Australia's National Science Agency

Saltbush forage improvement (Anameka™)

Impact Case study

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Contents

Table of Figures

Table of Tables

Table of Boxes

1 Executive Summary

Background

Atriplex nummularia, or Oldman Saltbush (OMSB) is a drought and salt tolerant shrub that is native to arid areas of Australia. Alongside other native shrubs it is adapted to dry, saline and nutrient deficient conditions and can often be planted in agricultural systems where traditional cereal crops cannot.

OMSB was identified for its ability to not only provide supplementary forage to fill annual feed gaps in livestock production but for its potential to use and regenerate land that is too saline, infertile or depleted for conventional crops and forages. It is also associated with environmental benefits such as preventing water recharge and mitigating dryland salinity and increasing biodiversity.

The challenge

Unfortunately, OMSB's ability to grow in dry, saline and nutrient deficient conditions is associated with high levels of salt and oxalates accumulation in its leaves, leaving it less palatable and decreasing nutritional value. Voluntary feed intake and digestibility (energy value) are primary drivers of on-farm profitability. Unfortunately, the majority of OMSB plants across Australia have digestibility that is sub-maintenance for mature sheep or cattle. Achieving on-farm economic benefits requires livestock to choose to voluntarily consume a suitable diet. Hence, a need to improve its digestibility and relative palpability was identified as the key selection traits if OMSB was to be adopted as a widespread productive feed-gap delivering economic and environmental benefits across the Australian landscape.

The response

CSIRO, alongside research partners in a multi-organisational R&D collaboration sought to improve OMSB suitability as a fodder supplement and began a saltbush research improvement program in mid 2000's. The program included clonal selection from a collection of wild germplasm leading to the selection and release of the elite variety, Anameka™ in 2015. Anameka™ was chosen on the basis of higher energy value and eight times more biomass than other saltbushes in the collection. It's nutritional profile and improved relative palatability increases voluntary livestock intake, provides higher energy values and increases livestock productivity.

CSIRO's contribution to this process was the application of deep multi-disciplinary understanding of farming systems, animal nutrition and plant science. Since 2015, CSIRO has led the program of work by carrying over the tender of Anameka™ and leading ongoing OMSB improvement research.

The impacts

Since 2014, over 287 producers have purchased and planted more than 2.4 million Anameka™ shrubs, equivalent to 3728 hectares at a recommended rate of 650 plants/ha.

We estimate that the net present value of the R&D investment into Anameka™ is approximately $12.3 million (or 3.4:1) in 2020/21 dollars at 7 per cent discount rate given model assumptions[1].

This positive return is reflective of a small incremental benefit to on-farm profits due to increases in wool quantity and decreases in supplementary feed costs. Sensitivity testing of key assumptions reveals that all results remain positive except when all forecasted sales beyond 2020 are removed (BCR of 0.94:1). This is to be expected given the relatively recent release of Anameka™ and implies that the overall positive investment return relies on continued adoption of Anameka™ in the coming years. Overall, the results provide confidence that the public investment in improved saltbush is delivering a positive return on investment.

This estimate of economic benefit is confined to the first-order market effects of marginal productivity improvement on-farm and does not capture other non-priced economic, environmental or social benefits. Adoption of OMSB reduces the risk exposure of farming enterprises by providing a buffer in poorer seasons, allowing deferred pasture grazing, backgrounding options for stock during summer and autumn and through improved animal health by increasing the availability of key nutrient and minerals and providing shade and shelter. It is also hypothesised that supplementation with OMSB may deliver value chain benefits through improvements in meat quality and shelf life.

Environmental benefits of the widespread adoption of OMSB are largely through the alleviation of dryland salinity and increased biodiversity. Dryland salinity is managed through deep, perennial shrub roots reducing rising water tables and preventing accumulation of salinity in the topsoil. Biodiversity is enhanced through the provision of an important vegetation understory and structural complexity that provides habitat for native biodiversity that would not otherwise exist in the highly modified agricultural landscapes.

It is hypothesised that there are social impacts proportional to the economic and environmental benefits of adoption of Anameka™. These economic and environmental benefits likely contribute to the maintenance of resilient and sustainable farming systems which in turn support the health and longevity of the surrounding agricultural enterprises and community. Finally, the revegetation of otherwise saline lands may deliver social benefit through the improvement of visual amenity.

Whilst CSIRO (and research partners) cannot and do not claim sole attribution to these benefits this case study provides confidence that the CSIRO and research partner R&D investment into improved Oldman Saltbush is delivering impact for the nation.

[1] *This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the CSIRO's are summarised in Figure 1.*

2 Acronyms

AWI	Australian Wool Innovation
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CRC FFI	Cooperative Research Centre Future Farm Industries
CRC PBDLS	Cooperative Research Centre Plant Based Dry Land Salinity
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DEPI VIC	Department of Environment and Primary Industries Victoria
DEWNR	Department of Environment, Water and Natural Resources (Australian Government)
FY	Financial Year
ha	hectares
LCDC	Land Conservation District Committees
MLA	Meat and Livestock Australia
NSW DPI	New South Wales Department of Primary Industries
NPV	Net Present Value
NIRS	Near Infrared Spectroscopy
OMSB	Oldman Saltbush
per comms	Personal communications
PV	Present Value
RIRDC	Rural Industries Research and Development Corporation
R&D	Research and Development
TBL	Triple Bottom Line
t	Tonnes

3 Purpose of the case study and audience

The purpose of this case study is to assess the retrospective and prospective benefits of CSIRO's research and development investment into the improvement of Oldman Saltbush, an iconic native Australian shrub sometimes used as forage in agricultural systems. The study highlights the economic, environmental and social benefits of the research, selection, development and commercialisation of an elite variety. The analysis provides an estimate of the benefit-cost ratio of the investments accompanied by a qualitative summary of the non-priced economic, environmental, and social benefits.

This report can be read as a stand-alone item or alongside other CSIRO Agriculture and Food evaluations to substantiate the impact and value of CSIRO's activities against funds and resources invested in this program.

CSIRO as a service provider to the Government and industry is highly focused on delivering value and impact through the scientific interventions that originate from research activities. The information is provided for accountability, communication, engagement and continuous improvement purposes. The study is also intended to serve as a tool to underpin strategic investment decision making. The intended audience includes Business Unit Review Panels, federal, state and local governments, the project's collaborators, CSIRO, universities and the general public.

4 Background

Oldman Saltbush

Atriplex nummularia, or Oldman Saltbush (OMSB) is a halophytic (salt tolerant) woody shrub, native to arid areas of Australia. Alongside other shrubs from the Chenopodiaceae family it is adapted to dry, saline and nutrient deficient conditions and can often be planted in agricultural systems where traditional cereal crops cannot (Li et al. 2018).

Native perennial shrubs, including OMSB, have been identified for their ability to not only provide supplementary forage to fill annual feed gaps in livestock production but for their potential to use and regenerate land that is too saline, infertile or depleted for conventional crops and forages (Salem et al. 2010; CSIRO, 2016). They are associated with environmental benefits such as preventing water recharge and therefore mitigating dryland salinity (Bennett et al. 2012), and increasing biodiversity (Collard and Fisher, 2010; CSIRO, 2016).

It has also been demonstrated that the use of native shrubs as forage supplementation may lead to improved meat quality due to the presence of Vitamin E (Peace et al. 2010), potential improvement in animal health and reduced mortality (Norman et al. 2019; CSIRO, 2016) and provide beneficial shade and shelter for livestock (Revell et al 2013). New work is testing hypotheses regarding reproduction rates during heat stress events and understanding the role of saltbush as a shelter plant for ewes with multiple offspring.

Challenges

Feed-gaps emerge in southern Australia grazing and mixed farming enterprises during late summer and autumn when biomass and nutrients become more scare. This requires costly supplementation of livestock with grain and influences the carrying capacity of the entire farm (Li et al. 2017). Consequently, the use of long-lived perennial native shrubs like OMSB for supplementation particularly on otherwise marginal land, provide an attractive, low input, supplementary feed strategy.

Unfortunately, OMSB's ability to grow in dry, saline and nutrient deficient conditions causes it to accumulate high levels of salt (sometimes in excess of 25%) and oxalates in leaves leaving it less palatable and decreasing nutritional value (Salem et al 2010, Pearce et al. 2010). Achieving on-farm economic benefits requires sheep to choose to voluntarily consume the shrub. Hence, a clear need to improve its palpability and digestibility was identified if it was to be a widespread productive feed-gap supplement.

Whole-of-farm modelling across several rainfall zones suggested that improving the energy value of native shrubs, including OMSB, would substantially increase farm profitability (O'Connell et al 2006). In response, a multi-organisational R&D collaboration to improve OMSB commenced to advance its suitability as a fodder supplement with both economic and environmental benefits for the Australian landscape.

CSIRO's Response: Anameka™

CSIRO and research partners domesticated the iconic species through 10 years of R&D. Over a series of projects scientists systematically collected shrub germplasm and conducted experiments to characterise and test the material. Eventually this led to the successful selection and commercialisation of an elite line of Oldman Saltbush, *Anameka™.*

Anameka™ was commercialised in 2015 on the basis of higher energy value and eight times more biomass than the mean of the saltbushes collected across Australia and tested. It's nutritional profile (organic matter digestibility of 64%, crude protein of 19.5% and 25% ash) and improved relative palatability is likely to increase voluntary livestock intake, provide higher energy values and increased livestock productivity. It is an individual female plant selected from 60,000 plants that were collected across Australia and currently requires vegetative propagation and planting as nursery raised cuttings.

CSIRO's contribution to this process was the application of deep multi-disciplinary understanding of farming systems, animal science and plant nutrition. Since the closure of the Future Farm Industries CRC in 2015, CSIRO has led the program of work by carrying over the commercialisation and tender of Anameka™.

Chatfields Tree Nursery in Tammin, Western Australia was awarded the national license to propagate and sell Anameka™[2]. Since 2014, over 287 producers across Australia have now

[2] Chatfields Nursery also employs sub-contracted nurseries to propagate Anameka™

purchased and planted more than 2.4 million Anameka™ shrubs, equivalent to 3393 hectares at the recommended rate of 650 plants/ha.

Since the release of Anameka™, research investment continues (in partnership with research development corporations and government) for future commercialisation of elite varieties that can be planted by seed. CSIRO and its Australian Government partners have also successfully exported Anameka™ to University of Agriculture, Faisalabad for possible future management of saline and arid soils in Pakistan and have facilitated training and development of female smallholder livestock enterprises in Afghanistan in village-based saltbush production systems. Through the course of this research CSIRO has become the Australian leader in native shrubs research in farming systems. CSIRO has also earned an international reputation in the measurement of shrub nutritional value through pioneering the application of near-infrared spectroscopy (NIRS) measurement of shrub nutritional value (CSIRO per comms, 2020).

Evolution of OMSB improvement research

OMSB research has occurred in piecemeal across many different projects and organisations since 2005. To this day it does not operate through a dedicated standalone research program. The research first originated within the 'Flora search' and 'ENRICH' Cooperative Research Centre (CRC) projects where large-scale systematic investigation into Australian native shrubs took place. Initially, over 100 species were evaluated for their potential to contribute to agricultural systems resulting in the selection of 10 forage shrub species deemed most suitable and with the most potential, including OMSB (RIRDC, 2009).

Within Flora search, an extensive review of OMSB (and other shrubs) was conducted and OMSB identified for its immediate potential for development. Regional collections of germplasm and field trials indicated it had potential for making improvements in edible biomass and that further research into direct seed techniques, livestock preferences and understanding shrub nutrition should take place (RIRDC, 2009). CSIRO played an advisory role during these years.

CSIRO joined the research formally in 2008 and took on a lead role from 2013. The direct research related to selection of Anameka™, including the commercialisation process largely took place within the CRC FFI research program. When the CRC closed in 2015, the tender and germplasm were signed over to CSIRO. Since commercialisation, extension work has been supported through an Australian Government Department of Agriculture and Water Resources project, MLA, AWI and CSIRO. Further R&D of improved saltbush continues at CSIRO with support from MLA and AWI.

Many producer groups, local farming system groups, land conservation district committees and individual producers have contributed to the research. This includes providing land for trials, sheep and equipment for grazing studies, bulking up material for vegetative clones and facilitating training and extension.

Stakeholders

There have been many stakeholders across the life of saltbush improvement R&D. Due to the historical and piecemeal nature of much of the research each individual contribution was not able to be individually summarised. Box 1 alphabetically lists all known domestic stakeholders contributing to OMSB improvement R&D both large and small, in-kind and financial. Impacts described in this case study are a shared success by all.

Box 1 Alphabetical list of known domestic stakeholders in OMSB improvement research

Australian Centre for International Agricultural Research
Agrifutures Australia (formerly Rural Industries Research and Development Corporation)
Australian Government Department of Agriculture and Water Resources (formerly DAFF)
Australian Government Department of Environment and Water (formerly DEWNR)
Australian Government Department of Foreign Affairs and Trade
Australian Wool Innovaton
Chatfields Tree Nursery
CSIRO
CRC Future Farm Industries
CRC Plant Based Management of Dryland Salinity
Forest and Wood Products Australia
Gillamii Centre
Kellerberrin LCDC
Katanning Landcare
Land and Water Australia
Meat and Livestock Australia
Moore Catchment Council
New South Wales Government Department of Primary Industries
South Australian Research and Development Insitute (through the South Australian Department of Primary Industries and Resources)
South Australian Government Department of Water, Land, Biodiversity and Conservation
Southern Dirt
South West Catchments Council
Tammin LCDC
The York family (Anameka farm, Tammin)
Tulla Natives
University of Western Australia
Various host producers
Victorian Government Department of Environment and Primary Industries
Western Australian Government Department of Conservation
Western Murrary Land Improvement Group
Wongan Hills Tree Farm
Yarra Yarra Catchment Council

An impact pathway is used to identify the causal relationship of a project from the inputs through to impacts. Section 5 illustrates the impact pathway for the Oldman Saltbush improvement research investment.

5 Impact pathway

INPUTS → ACTIVITIES → OUTPUTS → OUTCOMES → IMPACT

INPUTS

Funding

- CSIRO funding and in-kind contribution
- External financial and in-kind contribution by:
  - Australian Wool Innovation
  - Meat and Livestock Australia
  - CRC Plant based management for dryland salinity and its stakeholders
  - CRC Future Farm Industries and its stakeholders
  - South Australian Research and Development Institute (SARDI)
  - Producer Groups
  - Farming system groups
  - Local catchment groups and councils
  - State Government Agriculture Departments (NSW, WA, SA)
  - Commercial nursery's
  - International work - ACIAR, ICARDA, Murdoch University and DFAT
  - Department of Agriculture and Water Resources funding

Research Capabilities

- CSIRO background knowledge and multi-disciplinary expertise in shrub biomass assessment, ruminant nutrition, grazing management, sheep productivity and health, systems modelling and plant ecology and agronomy
- Access to infrastructure and resources to execute projects (e.g. on-site and off-site facilities – nutrition labs, private farms, commercial nurseries etc.)

Translational and Commercialisation Support

- Commercialisation by CRC Future Farm Industries
- Commercialisation execution by commercial industry partner (Chatfields Nursery, Tammin)

ACTIVITIES

Research and Development

- Improved saltbush selection from wild germplasm research and development including:
  - Seed collection
  - Shrub evaluation
  - Agronomy and propagation
  - Development of novel plant screening methods using sheep nutritional wisdom
  - Genotype evaluation in the field
  - Genotype experiments evaluation
  - Metabolism crate experiments for the key selection trait – energy value
  - Near infrared spectroscopy calibrations to predict energy value of shrubs
  - Commercial cloning viability testing
  - Farm systems modelling

Significant research collaboration and co-operation with and between stakeholders at all stages of R&D

Engagement with end-users and industry at all stages of R&D including ongoing engagement and evaluation with farming systems groups and communities

International engagement with peers in Jordan, Pakistan and Afghanistan

Translation activity of improved shrub

- Vegetative propagation.
- Trademarking of Anameka™

OUTPUTS

Oldman Saltbush variety

- Anameka™, released in 2015, selected for higher feeding value and relative palatability to sheep
- Novel method in Near Infrared Spectroscopy measurement of shrub nutritional value
- NIRS calibrations for Australian native shrubs (including saltbush)
- New knowledge in shrub agronomy, production animal nutrition, farming systems implications of drought tolerant natives and shrub management
- New saltbush for the human food market

External Network:

Working and productive networks and relationships between CSIRO, universities, state departments of agriculture, research development corporations, local farming system groups and commercial partners, Global partnerships in Pakistan and Afghanistan

Awards

- Eureka Prize for Sustainable Agriculture, 2013
- Shortlisted in Shell Australian Innovation Challenge, 2015
- Delicious state produce award for 'SeaKiss' awarded to Moojepin foods, 2021

Training

- Saltland training course for shrub adoption (includes Anameka™) run in partnership with local farming system groups and nurseries

Other

- Anameka™ trademark
- Publications

OUTCOMES

Uptake and adoption

- Successful commercial adoption, propagation and retailing of Anameka™ by Chatfields Nursery since 2015
- Widespread adoption of Anameka™ by mixed farm and grazing operations across western and parts of eastern Australia as forage supplement on marginal, saline land
- New commercial nursery revenue stream
- Significant increase and adoption of Oldman Saltbush generally and interest in forage shrubs since the release of Anameka™
- Australian leader in native shrubs in farming systems and International reputation in forage shrubs in farming systems and measurement of shrub nutritional value
- Global leader in near-infrared spectroscopy (NIRS) for measurement of shrub nutritional value
- Global partnership work in Pakistan and Afghanistan with ACIAR, Murdoch University and DFAT including:
  - Successful exportation of Anameka™ to University of Agriculture, Faisalabad for possible future management of saline and arid soils in Pakistan
  - Training and development of female smallholder livestock enterprises in Afghanistan in village-based saltbush production systems

IMPACT

ECONOMIC IMPACT

- Improved farm profitability due to a perennial forage shrub with higher feeding value and relatively palatability (e.g. greater livestock carrying capacity, increase in wool production and strength and/or improved animal health).
- Reduced farm seasonal risk exposure and risk in decision making particularly in poorer years due to filling the feed gap and improved drought resilience and/or ecosystem services
- Potential improvement in retailer profitability due to increased shelf life (meat stays redder for 2-3 days longer) due to greater Vitamin E and other anti-oxidants

ENVIRONMENTAL IMPACT

- Ecosystem services including
  - Improved landscape functioning through reduced risk of dryland salinity. Risk of salinity reduced due to reduction in water table preventing future recharge.
  - Habitat for beneficial insects, native birds and lizards
  - Greater plant diversity and re-colonisation of native species in revegetated paddocks

SOCIAL IMPACT

- Potentially more resilient rural communities due to improved financial resilience of mixed farm and grazing operations
- Improvement to visual amenity due to reduced bare salt land and degraded land

2005 – 2021 → 2015 – 2021+

Figure 1 Impact pathway for saltbush forage improvement (Anameka™)

6 Impact Evaluation

Inputs

OMSB R&D improvement is a collaborative program of research. CSIRO has played a leading role since 2013. Other leading roles have been held by the CRC Future Farm Industries, the CRC for Plant Based Dryland Salinity and the South Australian Government through SARDI. Based on available information we have estimated the R&D inputs by year. These inputs are *not* reflective of the 'effort' of each organisation and should only be viewed as total annual collaborative input into saltbush improvement R&D. The inputs estimated are for Oldman Saltbush improvement in total not just Anameka™ development.

CSIRO's inputs

- CSIRO Funding: $1.08 million (nominal, undiscounted); For more details see Table 1.
- CSIRO background knowledge and multi-disciplinary expertise in shrub biomass assessment, ruminant nutrition, grazing management, sheep productivity and health, systems modelling and plant ecology and agronomy
- Access to infrastructure and resources to execute projects (e.g. on-site and off-site facilities – nutrition labs, sheep research facility at Floreat, private farms, commercial nurseries etc.)

Partner inputs

- External R&D Funding: $1.74 million (nominal, undiscounted).
- Commercialisation carried out by the CRC Future Farm Industries
- Other in-kind contributions *not* captured in the analysis include any additional in-kind producer groups and local farming group contributions outside of formal projects and any additional in-kind effort by research partners not reflected in financial budgets. In particular, in-kind contributions by the York Family in Tammin are acknowledged.

It is estimated that $2.83 million (nominal, undiscounted) has been invested into OMSB improvement, which includes the selection and commercialisation of Anameka™.

Table 1 Estimated R&D inputs to saltbush improvement FY2005-FY2023

	CSIRO	CRC PBDLS*	CRC FFI**	SARDI	AG DAFF	AWI	WA DAF	ACIAR	MLA	TOTAL
FY2005		$ 84,580								**$ 84,580**
FY2006		$ 124,677								**$ 124,677**
FY2007		$ 38,940								**$ 38,940**
FY2008		$ 10,000								**$ 10,000**
FY2009				$ 100,000						**$ 100,000**
FY2010				$ 100,000						**$ 100,000**
FY2011			$ 98,550							**$ 98,550**
FY2012			$ 153,350							**$ 153,350**
FY2013	$ 261,414		$ 254,225							**$ 515,639**
FY2014	$ 226,884		$ 133,500		$ 112,574	$ 6,000				**$ 478,958**
FY2015	$ 70,395		$ 119,000		$ 36,491	$ 6,000				**$ 231,886**
FY2016	$ 87,941				$ 46,606	$ 10,000	$ 70,000			**$ 214,547**
FY2017	$ 276,247				$ 21,741	$ 4,000	$ 30,000	$ 4,450		**$ 336,438**
FY2018	$ 5,618							$ 4,450		**$ 10,068**
FY2019	$ 5,806								$ 62,117	**$ 67,924**
FY2020	$ 55,682								$ 23,594	**$ 79,277**
FY2021	-$ 28,232								$ 66,375	**$ 38,143**
FY2022	$ 32,644								$ 27,445	**$ 60,089**

FY2023	$ 90,909									$ 90,909
TOTAL	**$ 1,085,310**	**$ 258,197**	**$ 758,625**	**$ 200,000**	**$ 217,412**	**$ 26,000**	**$ 100,000**	**$ 8,900**	**$ 179,531**	**$ 2,833,974**

SOURCE: CSIRO, RIRDC (2009)

**CRC PBDLS and CRC FFI capture numerous stakeholders' contributions*

Note: This estimate of R&D input is based on expert CSIRO advice of the proportional effort of saltbush improvement within other projects. External organisation investment post FY2014 is based on annual revenue received by CSIRO and may not reflect the actual year of R&D expenditure. CSIRO investment is negative in FY2021 due to in-kind investment cash flows and external revenue calculations, CSIRO in-kind investment is positive across the projects and years overall.

Activities

Research and Development

R&D into the elite clone selection from wild germplasm involved:

- Seed collection
- Shrub evaluation
- Agronomy and propagation
- Development of novel plant screening methods using sheep nutritional wisdom
- Genotype evaluation in the field
- Paddock scale evaluation of animal growth and wool production
- Metabolism crate experiments to develop a range of saltbush 'standards' to allow development of accurate lab methods to measure the key selection trait – energy value
- Near infrared spectroscopy calibrations to predict nutritional value of shrubs
- Commercial cloning viability testing
- Farm systems modelling

An approximate timeline of the Anameka™ research, development and commercialisation activity is illustrated in Table 2. Each of these activities required significant research collaboration and co-operation with and between stakeholders listed in Box 1. The research partners maintained engagement with end-users and industry at all stages of R&D including ongoing engagement and evaluation with farming systems groups and communities. The majority of the field work was conducted on private farms.

Translation and commercialisation

In the final stage of research development, the researchers bulked up and compared feeding value of the four most promising clones on a commercial farm until Anameka™ was selected. The material was then provided to the awardees of the exclusive license, Chatfields Nursery. Chatfields vegetatively propagate material for commercial sale each year and execute commercialisation of Anameka™. They manage promotion of the plant at field days and through social media. They also provide advice to new farmers, assist them to select the optimal site and help them with planting logistics. Some propagation and sales occur through sub-contracted nurseries, with Chatfield actively seeking to increase quantity and geographical footprint, while maintaining high quality product and good information.

Trademarking of Anameka™ was carried out within the CRC Future Farm Industries and all trademark and germplasm rights were transferred to CSIRO at the conclusion of the CRC in 2015. Chatfields Nursery pays CSIRO a small fee annually to maintain the trademark. CSIRO does not earn any other royalties or financial returns from Anameka™. This decision was in part due to the many stakeholders who contributed, the desire to keep the cost down to optimise adoption (and achieve environmental benefits) and the projected royalties relative to cost of administration. This model may not apply to future seed lines.

Since Anameka's™ release extension work to promote adoption has been carried out through financial and in-kind support of CSIRO, MLA, AWI, DAFF and various local stakeholders. This includes contribution to a Saltland training course for shrub adoption that is run in partnership with local farming system groups. CSIRO contributes information for the 'Saltland Genie" app that is being developed by the Gilliamii Group, DPIRD, WA State Government.

Box 2 The York family (Tammin, Western Australia)

Anameka™ was named in recognition of the York family (Tammin, Western Australia) after their farming business, Anameka. Tony and Simon York providing ongoing support throughout the research program as a host site, and provided ideas, time, and ongoing enthusiasm for saltland revegetation. They were an early adopter of Anameka™ and continue to increase Anameka™ across their property.

Tony and Simon York

SOURCE: CSIRO (2021)

International activity

In partnership with the Australian Government's Australian Centre for International Agricultural Research (ACIAR) and the Department of Foreign Affairs and Trade, CSIRO successful exported Anameka™ cultivars to the University of Agriculture in Faisalabad (UAF) in September 2018. This parallel activity to the domestic R&D and extension of Anameka™ is intended to facilitate further research into the potential for elite saltbush in the arid and saline areas of Pakistan. This is intended to lead to potential future improvements in the livelihoods of smallholders in arid and saline areas of Pakistan. These plants are currently being grown at the UAF as a future source of germplasm for in-country experiments (Norman and Barrett-Lennard, 2019).

Future saltbush improvement research

Since commercialisation of Anameka™, CSIRO and research partners are continuing to build seed lines, investigate seed coating and establishment methods and evaluating germplasm for future potential breeding and elite varieties using Anameka™ and the other elite material from the collection as a parents. Anameka™ is expected to be the first of a future cohort of improved OMSB varieties.

Outputs

Elite saltbush variety and trademark

- Anameka™, selected for its higher feeding value and relative palatability to sheep was trademarked and commercially released in 2015.

Novel method in Near Infrared Spectroscopy measurement of shrub nutritional value

During the course of the research, CSIRO developed Near Infrared Spectroscopy (NIRS) calibrations for OMSB and other Australian native shrubs. The development of this novel method of shrub nutritional value measurement allowed the researchers to measure shrub nutritional value for the first time globally (CSIRO per comms, 2020) and to predict energy values of the OMSB plants under evaluation.

These calibrations are now being used for the development of a national NIRS platform to allow for rapid and less expensive plant screening tools in partnership with MLA and the NSW Department of Primary Industries (CSIRO per comms, 2020).

New research knowledge

Across the research program, new research knowledge in shrub agronomy, animal production nutrition and farming systems implications of drought tolerant natives and shrub management was realised. This new knowledge has been captured in numerous publications; a selection of key publications is listed below.

Key Publications

Norman H, Duncan E, Masters D (2019*) Halophytic shrubs accumulate minerals associated with antioxidant pathways* Grass and Forage Science 2019; 74:345-355

Li X, Norman H, Hendry J, Hulm E, Young P, Speijers J, Wilmot, M (2018) *The impact of supplementation with Rhagodia preissii and Atriplex nummularia on wool production, mineral balance and enteric methane emissions of Merino sheep* Grass Forage Science 2018; 73;381-391

Salem BH, Norman HC, Nefzaoui A, Mayberry DE, Pearce KL, Revell, DK. (2010) *Potential use of oldman saltbush (Atriplex nummularia Lindl.) in sheep and goat feeding* Small Ruminant Research 91 (2010) 13-28

Pearce KL, Norman HC, Hopkins DL. (2010) *The role of saltbush-based pasture systems for the production of high quality sheep and goat meat* Small Ruminant Research 91 (2010) 29-38

New saltbush for the human food market

During the course of research, a commercialisation opportunity was presented to CSIRO by a producer interested in the bush food market. A 'tasty' clone (according to sheep) from the research was selected titled 'SeaKiss' and licensed to Moojepin foods. A small royalty per shrub is received by CSIRO (CSIRO per comms, 2021) earning $3348 in 2019/20 and $8712 in 2020/21 (CSIRO per comms). Moojepin foods won a Delicious state produce award with SeaKiss in 2021.

External Networks

The piecemeal project nature of this research program and the broad number and disciplines of stakeholders involved has required the establishment and maintenance of working and productive networks and relationships between CSIRO, universities, state departments of agriculture, research development corporations, local farming system groups and commercial partners.

In conjunction with the Australian Government, CSIRO has created and is maintaining global partnerships in Pakistan and Afghanistan through the extension of Anameka™ and saltbush improvement research internationally.

Awards

- Eureka Prize for Sustainable Agriculture, 2013
- Shortlisted in Shell Australian Innovation Challenge, 2015
- Moojepin foods won a Delicious state produce award for SeaKiss, 2021

Training

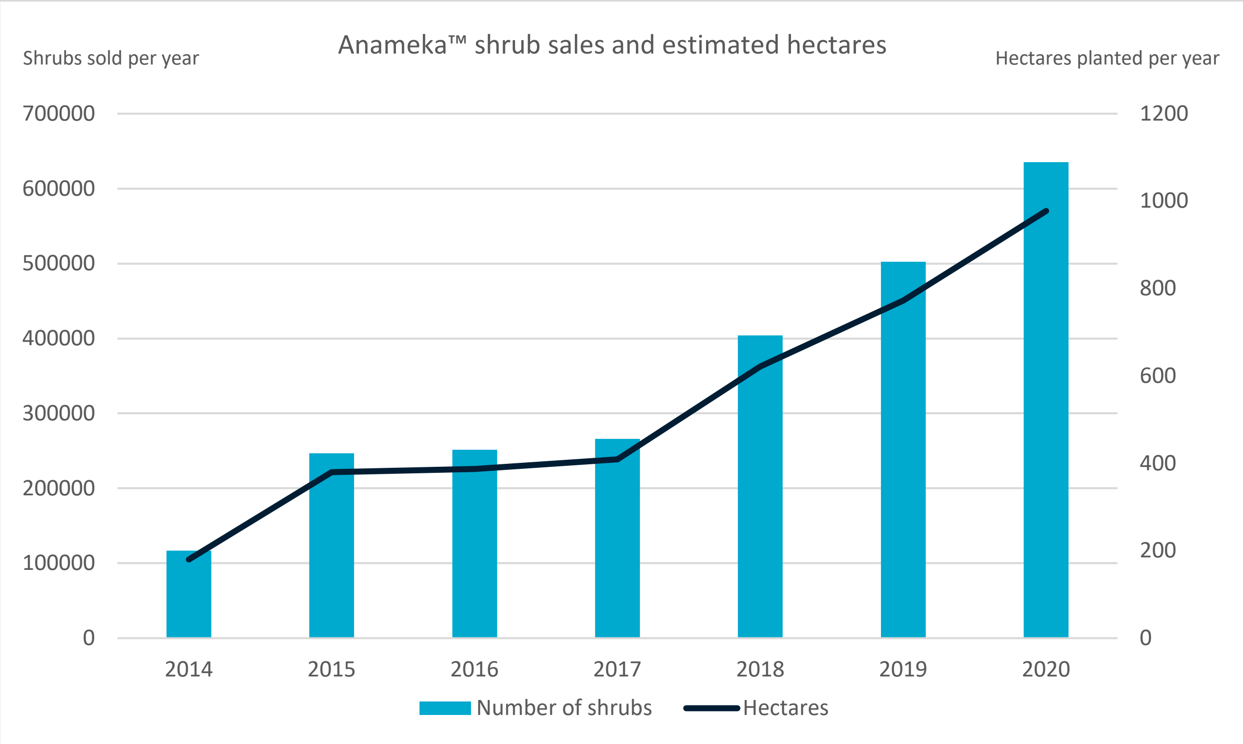
In partnership with local farm systems groups and supported by the Australian Government and RDC's, CSIRO administers a Saltland training course for shrub adoption which includes promotion of Anameka™.

Outcomes

Uptake and adoption

There has been successful commercial adoption, propagation and retailing of Anameka™ by Chatfields Nursery and their contract nurseries since 2015 (following research release in 2014). Adoption of Anameka™ to date is largely by mixed (cropping/sheep) operations in southern Western Australia (~95%) with smaller sales in NSW (~1.69%), Victoria (~3%) and South Australia (~0.29%). Adoption has been stronger in WA as that has been where nurseries have been situated and quarantine restrictions have limited plan movement. This is being addressed with Tulla Nurseries in NSW. Figure 1 illustrates sales of Anameka™. Since 2014 over 287 producers have purchased and planted more than 2.4 million Anameka™ shrubs, equivalent to 3728 hectares (at a recommended rate of 650 plants/ha).

Figure 2 Anameka™ sales and estimated hectares 2014-2020

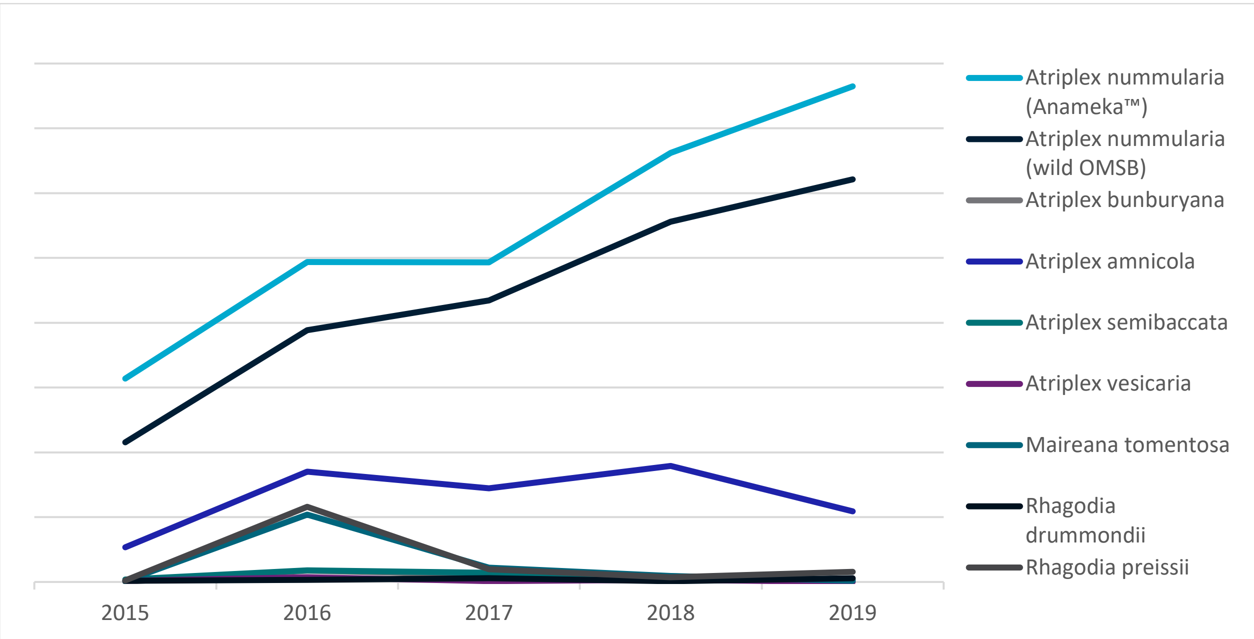


SOURCE: CSIRO

Catalyst for interest in OMSB generally

The release and promotion of Anameka™ is believed to have been a catalyst and demand-pull for sales of OMSB more generally. Data illustrated in Figure 3 illustrates OMSB sales trends relative to other native forage shrubs for the same period.

Figure 3 Native forage shrub sale trends since Anameka™ release



SOURCE: CSIRO

Research reputation

Through the course of the saltbush improvement research CSIRO has earned an international reputation in forage shrubs in farming systems research and the measurement of shrub nutritional value through near-infrared spectroscopy (NIRS). The novel application of NIRS measurement for measuring nutritional value of forages is now being leveraged in partnership with NSW DPI to measure and calibrate the nutritional value of all Australian forages. This rapid and inexpensive testing will allow all Australian plant breeders to optimise their breeding programs for forage nutritional value (CSIRO per comms, 2021).

International outcomes

The successful exportation of Anameka™ to the University of Agriculture in Faisalabad may lead to future improvements in the management of saline and arid soils in Pakistan and smallholder livelihoods. Likewise, the training and development of female smallholder livestock enterprises in Afghanistan in village-based saltbush production systems (using elite seed lines from the project) may lead to outcomes and impacts in these locations. There was limited information available to characterise the realised or potential outcomes of the international extension of Anameka™ thus far. Data collection related to the outcomes of international extension of Anameka™ is encouraged to inform future case study updates.

Table 2 Anameka™ approximate R&D and adoption timeline

<table>
<tr><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021+</th></tr>
<tr><td colspan="10">← R&D →</td><td>Commercialisation</td><td colspan="6">Market sales and adoption</td></tr>
<tr><td>Seed collected from 20 individual female plants within 27 populations across Southern Australia</td><td colspan="4">60,000 plants assessed in WA, SA and NSW.
Agronomic traits, sheep preferences and nutritional value evaluated.
30 genotypes per site selected and vegetatively propagated.</td><td colspan="5"></td><td rowspan="4">Anameka™ commercialised as a vegetatively propagated variety.
Chatfields Tree Nursery (Tammin) awarded national license.
CRC FFI closes and Anameka™ trademark tender awarded to CSIRO and germplasm signed over to CSIRO.</td><td colspan="6"></td></tr>
<tr><td colspan="3"></td><td colspan="3">90 genotypes compared at 3 new sites in WA, SA and NSW.
Agronomic traits, sheep preferences and nutritional value.
The best 12 genotypes identified.</td><td colspan="4">12 genotypes compared with commercial material in experiments at 12 producer sites.
Metabolism crate feed experiment to confirm digestibility.
Testing for commercial cloning viability.</td><td colspan="6"></td></tr>
<tr><td colspan="10"></td><td colspan="6">Anameka™ clone vegetatively propagated by Chatfields Tree Nursery and sub-contractor nurseries in Western Australia.</td></tr>
<tr><td colspan="10"></td><td colspan="4"></td><td>Becomes available in NSW, Vic and SA through contract nursery.</td><td></td></tr>
<tr><td colspan="10"></td><td></td><td colspan="6">CSIRO, MLA, AWI and local farming groups adoption support work through paddock scale demonstrations</td></tr>
</table>

SOURCE: CSIRO, Chatfields Nursery et al. (Nd)

Impacts

Table 3 Summary of Australian program impacts using CSIRO triple bottom line (TBL) benefit classification approach

Type	Category	Indicator	Description
Economic	Productivity and efficiency	Improved mixed and grazing farm operations productivity and profitability	Improved farm profitability due to an elite OMSB shrub with a higher feeding value and relatively palatability leading to greater livestock carrying capacity, reduced supplementation costs and/or increased wool production and strength.
	Management of risk and uncertainty	Reduced farm seasonal risk exposure	Reduced farm seasonal risk exposure and risk in decision making particularly in poorer years due to filling the feed gap and improved drought resilience and/or ecosystem services.
	Productivity and efficiency	*Potential* improvement in retailer profitability due to improved meat shelf life and improved wool quality and strength	Potential improvement in profitability due to improved meat quality and shelf life and wool quantity and strength due to improved nutrients and Vitamin E.
	Animal health and prosperity	Improvement in animal health and reduced mortality	Potential healthier animals and reduced mortality due to minerals and antioxidants in saltbush.
Environmental	Land quality	Ecosystem services delivered through larger presence of native perennial shrubs	Improved landscape functioning through reduced risk of dryland salinity. Risk of salinity reduced due to reduction in water table preventing future recharge.
	Ecosystem health and integrity (natural capital)	Ecosystem services delivered through increased presence of beneficial biodiversity	Greater biodiversity through provision of shrub habitat for beneficial insects, native birds and lizards.
Social	Resilience	Sustained rural communities throughout Anameka™ crop area	Improved resilience of rural communities reliant on mixed farming and grazing industries, particularly in areas of dryland salinity due to improved profitability and reduced seasonal risk exposure afforded by adoption of elite OMSB shrub.
	Social license	Improvement to regional visual amenity	Improvement to visual amenity due to reduced bare salt land and degraded land.

7 Economic modelling

Cost Benefit Analysis

This section details the method of calculating the benefit cost ratio (BCR) in this analysis.

The formula for calculating a benefit cost ratio is defined as economic benefits (Present Value) divided by the research, adaptive development and extension costs (Present Value).

$Benefit\ Cost\ Ratio = PV(B_t)/\ PV(C_t)$

Where

$PV(B_t)$ *is the present value of the benefits at time t*

$PV(C_t)$ *is the present value of the costs at time t*

The benefits calculated in the analysis are the net benefits from the program, that is, the difference between the ‘with’ and ‘without program’ scenarios. Costs and benefits have been recalculated in order for them to be expressed in a dollar value at a common point in time, namely in 2019/20 AUD dollars, using the Consumer Price Index. Present value calculations of costs and benefits have also been harmonised so that they have a common base year (2019/20) across the program. A real discount rate of 7 per cent has been assumed in these present value recalculations[3].

The costs considered in the cost-benefit analyses include the costs incurred by CSIRO and the research partners to produce the research outputs. Additional in-kind contribution by CSIRO or others was not captured due to data limitations. Usage and adoption costs borne by end-users (such as the cost of vegetative propagation and marketing by licensed commercial nurseries) are also included.

The economic assessment for this study focuses on the adoption of Anameka™ by farming enterprises in Australia. This section provides an estimate of the realised and potential future impacts through an incremental profit farm level approach capturing the first round effects.

Given that the incremental farm level approach does not account for second order market effects, the potential effects of a supply shift on the market are discussed in the sensitivity analysis (Section 7). This is not part of the CBA but helps provide context and consideration for the broader impact on industry as a result of the assumed productivity benefits on individual farms.

Perspective and stakeholders

For most CSIRO research, the quantification of benefits is kept limited to the national level. Anameka™ is currently only available for commercial sale in Australia. As the CBA needs to be conducted from Australia’s perspective, it includes economic costs and benefits arising from CSIRO as well as other potential stakeholders of this project. Given the direct benefits accrue to southern Australian farming enterprises in areas where Anameka™ can be planted, the distribution of benefits in this analysis is skewed towards these stakeholders.

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[3] *As per CSIRO (2020) Impact Evaluation Guide p. 13*

CBA cases

Cost benefit analysis has been conducted for the period FY2005 to FY2040 and estimates the first-round effects of the elite Anameka™ saltbush on the Australian economy and community. This analysis determines:

- A base case (status quo) i.e. a benchmark to compare counterfactual scenario representing the possible outcome in the absence of the introduction of an elite saltbush variety, and
- The project case that estimates incremental farm level profit benefits from adoption of Anameka™.

Base Case (counterfactual) – without improved OMSB

The counterfactual represents a situation where CSIRO and research partners did not engage in elite saltbush selection and commercialisation and only standard, non-improved saltbush is available for adoption. According to saltbush researchers, there is a market failure in saltbush improvement due to small profit margins as shrubs are long lived and planted at low numbers per hectare (CSIRO, per comms 2020). It is reasonable to assume that in the absence of the largely publicly funded CRC work and CSIRO led work since 2013 (largely funded by public institutions and some industry RDC funding) there would not have been an elite OMSB developed. Hence, the base case is a scenario where farmers plant unimproved 'standard' OMSB.

The analysis assumes that in the counterfactual scenario, all enterprises adopting Anameka™ would have adopted unimproved OMSB in the absence of the research improvement program. This likely underestimates the potential benefits as the benefits relative to no shrub adoption are larger (CSIRO, 2016) and many may not have adopted any OMSB in the absence of Anameka™.

Project case – with elite OMSB Anameka™

In the project case, the elite saltbush Anameka™ is modelled to result in a marginal increase in gross margin per hectare on the livestock enterprise portion of mixed-sheep farm enterprises in response to an increase in wool production and reduction in supplementary feeding[4]. No other benefits are modelled. This assumes only the livestock gross margin portion of the farm is impacted, a necessary simplification given data and resource limitations.

This information is based on the most specific Anameka™/elite saltbush impact data available (CSIRO, 2016) informed by animal experiments, field trials and bioeconomic modelling of two representative mixed-sheep enterprises in low and high rainfall regions of southern WA. As 95% of Anameka™ adoption has occurred in WA and on mixed-sheep enterprises in southern WA, this is considered a reasonable extrapolation.

As such, this analysis provides a *broad ballpark estimate only of potential Anameka™ impact* based on extrapolating these results across the adoption data and assumptions about adopting farm enterprises and projected sales. Other productivity related benefits (and environmental and social

[4] Supplementation using Anameka™ has demonstrated a 25% increase in wool quantity and decrease in supplementary feed bill (CSIRO, 2016).

benefits) are discussed qualitatively in Section 8. Sensitivity testing on the assumptions is documented in Section 7.

Time period and Costs

This analysis is based on saltbush improvement research commencing in FY2005 and ongoing to FY2023. For details on costs and timeline of the program see Inputs section.

Table 4 CBA Analysis – Timeline and Costs Table

Timeline	Costs: FY2005- FY2023 Benefits: Ex-post: FY2014 to FY2020 Ex-ante: FY2021 to FY2040
Costs	It is estimated that CSIRO and partners invested $2.83 million (nominal, undiscounted) financially towards the total R&D for saltbush improvement. This likely overestimates the financial inputs for Anameka™ development alone.

The analysis involves a component of ex-post analysis (relating to the costs and benefit in the period FY2005 to FY2020), but also a component of ex-ante analysis forecasting the benefits flowing from the research activities over the period FY2021 to FY2040. It should be noted that benefits may continue to accrue to Anameka™ planted after 2031 but no sales beyond 2031 have been estimated. Sales projections of Anameka™ for the period 2021-2031 are based on a declining per cent annual increase on historical increases.

No benefits beyond FY2040 have been estimated. FY2040 was chosen to capture the assumed 20-year productive life benefits of Anameka™ that was planted in the ex-post analysis period. All benefits are capped at FY2040 regardless of year planted.

Usage and adoption costs

The commercial nursery partner and contract nurseries vegetatively propagate Anameka™ and conduct sales. As these activities are required to bring the research outputs to market they are considered usage and adoption costs and are subtracted from the benefits in the cost benefit analysis[5]. As costs of nursery production are not available, the estimated price of OBSM shrubs ($.055/shrub for unimproved seed grown saltbush and $0.83/shrub for Anameka™: CSIRO per comms, 2021) are used as a proxy for commercial costs per shrub using the assumption that price equals marginal cost. This is likely to overstate commercial costs and therefore, understate program benefits.

It is estimated that it costs $700/ha to plant Anameka™ and $500/ha to plant unimproved OMSB on average. This is captured in the farm gross margin analysis and also tested in sensitivity testing to a higher and lower net difference. There are reportedly little to no further on-farm management costs (CSIRO, per comms 2021; Chatfield Nursery, Nd).

[5] *Based on CSIRO (2020), 'Impact Evaluation Guide' p. 30*

Attribution

As described in Section 4, there have been many stakeholders across the life of saltbush improvement R&D. CSIRO has played a leading role since 2013 and continues to lead to saltbush research and development supported by financial contributions from the Australian Government and Research Development Corporations. CSIRO impact assessments require an estimate of research impact proportional to CSIRO to calculate CSIRO return on investment. CSIRO's attribution to benefits is modestly estimated to be 20%. Stakeholders were not available to inform this estimate and it is an author assumption only. Using a cost share estimate was not possible in this analysis due to the unknown proportions of contributions within the CRC investments.

Quantifying Benefits – Incremental farm profit

Incremental farm level profits herein are estimated through the difference in marginal gross margin per hectare afforded by an increase in wool quantity, decrease in supplementary feed costs and offset by planting costs in an average season. This is sensitivity tested for gross margin results in poorer and good seasons. The model makes a series of assumptions based on saltbush recommendations in the literature and corroborated through personal communications with native forage shrub researchers.

In this analysis, only mixed-sheep farming enterprises in Southern WA are represented and only gross margin improvements to the livestock portion of the farm pasture area are captured as benefits. It is acknowledged that this is a broad simplification but necessary given data limitations. Adoption data is split broadly based on low or high rainfall regions based on sales data with a known location. There is insufficient data to model benefits beyond this at this time.

In this analysis it is assumed that Anameka™ is planted to land equivalent to 20% of the total farm pastures (sensitivity tested at 10 and 30%). This is a necessary assumption in the absence of more detailed adoption data and is based on the proportion modelled in CSIRO (2016) and personal communications with native forage shrub researchers (CSIRO per comms, 2021). It is equivalent to every 1 hectare of saltbush providing gross margin benefit to 5 hectares of farm livestock pastures. The sensitivity test ranges provide a ballpark estimate around this assumption.

Table 5 Economic benefits assessment model assumptions

Model assumptions		
Description	**Assumption**	**Source**
Incremental increase in livestock GM/ha (across farm pasture) due to wool quantity and supplementary feed costs benefits (*Low rainfall region, average season*)	$16/ha	CSIRO (2016) and inflated using ABS CPI to 2020/21 $AUD
Incremental increase in livestock GM/ha (across farm pasture) due to wool quantity and supplementary feed costs benefits (*High rainfall region, average season*)	$53/ha	CSIRO (2016) and inflated using ABS CPI to 2020/21 $AUD
Anameka™ planting establishment costs	$700/ha	CSIRO per comms (2020)
Unimproved saltbush planting establishment costs	$500/ha	CSIRO per comms (2020); NSW DPI (Nd)

Anameka™ sales projections	25% first year, dropping annually by 5% to 10% steady state growth	CSIRO per comms (2020)
Productive life of Anameka™/OMSB	20 years	Chatfields Nursery (Nd); CSIRO per comms (2020)
Type of enterprise adopting Anameka™	Western Australian Southern mixed crop sheep (merino) enterprise	CSIRO per comms (2020)
Proportion of Anameka™/saltbush planted to farm pasture land benefiting	20%	CSIRO (2016) and CSIRO per comms (2021)
Recommended Anameka planting rate	650 plants per hectare	CSIRO per comms
No grazing in first year of establishment	Grazing from 12 months onwards	NSW DPI (Nd); WA DPIRD (2020b)
Low rainfall region/high rainfall region adoption	66%/34%	Author estimation based on sales data and low term average rainfall data

The assumptions made here are conservative but should be viewed with caution due to limitations in data available, the use of representative farms and broad calculated assumptions based on anecdotal advice. Hence, this analysis provides a *ballpark estimate only* of the realised and potential net benefits of the adoption of Anameka™. Sensitivity testing is conducted on all key parameters.

8 Results

As stated above, the economic benefits captured in this analysis are the aggregated incremental farm level profits of adopting the elite Anameka™ saltbush over an unimproved Oldman saltbush shrub[6]. To estimate the return to overall investment, all known (or estimated) R&D, and end-user adoption costs are included. On this basis, the Net Present Value (NPV) and benefit cost ratio (BCR) for Australia is presented in Table 9. However, this should be interpreted in the context of the parameter range testing and the second-order market effects (not captured in an incremental farm profit level approach) discussed in the sensitivity analysis. **The whole of program result is a NPV of $12.3 million (2020-21 AUD) with a BCR of 3.4:1.**

Table 6 Anameka™ case-study CBA results. Basis: all investment costs (all $ in million, 2020/21 AUD)

Scenario	PV costs	PV benefits	NPV	BCR
Improved farm level profits due to adoption of elite Anameka™ saltbush over unimproved saltbush	5.0	17.3	12.3	3.4:1

Note: Real Discount rate of 7 per cent per annum, based on CSIRO. Feb 2020, 'Impact Evaluation Guide'. Source: CSIRO.

[6] *Second-round effects are discussed in the sensitivity analysis.*

To estimate the return on CSIRO's contribution to saltbush improvement, it is assumed that 20% of benefits are attributable to CSIRO. **On this basis, the NPV and BCR for CSIRO is calculated as NPV $1.9 million AUD with a benefit-cost ratio of 2.2:1.**

Table 7 CSIRO only Anameka™ case-study CBA results. Basis: CSIRO investment costs (all $ in million, 2020/21 AUD)

Scenario	PV costs	PV benefits	NPV	BCR
Improved farm level profits due to adoption of elite Anameka™ saltbush over unimproved saltbush	1.5	3.4	1.9	2.2

Note: Real Discount rate of 7 per cent per annum, based on CSIRO. Feb 2020, 'Impact Evaluation Guide'. Source: CSIRO.

The results indicate that the CSIRO and research partner investment into saltbush improvement research has a net positive impact. These results are based on conservative assumptions and underestimate the BCR as *total* saltbush improvement R&D costs are included not just the R&D costs to develop Anameka™. The analysis also underestimates benefits by assuming that all adopters would have adopted unimproved saltbush (instead of not adopting anything[7]) in the absence of Anameka™. Overall, this modest positive result provides confidence that the public investment in improving saltbush and selecting an elite variety has been a wise public investment.

Sensitivity Analysis

Sensitivity analysis has been conducted to account for the inherent risks in model assumptions and to gauge the effect of deviation in the parameters presumed for the analysis. The CBA is necessarily based on a series of assumptions which implies that there is a degree of uncertainty around the results. To address the above issues, sensitivity analysis (see Table 11) is performed on each key parameter. Sensitivity testing is performed on whole program costs and benefits.

Testing from the lowest to highest ranges on key all parameters maintained a modest but positive NPV and BCR in all cases. The estimate for commercial nursery propagation and sales costs (deducted from benefits as usage and adoption costs to bring the research output to market) did not significantly impact the NPV or BCR even when doubled or tripled. Note that the inclusion of shrubs is expected to buffer against 'poorer' seasons as demonstrated in bioeconomic modelling results (CSIRO, 2016) as the addition of shrubs are likely to yield the greatest relative gain in poorer seasons.

Table 8 Sensitivity testing results (each parameter range tested individually; all others held equal)

Parameter		Low	Assumption (Model)	High
Discount rate		**5%**	**7%**	10%
	NPV	17.8	12.3	5.8
	BCR	5.0:1	3.4:1	1.9:1
Marginal increase in livestock GM/ha due to increased wool quantity and reduced		**$11/h and $107/ha "good season"**	**$16/ha and 53/ha "average season"**	**$20/ha and 320/ha "poor season"**
	NPV	9.4	12.3	14.5

[7] As per CSIRO (2016) the net benefit between elite and no shrub scenario is larger than between elite and standard shrubs.

supplementary feeding costs (low/high rainfall)*	BCR	2.8:1	3.4:1	3.8:1
Proportion of farm pasture benefiting from saltbush hectare (saltbush ha: farm pasture ha)		**30% (1ha:3.33ha)**	**20% (1ha:5ha)**	**10% (1ha:10ha)**
	NPV	4.0	12.3	36.8
	BCR	1.8:1	3.4:1	8.3:1
Net difference in Anameka™ establishment costs relative to unimproved saltbush p/ha		$500/ha	$200/ha	$100/ha
	NPV	6.6	12.3	14.1
	BCR	2.3:1	3.4:1	3.8:1

The above results are performed with both the ex-post (sales FY2014-FY2020) and ex-ante (forecasted sales FY2021 to FY2030) components of the analysis. Given that forecasting sales has a high degree of uncertainty, the results are tested with the removal of all forecasted sales. The result (all other assumptions held constant) is a marginally negative BCR of 0.94:1. This is to be expected given Anameka™ only became available relatively recently and sales and awareness about Anameka™ adoption are still building. This indicates that the positive return on research investment relies on continued adoption of Anameka™ in the coming years.

Second round economic effects of improved productivity on farm

The incremental farm profit approach utilised in this analysis only accounts for the first-round effects of a productivity increase, that is the value of an increase in sheep productivity per hectare calculated on fixed prices and areas. However in the medium to longer term, widespread adoption of a profitable new technology will result in expansion in the aggregate supply of sheep products, with consequent impacts on prices and volumes at all other stages of the value chain. The aggregate benefits of these price and quantity changes in the value chain are measured by changes to producer and consumer surplus.

Thus, the CBA analysis in this case study does not illustrate how the gross benefits from the increase in sheep industry productivity are distributed across the various stakeholders nor how overall producer or consumer surplus change may change as it flows through the market.

Equilibrium Displacement Models (EDM) are often used to estimate the relative returns of agricultural R&D induced shifts in supply and demand. For example, a recently validated EDM model for the Australian Sheep Meat Industry (Mounter et al. 2019), calibrated for current Australian sheep industry structure and conduct, estimates that for a 1% shift in lamb or mutton productivity at the farm level, about 35—43% is retained by farmers, about 10-26% is distributed to value chain participants, and about 30-54% is distributed to final consumers (Ibid, 2019). Note that in cases where a high proportion of output is exported, as in Australian sheep meat markets, many of these consumers will be overseas.

The net benefits calculated in the analysis should be interpreted as a ballpark approximation of present value benefit, representing aggregated on-farm profits only. Any discussion of national benefits should be considered in the context of potential flow-on and distributional affects across the value chain.

9 Non-quantified impacts

Non-priced economic impacts

Farm risk and other production benefits

In addition to an incremental improvement in livestock gross margin, Anameka™ allows the farming enterprise to potentially defer grazing of winter pastures (particularly during establishment) boosting pasture productivity and can facilitate backgrounding of young stock during summer and autumn (Chatfields Nursery, Nd). As described above, the addition of shrubs to the farming system is also likely to provide a buffer against the impact of poorer seasons generally, thus reducing risk (CSRIO, 2016). These potential economic impacts are not captured in the quantitative analysis.

Animal health

OMSB (alongside other native shrubs) has the potential to contribute to healthier animals through the increased availability of key vitamins and minerals that are lacking in many grazing systems in summer and autumn. OMSB are thought to have higher antioxidant capacities due to their adaptation to environments with high oxidative stress Examples include Vitamins E and A, sulphur, selenium, zinc, manganese and copper. (CSIRO, 2016). These vitamins and minerals are all associated with antioxidant pathways and deficiency can lead to suboptimal productivity or even mortality for reproducing or growing animals during heat stress events (Norman et al. 2019).

Norman et al. (2019) demonstrate that many shrubs including OMSB's Anameka™ *specifically*, have the necessary mineral elements in excess of the requirements of grazing livestock. Future targeted selections based on Anameka™ as a parent may even allow further optimisation of mineral accumulation to support animal health (Ibid, 2019). These potential improvements to health through the incorporation of Anameka™ into the farming system are likely to be associated with on-farm productivity and economic benefit, the extent to which is unknown at this time. A new project, in conjunction with MLA, UWA and Murdoch University, will seek to quantify the benefits to reproduction, survival, and welfare in the near future (CSIRO, per comms 2021). Further, the provision of shade and shelter by perennial saltbush shrubs has been noted as a potential benefit to animal health (Revell et al. 2013).

Meat quality and shelf life

The potential OMSB, to improve meat quality and shelf life has been recognized. Largely through increased Vitamin E (and possibly the minerals associated with antioxidant pathways) saltbush may improve meat quality through the production of a carcass that has proportionally more lean muscle, less fat and improved meat colour stability (Pearce et al 2010). Meat quality through taste and shelf life may also be positively benefited through the increased presence of Vitamin E (Ibid, 2010). This may lead to increased economic return for producers, wholesalers and retailers of meat sourced from farming systems adopting shrubs such Anameka™, though the extent is unknown at this time.

Environmental impacts

As a native Australian shrub adapted to dry, saline and nutrient deficient conditions, OMSB can often be planted in agricultural systems where traditional cereal crops and pasture legumes cannot survive (Li et al. 2017). OMSB has very deep roots and a C4 photsynthetic pathway, so it actively grows in the summer and autumn periods and utilises out-of-season rainfall for growth. As a woody shrub to 2m in height, it introduces of a new vegetation layer in the agricultural system and has been associated with the delivery of a number of ecosystem services on the landscapes they are established across.

Improved landscape functioning

Through the better use of water and reduction of water leakage to the water table, the shrubs have the potential to reduce the effects of dryland salinity. As dryland salinity is one of the major risks to agriculture and the natural environment this is possibly the largest environmental and system benefit of furthering adoption of OMSB across the landscape. Through the deep, perennial roots the shrubs reduce rising water tables and prevent accumulation of further salinity in the topsoil. Data from a paired catchment study (Bennett et al. 2012) demonstrated that establishment of saltbush does this by stabilising the saline area through added ground cover, minimising soil erosion and reducing salt, nutrient and sediment run-off. In the study, one tenth of the salt was discharged from the catchment with an established saltbush system.

Improved biodiversity

The establishment of saltbush to agricultural systems has also been associated with adding a vegetative layer missing from typical agricultural landscapes. Collard and Fisher (2010) suggest that the (re)establishment of woody perennials like Saltbush provides an important vegetation understory and structural complexity that provides habitat for native biodiversity, thereby 'softening' the otherwise highly modified environments. Both the literature and anecdotal landholder comments have linked increased activity of native invertebrates, reptiles and birds with planted Oldman Saltbush systems though this is likely to vary in magnitude depending on the location (Ibid, 2020).

The environmental benefits attributable to the saltbush improvement R&D are proportional to the extent to which Anameka™ (and possibly broader saltbush adoption) have been adopted over and above what they otherwise would have been due to the release and promotion of the more palatable and productive clone. While CSIRO and the research partners cannot and do not claim sole attribution to the environmental benefits of Oldman Saltbush it is clear that the literature evidences environmental benefits from the shrubs incorporation into modern farming systems and further widespread adoption on elite varieties will likely extend the realisation of these benefits across the landscape.

Social impacts

Sustained regional communities

It is hypothesised that there are social impacts proportional to the economic and environmental benefits of adoption of Anameka™. These economic and environmental benefits likely contribute to the maintenance of resilient and sustainable farming systems (at a minimum through maintaining herd/flock sizes and increased ability to endure poor seasons) which in turn support the health and longevity of the surrounding agricultural enterprises and communities. Livestock production tends to support greater numbers of people in rural communities than cropping operations.

Improved visual amenity

The revegetation of otherwise saline lands with OMSB may deliver social benefit through the improvement of visual amenity (WA DPIRD 2020; RIRDC 2009). The presence of saline land or marginal is typically viewed as negative and its rehabilitation associated with satisfaction for landholders and the community. This benefit is likely inversely proportional to the size of the property as smaller lifestyle purchases typically have a higher proportion of value tied to visual amenity (MLA, 2006).

10 Future applications of research

Anameka™ and saltbush improvement research is ongoing. CSIRO and research partners are continuing to investigate the development of direct seeding to reduce establishment costs of elite material and continuing to build seed lines and evaluation of germplasm for future development elite varieties for new niches/opportunities. Carbon and natural capital markets provide significant opportunities for the shrub germplasm. Research is also underway to quantify the benefits in sheep reproduction rates, lamb survival and welfare with saltbush present as supplement and shelter in the production system. The impact of climate change in southern Australia is likely to expand the scope for drought tolerant shrubs.

11 Limitations

This evaluation used a mixed methodology to assess research impact of saltbush research improvement. It combined quantitative and qualitative methods to illustrate the nature of economic, environmental, and social impacts. In cases where the impacts can be assessed in monetary terms, a CBA was used as a primary tool for evaluation. As a methodology for impact assessment, CBA relies on the use of assumptions and judgments made by the authors, informed stakeholders and the literature.

This impact case study has limitations due to needing to make assumptions about R&D inputs, the counterfactual, representative farm characteristics and projections of future shrub sales. Quantitative benefits were estimated based on extrapolation of results from two farm enterprises and incremental profits reported in CSIRO (2016). As such, the accuracy of the results relies on these results being suitably representative of end-user adoption broadly. Sensitivity testing is conducted on all key parameters to provide estimate ranges given the uncertainty.

Thus, the case study provides a ballpark estimate of the realised and prospective impact of Anameka™ and improved saltbush generally and results should be interpreted within the context of the data available and assumptions made.

may assist extension efforts.

12 Confidence Rating

Data that underpins the CBA is based on ex-post and ex-ante information. As a result, some of it is inherently uncertain. The analysis is performed using CSIRO internal information, inputs from external organisations and calculated assumptions thereby making results approximations only. In all instances, lower-bound estimates and conservative assumptions have been used to remain conservative. Due to scope, time and informational availability constraints, further refinement of these estimates is not viable.

The author determines the confidence rating of the quantitative component of the assessment as medium.

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