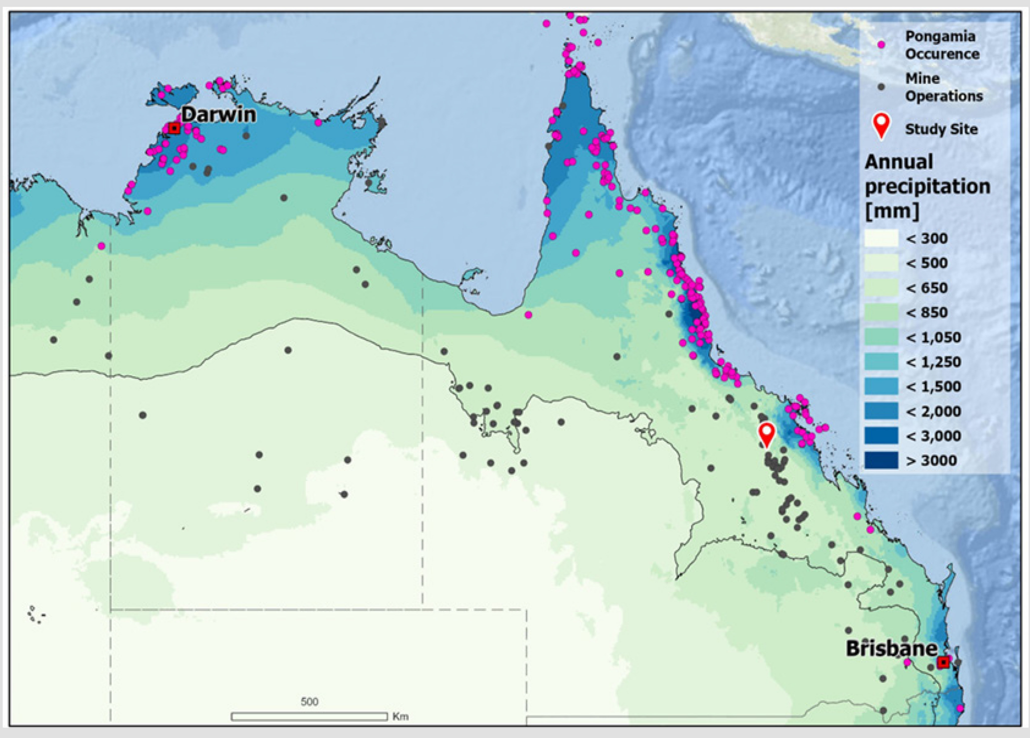
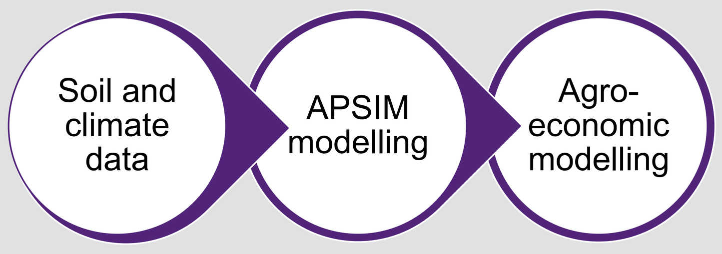


Figure 1: The map indicates the presence of Pongamia trees and mine operations in northern Australia

METHODS



The approach included spatial analysis, APSIM modelling and economic modelling.

Agro-Climatic Characterisation:

- Conducted in Central Queensland mining region.
- Used public datasets (climate, soil, land use, topography) and local soil surveys.
- Analysed spatial soil/land data and climatic conditions (temperature, rainfall, frost).
- Assessed soil properties against Pongamia plantation requirements.

APSIM Modelling:

- Developed models using regional and local data, public sources, and literature.
- Simulated Pongamia growth and yield under various scenarios:
- ❑ Irrigation Duration: 0 to 6 years post-planting.
- ❑ Water Quality: Non-saline to highly saline.
- ❑ Soil Types: Vertosol and Sodosol.
- ❑ Climate Series: 1933-1962, 1963-1992, 1993-2022.

Economic Modelling:

- Estimated benefits of Pongamia plantations at South Walker Creek mine.
- Quantified revenue, costs, net present value (NPV), and internal rate of return (IRR) based on APSIM

RESULTS

Agro-climatic characteristics

Rainfall: Annual rainfall ranged from 250–1400 mm, with a 10-year average of 500–800 mm.
Frost Days: 1–9 frost days annually, 10-year average: 3 days.
Temperature: Max: 17–44°C; Min: -1.1–28°C.
Soil: Some areas had unsuitable chemical and physical properties.

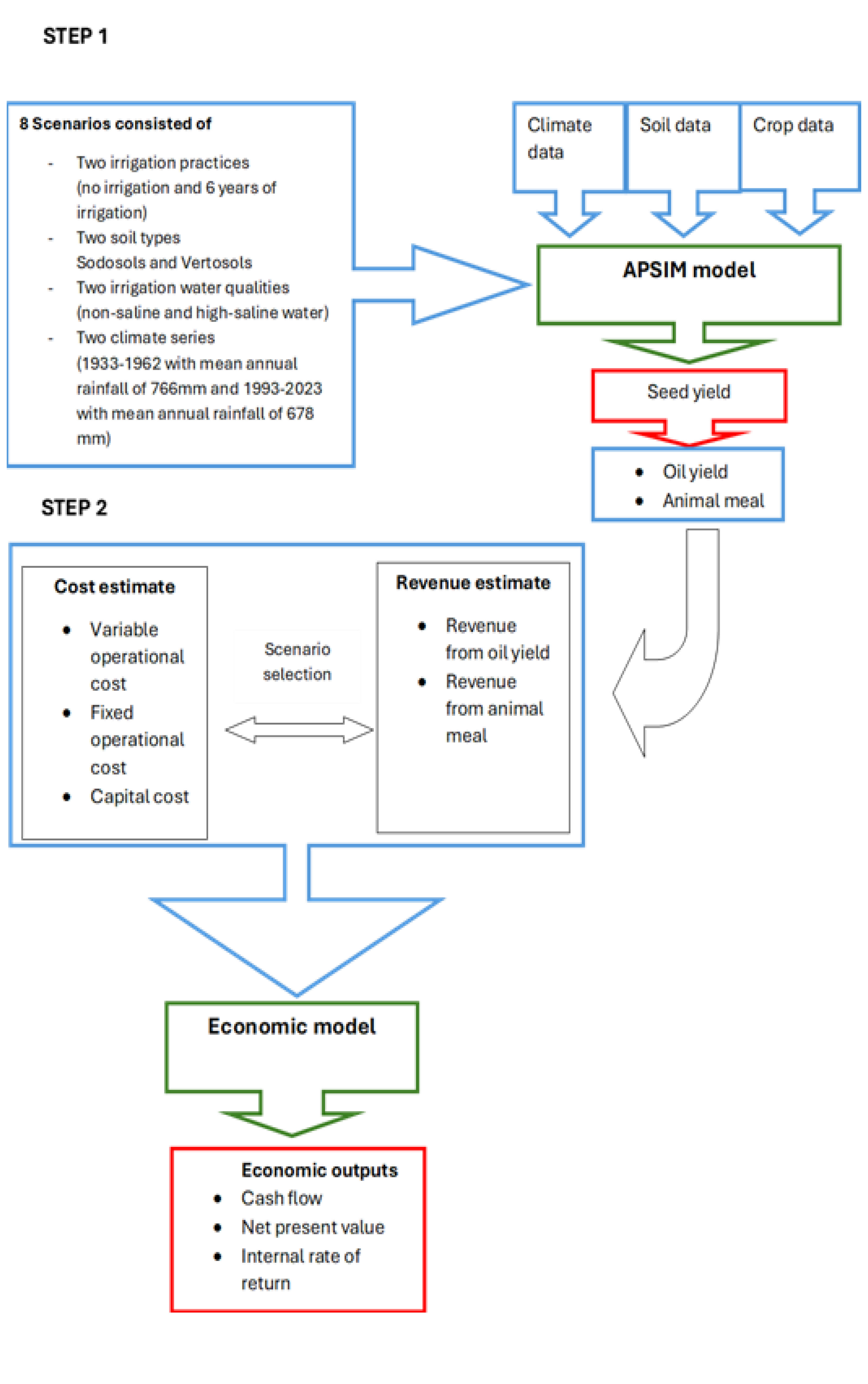


Figure 2: Flowchart indicating the steps followed to develop the agro-economic model

APSIM modelling result

Seed yield

- Higher yields were observed on Vertosol soils compared to Sodosol (Figure 3).
- Irrigation duration had no significant effect on Sodosol but was crucial for Vertosol, with yields decreasing without irrigation (Figure 3a).
- Yield declined as irrigation water salinity increased (Figure 3b).
- Lower rainfall led to reduced seed yields for both soils (Figure 3c).

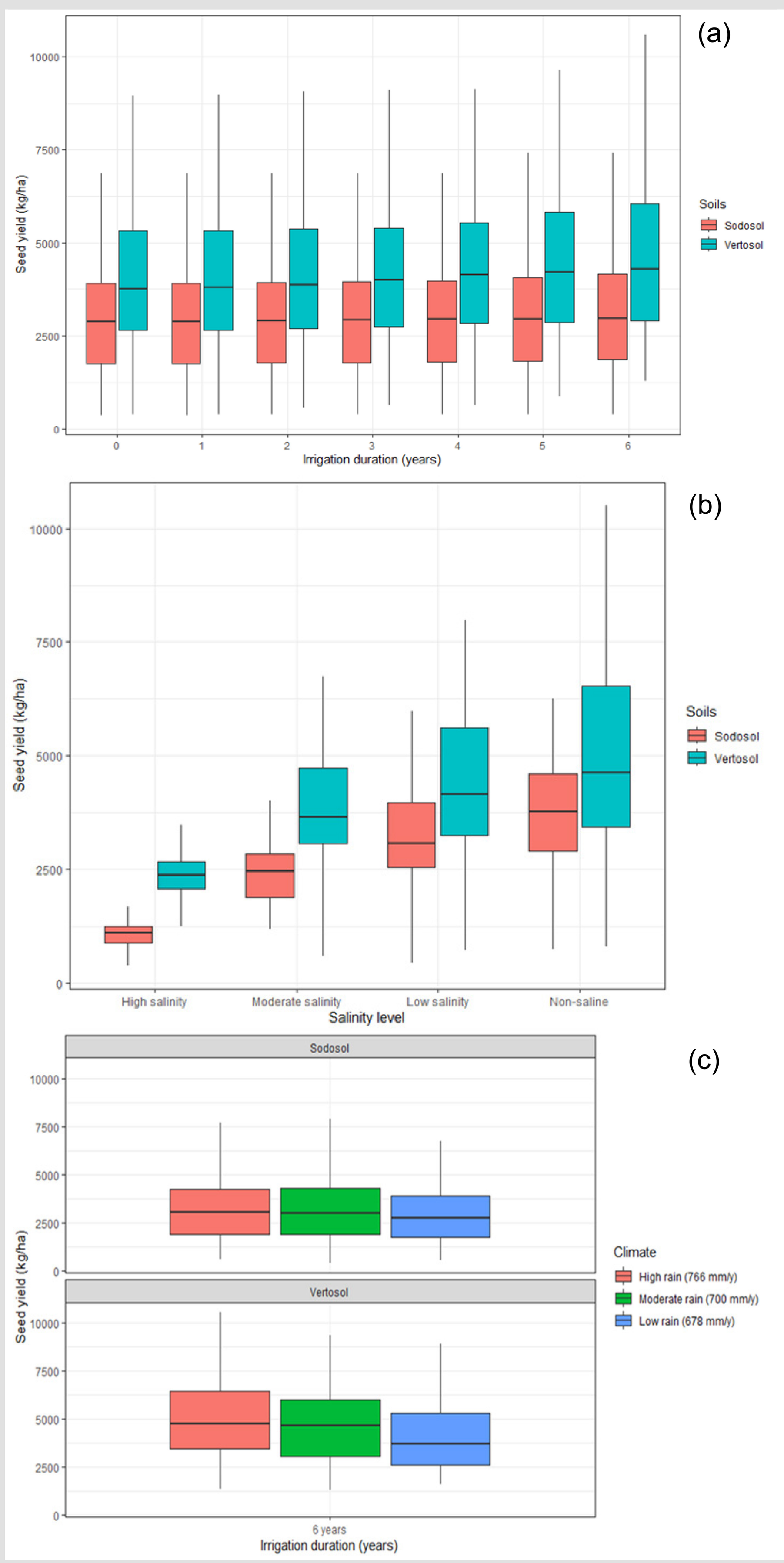
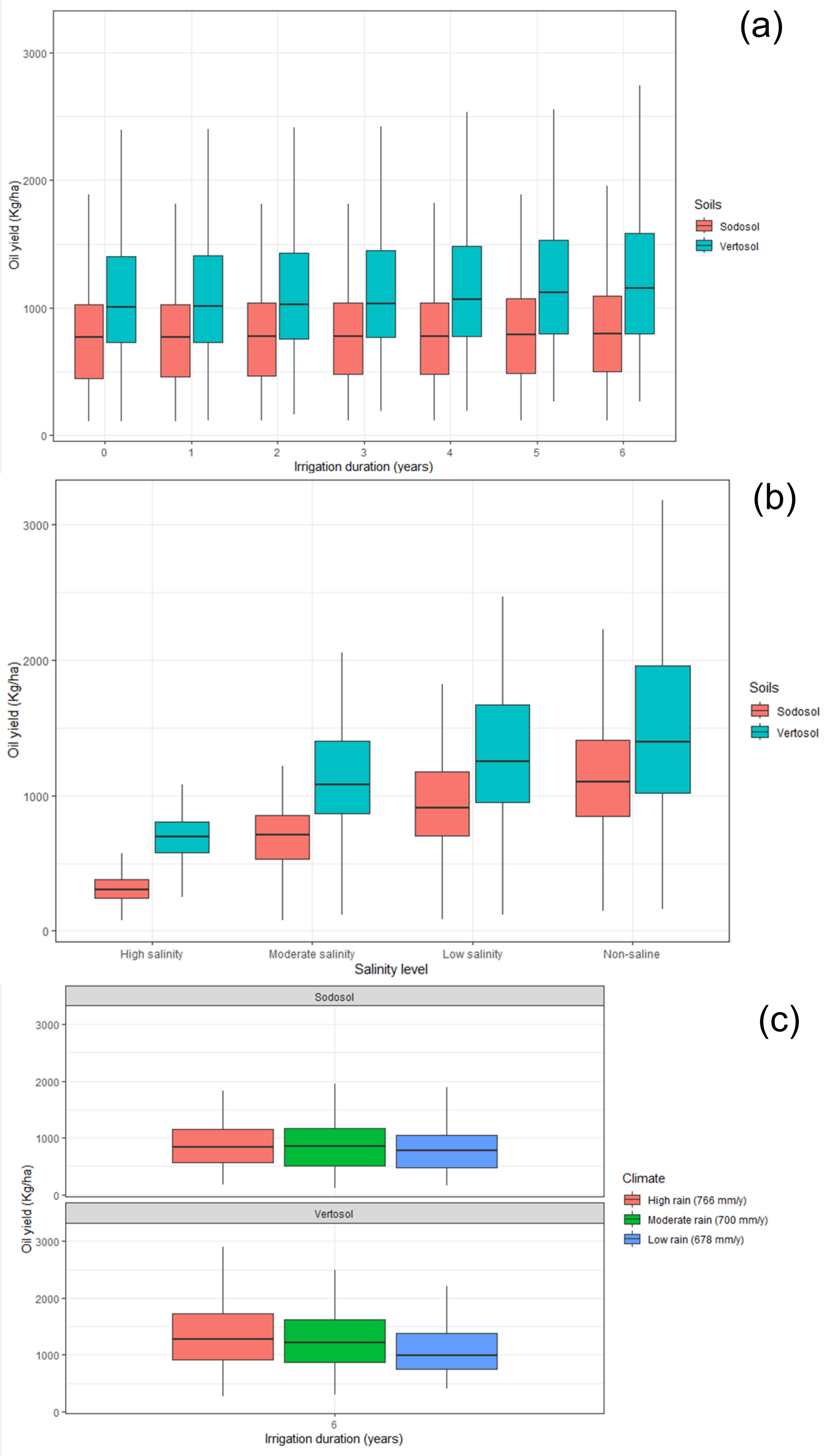


Figure 3: APSIM modelling results; (a) simulated seed yield on Sodosol and Vertosol under different durations of irrigation at establishment stage, (b) the simulated seed yield on Sodosol and Vertosol under different irrigation water qualities, (c) simulated seed yield on Sodosol and Vertosol over three 30-year periods with different annual average rainfalls.

APSIM modelling result

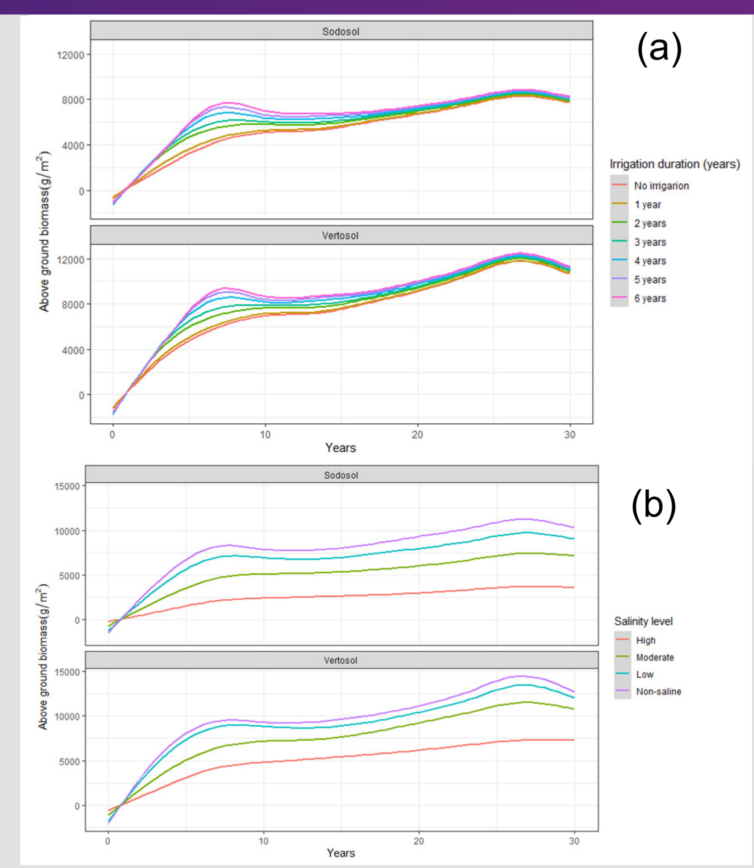


Oil yield

- Oil yield trends mirrored seed yield patterns (Figure 4).
- Maximum oil yield (1704.6 kg/ha) occurred on Vertosol with six years of non-saline irrigation .
- Lower rainfall and high salinity irrigation water significantly reduced oil yields.

Figure 4: APSIM modelling results; (a)The calculated oil yield on Sodosol and Vertosol under different durations of irrigation at establishment stage; (b) The calculated oil yield of on Sodosol and Vertosol under different irrigation water qualities; (c) The calculated oil yield of on Sodosol and Vertosol under different amounts of rainfall over three 30-year periods with different annual average rainfalls

APSIM modelling result



Biomass

- Maximum biomass was observed at early growth stage while irrigation duration was 6 years (Figure 5a).
- Biomass reduced significantly with increase of salinity in irrigation water (Figure 5b).

Figure 5: APSIM modelling results; (a)Pongamia biomass on Sodosol and Vertosol under different durations of irrigation at establishment stage; (b) biomass on Sodosol and Vertosol under different irrigation water qualities

Agro-economic modelling

Scenario	Oil selling price 1.5 AUD/L					Oil selling price 2 AUD/L				
	Revenue from animal meal (AUD Million)	Revenue from oil (AUD Million)	Total revenue (AUD Million)	NPV (AUD)	IRR	Revenue from animal meal	Revenue from oil (AUD Million)	Total revenue (AUD Million)	NPV (AUD Million)	IRR
1	13.35	30.03	43.38	-14.61	1%	13.35	40.04	53.39	-8.23	2%
2	9.96	22.40	32.36	-21.17	-1%	9.96	29.87	39.82	-16.34	0%
3	19.60	44.10	63.71	-2.55	3%	19.69	59.07	78.76	6.67	4%
4	12.57	28.27	40.84	-15.87	0%	12.62	37.87	50.49	-9.78	1%
5	6.25	14.05	20.30	-28.52	-4%	7.79	18.74	26.52	-25.43	-2%
6	2.75	6.18	8.93	-35.82	-7%	2.75	8.24	10.99	-34.45	-6%
7	11.14	25.07	36.22	-18.56	-7%	11.14	33.43	44.57	-13.12	-6%
8	13.44	30.23	43.67	-12.66	1%	13.44	40.31	53.74	-5.82	2%

Figure 6: Total 30-year revenues, NPV and IRR of a Pongamia plantation for eight defined scenarios in Table 5 and two oil prices

A greater seed yield results in a greater total revenue. However, the profitability depends on seed yield as well as oil price and discount rate, in which an adjustment in oil price and/or discount rate may be able to make plantation profitable if the seed yields are not low (below 17 kg/tree/year) (Figure 6).

CONCLUSIONS

- The study confirmed suitable climatic conditions for growing Pongamia in the region, but irrigation during establishment and frost-free periods are critical for high yields.
- Irrigation is most effective during the first six years and during extreme dry years.
- APSIM modelling indicated that the region can support Pongamia plantations, with Vertosol soils offering better growth and higher yields.
- Six years of irrigation at the establishment stage significantly boosts biomass and seed yield.
- Irrigation with non-saline water is essential for optimal growth and yield.
- Profitability of plantations under optimal irrigation depends on oil price and discount rate.

m.shaygan@uq.edu.au
Mandana Shaygan
Smi.uq.edu.au

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