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An Economic Analysis of GRDC Investment in the Future Farm Industries CRC: Salt Tolerant Cereals and EverCrop

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Impact Assessment: An Economic Analysis of GRDC Investment in the Future Farm Industries CRC: Salt Tolerant Cereals and EverCrop

Executive Summary

GRDC has been investing since 2001 in the Cooperative Research Centre for Plant Based Salinity and Water Quality (hereafter known as the Salinity CRC) as well as the Cooperative Research Centre for Future Farm Industries (CRC FFI) that continued much of the work of the Salinity CRC. A large part of the GRDC investment during the period of both CRCs has been in two major areas:

- Development of a Salt- and Waterlogging-Tolerant Cereal
- Development of the Role of Perennials in Mixed Farming Systems

While the tolerant cereal initiative advanced knowledge and made some progress towards the development of a salt- and waterlogging-tolerant cereal through crossing wheat with Hordeum species, the objective of the development of an enhanced germplasm that could be used by wheat breeders was not achieved by the end of the investment. Any benefit that can be attributed to the investment therefore will depend on further investment that might occur.

The investment in identifying new perennial species and evaluating both new and existing perennial species in mixed farming systems has been more successful. Some useful system niches for several new perennial species have been identified; however, use of such species to date has been somewhat limited. Likewise, important knowledge regarding companion cropping with lucerne and other perennials was produced showing that companion cropping can lower watertables significantly. However, due to competition for soil moisture, crop yields are lowered and while some adoption of the practice has occurred, adoption has not been widespread.

The impact of lucerne and other perennials on groundwater recharge has been confirmed in the earlier projects where the lucerne is grown on farm, but larger area impacts particularly where regional and intermediate groundwater systems exist are likely to require significant areas of lucerne planted in the area to make much difference.

Along with other investments, one contribution of the investments being evaluated has been in raising awareness of opportunities and potential profitability of lucerne and provided greater confidence for mixed farming operators to invest in lucerne as a deep rooted perennial. In addition an improved extension framework for lucerne was developed that has contributed to some adoption of lucerne in this regard.

More recently, other roles that perennials may play via rotations in mixed farming systems have also been explored and highlighted including increased seasonal feed availability for livestock allowing higher stocking rates, improved weed and disease control in crops and the contribution from pasture legumes as a source of nitrogen. In a wider context, the investment has assisted farmers in decisions concerning the integration of perennials into their mixed farming systems on a whole-farm basis from profitability, diversification and resilience, and environmental points of view.

A summary of benefits from both investments is provided in the following table.

Economic • Potentially higher valued land use option of a cereal suited to saline and waterlogged land. • Increased profitability for some mixed farming systems from increased use of lucerne via phase farming. • Increased profitability from use of other perennials in mixed farming systems. • Reduced income variability for some mixed farming systems due to a strengthening of the livestock enterprise without reducing cropping intensity. • Reduced recharge of groundwater due to increased use of perennials.
Environmental • Increased area of perennials in mixed farming systems leading to reduced erosion and soil loss from increased ground cover in summer and autumn. • Potential for reduced use of crop chemicals from control of disease and some weeds via rotations with pasture perennials.
Social • Increased capacity in farming systems research in Australia. • The presence of 'more green in the landscape' leading to reduced farmer stress during the summer autumn period. • Reduced variability of community income in some regions with mixed farming systems.

A conservative estimate has been made of the profitability gain likely and assumptions on the area that will be planted to perennials in the future given the investment up to June 2011. This estimate, together with an estimate of the value of progress made with the salt-tolerant cereal, has been translated into investment criteria.

The results indicate that, given the assumptions made, the total investment to June 2011 will provide positive but conservative returns. The net present value for the total investment (GRDC and others) of $33 million (present value of costs in 2010/11 $ terms) is estimated at over $17 million giving a benefit cost ratio of 1.5 to 1 and an internal rate of return of 6.9%. About 5% of the expected total benefits were contributed by knowledge produced by the salt and waterlogging projects, with 95% from the perennial incorporation projects.

It should be noted that if total further investment was provided of $2.8 million per annum for three years (present value of additional costs of $7.4 million) to extend the existing perennial project (FFI00003), and this resulted in maximum adoption levels increasing from 20% to 40% in the uniform rainfall zone, 7.5% to 15% in the medium rainfall zone and 10% to 20% in the mallee, the additional benefits were estimated at $47 million (present value of benefits), yielding a benefit cost ratio of over 6 to 1. This would require an additional number of 611 farms adopting perennials into their systems due to the new three year investment to achieve this return.

1. Introduction

The Cooperative Research Centre for Future Farm Industries (CRC FFI) was established in 2008 and has its broad focus on improving productivity of Australian broadacre agriculture by developing new and innovative farming systems and technologies. In addition to productivity and profitability goals, the CRC FFI has also set out to improve farming system resilience to salinity, waterlogging and climate variability and potential climate change. A significant outcome type being pursued therefore is environmental as well as productivity.

GRDC has been investing since 2001 in the Cooperative Research Centre for Plant Based Salinity and Water Quality (hereafter known as the Salinity CRC) as well as in the CRC FFI since 2008. GRDC currently invests $750 000 a year in the CRC FFI and this will continue until 2015.

A large part of the past GRDC investment in both CRCs has been in two major projects:

- Development of a Salt- and Waterlogging-Tolerant Cereal
- Development of the Role of Perennials in Mixed Farming Systems (*EverCrop and EverCrop Decide).*

Salt- and Waterlogging-tolerant Cereals

Large areas of Australian cropping land are salt affected and more areas are at risk of salt constraints. Some land areas are also constrained in their cropping capacity by waterlogging. These salty and waterlogged areas cannot produce crops economically. This constraint is not confined to Australia and there are significant areas of cropping land around the world that are similarly affected. Being able to breed a salt- and waterlogging-tolerant cereal could enable significant areas of land to move to higher value uses.

Increased Use of Perennials in Mixed Farming Systems

A range of remedial options was identified in the 1990s for potentially reducing groundwater recharge and associated dryland salinity and waterlogging during the cropping season. One of these options was the use of perennial plants, particularly deep-rooted perennials that could be integrated with cropping systems and utilise more water during the summer growing season. While this may have constrained the perceived average annual farm profitability via reducing the average area of cropped land, the advantage of drawing down the water table was postulated to minimise salinity and waterlogging constraints over time and hence contribute to the overall economic viability of the farming system in the long term.

An earlier economic evaluation analysis addressed a significant GRDC investment in reducing recharge through use of perennials (mainly lucerne). GRDC projects included in this investment were:
DAW659: Farming Systems with Lower Recharge for WA
DAW722: Warm season cropping systems on the south coast of WA
UWA345: Lucerne intercropping for sub-soil water management
DAV453: Increasing lucerne adoption in farming systems: an integrated approach
UWA339: Low recharge farming systems for the southern wheat belt of Western Australia based on lucerne
BRS00005: Targeting salinity at the farm-scale: empowering landholders through practical interpretation of airborne geophysical surveys

RDC10: Contribution towards UWA60A: Perennial grain crops for high water use.
LWR20: Contribution towards UMU17: A simple computer program for dryland salinity management Australian wide (FLOWTUBE).

The most important output from the investment in GRDC's 'reducing recharge' cluster of projects was the extension of the knowledge base for integrating lucerne into farming systems in southern cropping regions (predominantly winter cropping). The investment raised awareness of opportunities and potential profitability and provided greater confidence for cropping farmers to invest in lucerne as a deep rooted perennial.

The first part of the investment being analysed in the current evaluation is a parallel investment except that perennials other than lucerne were addressed, as was companion cropping and an improved extension framework. However, the more recent thrust of the CRC investments in the role of perennials in mixed farming systems (the EverCrop initiative) has been on whole farm systems (improvements in both livestock and crop enterprises) with an emphasis on increasing profitability and diversification as well as environmental benefits.

2. Project Investment

Projects Funded by GRDC
The major investment areas in the two CRCs have been in two principal areas, perennial based farming systems (four projects) and developing a salt- and waterlogging-tolerant wheat (three projects). Table 1 provides the broad details of these seven projects, while Table 2 provides the stated objectives of each project.

Table 1: Principal CRC Projects Funded by GRDC

Project Code and Title	Other Details
UWA397: National Field Evaluation and Selection of New Pasture Plants from the Salinity CRC to Improve Hydrological Stability of Farming Systems	Organisation: Salinity CRC and Future Farm Industries CRC Period: March 2002 to June 2008 Principal Investigator: Brian Dear
UWA398: Development of a Salt Tolerant Cereal Using Wide Crosses of Wheat with Wild Hordeum Species	Organisation: Salinity CRC Period: June 2002 to July 2007 Principal Investigator: Tim Colmer
UWA396: High Water–Use Farming Systems that Integrate Crops with Perennial Pastures	Organisation: University of Western Australia Period: March 2002 to June 2008 Principal Investigator: Roy Latta, Brian Dear, Perry Dolling
FFI00001: Development of Salt- and Waterlogging-Tolerant Wheat	Organisation: Future Farm Industries CRC Period: July 2007 to June 2008 Principal Investigator: Tim Colmer
FFI00002: Development Phase- EverCrop and EverCrop Decide	Organisation: Future Farm Industries CRC Period: July 2007 to June 2008 Principal Investigator: Mike Robertson
FFI00003: EverCrop and EverCrop Decide: Developing the Role of	Organisation: Future Farm Industries CRC Period: July 2008 to June 2011

Perennials in Mixed Farming Systems	Principal Investigator: Rick Llewellyn
FFI00004: Development of a Salt- and Waterlogging-Tolerant Wheat	Organisation: Future Farm Industries CRC Period: July 2008 to June 2011 Principal Investigator: Tim Colmer

Table 2: Project Codes and Stated Objectives

Project Code	**Stated Objectives**
UWA397: National Field Evaluation and Selection of New Pasture Plants from the Salinity CRC to Improve Hydrological Stability	• To develop new perennial legumes, grasses and salt-tolerant species which can be used in crop-pasture rotations to reduce recharge and increase the options for controlling the spread of dryland salinity and the decline in water quality
UWA398: Development of a Salt Tolerant Cereal Using Wide Crosses of Wheat with Wild Hordeum Species	• To screen wild Hordeum germplasm to determine which species are potential gene donors for salt- and waterlogging-tolerance and which can be hybridised with bread wheat
UWA396: High Water–Use Farming Systems that Integrate Crops with Perennial Pastures	The broad aim was to provide productive farming system options which integrate perennial pastures into annual cropping systems. Specific objectives were: • To evaluate and develop strategies to companion/over crop established lucerne with field crops • To assess the interactive performance of plant densities and spatial configurations through water use productivity and competitiveness of lucerne and alternative perennials in phase farming systems • To validate and support APSIM model outputs to assess the risk of perennial based farming systems on a region and farm scale • To identify areas of the western and southern wheat belt that are the most suitable for lucerne phase farming or companion farming strategies. A variation (and extension for two years) of the project occurred in 2006 and had the following objectives: • To identify and understand the factors that influence a farmer's decision to adopt or not to adopt lucerne technologies • To develop a targeted and individualised extension strategy in partnership with those groups most likely to influence farmer decision making • To develop a national extension framework which is regionally delivered for future investment into lucerne extension and other technical innovations which impact on farming systems
FFI00001: Development of Salt- and Waterlogging-Tolerant Wheat	• To build on the previous success in the Salinity CRC with use of sea barley grass x wheat crosses to develop a salt– and waterlogging-tolerant wheat capable of extending cropping into mildly affected salt land (about 500,000 ha) with salinity levels too high for existing crops
FFI00002: Development Phase-EverCrop and	• To prioritise through a wide ranging consultative process and through the use of pre-experimental modelling, the zones and issues in which future investment under the EverCrop banner should be targeted

EverCrop Decide	
FFI00003: EverCrop and EverCrop Decide: Developing the Role of Perennials in Mixed Farming Systems	• To develop new or modified farming systems in each of three agro-climatic zones, incorporating perennials that improve profit, diversify enterprises and provide positive environmental impacts • To develop ways to overcome constraints to the adoption of perennials in cropping systems by documenting the costs and benefits of particular uses of perennials in mixed farming systems relative to other options • To develop cropping systems analysis tools and approaches that allow farmers and agribusiness to evaluate the placement, duration and management of perennials in farming landscapes
FFI00004: Development of a Salt- and Waterlogging-Tolerant Wheat	• The overall aim is to build on research conducted within the Salinity CRC with further germplasm development towards possible commercialisation of *H. marinum*-wheat amphiploids as a feed-quality cereal for salt affected land. Specific objectives were: o To deliver new knowledge on the tolerance of these materials to combined salt and waterlogging stresses, including under field conditions o To deliver the most tolerant *H. marinum* wheat amphiploids (2 spring wheats, 1 winter wheat) transferred back to a wheat cytoplasm to restore fertility (potential feed cereal for salt land) o To deliver other *H. marinum* wheat cytogenetic stock (chromosome addition lines in an Australian wheat background) with potential value as future pre-breeding materials for milling quality wheat

Investment Inputs

Estimates of the funding by GRDC and others by project by year for the seven projects are provided in Tables 3 and 4. Table 5 provides a summary of the total GRDC and partner investment by year across all seven projects.

Table 3: Investment by GRDC by Project for Years Ending June 2002 to June 2011 (nominal $)

YE June	UWA397	UWA398	UWA396	FFI00001	FFI00002	FFI00003	FFI00004	Total
2002	516,000	134,891	115,109	0	0	0	0	766,000
2003	500,000	113,639	136,376	0	0	0	0	750,015
2004	500,000	120,592	129,429	0	0	0	0	750,021
2005	500,000	157,902	94,979	0	0	0	0	752,881
2006	500,000	161,903	88,331	0	0	0	0	750,234
2007	0	0	169,076	0	0	0	0	169,076
2008	0	0	168,865	125,581	99,223	0	0	393,669
2009	0	0	0	0	0	579,790	170,210	750,000
2010	0	0	0	0	0	554,354	195,646	750,000
2011	0	0	0	0	0	557,922	192,078	750,000
Total	2,516,000	688,927	902,165	125,581	99,223	1,692,066	557,934	6,581,896

Source: GRDC proposals and final reports

Table 4: Investment by GRDC Partners by Project for Years ending June 2002 to June 2011 (nominal $)

YE June	UWA397	UWA398	UWA396	FFI00001	FFI00002	FFI00003	FFI00004	Total
2002	1,086,722	10,733	250,000	0	0	0	0	1,347,455
2003	1,119,767	10,733	250,000	0	0	0	0	1,380,500
2004	1,131,193	174,343	646,500	0	0	0	0	1,952,036
2005	1,208,998	163,693	802,592	0	0	0	0	2,175,283
2006	1,261,062	147,423	880,902	0	0	0	0	2,289,387
2007	0	181,969	446,000	0	0	0	0	627,969
2008	0	0	456,000	71,800	141,540	0	0	669,340
2009	0	0	0	0	0	1,820,720	92,575	1,913,295
2010	0	0	0	0	0	1,850,156	92,575	1,942,731
2011	0	0	0	0	0	1,839,188	92,575	1,931,763
Total	5,807,742	688,894	3,731,994	71,800	141,540	5,510,064	277,725	16,229,759

Source: Partners' investment based on project proposals

Table 5: Total Investment in Seven CRC Projects for Years Ending June 2002 to June 2011 (nominal $)

Year ending June	GRDC	Partners	Total
2002	766,000	1,347,455	2,113,455
2003	750,015	1,380,500	2,130,515
2004	750,021	1,952,036	2,702,057
2005	752,881	2,175,283	2,928,164
2006	750,234	2,289,387	3,039,621
2007	169,076	627,969	797,045
2008	393,669	669,340	1,063,009
2009	750,000	1,913,295	2,663,295
2010	750,000	1,942,731	2,692,731
2011	750,000	1,931,763	2,681,763
Total	6,581,896	16,229,759	22,811,655

3. Outputs

A summary of the principal outputs (and expected outputs in the case of projects not yet completed) from each of the projects is reported in Table 6.

Table 6: Summary of Principal Outputs by Project

Project	Principal Outputs
UWA397: National Field Evaluation and Selection of New Pasture Plants from the Salinity CRC to Improve Hydrological Stability	General • Identification and selection of new deep rooted herbaceous perennials and salt-tolerant species to address dryland salinity in cropping areas of southern Australia. • Extensive evaluation of forage plants including 790 accessions from 282 species and 102 genera at over 40 sites in southern Australia.

	• Addressed both recharge and discharge areas. • Established a range of field evaluation nurseries. • Interaction with the breeding and selection program funded by the CRC. • Extensive list of scientific papers published in relation to the project findings. Specific • Species identified with drought tolerance, acid or salt tolerance and increased ground cover. • Identified that there may be an expanded role for subtropical grasses for mixed farms in NSW and a part of the WA grain belt. • Identified *Cullen Australasicum* as a new drought tolerant shrub for the low rainfall cereal belt. • Identified chicory as a deep rooted acid tolerant forage break crop in rotations. However, no medicago or chicory accessions showed sufficient merit to avoid significant breeding being required to fully exploit the advantages of these species. • Identified and developed *Melilotus siculus* as a new highly salt-tolerant legume. • Selection and release of the first cultivar of *Austrodanthonia caespitose* (wallaby grass) for the low input, low rainfall grain belt. • Lucerne proved to be the most persistent and drought tolerant perennial legume evaluated across a diversity of environments. • Species such as chicory, phalaris and perennial veldt grass had potential to reduce recharge by drying the soil profile compared to the benchmark set by lucerne. • Summer dominant perennial grasses from the Mediterranean had potential to increase ground cover and boost winter feed in temperate regions of the wheat belt. • The subtropical legume *Lotononis bainesii* was considered a well adapted legume for regions receiving summer rainfall. Superior genotypes of Lotononis were identified that were better adapted to the WA environment. However, none of the *Lotononis bainseii* types had reached a stage ready for commercialisation (seed size constraint). • Three new cultivars of *Lotus conniculatus* were developed and commercialised with assistance from the project (first acid soil- and waterlogging-tolerant perennial legumes adapted to Australian conditions).
UWA398: Development of a Salt Tolerant Cereal Using Wide Crosses of Wheat with Wild Hordeum Species	• Research extended a previous GRDC investment in this area - UWA340 - that had identified one species (*Hordeum marinum)* based on waterlogging tolerance only. • Access gained to the most comprehensive international collection of wild Hordeum germplasm. • Screening as to which Hordeum species were potential salt- and waterlogging-tolerant.

	• Physiological screening identifying sources of tolerance to salinity and waterlogging in wild Hordeum germplasm sourced internationally and from Australia. • Crossed priority accessions of Hordeum with wheat to develop amphiphloids. • Successfully crossed *Hordeum marinum* (sea barleygrass) directly with some Australian wheats. • Evaluation of expression of tolerance in progeny from wheat-Hordeum crosses. • Demonstrated improved tolerances in the amphiploids. • Discovered sodium exclusion in a disomic chromosome addition line. • New knowledge produced on the stress physiology of wild Hordeum species and on the cytogenics of *H marinum* – wheat hybridisations. • Project delivered proof of concept for the development of a salt- and waterlogging- tolerant cereal. • The H90-Westonia amphiploid and other amphiploids were being trialled on saline land in 2008. • Potentially, germplasm would become available as pre-breeding material for integration into Australian wheat breeding programs.
UWA396: High Water–Use Farming Systems that Integrate Crops with Perennial Pastures	• Defined 7 regions across southern and western Australia and attempted to define technical and agronomic constraints to lucerne adoption using a mix of field trials and modelling. • Gathered data sets on water use and productivity data for use in model simulations and commenced phase farming and companion cropping studies in all southern states. • Companion cropping (oversowing crop into lucerne) to maintain reduction in soil water at depth in summer resulted in lowered crop yield. • Completed sensitivity studies of lucerne cropping in 10 locations across the wheat belt. • Improved understanding of different perennial adoption categorisations among producers. • Built and tested a draft framework for lucerne extension. • Developed a set of strategies for lucerne extension including targeting specific audiences and activities in the different states. • Journal and conference papers published.
FFI00001: Development of Salt- and Waterlogging-Tolerant Wheat	• Continuation of Project UWA 398 enabling germplasm development to continue during the transition to the FFI CRC. • Six additional *H marinum*–wheat amphiploids produced including some crossed with a long season dual purpose winter wheat (amphiploids had been produced only from spring wheats previously). • Bulk seeds of amphiploids (8 were then available) and addition lines (5 then available). • Initial backcrosses (3) of amphiploids as a first step in cytoplasm transfer to wheat (for restoration of wheat fertility).

FFI00002: Development Phase-EverCrop and EverCrop Decide	• Continuation of UWA398 and UWA396 to build greater perenniality into mixed farming systems. • Assembly of multi-disciplinary teams in different cropping regions/nodes. • Issues identified in each zone through consultation and modelling where the incorporation of perennials could contribute. • Pre-experimental modelling (MIDAS, farm budgeting and APSIM simulations) results provided information on the costs and benefits of particular uses of perennials in mixed farming systems in each target environment. • Involvement and commitment of regional partners in the pending on-ground activity. • Business case developed for a three year investment focusing on perennials in cropping systems. • Issues to be addressed in the uniform rainfall zone included the use of chicory and perennial grasses in short phased rotations. • Issues to be addressed in the low rainfall mallee were permanent perennials planted in marginal areas of the landscape, and the incorporation of perennials into rotations within the cropping system on a non-permanent basis. • Issues to be addressed in the medium rainfall area of WA were perennial options in conjunction with crop including subtropical grasses, siratro and lucerne, and possibly other legume species.
FFI00003: EverCrop and EverCrop Decide: Developing the Role of Perennials in Mixed Farming Systems	General • RD&E approach that integrated field experimentation, on farm trials, farmer participation, farm case studies, biophysical and whole farm bio-economic analysis. • On-farm experiments at plot and paddock scale with leading farmers and farm-based groups in different cropping regions. • Development of industry/grower group cooperation and a participative farming systems research structure with strong grower engagement. • Analysis of commercial farms' potential management of perennials in terms of economics and natural resource management to understand the drivers and constraints to adoption. • EverCrop Decide provided systems modelling capacity for analysis of experimental work and the evaluation of the role for perennials under possible future climate and market scenarios. • New or modified farming system options in each of three regions that incorporate perennials, increase profit, and provide diversity and positive environmental impacts. • Documentation of costs and benefits of incorporating perennials in mixed farming systems in order to help overcome constraints to adoption. • Cropping systems analysis tools that allow farmers and

	agribusiness to evaluate the placement, duration and management of perennials in farming landscapes. • Conference papers, Technical Bulletins and extension publications produced. • Identified future RD&E priorities for the three focus regions. Specific: Uniform Rainfall Zone • Survey of Southern NSW mixed farms showed 29% sown to pasture containing perennials. • MIDAS results showed farm profit increases are greatest if multiple perennial options are available, with lucerne having the largest impact. • The model showed that moving from an annual pasture-crop rotation to a rotation including lucerne increased farm profit by 30% and that adding chicory and perennial grasses to lucerne in the rotation increased farm profit by a further 11%. • Introducing additional perennial options leads to only small changes in optimal enterprise land mix (e.g. crop %) but much higher stocking rates and lower supplementary feeding levels. • Two farm case studies where increases in perennials have taken place supported the findings of the model (Reynolds, 2010a and Reynolds, 2010b). • Perennial grasses and chicory can complement the use of lucerne as they can be grown on soil types not suited to lucerne and they can also improve ground cover. • Early field results have raised questions concerning the need for cover-cropping in establishment. • Adoption of perennial mixes increases ground cover and improves soil health and soil carbon levels. • Farmers reported that an advantage of a strengthened livestock enterprise was its contribution to cash flows during periods of reduced income from cropping (an income stabilising benefit). Specific: Medium Rainfall Zone • Baseline status was 30,000 ha of perennial species, but fewer than 10 growers were pasture cropping. • Promising yield results were produced with Panic and Rhodes grass species. • MIDAS whole farm bioeconomic analysis showed pasture cropping can increase whole farm profit but other benefits (e.g. risk, ground cover) are important in determining overall advantage. Specific: Low Rainfall Zone • With variable rate inputs, cropping on substantial areas of Mallee farms could be shifted to non-crop uses without loss of profit. • While many farms have some perennial forage shrubs, it is more common for farms with saltbush to have only 1

	patch (41%). • Several alternative forage shrub species have shown promising early growth at two Mallee sites. • Some subtropical grass species being field evaluated in the southern Vic Mallee have shown some promise and longevity.
FFI00004: Development of a Salt- and Waterlogging-Tolerant Wheat	• Continuation of UWA 398 and FFI00001 • Four new H. marinum–wheat amphiploids using long-season wheats have been produced. • Glasshouse screening trials confirmed exceptional sodium exclusion of the amphiploids. • Field trials were undertaken in 2008 and 2009; however, low fertility prevented assessment of grain yield for the H90-Westonia amphiploid. • The transfer back to fertile wheat cytoplasm has not been successful to date. • Pre-breeding material for milling quality wheat is not yet available. • A high level of sterility exists in the amphiploid populations and it is understood that this may require a significant research effort to overcome.

4. Outcomes

A summary of the principal outcomes (and expected outcomes in the case of projects not yet completed) from each of the projects is reported in Table 7. Some of the outcomes presented are intermediate outcomes but are included here to show the pathway to a practice change (the final outcome).

Table 7: Summary of Principal Outcomes by Project

Project	**Principal Outcomes**
UWA397: National Field Evaluation and Selection of New Pasture Plants from the Salinity CRC to improve hydrological stability	• While the range of perennial options for various purposes was expanded, the range of options in the drier areas was more limited than in the higher rainfall areas. • Seed increase of the wallaby grass cultivar (*Austrodanthonia caespitose)* was undertaken in 2007-08. However, there was insufficient seed for commercial release by the end of the project (release to be managed by NSW Department of Primary Industries (DPI)). Usage was for degraded areas being retired from cropping in low rainfall areas. • A commercialisation process for the wallaby grass cultivar was initiated but progress has been slow. However, seed production capacity has been maintained at Dareton. There is increasing interest in both seed production and commercial use of this species (Trangie Wallaby grass) (Cathy Waters, NSW DII). • The EverCrop project will be trialling the wallaby grass cultivar in the mallee in the future. • Identified *Cullen Australasicum* as a new drought tolerant shrub for the low rainfall cereal belt. It is easy to establish

	and performed impressively in drought periods. It is not being sown commercially as there are no cultivars currently available. Development work still continues under the low rainfall perennial legume project of the FFI CRC (Richard Hayes, pers. comm., 2011). • Chicory is deep rooting and easy to establish, increases ovulation rates and provides ability to finish lambs. However, with the exception of 1 PhD and 1 state department's internal activities, there has been no further development of chicory since the cessation of UWA 397. It is not widely used for a disease break per se in crop rotations. Generally this is because it is perceived to be insufficiently persistent to be sown as a specialty pasture on its own (Richard Hayes, pers. comm., 2011). A benefit of chicory is its high initial productivity, yet most farmers are establishing it under a cover-crop preventing them from utilising year 1 production. Also, chicory has been recently found to have high levels of nitrogen mineralisation in the 6 months following its removal (Gardner, unpublished), yet the cropping systems have not been refined to take full advantage of this attribute leaving farmers with no knowledge about how a late removal system may be of benefit in a mixed farming context (Richard Hayes, pers. comm., 2011). No breeding program has been funded to date. • While *Melilotus siculus* was identified as a new highly salt tolerant legume, it has not been released as available rhizobia strains are not persistent over summer due to high salt levels. This issue is being addressed by the CRC. Nine strains of rhizobia have been short listed and are being evaluated for field persistence in SA and WA. More intensive studies on one strain (SRDI 554) in South Australia have shown improved survival of the strain over summer and greatly increased soil colonisation, resulting in increased and adequate levels of nodulation and plant growth in regenerating pasture. A strain will be selected and recommended as a special inoculant for messina and possibly burr medic grown on saline soils and is likely to be commercially available in 2014. Efforts to develop a cultivar of messina are continuing in parallel (Richard Hayes, pers. comm., 2011). • While lucerne proved to be the most persistent and drought tolerant perennial legume evaluated, it needed to be further bred to increase tolerance to grazing, waterlogging and acid soils. The breeding of lucerne has remained within the confines of the public breeding programs in SA and NSW and their respective commercial partners. A number of varieties being marketed as grazing tolerant are finding their way to market. Also, it is an objective of the state breeding programs to continue development of lucerne germplasm that is better adapted to acid soils (Richard Hayes, pers. comm., 2011). • While superior genotypes of Lotononis were identified,

	none of the *Lotononis bainseii* types have yet reached a stage ready for commercialisation (work on seed size is continuing). • Three new cultivars of *Lotus conniculatus* have been commercialised by PGG Wrightson with assistance from the project (Australian Wool Innovation (AWI) funded). They have stopped any further work on commercialising the cultivars from UWA397 in favour of developing the AWI lines, due largely to the increased summer survival of the latter lines. The latter lines are still not commercially available but are currently undergoing seed increase. Some resources from UWA397 assisted the development of the three cultivars which were handed over to PGG Wrightson by NSW I&I (Richard Hayes, pers. comm., 2011). • This project had a major influence on the direction of the current research program of the FFI CRC.
UWA398: Development of a Salt Tolerant Cereal Using Wide Crosses of Wheat with Wild Hordeum Species	• Further progress towards proof of concept was achieved. • While further progress in terms of crossing and evaluation took place, a saline-tolerant cultivar for feed wheat was not produced. • Pre-breeding material for neither feed wheat nor bread wheat has yet been developed.
UWA396: High Water–Use Farming Systems that Integrate Crops with Perennial Pastures	• Both field studies and modelling showed lucerne reduced moisture at depth. There is an abundance of evidence showing the superior soil drying characteristics of lucerne compared to annual and many perennial species. • The project showed that companion cropping was useful in that the lucerne reduced recharge but crop yields were sacrificed. There has been little increase in companion cropping with a major factor being the sequence of seasons that have been experienced. • Improved extension targeting occurred; also, the extension framework developed was used by the CRC's EverCrop Program. • Potentially, an increased level of adoption of lucerne has occurred where it is profitable. However, this varies with the region. For NSW, there has been no increase in phase farming, but this is largely to do with the fact that levels of phase farming with perennials (particularly lucerne) were already quite high. Some increase in phase farming with lucerne has most likely occurred in some other states due to the investment. • The project informed the direction of the EverCrop project in the Uniform Rainfall Zone which has spent the last 3 years refining decision support tools such as MIDAS to incorporate alternative species to lucerne, such as chicory and perennial grasses, to assist in overcoming some of the shortfalls of lucerne. It has also conducted a number of field activities to help farmers better establish lucerne in order to increase productivity of pastures and to overcome two significant barriers to lucerne adoption i.e. cost and risk of establishment failure (Richard Hayes,

	pers. comm., 2011). • More broadly, the project has contributed to improvements in decision making with regard to use of perennials in cropping systems.
FFI00001: Development of Salt- and Waterlogging-Tolerant Wheat	• Further progress towards developing a feed wheat cultivar that is salt- and waterlogging-tolerant. • Further progress towards developing germplasm that can be used in breeding programs to develop salt- and waterlogging- tolerant bread wheats. • The transfer back to wheat cytoplasm has not yet occurred.
FFI00002: Development Phase- EverCrop and EverCrop Decide	• Focus in the Uniform Rainfall Zone was on chicory and perennial grasses in short phased rotations. • One of the important activities was to develop a growth curve for chicory so that it could be included in models such as GrassGro or MIDAS. The project developed a MIDAS output showing that farm profitability is increased by 5% with the inclusion of a small component of these alternative perennials on farm, largely due to their capacity to increase stocking rate (Richard Hayes, pers. comm., 2011). • The previous project (UWA396) identified a role for alternative perennials to be used in conjunction with lucerne in mixed farming systems, and the first phase of EverCrop (FFI00002) confirmed that role in terms of the economic benefits and the other benefits that were not easily assigned a dollar value, such as increased groundcover. • EverCrop also determined the context for the adoption of these alternatives. Specifically, they were to be used in conjunction with lucerne (not instead of) and on a small proportion (5-8%) of the farm. The other key activities have been field based research to investigate ways to improve the establishment success of these pastures. This includes farmer participatory research that has helped demonstrate to farmers the real cost of a suboptimal pasture establishment (Richard Hayes, pers. comm., 2011).
FFI00003: EverCrop and EverCrop Decide: Developing the Role of Perennials in Mixed Farming Systems	• Increased understanding of constraints to adoption of perennial based cropping systems. • Through the participatory approach, the project demonstrated a simple point about an activity to which many farmers confessed to never previously giving much thought. It demonstrated the increased risk of failure of cover-cropping to pasture establishment, encouraging farmers to weigh up the risks in view of dry seasonal conditions. Some of the farmer collaborators stopped cover-cropping on account of the EverCrop activities (Richard Hayes, pers. comm., 2011). • The activities also gave researchers insights into why cover-cropping is still practised, helping to explain some of the non-economic drivers for the practice, particularly increased early groundcover.

	• Due to this approach the project is now working to deliver a more sophisticated extension message through a new decision support tool to help farmers weigh up the risk of when they might cover-crop and how, or when they might sow the pasture in the absence of a crop. • Potentially improved decision making on use of perennials by producers and advisers through development of tools and approaches to perennial based systems. • In the Uniform Rainfall Zone, it has been demonstrated that whole farm profit increases by 30-40% when perennials (including lucerne) are incorporated (Bathgate et al. 2010). • Additional sensitivity analyses are currently underway to explore the impact of changing input and commodity prices and of different soil types which are expected to provide more information on this topic. There would be instances where perennials increase whole farm profit by more than the above figure, and there will perhaps be instances where the use of perennials is shown to less of an advantage. These analyses are expected to be completed by 30 June 2011 (Richard Hayes, pers. comm., 2011). • Subtropical perennials that can increase profitability have been planted into mixed farming systems in the northern agricultural zone of WA. • Permanent perennials have been planted in marginal areas of the landscape in the mallee regions, and perennials have been incorporated into rotations within the mallee farming systems on a non-permanent basis. • An internal (CRC) review of the EverCrop project is to take place in 2011 and an independent external review commissioned by GRDC has taken place in March 2011.
FFI00004: Development of a Salt- and Waterlogging-Tolerant Wheat	• Further progress towards developing a feed wheat cultivar that is salt- and waterlogging-tolerant. • Further progress made towards developing germplasm that can be used in breeding program to develop salt- and waterlogging- tolerant bread wheats. • Low fertility is an issue with the amphiploids, but fertility is somewhat better in amphiploids with long-season winter wheats (that can be grazed or grown for grain) as compared with the spring wheats. The most-promising amphiploids in terms of fertility are one with Mackellar and another with Currawong (Tim Colmer, pers. comm., 2011). • Amphiploids tested in the glasshouse have displayed significant improvements in traits associated with salt tolerance and waterlogging tolerance. • Not all amphiploids produced have been evaluated at this stage, even under glasshouse conditions. Information available has been published in the scientific literature. • Field evaluations of one amphiploid concluded that it was similar in tolerance to a reputed salt-tolerant barley – but these field evaluations were restricted by sites and dry

	years (Tim Colmer, pers. comm., 2011). • The amphiploid with Mackellar produces only about 70% of the grain of Mackellar; next best is an amphiploid with Currawong with about 50% of the grain. These assessments were from glasshouse-grown plants (Tim Colmer, pers. comm., 2011). • The transfer back to wheat cytoplasm has not yet occurred and appears to be a major blockage to further progress. • A new FFI CRC policy is that only projects with deliverables likely to benefit farmers within the life of the CRC will proceed in the second half of the FFI CRC; hence this project will not receive further funding from the CRC after June 2011.

In summary, there has been no practical or on-ground outcome delivered to date by the investment in salt- and waterlogging-tolerant cereal development. However, given additional R&D resources after June 2011, this outcome could still be pursued, notwithstanding the decision by the FFI CRC to cease funding according to their new policy.

The principal outcomes of the investment in the role of perennials have been improved decision making regarding the incorporation of perennials into mixed farming systems. Specifically there has been:

- Increased adoption of lucerne into mixed farming systems.
- Increased adoption of other perennials (e.g. subtropical species, chicory) into mixed farming systems.
- Increased level of marginal crop land retirement due to a wider range of perennial availability, with associated improvement in livestock profitability and environmental gains from reduced erosion (wind and water).

5. Pathway to Adoption

New Cereal (Wheat) Variety

The project concerned with a salt-tolerant wheat is a strategic science project, with a potential long and costly pathway to adoption likely to have been recognised at the outset. The crosses with Hordeum would appear to have been promising regarding their increased salt- and waterlogging-tolerance but difficulties have been encountered in transferring these traits back to a fertile wheat cytoplasm.

There is considerable uncertainty regarding whether further work in this area will be funded when the current project comes to an end in June 2011. While proof of concept has been validated in part, considerable further time and resources may be required to take the current state of knowledge to a point where it can produce salt- and waterlogging-tolerant varieties or germplasm that can be used by wheat breeders.

Even then there may be another risk whether commercial wheat breeders can retain all desirable traits of current varieties as well as incorporate the additional tolerance to salinity and waterlogging. Other risk factors include the possibility that other initiatives in Australia and elsewhere regarding developing salt tolerant varieties may 'dilute' the potential benefits that the Hordeum cross may be able to deliver.

Having said that, if such as cultivar could be produced from the amphiploids, it would most likely be readily adopted across a significant area with implications for raising the value of enterprise outputs.

Increased Use of Perennials

The first two projects (UWA398 and UWA396) in the second investment area had a focus on the use and advantages of the then existing, as well as new, perennials with regard to their water use (principally from a hydrological viewpoint). The extension to UWA396 and the two more recent projects (FFI00002 and FFI00003) moved the investment focus to one of development and a broader view (e.g. role, integration, profitability) of a wide range of perennials in mixed farming systems.

The new farming systems focus was highly relevant as there are considerable constraints perceived by mixed cropping farmers to widespread incorporation of perennials.

First, identifying/adapting a new species**,** even if for small specific niches regarding climate or soil type, is not likely to be a simple or quick process.

Secondly, given the current level of profitability of crop production compared with livestock, increasing use of favoured perennials such as lucerne is not always acceptable to mixed farming system managers, particularly if cropping intensity has to be lowered. Adoption has already occurred for some perennial plants identified from this investment, but adoption has not occurred over extensive areas.

Thirdly, companion or pasture cropping faces a major constraint when crop prices are high relative to livestock due to the high opportunity cost of losing crop yield. The negative tradeoff between minimising recharge and crop yield has been exacerbated since the impact of decreasing recharge at the paddock scale may be minimal at a regional scale.

Fourthly, some cropping farmers would see moisture storage being depleted during summer and autumn by deep rooted perennials, so impacting on crop yield from the next crop planting.

On the other hand opportunities for increasing perennials in mixed farming systems systems are present including:

- The potential positive impact on average profitability from out-of-season high quality grazing from both lucerne and other perennials.
- The potential for decreased variability of farm income and greater flexibility and resilience of systems incorporating perennials (e.g. relative input and product price changes, climate change prospects, soil health).
- The potential positive impact on cropping enterprises from biological nitrogen fixation by legumes, crop weed control (e.g. herbicide–resistant crop weeds), and crop disease control.
- The potential for retiring land from cropping where the economics are not favourable and instead using the resource for perennials and grazing enterprises, potentially increasing average profitability and reducing income variation.

- The reduction in environmental impacts from a more continuous groundcover from perennials (wind and soil erosion).

Some adoption of improved farming systems from the investment up to June 2011 will have taken place due to the GRDC projects. Some further adoption is likely to continue for a few years into the future due to the momentum and interest the project nearing completion has engendered. However, if the EverCrop investment continues past June 2011, it is likely that adoption of existing knowledge and non-lucerne perennial legumes and grasses will be significantly increased. In addition, there are other new perennial plant species that are showing promise and where existing constraints to commercialisation and adoption are being addressed.

6. Benefits

Potential new land use cereal option

The first area of investment could lead to a significant new land use option for producers experiencing constraints to cropping from saline or waterlogged cropping land. Most likely initial cultivars developed and used would be feed wheat quality rather than a bread wheat quality. This would provide an increased productivity benefit compared to saline land use based on pasture.

This benefit is described here only as 'potential' in that the targeted germplasm has not yet been developed, and there is no certainty that it will be developed in future. Other initiatives in Australia (CSIRO, University of Adelaide) and elsewhere (CIMMYT) are pursuing the same objective but through different mechanisms. However, some of the other approaches are focussed on transient rather then dryland salinity. Nevertheless they pose a risk to the uptake of the technology being pursued in the CRC FFI investment being evaluated. The review paper by Colmer et al (2005) provides a framework for considering this issue.

Increased Adoption of Lucerne in Mixed Farming Systems

It is of interest to report the results from a survey of cropping farmers growing lucerne for at least five years in Western Australia in 2007 (Dolling and Wilkinson, 2010). About 76% had tried lucerne for the first time with the intention of controlling excess water. This reason for growing lucerne had fallen to 48% by 2007 with the main then current reason being production increases that have led to increased profitability.

The sources of this overall increased profitability have been assumed to include:

- Filling feed gaps in summer/autumn so lowering supplementary feeding costs
- Improved weed control and reduced usage of chemicals
- Higher crop yields due to reduced disease incidence
- Reduced fertiliser requirement due to biological nitrogen fixation of lucerne
- Increased crop yield in some years due to reduced waterlogging in winter but a reduced crop yield in some years due to reduction in stored soil water due to lucerne
- reduced wind and water erosion due to the increased ground cover

Increased Use and Potential Use of Other Perennial Species that Increase Profitability

The sources of benefits from incorporating other perennial species would include factors similar to those listed above for lucerne, but excluding nitrogen fixation for non leguminous species. Benefits have already been demonstrated and adopted from a range of perennial species and systems including:

- Chicory and perennial grasses in short phased rotations in the uniform rainfall zone
- Permanent perennials planted in marginal areas of the landscape in the mallee regions, and the incorporation of perennials into rotations within the cropping system on a non-permanent basis
- Subtropical perennials planted in the northern agricultural zone of WA that can increase profitability
- Increased profitability and reduced income variability on a whole farm basis from retirement of marginal cropping land and increases in stocking rate from use of perennials.
- Carrying out pasture cropping including benefits such as:
    - Increased organic matter, microbial activity and nutrient levels (Ferris et al, 2010).
    - Increased livestock carrying capacity and longer growing season (Ferris et al, 2010).
    - Reduced groundwater recharge with some income from crop retained.
    - But with lowered overall profitability caused by crop yield losses and the opportunity cost of establishing perennials; there is no definite answer to whether pasture cropping is viable in Western Australia (Ferris et al, 2010).

Other species that are showing promise and may deliver benefits in future include that can be attributed at least in part to the investment include a Wallaby grass cultivar (Austrodanthonia caespitose), Cullen Australasicum (a new drought tolerant shrub for the low rainfall cereal belt, Melilotus siculus (a new highly salt tolerant legume), Lotononis bainseii types, and new cultivars of Lotus conniculatus.

Other economic benefits include decreased variability of farm income and greater flexibility and resilience of systems incorporating perennials (e.g. relative input and product price changes, climate change prospects, soil health). Decreased income variability benefit may apply at both producer and the local community level.

Social

Social benefits from planting lucerne referred to in Ransom et al (2006) include the 'oasis' factor of having green in the landscape, and hence reduced farmer stress during the summer autumn period. This may also apply to other summer growing perennials.

A summary overview of these benefits from the investment in a triple bottom line categorisation is shown in Table 8.

Table 8: Categories of Benefits from the CRC Investment

<u>Economic</u> • Potentially higher valued land use option of a cereal suited to saline and waterlogged land. • Increased profitability for some mixed farming systems from increased use of lucerne via phase farming. • Increased profitability from use of other perennials in mixed farming

systems. • Reduced income variability for some mixed farming systems due to a strengthening of the livestock enterprise without reducing cropping intensity. • Reduced recharge of groundwater due to increased use of perennials.
Environmental • Increased area of perennials in mixed farming systems leading to reduced erosion and soil loss from increased ground cover in summer and autumn. • Potential for reduced use of crop chemicals from control of disease and some weeds via rotations with pasture perennials.
Social • Increased capacity in farming systems research in Australia. • The presence of 'more green in the landscape' leading to reduced farmer stress during the summer autumn period. • Reduced variability of community income in some regions with mixed farming systems.

Public versus Private Benefits

The economic benefits identified from the investment in the CRC will be captured predominantly by grain producers. Public benefits are mainly environmental and apply both on farm and to the wider community. The minor social benefits identified also apply to both grain producers and the local community.

Additionality

These two investments were targeted principally towards grain producers and initially towards addressing salinity and waterlogging issues so prominent in the early 2000s. The early investments would have been regarded as a medium to high priority by grain levy payers, particularly those then experiencing and those foreshadowing saline and waterlogging conditions on their farms. The second round of investment (the perennial project area) shifted towards more directly addressing profitability improvements as well as natural resource issues such as erosion.

However, in the event that the government matching contribution to GRDC were restricted, it is likely that the existing contribution by the grains industry would have fallen to a lower level. A summary is provided in Table 9.

Table 9: Potential Response to Reduced Public Funding to GRDC

1. What priority would these projects received when funded?	Medium to high priority for GRDC and industry
2. Would the investments still have been made in these projects if 50% less public funds were available to GRDC?	Yes, but with less total funding
3. Would industry and others have funded these projects if no public funds were available to GRDC?	Yes, but with significantly less total funding.

Distribution of Benefits along the Grains Supply Chain

Most benefits will be captured by grain producers and those operating mixed farming systems. There may be some benefits to seed producers of new plants identified and grown. Potential benefits could accrue to wheat breeders and feed wheat consumers if the tolerant cereal varieties were eventually produced.

Benefits to other Primary Industries
There will be benefits to wool, sheepmeat and beef producers who are also grain producers, but not classified as mixed farming systems.

Match with National Priorities
The Australian Government's national and Rural R&D priorities are reproduced in Table 10.

Table 10: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The GRDC investments were focused principally on National Research Priorities 1 and 3. The investment was focussed on Rural Research Priorities 1, 3 and 4 and addressed both supporting priorities.

7. Measurement of Benefits

Benefits Valued
The benefits valued in the following farm level investment analysis include:
- The contribution to knowledge made to the potential development of a salt- and waterlogging-tolerant cereal.
- The increase in area of lucerne integrated via phase farming into mixed farming systems.
- The increase in area of non-lucerne perennials integrated into mixed farming systems.

Benefits not Valued
The principal benefits not valued include:
- Reduced recharge of groundwater due to increased use of perennials.
- Increased area of perennials in mixed farming systems leading to reduced erosion and soil loss from increased groundcover in summer and autumn.

- Reduced income variability for some mixed farming systems due to a strengthening of the livestock enterprise without reducing cropping intensity.
- Potential for reduced use of crop chemicals from control of disease and some weeds via rotations with pasture perennials.
- Increased capacity in farming systems research in Australia.
- The presence of 'more green in the landscape' leading to reduced farmer stress during the summer autumn period.
- Reduced variability of community income in some regions with mixed farming systems.

Attempts at measuring some of these benefits could be made in future investment in order to provide credible information for valuation.

For example, a key driver of adoption of perennials is understood to be increased groundcover leading to reduced soil loss from water and wind erosion. The main areas of Australian wind erosion occur in the less than 500 mm rainfall zone including most of the Lake Eyre Basin and the lower Murray-Darling Basin (McTainsh et al 2001). An estimate of the cost of fertiliser to replace the nitrogen, phosphorus and trace element loss from one tonne of eroded soil was estimated in the range of $3.50 to $7 (Anon, undated). An average of soil fines loss of 2.5 tonnes per ha was measured on cropping paddocks on calcareous sandy loam soils on Upper Eyre Peninsula in 1994. An estimate of the cost of wind erosion in term of nutrient loss is therefore $13 per ha (1994 dollar terms). Questions that follow include: How often would this occur and what proportion of soil loss may be saved with the planting of perennials? Is this significant in terms of future productivity and/or nutrient loss? Does dust that settles on other farms constitute an additional resource gain to those farms?

Conservative off-site public impacts of wind erosion in South Australia (not including health costs) have been reported as an average of $1 to $6 million per annum with a median estimate of $3 m per annum (Anon, undated). Main components were additional cleaning of electricity transformers, cleaning of buildings and houses, road and railway maintenance (sand drift) airline disruption costs and increased road accidents. What proportion of such dust costs originate from mixed farming systems?

Development of a Salt-and Waterlogging-Tolerant Cereal
It is assumed that the development of a salt- and waterlogging-tolerant cereal is potentially achievable, and if so would be applicable to about 500,000 ha of land. However, there is significant uncertainty as to whether any further investment will take place, how long it may take, its costs and its probability of success. It is assumed that breeders may be able to produce a suitable variety from the enhanced germplasm once the sterility issue is overcome, but it is recognised that other initiatives may make any variety obsolete. These and other assumptions made to value the potential benefits are provided in Table 12.

Increase in Area of Lucerne Integrated into Mixed Farming Systems
Unit Value of Benefit
The major outcome from the earlier projects was a higher level of integration of lucerne into cropping systems and where lucerne enhanced both the productivity of the livestock system and the whole farming system. An overall average gain is assumed despite negative impacts of lucerne dewatering the soil profile in dry years leading to reduced yields.

Robertson (2006) reports profitability estimates from economic modelling across a range of WA regions where lucerne might be established. This data (shown in Table 11) has been a major source of information used to estimate the increase in net farm profitability from introducing lucerne into mixed farming systems.

Table 11: Increase in Profitability from Integration of Lucerne into Farming Systems in WA

Region	**Area of lucerne in 2001 (ha)**	**Livestock system to utilise lucerne**	**Percentage lucerne assumed**	**Added income pa per whole farm ha ($ per ha)**	**Added income pa per lucerne ha ($ per ha)**
WA Central Wheat Region	48,000	Merinos plus first cross lambs	12	3	25
WA South West	74,000	Specialist Wool	25	20	80
WA South Coast	28,000	Wool	20	8	40

Source: Robertson (2006)

In line with the above estimates, Kingwell (2003) reports that phase rotations that incorporate lucerne or lucerne rows with crop interows are both profitable systems. In many situations lucerne has boosted annual farm profit by $1 to $20 per ha of farm arable area, in spite of lucerne being planted on only a small area of the farm.

Another study involving an economic analysis of the introduction of lucerne into case study farms in Victoria showed that the average livestock gross margin increased by $106 per ha, with a range of $58 to $143 per ha (Ransom et al., 2006). Assuming no net change on overall crop gross margins, the $106 per ha increase translated to about $56 per ha (crop area was an average of 47% of total farm area) on a whole farm basis. Lucerne made up about 25% of the total farm area on these farms so that the gross margin increase due to lucerne was estimated at $224 per ha of lucerne planted.

Over a 7 year period on a whole farm cash flow basis the average profit increase was $93 per ha for one of the Victorian case study farms that had planted 40% of the farm to lucerne, equivalent to $232 per ha of lucerne planted. While the crop gross margin increased on a number of farms, on others it declined. Allowing for the fact that these case study farms may achieve higher profitability than the average, a net annual benefit of $100 per ha of lucerne is assumed from lucerne establishment on mixed cropping farms in the northern region of Victoria.

Given the above information, a conservative value of an additional $60 per ha of lucerne planted was used in the analysis.

Increased adoption due to CRC projects
The total amount of lucerne in WA mixed farming system regions in 2001 was about 150,000 ha (Robertson, 2006). Lucerne was already incorporated strongly into NSW mixed farming systems but it is assumed that adoption of lucerne in some Victorian mixed farming systems (existing adoption assumed at 100,000 ha) also may have

been enhanced. In both cases the increased adoption assumed is modest at an increase of 0.25 % for each of five years, with the first benefit occurring in the 2007/08 year. Total adoption due to the investment (mainly from Project UWA396) was therefore estimated at 625 ha for each of five years.

Increase in Area of Non-Lucerne Perennials Integrated into Mixed Farming Systems in the Uniform Rainfall Zone in Southern NSW

It is assumed there are approximately 2,000 mixed enterprise grain farms in the uniform rainfall zone and the average area of such farm is 2,111 ha. The latter estimate is based on the average farm size for mixed livestock farms in NSW from 2000 to 2009 (ABARES, 2011).

Unit benefit

Dear et al (2010a) estimated from MIDAS a whole farm profit of $191,000 with lucerne incorporated. With additional perennial grasses this increased to $198,000 and further increased to $207,000 with the addition of chicory. The average increase for these two technologies is taken as $10,666 per farm of 1,000 ha, or $10.67 per ha.

The analysis has used $5.33 per ha as the additional gain, a discount of 50% due to the potential of the MIDAS model to overstate profitability increases.

Adoption

Adoption of perennials was already apparent in the region. Dear et al (2010b) reported that 84% of farms reported having some pasture with lucerne, 48% with phalaris and 31% had native perennial grasses. Hence the CRC project would have increased the areas and possibly the diversity of some of these farms and introduced new perennials to other farms.

The CRC Adoption Tool has predicted a high level of final adoption (70%) for such a technology over a 20 year period. However, the current analysis assumes that the investment will finish by June 2011 and hence the maximum adoption is assumed to be only 20%. Further, it is not clear if the 70% estimate from the Adoption Tool takes into account that some farms may have already adopted perennials other than lucerne without the CRC projects. As there is still unfinished business in terms of modelling and further extension, if further investment occurs the current adoption estimate is most likely conservative. A sensitivity analysis would show the implications of such a change in the adoption assumption for the uniform rainfall zone.

Other assumptions for the uniform rainfall zone are shown in Table 12.

Increase in Area of Non-Lucerne Perennials Integrated into Mixed Farming Systems in the Medium Rainfall Zone in the Northern Agricultural Region of Western Australia.

It is assumed there are approximately 980 mixed enterprise grain farms in the northern agricultural region of WA and the average area of such farms is 2,189 ha. The latter estimate is based on the average total area of a mixed enterprise grain farm in WA (ABARES, 2011).

Unit benefit

The results of modelling in the region are not yet completed but it is likely that the incorporation of perennials will be shown to be profitable (Llewellyn, pers. comm., 2011). The analysis has assumed the gain will be approximately 50% of that demonstrated in the uniform rainfall zone (50% of $5.33 per whole farm ha).

No net profit has been assumed for pasture cropping. However, there may be another level of gain when those who have adopted the perennial grasses then carry out pasture cropping (Rick Llewellyn, pers. comm., 2011).

Adoption
Adoption of subtropical grasses was already apparent in the region. The CRC Adoption Tool has predicted a level of final adoption (20%) for such a technology over a 15 year period. However, the current analysis assumes that the investment will finish by June 2011 and hence the maximum adoption is assumed to be only 10%. Further, it is not clear if the 20% estimate from the Adoption Tool takes into account that some farms may have already adopted subtropical grasses (without the CRC projects). As there is still unfinished business in terms of modelling, further extension, and decision-support tool development and use, if further investment occurs the current adoption estimate is most likely conservative. A sensitivity analysis would show the implications of such a change in the adoption assumption for the medium rainfall zone.

Other assumptions for the medium rainfall zone are shown in Table 12.

Increase in Area of Non-Lucerne Perennials Integrated into Mixed Farming Systems in the Low Rainfall Zone in the Victorian and South Australian Mallee
It is assumed there are in the mallee regions of interest approximately 1,370 (978 mixed grain farms plus 25% of 1,569 specialist grain farms also considered potential adopters). The average total area of a mixed enterprise grain farm is 1,907 ha (Hooper and Levantis, 2011, p16).

Unit benefit
The results of modelling in the mallee region are not yet completed but model results to date (based on the incorporation of Old Man Saltbush to 5% of the farm area) show an increase in whole farm profitability of $20,000 per farm of 3,000 ha. The current analysis has assumed this gain will be approximately $4 per whole farm ha.

Adoption
Apart for saltbush, adoption of perennials was not widespread in the mallee. The CRC Adoption Tool has predicted a level of final adoption (20%) for the perennial technology over a 15 year period. However, the current analysis assumes that the investment will finish by June 2011 and hence the maximum adoption is assumed to be only 10%. As with the other regions, there is still unfinished business in terms of modelling, further extension, and decision-support tool development and use. If further investment occurs the current adoption estimate is most likely conservative. A sensitivity analysis would show the implications of such a change in the adoption assumption for the low rainfall zone.

Other assumptions for the low rainfall zone are shown in Table 12.

Table 12: Summary of Assumptions

Variable	Assumption	Source
Development of salt- and waterlogging–tolerant cereal		
Number of years of further R&D required before germplasm is available to breeders	8	Agtrans Research
Annual cost of further R&D	$1 m per annum	Agtrans Research
Probability of further investment occurring	50%	Agtrans Research
Probability of output success	50%	Agtrans Research
Probability of output being used (as other initiatives may produce a salt tolerant cereal beforehand)	60%	Agtrans Research
Breeding period required	8 years	Agtrans Research
Added costs of breeding	$100,000 per annum	Agtrans Research
Increased return over saltland pasture	$40 per ha average for feed and bread wheat	Blanchard (2006)
Potential land area that may grow tolerant cereal type	500,000 ha	Project proposals and final report
Level of maximum adoption	55% (average for feed and bread wheats)	Blanchard (2006)
Increased Area of Lucerne Integrated into Mixed Farming Systems		
Increase in gross margin per ha of lucerne	$ 60 per ha	Agtrans Research , based on Robertson (2006)and Ransom et al (2006)
Increased area of lucerne	250,000 ha times 0.25% = 625 ha per annum for five years	
Year of first benefit	Year ended June 2008	Agtrans Research
Increased Area of Other Perennials (non lucerne) Integrated into Mixed Farming Systems in the Uniform Rainfall Zone (Southern NSW)		
Number of mixed enterprise grain farms	2,000	Phil Price, pers. comm., 2011
Average area of a mixed enterprise grain farm	2,111 ha	Taken as average farm size for mixed livestock farms in NSW from 2000 to 2009 (ABARES, 2011)
Average increase in profitability due to addition of perennial grasses and chicory where lucerne already present	$5.33 per whole farm ha (average additional gain from perennial grasses and perennial grasses plus chicory)	Dear et al (2010a) estimate of $10,666 per annum per 1,000 ha farm ($10.67 per ha),

		discounted by 50% due to MIDAS overstating profitability
Year of first adoption	Year ended June 2011	Agtrans Research
Year of first benefit	Year ended June 2013	Agtrans Research
Period from year of first adoption to year of maximum adoption	20 years	CRC Adoption Tool
Level of maximum adoption due to the investment (assumes project investment finishes in June 2011)	Reduced to 20%, as analysis assumes no further investment from July 2011	Based on CRC Adoption Tool estimate of 70%
Increased Area of Other Perennials (non lucerne) Integrated into Mixed Farming Systems in the Northern Cropping Region of WA		
Average number of mixed enterprise grain farms	Estimated as 980 (Grain and Graze) of 2,819 mixed livestock farms in WA (ABARES,2011)	Grain and Graze (2011) ABARES (2011)
Average total area of a mixed enterprise grain farm in WA	2,189 ha	ABARES (2011)
Average increase in profitability from pasture cropping with subtropical perennial grasses	Breaks even in terms of average profits but adopted due to provision of increased ground cover and additional feed for livestock	Ferris et al, 2010
Average increase in profitability from incorporating subtropical perennial grasses	$2.66 per whole farm ha	Agtrans Research estimate of 50% of gain estimated for the Uniform Rainfall Zone ($5.33 per ha)
Year of first adoption	Year ended June 2011	Agtrans Research
Year of first benefit	Year ended June 2013	Agtrans Research
Period from year of first adoption to year of maximum adoption	15 years	CRC Adoption Tool estimated 10-30 years depending on situation regarding existing use of perennials
Level of maximum adoption due to the investment (assumes project investment finishes in June 2011)	Reduced to 7.5%, as analysis assumes no further investment from July 2011	Based on CRC Adoption Tool estimate of 5-20% depending on situation regarding existing use of perennials
Increased Area of Other Perennials (non lucerne)Integrated into Mixed Farming Systems in the Mallee Regions of VIC and SA (a)		
Number of mixed enterprise	1370 (978 mixed grain farms	Hooper and

grain farms	plus 25% of 1569 specialist grain farms also considered potential adopters)	Levantis (2011), p3
Average total area of a mixed enterprise grain farm	1,907 ha	Hooper and Levantis (2011), p16
Average increase in profitability from incorporating perennials	$4 per ha per whole farm area, discounted from model results due to MIDAS overstating profitability gains	Based on recent and preliminary MIDAS modelling results of Monjardino of about $6 per whole farm ha gain with 5% of typical farm under perennials
Year of first adoption	Year ended June 2012	Agtrans Research
Year of first benefit	Year ended June 2014	Agtrans Research
Period from year of first adoption to year of maximum adoption	20 years	CRC Adoption Tool, EverCrop Status Report, 2011
Level of maximum adoption due to the investment (assumes project investment finishes in June 2011)	10% of all mixed farming systems in SA and Vic Mallee regions (reduced as analysis assumes no further investment from July 2011)	Based on CRC Adoption Tool estimate of 20-30% reduced to accommodate existing adoption and low profitability, (EverCrop, 2011)

(a) While the project concentrated on the Victorian and South Australian Mallee areas in terms of interaction with producers, the findings of the project will most likely be applicable to the NSW Mallee area.

The estimates in Tables 11 to 12 are the most likely estimates for each variable. The probabilistic assumptions for those variables thought to be the most uncertain are provided later.

Results

All past costs and benefits were expressed in 2010/11 dollar terms using the Consumer Price Index (CPI). All benefits after 2010/11 were expressed in 2010/11 dollar terms. All costs and benefits were discounted to 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment (2010/11) to the final year of benefits assumed. The investment criteria estimated for the total investment are reported in Table 13 and for the GRDC investment alone in Table 14.

Table 13: Investment Criteria for Total Investment for Each Benefit Period (discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**	**30 years**
Present value of benefits ($m)	0.39	1.31	7.54	17.08	28.82	41.07	50.68

Present value of costs ($m)	33.05	33.05	33.05	33.05	33.05	33.05	33.05
Net present value ($m)	-32.66	-31.74	-25.51	-15.97	-4.23	8.02	17.63
Benefit cost ratio	0.01	0.04	0.23	0.52	0.87	1.24	1.53
Internal rate of return (%)	Negative	Negative	Negative	0.7	4.2	6.1	6.9

Table 14: Investment Criteria for GRDC Investment for Each Benefit Period (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years	30 Years
Present value of benefits($m)	0.11	0.38	2.18	4.95	8.35	11.90	14.69
Present value of costs ($m)	9.67	9.67	9.67	9.67	9.67	9.67	9.67
Net present value ($m)	-9.55	-9.29	-7.48	-4.72	-1.31	2.24	5.02
Benefit cost ratio	0.01	0.04	0.23	0.51	0.86	1.23	1.52
Internal rate of return (%)	Negative	Negative	Negative	0.7	4.2	6.0	6.9

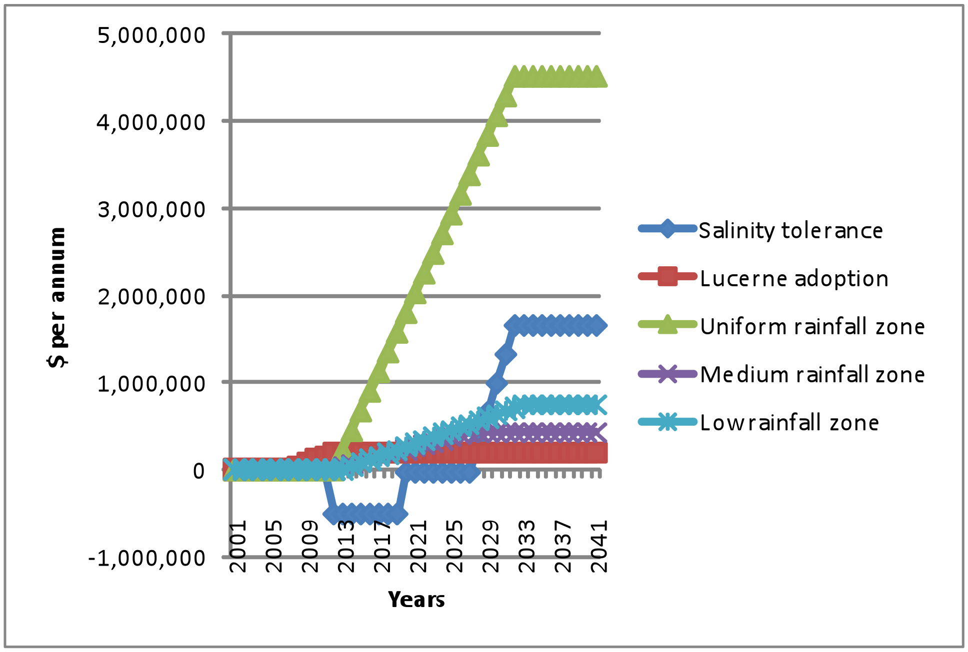
Estimates of the proportion of benefits derived from each source of benefit are provided in Table 15.

Table 15: Source of Benefits for the Total R&D Investment (discount rate 5%, 30 years)

Source	Present Value of Benefits (PVB) (m$)	Proportion of PVB (%)
Salt and waterlogged tolerant cereal	2.77	5.46
Increased area of lucerne	3.28	6.47
Perennials in uniform rainfall zone	35.28	69.61
Perennials in medium rainfall zone	3.95	7.80
Perennials in low rainfall zone	5.40	10.66
Total	50.68	100.0

The annual undiscounted benefit cash flows for the total and GRDC investments are shown in Figure 1.

Figure 1: Annual Total Benefit Cash Flow



Sensitivity Analyses

Sensitivity analyses were carried out on several variables for the GRDC analysis with results reported in Tables 16 to 18. The sensitivity analyses were performed using a 5% discount rate with benefits taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 16 shows the changes in the investment criteria when the discount rate changes. At a 10% discount rate, the investment is no longer viable. This is due to the long time frames in delivering benefits.

Table 16: Sensitivity to Discount Rate
(GRDC investment, 30 years)

Criterion	Discount Rate		
	0%	5% (Base)	10%
Present value of benefits ($m)	38.44	14.69	6.51
Present value of costs ($m)	7.53	9.67	12.50
Net present value ($m)	30.91	5.02	-5.99
Benefit cost ratio	5.11	1.52	0.52

Table 17 shows the sensitivity of the investment criteria to changed assumptions regarding the maximum level of adoption for each of the three rainfall zones, with the salinity tolerance benefit and the lucerne benefit remaining unchanged.

As for unit benefits, the investment criteria are quite sensitive to the maximum level of adoption assumed. The break-even maximum adoption level was 61% of the base levels assumed, resulting in 12% for the uniform rainfall zone, 5% for the medium rainfall zone and 6% for the mallee region.

Table 17: Sensitivity to Changes in Maximum Adoption Level for Uniform, Medium and Low Rainfall Zones
(GRDC investment, 5% discount rate, 30 years)

Criterion	**Unit benefit**		
	Half	**Base level of maximum adoption (20%, 7.5% and 10%)**	**Double**
Present value of benefits ($m)	8.22	14.69	27.62
Present value of costs ($m)	9.67	9.67	9.67
Net present value ($m)	-1.45	5.02	17.96
Benefit cost ratio	0.85	1.52	2.86
Internal rate of return (%)	4.3	6.9	10.03

The sensitivity of the investment criteria to changed assumptions regarding the unit benefit from each of the three rainfall zones when the unit benefit is halved or doubled was similar to the result for halving or doubling the adoption assumptions shown in Table 17. The break-even unit benefit was 61% of the base levels.

Future Investment in the CRC Perennial Project Area

As the economic modelling work has not yet been completed in the medium and low rainfall zones, the investment criteria estimated in this analysis are probably conservative, particularly regarding the level of maximum adoption. It might be expected that if the investment continued for a further three years, the level of maximum adoption could at least double. Further, not all field trials are completed and there are other perennial species that may show improvements over the existing species assumptions.

If it is assumed that the investment in the perennial project continued for a further three years (that is until June 2014) at $2.7 million per annum, and that level of maximum adoption doubled, the investment criteria for the cluster would increase as shown in Table 18.

Table 18: Investment Criteria with Increased Investment into Perennial Incorporation into Mixed Farming Systems 2012-2014
(Total investment, 5% discount rate, 30 years)

Criterion	**Scenario**		
	Include new investment and increased adoption rates	**Base for Cluster**	**Marginal cost and benefits of potential new 3 year investment**

Present value of benefits ($m)	95.32	50.68	47.34
Present value of costs ($m)	40.40	33.05	7.35
Net present value ($m)	54.91	17.63	39.98
Benefit cost ratio	2.36	1.53	6.44
Internal rate of return (%)	9.3	6.9	23.2

8. Confidence Rating

The results produced are highly dependent on the assumptions made, many of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 19). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made
Medium: denotes only a reasonable coverage of benefits or some significant uncertainties in assumptions made
Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 19: Confidence in Analysis of HSD Investment

Coverage of Benefits	**Confidence in Assumptions**
High	Medium

9. Conclusions

The investment in the development of a salt- and waterloggiong-tolerant cereal advanced knowledge and made considerable progress towards a practical outcome through crossing wheat with Hordeum species. However, the objective of the development of a cultivar or an enhanced germplasm that could be used by wheat breeders was not achieved by the end of the investment. The crosses with Hordeum would appear to have been promising regarding their increased salt- and waterlogging-tolerance but difficulties have been encountered in transferring these traits back to a fertile wheat cytoplasm.

A new FFI CRC policy is that only projects with deliverables likely to benefit farmers within the life of the CRC will proceed in the second half of the FFI CRC; hence this project will not receive further funding from the CRC after June 2011.

While proof of concept has been validated in part, considerable further time and resources may be required to take the current state of knowledge to a point where it can produce field-relevant outcomes. The economic analysis has recognised there is significant uncertainty as to whether any further investment will take place, how long it may take, its costs and its probability of success.

The second set of projects concerned with identifying new perennial species and evaluating both new and existing perennial species in mixed farming systems has been more successful. Some useful system niches for both new and existing perennial species have been identified.

Likewise, important knowledge regarding companion cropping with lucerne and other perennials was produced showing that companion cropping can lower watertables significantly. However, due to competition for soil moisture, crop yields are lowered and while some adoption of the practice has occurred, adoption has not been widespread.

Along with other investments, one contribution of the earlier projects in this cluster has been in raising awareness of opportunities and potential profitability of lucerne and provided greater confidence for mixed farming operators to invest in lucerne as a deep rooted perennial. In addition an improved extension framework for lucerne was developed that has contributed to some adoption of lucerne in this regard.

A major finding was that perennials other than lucerne may play an income enhancing role in mixed farming systems. Benefits identified include increased seasonal feed availability for livestock allowing higher stocking rates, improved weed and disease control in crops and the contribution from pasture legumes as a source of nitrogen. In a wider context, the investment has commenced assisting farmers in decisions concerning the integration of perennials into their mixed farming systems on a whole-farm basis from profitability, diversification and resilience, and environmental points of view.

The approach in EverCrop integrated field experimentation, on farm trials, farmer participation, farm case studies, biophysical and whole farm bio-economic analysis. The investment has indicated potential profitability gains that can be made with incorporating perennials other than lucerne in the Uniform Rainfall Zone in southern NSW, but results for the other two regions (Medium Rainfall Zone in Western Australia) and the Low Rainfall Zone (Mallee Regions in South Australia and Victoria) are incomplete as part of GRDC Project FFI00003. However, potential profitability gains are likely.

The benefits from the investment in perennial incorporation are most likely underestimated due to the fact that natural resource management benefits, while identified, were not valued in the economic analysis. Attempts at measuring some of these benefits could be made in future investment in order to provide credible information for valuation. For example, a key driver of adoption of perennials is that they provide increased groundcover in summer and autumn that reduces soil loss.

Further adoption assumptions do not extend outside of the three regions applicable to the latest CRC project (FFI00003). The investment in FFI00003 will cease in June 2011. This has constrained the assumptions regarding adoption as not all field trials are completed, and further modelling, decision-support tool development and usage is still required and, if carried out in any continued investment, is likely to increase adoption significantly.

The results indicate that, given the assumptions made, the total investment to June 2011 will provide positive but conservative returns. The net present value for the total investment (GRDC and others) of $33 million (present value of costs in 2010/11 $ terms) is estimated at over $17 million giving a benefit cost ratio of 1.5 to 1 and an internal rate of return of 6.9%. About 5% of the expected total benefits were contributed by knowledge produced by the salt and waterlogging projects, with 95% from the perennial incorporation projects.

It should be noted that if total further investment was provided of $2.8 million per annum for three years (present value of additional costs of $7.4 million) to extend the existing perennial project (FFI00003), and this resulted in maximum adoption levels increasing from 20% to 40% in the uniform rainfall zone, 7.5% to 15% in the medium rainfall zone and 10% to 20% in the mallee, the additional benefits were estimated at $47 million (present value of benefits), yielding a benefit cost ratio of over 6 to 1. This would require an additional number of 611 farms adopting perennials into their systems due to the new three year investment to achieve this return.

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