Australia's National Science Agency

Phalaris Breeding Program Impact Case Study

March 2021

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Acronyms

AT	Acid tolerance
AWI	Australian Wool Innovation
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DSE	Dry Sheep Equivalents
DPI	Department of Primary Industries
FY	Financial Year
GT	Grazing tolerance
ha	hectares
kg	kilograms
LWRRDC	Land and Water Resource Research Development Corporation
Nd	No date
NSW	New South Wales
NPV	Net Present Value
PBR	Plant Breeders Rights
per comms	Personal communications
PV	Present Value
RDC	Rural Development Corporation
R&D	Research and Development
SA	South Australia
TBL	Triple Bottom Line
t	tonnes
VIC	Victoria

1 Executive Summary

1.1 The challenge

Phalaris (*Phalaris aquatica L.)* is a temperate, cool-season, long-lived perennial grass sown in medium rainfall regions and exploited as a pasture species mainly for beef and sheep grazing. It was in Australia that its potential as a pasture species was first identified in the late 19th century (Oram et al. 2009) and contemporarily it is *'unique on the world scale in its importance to the grazing industries of southern Australia' (*Smith, 2013).

Unimproved Phalaris while identified as a productive pasture grass has deficiencies such as the tendency to shed seeds, have low yields of harvestable seed and occasional toxicity. CSIRO plant breeders in the middle of the 20th century identified that there was a need for improved Phalaris that would overcome these characteristics and be more productive, persistent, and hardy for the grazing industries of Australia.

1.2 The response

Commencing in the late 1950's CSIRO maintained the 'pre-eminent' Phalaris breeding program and conducted the most effort globally in Phalaris breeding for many decades until its conclusion in 2017. Twelve improved varieties were released, successfully extending the potential zones of adaptation of Phalaris and improving its seasonal growth, grazing tolerance, persistence, seed production and grazing productivity. This was achieved through the discovery and exploitation of new domestication, production and persistence traits in partnership with Rural Development Corporations, State Agricultural Departments and commercial seed partners. The program's prominence is such that much of today's globally cultivated Phalaris varieties have leveraged on the genetic improvement legacy of the CSIRO breeding program.

1.3 The impacts

CSIRO's improved Phalaris varieties have been widely adopted across the Australian landscape. It is estimated that between 1990 -2020 4.4 million kilograms of certified CSIRO Phalaris seed has been sold equating to 1.48 million hectares at the recommended sowing rate of 3kg/ha.

We estimate that the net present value of benefits across the most recent seven varieties is approximately $5163.9 million (or 55:1) in 2019/20 dollars at 7 per cent discount rate given model assumptions[1]. This significant return is reflective of the long, stalwart investment in Phalaris breeding delivering realised and prospective benefits across 50 years. Sensitivity testing reveals that even at the most pessimistic lower-range parameters the results are modest but positive. Overall,

[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.*

this provides confidence that the public investment in improved Phalaris breeding in recent decades has delivered 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. Improved Phalaris is also associated with reducing the risk exposure of grazing enterprises by providing a more reliable pasture that has improved establishment and persistence and is hardier to drought conditions. Phalaris as a deep-rooted perennial pasture is also associated with environmental benefits through the ecosystem services of improved groundcover and reducing deep-drainage, nitrate losses, soil erosion, weed incursion and soil acidification.

It is hypothesised that there are social impacts proportional to the economic and environmental benefits of improved Phalaris on farms. Improved financial resilience in grazing enterprises due to these characteristics is likely to have contributed broadly to social resilience in rural and regional communities where these farming industries are a significant economic driver.

Whilst CSIRO cannot and does not claim sole attribution to these benefits this case study provides confidence that the CSIRO and research partner R&D investment into improved Phalaris pastures has delivered positive impact for the nation.

Unintended impacts of occasional but rare Phalaris toxicity and perceived environmental costs due to widespread adoption of Phalaris by the grazing industries are acknowledged.

2 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 breeding program for improved *Phalaris*, an important temperate perennial grass in south-eastern Australia. The study highlights the economic, environmental and social benefits of the selection, development and commercialisation of the improved varieties to Australia. The analysis provides an estimate of the benefit-cost ratio of the investments accompanied by a qualitative summary of the other 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.

3 Background

Phalaris in Australia

Phalaris (*Phalaris aquatica L.)* is a temperate, cool-season and long-lived perennial grass sown in medium rainfall regions of southern Australia. It is native to the Mediterranean and North-West Africa and first introduced into Australia in the 19th century. The first popular introduction in the early 20th century known as *'Australian'* proved well adapted and it was in Australia that the value of Phalaris was first recognised and exploited as a pasture species (Oram et al. 2009).

Contemporarily, improved Phalaris varieties are valued for their high production through autumn-winter-spring and high persistence through both regular and severe drought events and is the most important sown temperate perennial grass in large areas of south-eastern Australia that are too dry for use of perennial ryegrass. Phalaris is now unique on the world scale in its importance to the grazing industries of southern Australia (Smith, 2013) and CSIRO's longstanding and stalwart investment into improved Phalaris pastures is undoubtedly a significant contributor to the pasture's Australian success.

CSIRO's Response: Phalaris variety improvement

CSIRO's research program of Phalaris breeding began in the late 1950's and was the sole Australian breeder until 2000. Breeding continued internally for almost six decades until its conclusion in 2017. Until approximately the 2010's, CSIRO Phalaris varieties made up almost the whole propriety commercial Phalaris market domestically (CSIRO per comms, 2020) and the CSIRO program is known as the '*pre-eminent force in Phalaris breeding'* such that most cultivated varieties both domestically and internationally are likely to have leveraged genetic improvement from the CSIRO breeding program legacy to some degree (NSW DPI, per comms 2021; Gapare, Nd unpublished).

> *'I don't think there would be a better example of an agency coming in and making productivity improvements like CSIRO has done when coming in and making improvements to Phalaris….It has had an immense impact on the commercial pastures marketplace'.*
>
> (NSW DPI, per comms 2021)

Targets of the CSIRO program of research were largely better establishment, improved winter growth rates, filling winter feed gaps, increased adaptation for lower rainfall areas and removal of alkaloid toxicity (CSIRO per comms. 2020). Among other things, the program successfully improved productivity, the potential zones of adaptation of Phalaris, the seasonal growth, grazing tolerance and seed production of Phalaris through the discovery and exploitation of new domestication, production and persistence traits (Smith, K. 2013; NSW DPI per comms 2021; Oram et al. 2009).

Twelve varieties have been released across the lifespan of the program (See Table 4) commencing with the release of SiroSeedmaster and Sirocco in 1965 and 1967 respectively. Sirosa and Sirolan followed in 1974 and 1978 introducing higher seedling vigour for easier establishment, higher winter activity for improved productivity and lower tryptamine alkaloid content. The major discovery of the 'very rare mutant' (Oram et al. 2009) for intact-rachilla seed retention by the CSIRO breeding program shortly afterwards led to the release of Uneta in 1982. This research milestone enabled all future varieties to be seed retaining increasing seed yield and facilitating greater seed production.

The popular variety, Holdfast, was released in 1991 with both seed-retention and productivity attributes followed by Atlas PG in 1996 for higher summer dormancy in drier areas. Following greater emphasis on persistence in the breeding program, Landmaster was released in 1996 (for shallow, stony and moderately acidic soils in recharge areas) and Advanced AT (for strongly acidic soils) and Holdfast GT (winter-active with improved grazing tolerance) were released in 2008 (Smith. 2013). The final CSIRO variety, Horizon, is due for release in 2021. It is a winter active and summer-dormant variety for drier margins (CSIRO per comms, 2020).

The breeding research program was supported financially by CSIRO, Australian Wool Innovation and other rural development corporations such as Meat and Livestock Australia and the Land and Water Resource Research Development Corporation (LWRRDC). The cultivars were commercialised in partnership with Barenbrug Australia[2].

The available data indicates that approximately 4.44 million kilograms of certified CSIRO Phalaris cultivar seed have been sold since 1990. Based on a sowing rate of 3kg/ha this is approximately 1.48 million hectares of country improved with CSIRO Phalaris. The following case study attempts to capture the economic, environmental, and social impacts the adoption of this improved Phalaris pasture has delivered to the nation.

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[2] *Formerly known as Heritage Seeds (Seedmark).*

Following the conclusion of internal Phalaris breeding at CSIRO in 2017, CSIRO's Phalaris research output legacy is being leveraged through an external germplasm agreement with PGG Wrightson Seeds. As of 2021, PGGWrightson Seeds have exclusive rights to continue exploitation of the invaluable genetic material for future Phalaris forage pasture variety improvement and impact.

An impact pathway is used to identify the causal relationship of a project from the inputs through to impacts. Section 4 illustrates the impact pathway for the CSIRO Phalaris breeding program.

4 Impact pathway

INPUTS

Funding

- CSIRO (Plant Introduction Unit, Plant Industry, A&F) funding and in-kind support
- External investment by:
  - International Wool Secretariat/ Australian Wool Innovation
  - Future Farm Industries CRC
  - Land and Water Resource Research Development Corporation (LWRRDC)
  - Meat Research Corporation/Meat and Livestock Australia
  - State Government Agriculture Departments (NSW, VIC, SA)
  - NSW DPI and other state government agencies in-kind extension activity promoting of cultivars

Research Capabilities

- Background knowledge and expertise in pasture improvement breeding (since late 1950's) including geneticists, cytologists, physiologists, plant breeders and technicians
- Access to infrastructure and resources to execute projects (e.g. on-site and off-site facilities – laboratories, glasshouses, nurseries, field research stations)

Translational and Commercialisation Support

- Strategic commercialisation planning and execution by commercial industry partners

ACTIVITIES

Research and Development

- Improved Phalaris cultivar research and development including:
- Importation and introduction of new germplasm
- Research to improve understanding of attributes such as productivity, persistence, seed-retention and grazing tolerance
- Trait identification and validation
- Field trials and glasshouse/nursery
- Extensive germplasm evaluation
- Breeding and selection

Collaboration with key stakeholders in pasture improvement including State Government agriculture departments and Research and Development Corporations

Translation and commercialisation of improved cultivars

- Provision of seed to commercial partners for breeding to commercial quantities
- Registration of Plant Breeders Rights (PBR)
- Licensing activities with commercial partners
- Technology Summit, November 2018

OUTPUTS

New improved Phalaris varieties

SiroSeedmaster (1965)
Sirocco (1967)
Sirosa (1974)
Sirolan (1978)
Uneta (1982)
Holdfast (1991)
Landmaster (1996)
Australian II (1998)
Atlas PG (1998)
Holdfast GT (2009)
Advanced AT (2008)
Horizon (2021)

Germplasm pools

- General purpose winter-active pool
- Winter-active pool for acid and skeletal soils
- Winter-active pool with higher summer dormancy for drier margins
- Semi-winter dormant (Australian) pool
- Other germplasm held by CSIRO, DPI Victoria and Australian Pastures Genebank

New Phalaris knowledge and understanding including:

- Germplasm diversity
- Physiology of growth and survival
- Forage quality
- Discovery of 'intact-rachilla' seed retention
- Persistence factors (grazing, soil acidity, etc.)
- Alkaloids

External Network:

Working and productive networks and relationships between CSIRO, State Government agricultural departments, Research Development Corporations and commercial seed partners

OUTCOMES

Uptake and adoption

- Successful commercial adoption and retailing of CSIRO cultivars by Australian agribusiness
- Widespread adoption of CSIRO cultivars by grazing operations across South-Eastern Australia as productive and persistent perennial pasture grass of choice where it is too dry for perennial ryegrass to be grown

Revenue streams from the new cultivars for commercial partners and agribusiness retailers

CSIRO and Rural Development Corporation royalties

Sustained co-operative forage and pasture improvement research relationships between CSIRO and partners

CSIRO is sole Australian breeder and global leader in Phalaris breeding improvement 1960's – 2000

CSIRO breeding program genetic legacy present in global Phalaris cultivars

IMPACT

ECONOMIC IMPACT

- Improved livestock farm profitability due to a persistent perennial forage pasture with improved characteristics (e.g. greater livestock carrying capacity, grazing tolerance, drought tolerance, higher summer dormancy etc.)
- Reduced farm seasonal risk exposure due to improved drought resilience, reduced winter-feed gaps and/or delivery of ecosystem services

ENVIRONMENTAL IMPACT

Ecosystem services of:

- Improved groundcover
- Reduced deep-drainage and high-water tables
- Reduced nitrate losses
- Reduced soil erosion
- Reduced weed incursion
- Reduced soil acidification

SOCIAL IMPACT

- Potentially more resilient rural communities due to improved financial resilience of grazing industries

~1955 – 2017

1965 – Ongoing

Figure 1 Impact Pathway for CSIRO's Phalaris improvement breeding program

5 Impact Evaluation

5.1 Inputs

CSIRO Phalaris improvement breeding research commenced in the 1950's and concluded in 2017. There is no program-related information available for varieties released prior to 1991. As such, the seven varieties for which data is available are included in this analysis:

Holdfast (1991)

Landmaster (1996)

Australian II (1996)

Atlas PG (1998)

Holdfast GT (2009)

Advanced AT (2008)

Horizon (2021)

Input costs included are those directly related to breeding program R&D of these varieties and the input costs of two cultivars developed but not commercialised or released during this period.

CSIRO's inputs

- CSIRO Funding: $5.56 million (nominal, undiscounted); For more details see Table 1
- Background knowledge and expertise in pasture improvement breeding including geneticists, cytologists, physiologists, plant breeders and technicians
- Access to infrastructure and resources to execute projects (e.g. on-site and off-site facilities – laboratories, glasshouses, nurseries, field research stations)
- Internal CSIRO Business Development and Commercialisation (BD&C) in-kind commercialisation support

Partner inputs

- External R&D Funding: $2.28 million (nominal, undiscounted).
- CSIRO received significant financial investment for improved variety research and development from the Australian Wool Innovation and smaller contributions from the Land and Water Resources Research and Development Corporation and Meat and Livestock Australia in the period of analysis based on the available data
- Other in-kind contributions by NSW DPI and other State Government agencies and agricultural departments in formal and informal collaborations and general pasture extension has not been captured in this analysis but is acknowledged as a complementary activity to the success of pasture adoption broadly. The magnitude of these in-kind costs is unknown. Sensitivity testing in section 7 accounts for underestimation of inputs in the modelling.

It is estimated that $7.79 million (nominal, undiscounted) was invested into Phalaris R&D breeding of the seven commercial varieties (and two unreleased cultivars) captured in this analysis.

Table 1 R&D investment (nominal, undiscounted) into the breeding and release of 7 improved Phalaris varieties since 1991

Year	CSIRO	RDC's	TOTAL
1972/73	$ 37,500	$ -	**$ 37,500**
1973/74	$ 52,500	$ 17,500	**$ 70,000**
1974/75	$ 37,500	$ 12,500	**$ 50,000**
1975/76	$ 22,500	$ 7,500	**$ 30,000**
1976/77	$ 52,500	$ 17,500	**$ 70,000**
1977/78	$ 37,500	$ 12,500	**$ 50,000**
1978/79	$ 37,500	$ 12,500	**$ 50,000**
1979/80	$ 75,000	$ 25,000	**$ 100,000**
1980/81	$ 75,000	$ 25,000	**$ 100,000**
1981/82	$ 75,000	$ 25,000	**$ 100,000**
1982/83	$ 118,814	$ 39,605	**$ 158,418**
1983/84	$ 129,885	$ 49,644	**$ 179,529**
1984/85	$ 101,769	$ 18,846	**$ 120,616**
1985/86	$ 127,049	$ 23,528	**$ 150,577**
1986/87	$ 154,456	$ 19,307	**$ 173,763**
1987/88	$ 194,408	$ 10,232	**$ 204,640**
1988/89	$ 131,864	$ 182,138	**$ 314,001**
1989/90	$ 191,551	$ 192,993	**$ 384,544**
1990/91	$ 291,989	$ 179,278	**$ 471,267**
1991/92	$ 267,162	$ 198,242	**$ 465,405**
1992/93	$ 226,112	$ 153,398	**$ 379,509**
1993/94	$ 187,207	$ 121,316	**$ 308,523**
1994/95	$ 288,539	$ 51,743	**$ 340,282**
1995/96	$ 323,954	$ 56,237	**$ 380,191**
1996/97	$ 118,810	$ 39,603	**$ 158,413**
1997/98	$ 304,301	$ 101,434	**$ 405,734**
1998/99	$ 314,427	$ 104,809	**$ 419,236**
1999/00	$ 320,249	$ 106,750	**$ 426,998**
2000/01	$ 330,806	$ 110,269	**$ 441,074**
2001/02	$ 273,572	$ 91,191	**$ 364,762**
2002/03	$ 172,220	$ 57,407	**$ 229,627**
2003/04	$ 168,700	$ 56,233	**$ 224,933**
2004/05	$ 56,216	$ 18,739	**$ 74,955**
2005/06	$ 58,299	$ 19,433	**$ 77,732**
2006/07	$ 59,231	$ 19,744	**$ 78,975**
2007/08	$ -	$ -	**$ -**
2008/09	$ 15,000	$ 5,000	**$ 20,000**

2009/10	$ 15,000	$ 5,000	**$ 20,000**
2010/11	$ 15,000	$ 5,000	**$ 20,000**
2011/12	$ 15,000	$ 5,000	**$ 20,000**
2012/13	$ 15,000	$ 5,000	**$ 20,000**
2013/14	$ 15,000	$ 5,000	**$ 20,000**
2014/15	$ 22,500	$ 7,500	**$ 30,000**
2015/16	$ 22,500	$ 7,500	**$ 30,000**
2016/17	$ 15,000	$ 5,000	**$ 20,000**
TOTAL	**$ 5,564,089**	**$ 2,227,116**	**$ 7,791,204**

SOURCE: CSIRO

Note: R&D input costs are based on the available CSIRO financial records and estimates by CSIRO researchers where financial records are unavailable. Data for years prior to 1996/97 are in 1996/97 $AUD. In-kind input estimates were unavailable.

5.2 Activities

Research and development of the new varieties included importation and introduction of new germplasm, attribute research, trait identification and validation, glasshouse, nursery and field trials, germplasm evaluation and breeding and selection. The seed of cultivars selected for commercialisation were provided to the commercial partner for bulking up to commercial quantities for release. Plant Breeders Rights (PBR) were registered and ongoing licensing activities with commercial partners for the duration of the PBR were managed.

5.3 Outputs

Improved varieties and germplasm pools

The fundamental output of the Phalaris breeding improvement program is commercially released, improved Phalaris varieties. The 12 CSIRO varieties released since the program commenced, their characteristics and research and commercialisation details are summarised in Table 4.

Through the breeding program, CSIRO has developed a number of germplasm pools. These germplasm pools are maintained and may be exploited for future breeding. These include:

- General purpose winter-active pool
- Winter-active pool for acid soils
- Winter-active pool with higher summer dormancy for drier margins
- Semi-winter dormant (Australian) pool
- Other germplasm held by CSIRO, DPI Victoria and Australian Pastures Genebank.

New research knowledge

The CSIRO Phalaris research breeding program discovered new knowledge and understanding of Phalaris. In particular, contributions were made to understanding of germplasm diversity, the physiology of Phalaris growth and survival, forage quality, the discovery of ‘intact-rachilla’ seed retention and persistence factors related to grazing and soil acidity.

According to a pastures research scientist (NSW DPI per comms, 2021) the discovery of the intact rachilla mechanism of seed retention by CSIRO completely '*revolutionised the whole game*'. By discovering the gene that holds the seed in the head for longer, seed yield was able to be increased substantially and underpins the quantities able to be produced for sowing likely making the price at which Phalaris seed is sold more affordable and reliable (Ibid, 2021). All CSIRO varieties since Uneta possess this trait.

Key Publications

A list of key publications in the last two decades is located in Appendix B.

5.4 Outcomes

Uptake and adoption

According to Smith (2013), Phalaris is the most important sown temperate perennial grass in drought-prone permanent pasture areas of south-eastern Australia and is unique on the world scale in its importance to the grazing industries of southern Australia. It is reasonable to conclude that the widespread adoption of perennial Phalaris pastures across grazing enterprises of eastern Australia has been contributed to, in no small amount, by CSIRO's improved cultivars program investment. According to a Senior Research Scientist at NSW DPI, the synergies and interconnected nature between the expansion of perennial pastures across Australia (particularly Phalaris as the most important species) and the CSIRO breeding program are unmistakeable (NSW DPI, per comms 2021).

Figure 2 illustrates the known and estimated CSIRO Phalaris seed sales in tonnes by year. The low figure in 2002/03 and drop in sales in 2006 is associated with significant drought events. Some hectares sown will likely be replacing old Phalaris varieties at the end of their useful life, data is not available to distinguish this.

Overall, it is estimated that 1.48 million hectares have been sown with improved CSIRO Phalaris varieties between 1990 - 2020.

Table 2 summarises known and estimated seed sales of CSIRO Phalaris varieties since 1990 and estimated area sown based on the recommended rate of 3kg/ha. Data for the period FY1998-FY2008 is based on best available estimates in the absence of corporate data (CSIRO, per comms 2021). Smith (2013) corroborates that there were considerable Phalaris sales during this period. Table 2 does not include a projection of sales beyond 2019, which would include the latest variety Horizon due for commercial release in 2021 and ongoing future sales from Holdfast GT and Advanced AT. Figure 2 illustrates the known and estimated CSIRO Phalaris seed sales in tonnes by year. The low figure in 2002/03 and drop in sales in 2006 is associated with significant drought events. Some hectares sown will likely be replacing old Phalaris varieties at the end of their useful life, data is not available to distinguish this.

Overall, it is estimated that 1.48 million hectares have been sown with improved CSIRO Phalaris varieties between 1990 - 2020.

Table 2 Approximate seed sales and hectare adoption of CSIRO Phalaris varieties since 1990

	1990 - 1997	1998 – 2008*	2009 - 2019	Total
Kilograms of CSIRO Phalaris seed sold	636,708	2,610,550	1,197,200	**4,444,458**

Hectares	212,236	870,183	399,067	**1,481,486**

**Data for this period is an estimate only based on informed CSIRO assumptions using Australian Seed Association data.*

SOURCE: CSIRO, BARENBRUG AUSTRALIA, AUSTRALIAN SEED ASSOCIATION via CSIRO per comms (2021)

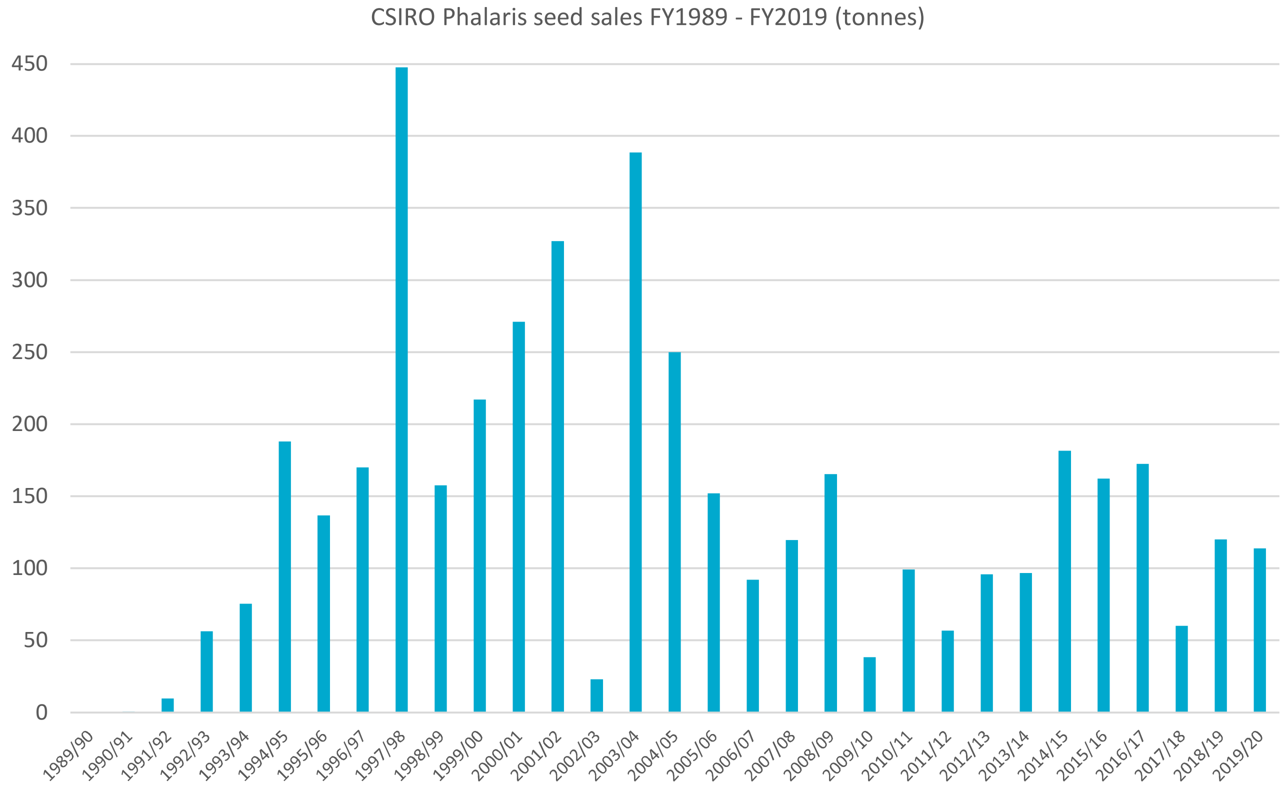

Figure 2 CSIRO Phalaris seed sales FY1989-FY2019*

SOURCE: CSIRO, BARENBRUG AUSTRALIA, AUSTRALIAN SEED ASSOCIATION

**Data is based on available corporate data and informed estimates by CSIRO*

Sustained co-operative relationships

The research program necessitated productive working networks and relationships between CSIRO, state government agricultural departments, research development corporations and commercial seed partners over many decades. The longevity of the program and repeated success in delivering successful commercial varieties to the market speaks to the quality of these inter-organisational relationships. NSW DPI note that there has been a long history of ongoing mutually beneficial formal and informal collaborations between CSIRO researchers and agency staff in pasture improvement research broadly, (NSW DPI, per comms 2021).

Of note, a representative from the commercial seed partner stated:

> *"…the commercial relationship in recent years with CSIRO has been excellent. [We] have found CSIRO supportive and responsive to the needs of the commercial company to do what they need to do, which is important from the perspective of a commercial seed partner and not a guaranteed experience with all public organisations."*

(Barenbrug Australia, per comms, 2021)

Royalties

CSIRO receives sales royalties from the commerical seed partner, a proportion of which is distributed to the partner Rural Development Corporations. Table 3 illustrates recent CSIRO Phalaris net royalties based on available data. Total incremental profit estimated at the farm level in the model captures total benefit, a portion of which is then distributed to CSIRO (and others) as royalties. In addition, the exclusive external germplasm agreement with PGG Wrightson Seeds for the ongoing exploitation of CSIRO Phalaris genetic material yielded $25,000 in revenue to CSIRO in 2019/20 and may yield future royalties to CSIRO should PGG Wrightson pursue commerciaisation of new varieties in the future (CSIRO per comms, 2021).

Table 3 Recent CSIRO Phalaris net royalties (nominal)

Year	CSIRO net royalties
2010/11	$ 20,343
2011/12	$ 51,292
2012/13	$ 38,592
2013/14	$ 32,973
2014/15	$ 35,855
2015/16	$ 45,782
2016/17	$ 63,129
2017/18	$ 53,730
2018/19	$ 51,508
Total	**$ 393,204**

SOURCE: CSIRO

Table 4 CSIRO improved Phalaris cultivars summary

Name	Year released	Suitability/purpose	Phase of breeding program		Approximate R&D years	Commercial partner	PBR
SiroSeedmaster	1965	Higher seed yield than 'Australian'	Productivity, Adaptation & Alkaloids		Late 1950s - 1965	Nil	-
Sirocco	1967	Drier margins, longer summer drought, winter-active, summer-dormant			Late 1950's - 1967	Nil	-
Sirosa	1974	General purpose - higher seedling vigour and winter production than 'Australian', suited to well-fertilised, highly productive pastures best managed rotationally with strategic rests			Early 1960s - 1974	Nil	-
Sirolan	1978	Drier margins - winter active, cropping zone, reduced alkaloid levels			Early 1960s - 1978	Nil	-
Uneta	1982	Higher seed retention than 'Australian'	Productivity, Adaptation & Alkaloids	Seed retention	1972 - 1982	Nil	-
Holdfast	1991	General purpose - seed retaining replacement for 'Sirosa', suited to well-fertilised, highly productive pastures best managed rotationally with strategic rests			1972 - 1991	Seedmark	Cert no: 82 (expired)
Landmaster	1996	Marginal soils - shallow, stony and acidic soils typically on mid and upper slopes where rechange occurring	Persistence traits		1983/84 – 1995/96	Seedmark	Cert no: 613 (expired)
Australian II	1998	Seed-retaining replacement for 'Australian' and 'Uneta'			1989/90 – 1995/96	Seedmark	Cert no: 1162 (expired)
Atlas PG	1998	Drier margins, cropping zone, winter-active, summer-dormant			1988/89 – 1995/96	Seedmark	Cert no: 1204 (expired)
Holdfast GT	2009	General purpose – seed-retaining, winter active with improved tolerance of heavy grazing pressure			1989/90 – 2004/05	Heritage Seeds	Cert no: 3721
Advanced AT	2008	Improved aluminium tolerance for strongly acidic soils, best managed rotationally			1983/84- 2003/04	Heritage Seeds	Cert no: 3720
Horizon	2021*	Drier margins, winter active, summer-dormant, more persistent than Atlas PG			1998-2017	Barenbrug Australia	Accepted

SOURCE: CSIRO, Intellectual Property Australia

5.5 Impacts

Table 5 Summary of project impacts using CSIRO triple bottom line (TBL) benefit classification approach

Type	Category	Indicator	Description
Economic	Productivity and efficiency	Improved grazing operation productivity and profitability	Improved Phalaris pastures enabling higher livestock carrying capacities per hectare due to greater pasture productivity
	Management of risk and uncertainty	Reduced farm seasonal risk exposure	Reduced farm seasonal risk exposure due to improve persistence, establishment and drought resilience and ecosystem services afforded by improved perennial Phalaris pastures
Environmental	Land quality	Ecosystem services delivered through improved persistent, perennial Phalaris forage crop coverage	Improved perennial Phalaris pastures providing Higher ground cover Reduced weed invasion Reduced deep drainage Reduced soil acidification Greater carbon sequestration
Social	Resilience	Sustained rural communities throughout Phalaris crop area	Improved resilience of rural communities reliant on the grazing industry due to improved profitability and reduced seasonal risk exposure of grazing farms

For the productivity and efficiency benefits identified, economic impact is estimated in monetary terms as discussed in the section below. Other economic benefits, environmental and social benefits are noted qualitatively in Section 8 based on the available literature and interviews with informed stakeholders.

6 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 its research partners to produce the research outputs. Additional in-kind contribution by CSIRO or others was not captured due to data limitations. Where data is available, usage and adoption costs borne by end-users (such as the cost of seed production and marketing) are also included. In this analysis, a broad proxy estimate (tested in sensitivity analysis) intended to capture potential annual commercial seed partner activity was included to moderate the total benefits for usage and adoption costs. A broad estimate was necessary in the absence of real world data.

The economic assessment for this study focuses on the adoption of the seven most recent CSIRO Phalaris varieties by grazing 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 of improved Phalaris pastures on individual farms.

Perspective and stakeholders

For most CSIRO research, the quantification of benefits is kept limited to the national level. In this instance, the benefits will be contained to Australia, particularly in light of the Oram et al. (2009) assessment that a Phalaris cultivar selected in one country is often not optimal for other countries. 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 grazing enterprises in areas where Phalaris is sown, the distribution of benefits in this analysis is skewed towards these stakeholders.

CBA cases

Cost benefit analysis has been conducted for the period FY1972 to FY2039 and estimates the first-round effects of CSIRO's improved Phalaris cultivars 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 improved CSIRO Phalaris varieties, and

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

- The project case that estimates incremental farm level profit benefits from adoption of improved CSIRO Phalaris varieties.

Base Case (counterfactual) – without improved CSIRO Phalaris scenario

The counterfactual represents a situation where CSIRO did not engage in improved Phalaris breeding, and non-improved Phalaris pasture is sown (i.e. original cultivar '*Australian'*). CSIRO was the sole Phalaris breeder in Australia from the late 1950's to 2000 and employed unique multidisciplinary expertise, infrastructure and equipment to conduct Phalaris breeding research. This research led to the discovery, exploitation of new domestication, production and persistent traits resulting in distinct improvements in the varieties it released (Smith, K. 2013).

However, we cannot assume that there would have been no other Australian breeding of Phalaris in the past six decades in the absence of the CSIRO program. Therefore, we include a 20% discount on the incremental profit gain we are estimating that is attributable to CSIRO Phalaris varieties to account for a non-zero gain in the counterfactual scenario[4]. This 20% discount in benefits is arbitrary but kept modest to account for the significant and long-lived investment that CSIRO made into Phalaris breeding, particularly as the sole Australian breeder until 2000. This is tested at 0% and 50% in sensitivity testing.

Project case – with improved Phalaris scenario

In the project case, improved CSIRO Phalaris varieties are modelled to have a small incremental net profit gain (through higher sheep DSE/ha carrying capacity). Given lack of data to inform incremental benefits of CSIRO varieties over un-improved Phalaris varieties, the lower bound estimate of the best available data (+2.5 DSE/hectare) is used as a broad proxy measurement of productivity benefits and is homogeneously applied across all seven CSIRO varieties included in the analysis. This is tested in sensitivity testing to an even lower bound of +1 DSE/ha. A perennial pastures senior research scientist at NSW DPI advises that there is approximately a 25% productivity gain attributable to CSIRO varieties (Holdfast/Landmaster) relative to the unimproved cultivar *Australian* (NSW DPI, per comms, 2021). This 25% approximation is consistent with the +2.5 DSE/ha in Smith (2013) given that the NSW average sheep gross budgets used in this analysis are based on country carrying 10 DSE p/ha. Finally, whole-of-farm bioeconomic modelling considering the profit implications of introducing perennial pastures species such as Phalaris has demonstrated increased carrying capacity and farm profit (Future Farm Industries CRC, 2010). While the analysis was compared to an annual pasture, this strengthens our scenario model of a marginal increase in carrying capacity per hectare.

It should be noted that the CSIRO varieties were bred for different improvements but only a single benefit (productivity) is captured here and applied homogeneously across the varieties. As such, this analysis provides a broad ballpark estimate only. Other productivity related benefits (and environmental and social benefits) are discussed qualitatively in Section 8. Sensitivity testing on the assumptions is documented in Section 7.

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[4] *Benefits may also have been delayed in the counterfactual scenario. The model remains conservative by not delaying benefits in the counterfactual.*

Time period and Costs

CSIRO's internal Phalaris breeding research concluded in 2017. For the purpose of this assessment, the analysis is based on research activity since the commencement of Holdfast breeding in FY1972 until the final internal CSIRO variety Horizon, released in 2021[5]. For details on costs and timeline of the program see Inputs section.

Table 6 CBA Analysis – Timeline and Costs Table

Timeline	Costs: FY1972- FY2016 Benefits: Ex-post: FY1989 to FY2019 Ex-ante: FY2020 to FY2039
Costs	It is estimated that CSIRO and partners invested $7.79 million (nominal, undiscounted) financially towards the total R&D FY1972 and FY2016. No investment has gone into improved variety breeding since 2017.

The analysis involves a component of ex-post analysis (relating to the costs and benefit in the period FY1979 to FY2019), but also a component of ex-ante analysis forecasting the benefits flowing from the research activities over the period FY2020 to FY2039. It should be noted that benefits may continue to accrue for CSIRO Phalaris varieties sown after 2030 but no sales beyond 2030 have been estimated.

No benefits beyond FY2039 have been estimated. FY2039 was chosen to capture the assumed 20-year productive life benefits of Phalaris that was sown in the ex-post analysis period. All benefits are capped at FY2039 regardless of year sown.

Usage and adoption costs

CSIRO's commercial seed partner took CSIRO Phalaris varieties to market through the bulking up of commercial seed quantities and their marketing, promotional and extension activity associated with the release of a commercial variety. As these activities are required to bring the research outputs to the market they are considered usage and adoption costs and are subtracted from the benefits in the cost benefit analysis[6].

Actual commercial seed partner costs were unavailable at the time of this analysis. An estimate of $500,000 annually for the period FY1989-FY2039 was included in the analysis. This was tested in sensitivity testing to significantly higher and lower estimates.

Attribution

CSIRO was the primary source of research, breeding expertise and R&D activity throughout the program. This was funded in part through financial co-contribution by Australia Wool Innovation and smaller contributions by other Rural Development Corporations.

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[5] *Therefore, this analysis encompasses Holdfast (1990), Landmaster (1996), Australian II (1998), Atlas PG (1998) , Advanced AT (2008), Holdfast GT (2009) and Horizon (2021).*

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

Based on the R&D cost sharing approach in present values, this case study will attribute total benefits as follows[7]:

Table 7 Attributed share of impact based on cost-share approach

	CSIRO	RDCs
Impact attribution	72%	28%

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 productivity and offset by destocking during pasture establishment. The model makes a series of assumptions based on Phalaris pasture recommendations in the literature, corroborated through personal communications with CSIRO Phalaris breeders and informed industry stakeholders. Representative NSW DPI sheep enterprise budgets are utilised in this analysis that capture ongoing costs of maintaining improved pastures. There are no other specific on-farm adaption costs required to be captured (CSIRO, per comms 2020). It is assumed that there is no difference in pasture establishment costs between the unimproved *Australian* Phalaris and CSIRO Phalaris varieties.

In this analysis, only the sheep industry is represented. There may be benefits of farm operations switching to other enterprises due to the productivity gains afforded by improved Phalaris, but these potential shifts are not captured in this analysis. Similarly, it is acknowledged that mixed and cattle enterprise operations are not represented as there was insufficient data to model benefits outside of the sheep industry and time and resource constraints. In this analysis it is assumed that Phalaris seed purchased and sown goes to the most suitable soils first. As new varieties become available, they are sown to further country spreading out across the landscape.

Table 8 Economic benefits assessment model assumptions

Model assumptions		
Description	**Assumption**	**Source**
Incremental improvement in productivity per hectare	+ 2.5 DSE/ha	Smith et al. (2013), CSIRO per comms. 25% increase in productivity relative to un-improved *Australian* cultivar. (NSW DPI, per comms, 2021)
Productive lifespan of improved Phalaris pasture	20 years	CSIRO per comms (2020)
Hectares sown per kilogram of seed	3 kg/ha	NSW DPI (2000), CSIRO per comms (2020)
No grazing in year of establishment	No stock in year of establishment	NSW DPI (2000)
Representative sheep DSE gross margin p/ha	$50/ha	Average based on NSW DPI representative sheep budgets 2019/20. CSIRO, per comms (2020).
Moderation of incremental benefits to account for non-zero productivity gain in counterfactual scenario	20%	Author estimation

[7] *Note that any currently un-accounted for in-kind costs would impact this cost share if these costs were known.*

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

7 Results

As stated above, the economic benefits captured in this analysis are the aggregated incremental farm level profits of adopting an improved CSIRO Phalaris pasture over an unimproved Phalaris pasture[8]. To estimate the return to overall investment, all known (or estimated) R&D, commercialisation 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. NPV of $5163.1 million (2019-20 AUD) over a period of FY1972-FY2039 with a BCR of 55:1.

Table 9 Phalaris case-study CBA results. Basis: all investment costs (all $ in million, 2019/20 AUD)

Scenario	PV costs	PV benefits	NPV	BCR
Improved farm level profits due to more productive Phalaris pasture	95.8	5259.8	5163.9	55:1

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

To estimate the return on CSIRO's financial contribution to Phalaris breeding and research, it is assumed that CSIRO's estimated share of total costs is a suitable proxy for its share of attributable benefits. On this basis, the NPV and BCR for CSIRO is calculated as below:

- NPV: $3718.5 million AUD over a period of FY1972-FY2039 with a benefit-cost ratio of 55:1.

Table 10 CSIRO only Phalaris case-study CBA results. Basis: CSIRO investment costs (all $ in million, 2019/20 AUD)

Scenario	PV costs	PV benefits	NPV	BCR
Improved farm level profits due to more productive Phalaris pasture	68.5	3787.0	3718.5	55:1

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 Phalaris breeding research has been positive. The high NPV result despite maintaining conservative and lower bound model assumptions is reflective of the long period of analysis captured in this analysis (51 years of benefits) given the long life of the program. Overall, this result provides confidence that the public investment in improved Phalaris breeding in recent decades has been impactful.

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

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 **Error! Reference source not found.**) is performed on each key parameter. Sensitivity testing is performed on whole program costs and benefits.

Testing from the lowest to highest ranges on all parameters maintained a positive NPV and BCR. Commercial seed partner costs (deducted from benefits as usage and adoption costs to bring the research output to market) did not significantly impact the NPV or BCR at even the highest estimate. All other ranges produced results within expectations.

If we simultaneously lower both the incremental productivity gain to 1 DSE/ha and the average gross margin DSE/ha to $30 (not illustrated in the table) the benefit cost ratio lowers to 13:1 (NPV of $1120.7m). This provides confidence that even at more conservative levels of on-farm incremental benefit (i.e. the only benefit obtained is 1 extra DSE per hectare and financial returns are low per hectare on average) the return on investment of the Phalaris breeding program is more modest, but still positive.

Table 11 Sensitivity testing results (each parameter range tested individually; all others held equal)

Parameter		Low	Assumption (Model)	High
Discount rate		**5%**	**7%**	10%
	NPV	4371.5	5163.9	6915.8
	BCR	83:1	55:1	30:1
Increased productivity due to improved CSIRO Phalaris varieties		**1 DSE/ha**	**2.5 DSE/ha**	**5 DSE/ha**
	NPV	1971.9	5163.9	10484
	BCR	22:1	55:1	110:1
Average gross margin DSE/hectare		**$30**	**$50**	**$70**
	NPV	3035.9	5163.9	7292
	BCR	33:1	55:1	77:1
Non-zero counterfactual productivity gain		**0%**	**20%**	**50%**
	NPV	6494	5163.9	3168.9
	BCR	69:1	55:1	34:1
Commercial seed partner annual costs to take seed to market		**$100,000**	**$500,000**	**$2,000,000**
	NPV	5212.2	5163.9	4983.1
	BCR	55:1	55:1	53:1

The above results are performed with both the ex-post (sales FY1989-FY2019) and ex-ante (forecasted sales FY2020 to FY2029) components of the analysis. Given that forecasting sales has a high degree of uncertainty, the results are tested with the removal of sales beyond 2019/20 (i.e. 386,317 hectares less). The result (all other assumptions held constant) is a slightly more modest BCR of 52:1 (NPV $4901.8). This provides confidence that even in the absence of further sales, the return to the Phalaris breeding R&D investment has been positive for the varieties and years in this analysis up until 2019/20.

Doubling the present value of R&D input costs to account for any potential underestimation of R&D costs returns a NPV of $5068.1m and BCR of 27:1. Finally, when all key parameters listed in Table 11 are set to their lowest range simultaneously[9], the NPV is reduced to $433.1m a 3:1 return on investment. This provides further confidence that the program returns a positive result at a wide range of potential model parameters, including the pessimistic scenario.

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 due to improved Phalaris pastures, 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.

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[9] *I.e. 10% discount rate, +1 DSE/ha, average gross margin $30/ha, 50% non-zero counterfactual productivity gain and $2 million per annum commercialisation costs.*

8 Non-quantified impacts

8.1 Non-priced economic impacts

The only economic benefit captured in the quantitative analysis is improved productivity reflected in increased carrying capacity per hectare. However, CSIRO's improved Phalaris varieties, particularly the later varieties, are associated with improved persistence, establishment success and drought tolerance (Culvenor et al. 2011; Smith 2013) which are related factors to productivity and economic benefit.

Improved persistence and establishment success are likely to lead to an economic benefit in the farming system through reducing risk exposure of the grazing enterprise. According to a senior pastures research scientist, the CSIRO varieties have given graziers more seed options to choose from (that are suitable to their conditions) that are more reliable in establishment and persistence thus increasing the chance of pasture improvement success. This reduces farm risk particularly throughout dry conditions (NSW DPI per comms, 2021).

8.2 Environmental impacts

Phalaris is a long-lived ground cover with deep root systems adapted to drought prone environments with hot dry summers and alongside other perennial pastures is associated with delivering a number of ecosystem services. These environmental benefits are likely to aid sustainability of the landscape and the grazing enterprises operating within them. These interrelated services include:

- Improved groundcover
- Reduced deep-drainage and high-water tables
- Reduced nitrate losses
- Reduced soil acidification
- Reduced soil and weed erosion

According to Hayes et al (2010a), there is little doubt that perennial pasture species, including Phalaris, contribute to reducing deep drainage across the landscape, a widely cited phenomenon in the literature. Deep drainage is a contributing factor to soil salinisation and acidification (Hayes et al, 2010b) and land degradation generally. While more summer-active perennials (such as lucerne) can do so to an even greater extent, Phalaris, as a deep-rooted and persistent perennial grass is associated with increased groundwater utilisation and use of water at depth (Heng et al. 2001, Hayes et al. 2010b; Ridley et al, 2017). This allows it to dry the soil profile, creating a buffer that reduces deep-drainage and re-charge of the water table. Phalaris is also linked to reducing nitrate losses (Ridley et al. 1999; Smith 2013) and the rate at which soils acidify (Ridley et al. 1999), improved groundcover and reduced weed incursion and soil erosion (Hayes et al. 2018; Smith 2013).

Thus, the literature indicates that Phalaris as a perennial pasture delivers environmental benefits through these ecosystem service functions particularly when compared to annual-based pastures. It's reputation as a persistent species reinforces its ability to deliver these services over extended periods of time and broadly across landscapes. Adoption of CSIRO's improved Phalaris varieties across large areas of Australia has undoubtedly contributed to delivering the environmental benefits listed above however, the extent to which these environmental benefits have been realised and the incremental difference relative to unimproved Phalaris will depend on a multitude of factors. As noted by NSW DPI (per comms, 2021) while CSIRO cannot claim sole attribution to these benefits, the CSIRO program has increased the potential zone of adaptation (Oram et al. 2009) of Phalaris and thus contributed to the delivery of environmental benefits over areas where it would not have been possible without the improved varieties.

8.3 Social impacts

As described above, the economic and environmental benefits to Australian grazing enterprises where improved Phalaris varieties have successfully been utilised is likely to have underpinned improved financial resilience and ecosystem health across these landscapes. There are likely to be broader social benefits realised across regional and rural Australian communities proportional to these benefits. The productivity and risk exposure benefits brought by sowing a successful perennial Phalaris pasture may be the difference between a grazing enterprise surviving drought periods or not (NSW DPI, per comms 2021), which has social impact (such as changes to family roles, workloads and networks, mental and physical health and availability and continuity of services with the community[10]) in the surrounding regional communities where the grazing industry is a significant economic driver. As a regional employer the grazing industry is highly concentrated in rural and regional communities. At least 90% of meat and livestock employees and 80% of meat processing employees reside regionally (MLA, 2020).

The extent to which CSIRO-improved Phalaris varieties have contributed to social benefit through rural community resilience is not immediately obvious or isolated. However the breeding, release, and extensive adoption of improved Phalaris varieties with economic and environment benefits over many decades is hypothesised to have contributed to the financial sustainability of grazing enterprises in circumstances where they may not have otherwise remained viable. In turn, grazing industry sustainability is likely to have contributed to positive social impact through increased longevity and resilience of regional communities.

9 Unintended impacts

Phalaris can sometimes, but rarely, cause toxicity in sheep and cattle due to the presence of alkaloids. There are two main condition known as Phalaris "staggers" or "sudden death" both typically related to green Phalaris when livestock are unaccustomed to it (Smith, 2013). The toxicity has been the subject of ongoing Phalaris research for decades, including throughout the research program at CSIRO where breeding for lower levels of alkaloids in modern varieties has been successful to a degree, but unable to eliminate the problem (Ibid, 2013; Oram et al. 2009). The rare

[10] *Drought Policy Review Expert Social Panel (2008)*

but occasional loss of livestock to these conditions is an unquantified but acknowledged potential un-intended impact of the adoption of improved Phalaris pastures.

Also acknowledged is the modern native ecological perspective of Phalaris as an environmental weed (e.g. White et al. 2018) although opinions differ on the degree of threat even among experts (Dorrough et al. 2018). In part this reflects the success of the species and the wide area over which it has been sown. In areas where it is well adapted, Phalaris can be very competitive on roadsides and in drainage lines. High dry standing biomass in unmanaged areas during summer can also increase the potential intensity of fires (Stoner et al. 2004).

10 Limitations

This impact case study has limitations due to significant gaps in sales and input information given the long historic nature of the research in question and lack of complete corporate records dating back to the early 1970s. There was limited specific data to inform quantitative benefits so use of broad proxy measures and calculated assumptions were required. These were informed by expert advice and the academic and grey literature. Qualitative summaries of benefits are based on the available existing literature and interviews with informed key stakeholders. Thus, the case study provides a ballpark estimate and picture of the realised and prospective impacts of improved CSIRO Phalaris varieties only and results should be interpreted within the context of the data available and assumptions made.

11 Confidence Rating

Data that underpins the CBA is based on information from the last 50 years. Due to the longer-term time frame some of it is inherently unreliable. The analysis is performed using CSIRO internal information (1972-2020), advice from external organisations, literature and calculated assumptions thereby making results approximations only. In all instances, lower-bound estimates and conservative assumptions have been used. 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.

Appendix A References

Australian Seed Association certified Phalaris seed data via R. Culvenor (CSIRO per comms, 2021)

Barenbrug Australia per comms (2021) Newman, A. 07/01/21

CSIRO per comms (2020) Culvenor, R. and Richardson, A.

CSIRO per comms (2021) Culvenor, R.

CSIRO (2020) Impact Evaluation Guide, February 2020.

Culvenor RA, McDonald SE, Veness PE, Watson D, Dempsey W (2011) The effect of improved aluminium tolerance on establishment of the perennial grass, phalaris, on strongly acid soils in the field and its relation to seasonal rainfall. Crop & Pasture Science 62, 413-426.

Dorrough J, Oliver I, Wall J (2018) Consensus when experts disagree: a priority list of invasive alien plant species that reduce ecological restoration success. Management of Biological Invasions 9: 3, 329-341

Drought Policy Review Expert Social Panel (2008) *It's About People: Changing Perspective.* A Report to Government by an Expert Social Panel on Dryness. Report to the Minister for Agriculture, Fisheries and Forestry, Canberra, 2008.

Future Farm Industries CRC (2020) *Impact of farm profit from incorporating perennial pastures in the rotation of crop-livestock enterprises in southern New South Wales: Base model scenarios for lucerne, chicory and perennial grasses* Future Farm Industries CRC Technical Report 5

Gapare, WJ, Kilian A, Stewart AV, Smith KF, Culvenor RA (nd, unpublished) Genetic diversity among wild and cultivated germplasm of the perennial pasture grass, Phalaris aquatica L., using DArTseq SNP marker analysis

Hayes, R.C., Dear, B.S., Li, G.D., Virgona, J.M., Conyers, M.K., Hackney, B.F., Tidd, J. (2010a) *Perennial pastures for recharge control in temperate drought-prone environments. Part 1: productivity, persistence and herbage quality of key species* New Zealand Journal of Agricultural Research, 53: 4, p283 — 302

Hayes, R.C., Li, G.D., Dear, B.S., Conyers M.K, Virgona, J.M., Tidd, J. (2010b) 'Perennial pastures for recharge control in temperate drought-prone environments. Part 2: soil drying capacity of key species', New Zealand Journal of Agricultural Research, 53: 4, 327 — 345

Hayes RC, Li GD, Norton MR, Culvenor R. (2018) Effects of contrasting seasonal growth patterns on composition and persistence of mixed grass-legume pastures over 5 years in a semi-arid Australian cropping environment. J Agro Crop Sci. 2018;00:1–15.

Heng L.K, White R.E, Helyar, K.R., Fisher, R., Chen, D. (2001) *Seasonal differences in the soil water balance under perennial and annual pastures on an acid Sodosol in south eastern Australia* European Journal of Soil Science, June 2001, Vol 52, p227-236

Intellectual Property Australia (Nd) Plant Breeders Rights Database Search <(ipaustralia.gov.au)>

Meat and Livestock Australia (2020) *State of the Industry Report: The Australian red meat and livestock industry* <State of the Industry Report mla.com.au>

Mounter, S., Zhang, Y., Griffith, G., (2009) *Calibrating and Validating an Equilibrium, Displacement Model of the Australian Sheep Meat Industry* Australasian Agribusiness Review Volume 27, Paper 5, ISSN:1833-5675

NSW Agriculture (2000) *Phalaris Pastures* Agfact P2.5.1, second edition < Phalaris Pastures (nsw.gov.au)>

NSW Department of Primary Industries (2016) *Temperate perennial pasture establishment guide: Steps to ensure success* <www.dpi.nsw.gov.au/tppeg>

NSW Department of Primary Industries (2019) *Livestock gross margin budgets.* Accessed Sheep gross margins April-September 2019. <Livestock gross margin budgets (nsw.gov.au)>

NSW DPI per comms (2021) Senior Research Scientist Hayes, R. 04/02/2021

Oram, R. N., Ferreira, V., Culvenor, R.A., Hopkins, A, A., Stewart, A. (2009) *The first century of Phalaris aquatica L. cultivation and genetic improvement: a review* Crop and Pasture Science, 60, 1-15

Ridley A.M, White R.E, Simpson R.J, Callinan, L. (1997) *Water use and drainage under Phalaris, cocksfoot, and annual ryegrass pastures*. . Australian Journal of Agricultural Research, 1997, Vol 48, p1011-23

Ridley A.M, Simpson R.J., White R.E. (1999) *Nitrate leaching under Phalaris, cocksfoot, and annual ryegrass pastures and implications for soil acidification*. Australian Journal of Agricultural Research, 1999, Vol 50, p55-63

Smith, K. (2013) *Developing a Phalaris pre-breeding plan -Phalaris 2020 vision better cultivars faster.* Final Report to Meat and Livestock Australia prepared by Smith, K at the University of Melbourne.

Stoner JR, Adams R (2018) Management implications of increased fuel loads following exotic grass invasion. Ecological Management & Restoration 5: 1, 68-69

White M, Cheal D, Carr GW, Adair R, Bolld K, Meagher D (2018) Advisory list of environmental weeds in Victoria. Arthur Rylah Institute for Environmental Research Technical Report Series No. 287. Available at https://www.ari.vic.gov.au/__data/assets/pdf_file/0027/125919/ARI-Technical-Report-287-Advisory-list-of-environmental-weeds-in-Victoria.pdf

Appendix B Key Publications

Culvenor RA, Wood JT, Oram RN (1996) Comparison of winter-active phalaris with the Australian cultivar under rotational grazing 2. Dry matter on offer, pasture composition and animal production. Australian Journal of Experimental Agriculture 36, 287-297.

Requis J, Culvenor RA (2004) Progress in improving the aluminium tolerance in the perennial grass, phalaris. Euphytica 139, 9-18.

Culvenor RA, Boschma SP (2005) Evaluation of phalaris (Phalaris aquatica L.) germplasm for persistence under grazing on the North-West Slopes, New South Wales. Australian Journal of Agricultural Research 56, 731-741.

Culvenor RA, Boschma SP, Reed KFM (2007) Persistence of winter-active phalaris breeding populations, cultivars and other temperate grasses in diverse environment of south-eastern Australia. Australian Journal of Experimental Agriculture 47, 136-148.

Culvenor RA, Boschma SP, Reed KFM (2009) Response to selection for grazing tolerance in winter-active populations of phalaris (Phalaris aquatica L.). 1. Persistence under grazing in three environments. Crop & Pasture Science 60, 1097-1106.

Culvenor RA, Boschma SP, Reed KFM (2009) Response to selection for grazing tolerance in winter-active populations of phalaris (Phalaris aquatica L.). 2. Correlated response in yield potential, plant characteristics, and alkaloid levels. Crop & Pasture Science 60, 1107-1116.

Oram RN, Ferreira V, Culvenor RA, Hopkins AA, Stewart A (2009) The first century of Phalaris aquatica L. cultivation and genetic improvement: a review. Crop & Pasture Science 60, 1-15.

Culvenor RA, McDonald SE, Veness PE, Watson D, Dempsey W (2011) The effect of improved aluminium tolerance on establishment of the perennial grass, phalaris, on strongly acid soils in the field and its relation to seasonal rainfall. Crop & Pasture Science 62, 413-426.

Culvenor RA, Simpson RJ (2016) Interaction of plant genotype and management in the persistence of a perennial grass exposed to grazing and soil fertility stresses. Grass and Forage Science 71, 540-558Outcomes

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