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Case Study

Climate Change Adaptation

Key findings

The O&A Business Unit's climate change research activities are uniquely placed to deliver significant economic, social and environmental benefits for Australia and the south Pacific region. Understanding the variable and changing climate allows industry and communities to prepare and respond.

CSIRO's Climate Change Adaptation (CCA) work is exemplified by two projects, namely the Climate Change in Australia - Resource Management (CCiA-RM) Project and the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Project. These two projects have produced the following outcomes:

- the enhanced scientific understanding of climate variability, extremes and change and associated physical hazards and impacts in Australia's Natural Resource Management (NRM) regions and in the western tropical Pacific
- the uptake and adoption of climate change planning and adaptation data available for Australia and South Pacific by government, business and the broader community
- uptake and adoption of CSIRO climate related services by a broad range of interested parties (beyond the initially targeted NRM groups and Pacific Island Countries (PIC) governments) for a diversity of purposes/applications
- the availability of outreach and capacity building services to ensure communities can make best use of projections for planning/adaptation and climate-related disaster risk management
- greater confidence in the design and planning of adaptation strategies and climate-related disaster risk management based on the availability of improved scientific data and information which has increased awareness of climate change and its impacts.

CSIRO's CCA work delivers greater certainty around issues relating to the planning and implementation of climate change adaptation measures. However, given the long-time horizons involved, and the relatively early stage of implementation, the full impacts of the work will not be realised for many years. Nevertheless, early applications point to the significant role the climate projections play in assisting NRMs and PIC partner countries to assess options for climate adaptation measures and significant benefits are already being realised across both the CCiA-RM Project and the PACCSAP Project, such as:

- better targeted adaptation and disaster preparedness actions based on robust climate projections which in turn leads to a reduction in economic losses due to the adoption of more effective measures
- better targeted resilience preparations to protect against extreme events – with the total economic cost of natural disasters (most of which will be exacerbated by climate change) expected to reach $39 billion per year by 2050, there is significant scope to realise significant economic savings and broader community benefits
- reduction in potential health and broader social costs arising from climate change including significant, and often long-term, social impacts, including death and injury and impacts on employment, education, community networks, health and wellbeing
- while a reduction in infrastructure losses is encompassed in broader economic impacts, it is highlighted given its vulnerability to climate chance outcomes and due to significant impacts arising from infrastructure losses/disruptions including public

service infrastructure and services (energy, communications, water, transport and private infrastructure losses (homes and other private rural infrastructure)

— better use of financial, community and natural resources through better/more informed planning decisions based on the projections data and use of the tools developed by the projects.

The cost-benefit analysis is strongly positive – the present value of R&D costs for both projects is $48.7 million (2018 dollars, 7 per cent discount rate) while benefits are $739.6 million. The NPV of the project is estimated at $691.0 million giving a benefit-cost ratio of 15.19.

Innovation impact

CSIRO has established itself as a global leader in the field of robust climate projections, coupled with a multitude of application tools enabling their direct application to regional, national and local adaptation and disaster mitigation planning and project implementation. This skill set affords CSIRO a significant opportunity to develop a niche export market for products and/or services that can be delivered off the back of this expertise – as already demonstrated by its climate projections work for the Asian Development Bank.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework in the case study into CSIRO's engagement in Climate Change Adaptation and climate related disaster risk management (CCA) work are summarised in **Figure 1**. Two projects have been identified which exemplify CSIRO's work in climate change adaptation: the Climate Change in Australia - Resource Management (CCiA-RM) Project and the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Project (consisting of three phases detailed at 1.2 below) - they are used as the basis of the CCA Case Study.

FIGURE 1 CCA CASE STUDY – IMPACT FRAMEWORK DIAGRAM

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
– Departmental (Foreign Affairs and Environment) funding – CSIRO co- contribution – International, national and state data bases – BoM sub-contracted work – NRM cluster and PIC agency work – Background IP/prior climate work	– Modelled new climate projections for Australia and the South Pacific – Detailed climatology for PICs – Determined the elements of climate change of highest priority to NRMs and PICs – Framework design to coordinate existing and new climate projections – Website development, web materials and reports for use by NRM clusters, PICs and other end user stakeholders – Direct assistance for end user applications	– Development of two websites – Climate Change in Australia: Projections for Australia's NRM Regions and the Pacific Climate Change Science websites – Numerous publications – Management decision support tools for NRM groups and PICS – Direct services arising from data applications – Tools to access relevant climate projections – Outreach and communications materials, skills based training and technical workshops	– Enhanced scientific understanding in relation to climate change impacts – Uptake and adoption of climate change planning and adaptation data available for Australia and South Pacific – Uptake and adoption of data/services by interested parties – Outreach and capacity building services ensure communities can make best use of projections for planning/adaptation – Greater confidence in the design of adaptation strategies – Improved planning practices	– Better targeted adaptation actions based on robust climate projections – Reduction in economic losses due to more effective adaptation measures – Better targeted resilience preparations to protect against extreme events – Reduction in potential health costs – Reduction in broader social costs – Reduction in infrastructure losses – Better use of financial, community and natural resources

SOURCE: ACIL ALLEN CONSULTING

1. Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from CSIRO's involvement in CCA.

This evaluation is being undertaken to assess the positive impacts arising from the CCA work undertaken by CSIRO. However, it can also be used to inform a range of other stakeholders. The case study can be read as a stand-alone report or aggregated with other case studies to substantiate the impact and value of the Oceans and Atmosphere (O&A) Business Unit's activities as a whole relative to the funds invested in these activities.

The information in this case study is provided for accountability, communication and continual improvement purposes. This case study is primarily intended to inform the independent review of the O&A Business Unit. Other audiences for this report include Members of Parliament, Government Departments, CSIRO and the general public.

2. Background

2.1 CSIRO engagement on climate issues

CSIRO's work on climate issues can be traced back to the late 1980s. It began as an initiative in the lead up to the UN Conference on Environment and Development, Rio de Janeiro, 1992[1]. The current extensive work program seeks to better appreciate the role of the atmosphere, oceans and land surface in the overall earth system and provide comprehensive, rigorous science to help Australia and its regional Asia-Pacific neighbours understand, respond to and plan for a changing climate.

CSIRO's climate change research can be grouped under several general themes/topics:

Agriculture and mining: primary industries – agriculture, fisheries, forestry and mining industries – are amongst the most sensitive sectors susceptible to climate risk. CSIRO is working with industry, enterprises and communities to help them adapt to climate change through the provision of practical strategies.

Disaster resilience and extremes: the frequency of extreme weather events such as severe temperatures, torrential rainfall, large hail, strong wind gusts and fire are likely to increase over coming decades due to climate change. CSIRO is working to help Australia better prepare for these events.

Managing ecosystems and biodiversity: Australia's natural species and ecosystems (both land and sea) are highly vulnerable to climate change and will have difficulty adapting to the rate and extent of projected changes. CSIRO is working to find effective adaptation responses to help manage and conserve ecosystems.

Built environment and cities: climate change threatens cities and rapidly urbanising coasts where most of the world's population lives. CSIRO is tackling climate-related urban sustainability challenges by delivering scientific solutions.

Major collaborations: CSIRO has been a partner in research cluster initiatives that have brought together diverse research capabilities to tackle climate change problems at a regional level (e.g. Queensland and coastal areas in relation to topics such as health and extreme weather events).

International: focused on climate adaptation research which contributes to development outcomes (i.e. increasing food and nutrition security, reducing poverty and increasing environmental sustainability).

Specific activities within the program include:

— atmospheric monitoring and modelling: to understand how interactions between the land and the atmosphere affect the earth system; and working with industry, regulators and the community in the search for solutions to our air pollution problems

[1] http://www.un.org/geninfo/bp/enviro.html

- State of the Climate reports: produced by CSIRO and the Australian Bureau of Meteorology (BoM), which provide a summary of observations of Australia's climate and analysis of the factors that influence it (the most recent being for 2016)
- collection of Cape Grim greenhouse gas data: greenhouse gas (GHG) data updated monthly
- participating in the collaboration for Australian Weather and Climate Research (CAWCR): a partnership between CSIRO and BoM
- examining the effect of climate change on the world's oceans and coastal waterways
- assisting coastal communities to consider how best to plan for sea-level rise
- providing the scientific knowledge needed to strengthen resilience to climate change by ensuring Australia and the South Pacific are well positioned to deal effectively with the impacts of climate change by identifying practical and effective adaptation options for policymakers, industry and communities
- developing planning, design and management solutions to help cities and coasts adapt.

2.2 Climate change projections for Australia and the Pacific

This case study focuses on CSIRO's work in relation to climate change research. The case study examines research associated with two Commonwealth funding programs, namely the Pacific Climate Change Science Program and the Natural Resource Management Climate Planning Fund (NRM Fund). These programs began in 2008 and 2012 respectively, but the case study primarily focuses on post 2011 work, while recognising earlier contributory efforts – it uses expenditure from 2009 10 onwards (see **Table 1**).

In Australia, the focus of the project was to develop science relevant for NRM managers to assist them in planning how best to manage the impact of climate change on Australia's natural resources, and on regional areas more generally. For the Pacific, small island developing countries are amongst the most vulnerable to climate change. During this century, these countries will face increasing threats to sustainable development from the impacts of climate change. Sectors which are likely to be most affected include human health, infrastructure, coastal resources, disaster management, fresh water availability, agriculture, fisheries, forestry, marine ecosystems and tourism.

Climate Change in Australia - Resource Management Project

CSIRO was commissioned by the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE – later the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education (DIICCSRTE)) in September 2012 to deliver Element 1 of Stream 2 of the NRM Fund. Element 1 involved a specific focus on the development, coordination and delivery of climate change projections for use by NRM groups[2]. CSIRO was the lead agency engaged in delivering the CCiARM and the Bureau of Meteorology (BoM) was a key partner working with CSIRO through sub-contractual arrangements. In particular, CSIRO was required to:

- deliver a new suite of regional climate projections for the whole of Australia, including appropriate downscaled information
- ensure projections focused on the elements of climate change (covering best estimate and extreme projections of core climate variables) of highest priority to NRM groups (i.e. temperature, rainfall, wind)
- identify and deliver other secondary core climate variables (i.e. forest fire danger indexes, growing season changes, regional sea level rise, and marine variables such as sea surface temperature, salinity and ocean pH)
- develop an overarching framework to coordinate existing and new projections (including those developed by State governments)
- develop a one-stop-shop website for climate projections suitable for a multi-user clientele
- prepare reports for each NRM regional cluster and develop guidance for end users.

Subsequent work was funded by the Department of Environment and Energy (DOEE) through the National Environmental Science Program (NESP).

[2] NOTE: Australia has 56 regional natural resource management (NRM) organisations that cover all of Australia. They are a mix of government agencies and non-government organisations (NGOs) that deliver national priorities for natural resource management on the ground – they are a key conduit for government natural resource management support programs. They are aggregated into 8 regional clusters plus one overarching group – AdaptNRM – see https://nrmregionsaustralia.com.au/about-us/

Pacific-Australia Climate Change Science and Adaptation Planning Project (Science Component)

In 2008, the Australian Government launched the International Climate Change Adaptation Initiative to meet high-priority adaptation needs of vulnerable countries in the Asia-Pacific region, especially the Pacific Island countries (PICs) and East Timor. The Pacific Climate Change Science Program (PCCSP), which become the PACCSAP, was a key activity of the Initiative. It contributed to the implementation of the Pacific Islands Framework for Action on Climate Change 2006-2015.

CSIRO was one of two lead agencies for the science work undertaken as part of the overall PCCSP and PACCSAP programs. BoM had separate funding contracts with the client agency but worked closely with CSIRO on a collaborative basis across much of the scope of work for these programs. CSIRO's work on Pacific climate change science was developed to assist decision makers and planners in 14 Pacific Island countries and Timor-Leste to better understand how their climate and oceans have changed and how they may change in the future. The project consisted of three phases, with initial work under the $20 million Pacific Climate Change Science Program (PCCSP) (from July 2009 to December 2011). Its objectives were to:

— conduct a comprehensive climate change science research program aimed at providing in-depth information about the past, present and future climate in 15 partner countries

— build the capacity of partner country scientific organisations, and where feasible, to undertake scientific research to support the provision of this information

— disseminate the information to partner countries and other stakeholders.

The PCCSP was followed by the PACCSAP Science Program which commenced in July 2011 (the two Programs ran in parallel during the six-month period July-December 2011). PACCSAP (2011-15) enabled the Pacific Island countries to build resilience to current and future climate risks through delivering enhanced scientific understanding of climate variability, extremes and change, including over historical, current and future (multi-decadal) climate timescales. It achieved this through provision of new (e.g. wave climate data) and updated scientific data (utilising global climate models provided for IPCC fifth assessment report), and further information aimed at increasing awareness of climate change and its impacts, ultimately to facilitate better adaptation planning and climate-related disaster risk management. The legacy continues to be implemented through the final phase, the Pacific Climate Change Science and Services Outreach Project (delivered by CSIRO in 2016 - 2018).

3. Impact Pathway

3.1 Project inputs

The total funding of the CCA project elements considered was $29.103 million in cash and in-kind contributions – see **Table 1**. The Environment Department (in a variety of guises, DCCEE, DOEE, DIICCSRTE) provided $4.281 million towards the Climate Change in Australia – Resource Management Project while AusAID and the Department of Foreign Affairs and Trade (using the Environment Department as a conduit in some cases) provided $21.517 towards the Pacific-Australia Climate Change Science and Adaptation Planning Project. CSIRO made co-contributions to the CCiA-RM project totalling $3.305 million (around 44 per cent of the total cost of the CCiA-RM project element), and $150,000 towards PACCSAP, that is a co-contribution of around 12 per cent of the total CCA budget.

Table 1 SUPPORT FOR CCA PROJECT ELEMENTS

Contributor / type of support	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	TOTAL
Climate Change in Australia - Resource Management Project										
Cash										
DCCEE* to CSIRO	-	-	-	$3.162M	$585,000	$200,000	$200,000			**$4.147M**
DOEE** to CSIRO	-	-	-					67,000	67,000	**$0.134M**
In-kind/Co-contribution										
CSIRO internal resources	-	-	-	$83,000	$2.953M	$80,000	$55,000	67,000	67,000	**$3.305M**
Total				**$3.245M**	**$3.538M**	**$280,000**	**$255,000**	**134,000**	**134,000**	**$7.586M**
Pacific-Australia Climate Change Science and Adaptation Planning Project										
Cash* **										
PCCSP****	$4.0M	$5.0M	$1.0M							$10.0M
PACCSAP			$2.802M	$6.129M	$1.396M	$290,000				*$10.617M*
Science & Services Outreach								$300,000	$450,000	*$750,000*
In-kind/Co-contribution										
CSIRO internal resources	-	-	-	-	-	-	$150,000	-	-	*$150,000*
Total	**$4.0M**	**$5.0M**	**$3.802M**	**$6.129M**	**$1.396M**	**$290,000**	**$150,000**	**$300,000**	**$450,000**	**$21.517M**
GRAND TOTAL	**$4.0M**	**$5.0M**	**$3.802M**	**$9.374M**	**$4.934M**	**$570,000**	**$405,000**	**$434,000**	**$584,000**	**$29.103M**

*NOTE: * NRM FUND – INITIALLY DCCEE, SUBSEQUENTLY DIICCSRTE*

*NOTE: ** NESP FUNDING BY DOEE*

*NOTE *** FUNDING PRIMARILY FROM DEPTMENT OF FOREIGN AFFAIRS AAND TRADE; AND AUSAID (SOME DIRECTED THROUGH THE ENVIRONMENT DEPARTMENT)*

*NOTE **** ANNUAL BREAKDOWN OF $10M PROGRAM ARE ESTIMATES – PCCSP FUNDING TOTALED $20M SPLIT 50:50; BOM:CSIRO*

*NOTE ***** CSIRO EXPENDITURE ONLY (DOES NOT INCLUDE BOM SUBCONTRACTED EXPENDITURE)*

SOURCE: ACIL ALLEN CONSULTING BASED ON CSIRO ADVICE; PARTNERSHIP AGREEMENTS

CSIRO contributed background IP and expertise to both projects but only made an in-kind contribution to the CCiA-RM project. That said, CSIRO staff contributed effort over and above that associated with the financial support contributed by others. Key stakeholders such as the NRM groups and South Pacific island country agencies made substantive contributions to the projects. These were primarily in the form of discretionary in-kind contributions, especially by PIC partner countries (mainly from their Meteorological Services – with 14 services involved) and represent key project inputs.

3.2 Project activities

Climate Change in Australia - Resource Management Project

CSIRO's activities focused on:

- preparing new regional climate projections for the whole of Australia for use in NRM planning
- determining the elements of climate change of highest priority to NRMs and identifying key secondary core climate variables
- designing an overarching framework to coordinate existing and new climate projections
- developing a one-stop shop website
- developing high value added reports for NRM regional clusters and guidance for end users.

Pacific-Australia Climate Change Science and Adaptation Planning Project

The work was delivered in three phases:

Phase 1: the PACCSP work focused on establishing the first comprehensive scientific understanding of climate change in the Pacific, including climate variability, extremes and change in the western tropical Pacific; the first documented climatology for partner PICs featuring first regionally specific (CMIP3[3]) climate projections for each country; along with a comprehensive portfolio of communication products, capacity development resources and support and program governance.

Phase 2: the PACCSAP program Science Component continued the work of PCCSP in better understanding the science behind climate change in the western tropical Pacific, but also included the development of updated regional climate projections, along with associated on-line tools and other capacity development resources and support to assist PICs (and Timor-Leste) to better understand their climate.

Phase 3: focused on capacity building and facilitation to enable PICs to take full advantage of the scientific base and tools developed under PCCSP and PACCSAP, with emphasis on facilitating outreach of the science to sectoral stakeholders at a national/sub-national level in partner countries.

3.3 Project outputs

Climate Change in Australia - Resource Management Project

The outputs for CCiA-RM (these are similar for PACCSAP) can be grouped into the following categories:

- ***Products and services***: - including new and updated brochures, reports, videos, etc; case studies showing good examples of how the projections have been used; and outreach through briefings, presentations, committee representation, media, input to Government Inquiries, responding to Ministerial questions, etc
- ***Science***: - published research in peer reviewed literature; international linkages (i.e. sharing lessons learnt in developing climate projections internationally; input into Intergovernmental Panel on Climate Change (IPCC), WMO Global Framework for Climate Services); applications in the Pacific, Asian and Indian Ocean regions etc
- ***Relationships***: - maintenance of relationships with stakeholders; a 'Community of Practice' on using climate projections in impact assessment; and collaborative partnerships for co-production of knowledge
- ***Capacity***: - maintenance of science, technology and innovation capacity; capability to enhance awareness raising and appropriate uptake of information beyond the NRM sector; and maintenance of stakeholder engagement and new communication products.

The *Climate Change in Australia: Projections for Australia's NRM Regions* Website[4] is the major output from the CCiA-RM project. The comprehensive website and its associated suite of reports provides information about climate change projections for Australia. The website contains:

- climate change projections showing how Australia's climate may change in the future – using up to 40 global climate models, the projections represent the most comprehensive analysis of Australia's future climate undertaken to date
  - projections are spatially focussed around natural resource management regions (or clusters) for which information, data and reports are available
  - model outputs, including climate model data formulated for use in further studies or applications, are available to registered users
  - projections are summarised in the *Regional Climate Change Explorer* section
  - the *Historic Climate Change* section contains details of climatic trends gathered by science agencies using a range of atmospheric, terrestrial and marine sensors i.e. the Australian Climate Observations Reference Network – Surface Air Temperature dataset is based on a network of over 100 stations, with data for more than half of these starting in 1910
- 14 web-tools of differing complexity to support users in obtaining climate projections information
  - the data exploration tools enable users to see what climate models are projecting about future climate change for Australia

[3] World Climate Research Programme - Coupled Model Intercomparison Project Phase3 (CMIP3) and Phase 5 (CMIP5)
[4] https://www.climatechangeinaustralia.gov.au/en/

- a *Climate Campus* providing climate science education and guidance materials including information about the underpinning knowledge that is used when undertaking climate science research and climate change projections
- 'how to' information to assist users to put the projections information into practice as well as tools for communicators and educators, a Decision Tree and FAQs, including information on how to:
  - use projections data
  - get help finding the information needed
  - access the resources available to assist communication efforts
  - learn more about what is contained within the website
- an *Impacts and Adaptation* section delivering information developed by the NRM regions themselves with dynamic links to their publications and datasets (the NRMs provided this input). This:
  - brought together details of adaptation research conducted to develop a deeper understanding of how climate change will impact upon the diverse natural resources of the NRM regions and natural resource management activities
  - supported natural resource managers to plan for the impact of climate change on regions.
- a publications library that provides downloadable copies of the reports and brochures, links to key supporting research papers and downloadable figures and maps from the supporting Technical Report (see below)
- news and updates providing announcements about new and updated content, new publications and data, website enhancements and maintenance etc
- a 'Help Desk' support service (funded by DOEE and NESP).

Publications

The *Technical Report – Climate Change in Australia – Projections for Australia's NRM Regions*[5] presents a comprehensive assessment of past and future climate change in Australia. It provides the underpinning science for all other products and is the basis for other publications on regional impacts.

Separate Regional ('Cluster') Reports have been prepared for each of the eight NRM Clusters. Each Cluster Report contains a description of the relevant biophysical and climatological features in each cluster and is aimed at readers primarily interested in regional climate change projections and less interested in the technical details underpinning their production. The Cluster Reports aim to assist regional decision makers in understanding the important messages deduced from climate change projection modelling. These reports present a range of emissions scenarios across multiple variables and years and include relevant sub-cluster level information in cases where distinct messages are evident in the projections.

The Cluster Reports are supported by a series of brochures. For example, *Australia's Changing Climate*[6] is a high-level brochure summarising many aspects of climate change in Australia, including past variability and change, projections, impacts, mitigation and adaptation. Drawing on the 2015 region based projections, this brochure provides a 'whole of Australia' perspective. The brochure is designed to be easy to read, with extensive use of illustrations and figures. Other Cluster Brochures provide key regional messages - summarising key climate change projections for each of the eight clusters. In addition, *Regional Climate Wheels* (in effect an 'easy to use' guide) have been developed for each of the eight NRM Clusters.

Patents/Awards

There are no patents relating to the CCiA-RM project. The project staff were the recipient of an internal CSIRO Performance Cash Award in 2015.

Pacific-Australia Climate Change Science and Adaptation Planning Project

The *Pacific Climate Change Science* website[7] and its extensive content was initially developed as part of the PCCSP and hosted by CSIRO but was recently moved to the Secretariat of the Pacific Regional Environment Programme (SPREP). The website is a repository for most of the key scientific products from PCCSP and PACCSAP and serves the purposes of providing:

- data and web-tools of differing complexity to assist Pacific Island countries and Timor-Leste in better understanding their climate and to support users in obtaining climate projections information (including Pacific Climate Futures; Pacific Climate

[5] CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology , Australia

[6] https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/AUSTRALIAS_CHANGING_CLIMATE_1.pdf

[7] https://www.pacificclimatechangescience.org/

Change Data Portal; Southern Hemisphere Tropical Cyclone Data Portal; CliDE: Climate Data for the Environment; Seasonal Prediction of Sea Level Anomalies in the Western Pacific; Seasonal Prediction of Extreme Ocean Temperatures and Coral Bleaching)

- management decision support tools including direct services arising from data applications and tools to access relevant climate projections
- 'how to' information and tools/training modules to assist users apply the projections information. Each tool has sections on:
  - ***About*** – outlining what the tool enables and provides for users (e.g. the Southern Hemisphere Tropical Cyclone Data Portal plots the tracks of cyclones in the South Pacific from 1969, and allows users to analyse the tracks of historical tropical cyclones and relate them to the impact on lives and infrastructure recorded on the ground)
  - ***Relationship to other tools*** – e.g. the Southern Hemisphere Tropical Cyclone Data Portal and the Pacific Climate Change Data Portal are connected in the sense that daily rainfall data from the Pacific Climate Change Data Portal can be used to examine the impacts of a particular tropical cyclone that is available via the Tropical Cyclone Data Portal.
  - ***Who can use it*** - e.g. the Southern Hemisphere Tropical Cyclone Data Portal tool is able to be used by the public to examine the impacts of past tropical cyclones
- guidance services/products specifically designed for the application end of the spectrum (rather than for research purposes)
- animations which aim to increase awareness of the science and impacts of climate variability in the Pacific, and to provoke discussion around how communities can access forecast information and take 'low regrets' actions to prepare for future El Niño/La Niña events and adapt to climate change
- a library that holds downloadable copies of the reports and country brochures as well as links to key supporting research papers
- news and updates announcing new content, website maintenance, etc.

Publications

A range of journal publications and research papers are based on the overall work of the PCCSP project. *Climate Change in the Pacific: Scientific Assessment and New Research Volume 1: Regional Overview and Volume 2: Country Reports*[8] collects the scientific outcomes of the first phase of the project and presents the underlying scientific platform that supports later modelling and projections. *Volume 1* presents an overview of the region: analysis of large-scale climate phenomena such as the El Niño-Southern Oscillation; seasonal variability and past climate trends; and further develops regional climate change projections. *Volume 2* presents individual country reports which provide country specific projections and relevant climate information.

The suite of new products launched by PACCSAP immediately prior to close-out of the Program in 2014/15 included:

- Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014[9] - a detailed technical report of new scientific findings and projections for each partner country
- *Current and Future Climate (2015) country brochures* – plain language (English only) summaries of all country chapters from the 2014 technical report
- *Climate Change in the Pacific: a regional summary of new science and management tools (2015)*[10] - a concise, non-technical summary report of the new science at both regional and national level, aimed at policy-makers, planners and associated decision-makers
- *Climate Science in the Western Tropical Pacific: Training Materials (2015)* - technical training materials in digital format based on the 2014 technical report, which can be customised for each partner country, designed primarily to communicate to sectoral stakeholders
- *Climate Science Fact Sheets (2014)* – a set of five, two-page fact sheets, based on science behind regional-scale climate impacts in the western tropical Pacific; designed as resource documents for a general audience specifically explaining

[8] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports.

[9] Australian Bureau of Meteorology and CSIRO (2014). Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia

[10] CSIRO, Australian Bureau of Meteorology and SPREP (2015). Climate in the Pacific: a regional summary of new science and management tools, Pacific-Australia Climate Change Science and Adaptation Planning Program Summary Report. Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia.

Climate Change and Climate Variability, Climate Extremes, Large-Scale Climate Features, Ocean Acidification and Sea Level Rise

— *Pacific Climate Futures V2.0* – updated version of this on-line tool now incorporating latest CMIP5 climate model outputs for the Pacific and intermediate level on-line training.

Collectively, this suite of products, together with the previously released Climate Crab and Klaod Nasara[11] animations (2013) and other communication products and tools, provides a comprehensive package of scientifically validated resources for key stakeholders to utilise in order to facilitate broader sectoral communication, engagement, outreach and on-ground application. The scope of climate science provided by these new products includes:

— updated information about current climate seasonal cycles, observations and trends, with emphasis on mean and extreme temperature and rainfall, wind-driven waves and tropical cyclones

— multi-decadal climate projections under different emissions scenarios, including climate model evaluations and confidence statements, based on the latest CMIP5 Global Climate Model outputs aligned with the IPCC 5th Assessment Report, with emphasis on mean and extreme temperature and rainfall, drought, tropical cyclones, ocean acidification/coral bleaching, wind-driven waves and sea level

— enhanced understanding of large-scale climate processes, including the impacts of the El Nino Southern Oscillation on natural climate variability and extremes

— the sectoral impacts of climate variability, extremes and change at a regional scale for key climate variables, including air temperature, rainfall, sea-surface temperature, sea-level, ocean acidification and tropical cyclones.

Patents/Awards

There are no patents relating to the PACCSAP project. Project staff received an internal CSIRO Special Recognition Reward in 2012 for their work on PCCSP.

Innovation/commercialisation

While the outputs and outcomes of both the CCiA-RM and PACCSAP work are centred on public good aspects, both have scope for commercialisation under a number of business models, in particular through the provision of a range of climate change planning service opportunities looking at climate change risk assessment and adaptation measures (in effect selling joint expertise/products).

CSIRO has a real opportunity to compete in this space (which is undergoing a rapid growth in both interest and demand for services) given its name and branding; the robustness of the data that CSIRO now has; and the leading edge nature and breadth of the underpinning science. CSIRO holds the relevant background IP and has the expertise to handle the complexity in assessing and bringing together the 70+ different models involved in the projections, and the 4/5 different simulations resulting in over 200 output tables. Furthermore, CSIRO offers a significantly longer duration in its data projections - 30 years compared to competitor companies which are only working with 10 year data projections.

CSIRO is exploring the scope for business use based around a user pays model. International agencies (i.e. Asian Development Bank (ADB), World Bank, World Meteorological Organisation (WMO)) have initiated discussions with CSIRO about application of the approach elsewhere. This has resulted in work (at cost) in Malaysia, Vietnam, Philippines) and there is scope for expansion.

These initial forays into the commercial market, coupled with CCiA-RM and PACCSAP outcomes, provide a 'sales tool' to show what CSIRO can do elsewhere. However, licensing and related legal issues need to be resolved to enable the advancement of appropriate commercial practices.

3.4 Project Outcomes

[11] Pacific Climate Change Portal - https://www.pacificclimatechange.net/document/pacific-adventures-climate-crab-complete-kit; https://www.pacificclimatechange.net/document/cloud-nasara

Climate Change in Australia - Resource Management Project

While the initial remit of the CCiA-RM work was to service the eight NRM clusters through the delivery of climate projections, this was broadened to enable their use by other interested parties. The website is the primary access point and is the preeminent source of climate change planning and adaptation data in Australia.

Notable users/uses include:

— local government which employs the data for planning purposes – especially coastal zone planning

— high level climate change and adaptation information used for a variety of government/political purposes

— communication purposes – basic education on climate change and adaptation measures that may apply to specific regions

— project specific applications in agriculture and infrastructure planning areas (data mining).

The website consistently attracts around 3-5,000 users per month. In addition, between 3 and 10 more detailed enquiries are received each month which are handled through the help desk function facilitated via NESP funding. The website is held in high esteem with the 2017 survey of users[12] concluding:

> *"Overall, the Climate Change in Australia website appears to be still very useful to respondents in 2017. The majority of respondents have either agreed or strongly agreed with the statements[13]"*

Pacific-Australia Climate Change Science and Adaptation Planning Project

The successful execution of the project and the adoption of its outcomes by the 15 partner countries (which have limited capabilities and resources to direct to climate adaptation work) and the global climate change research community more generally is a significant outcome in and of itself. CSIRO's capacity to act as a 'trusted advisor' and work directly with key regional and partner country agencies to deliver independent, relevant work coupled with tools enabling its direct application, was vital to the successful execution of the project.

CSIRO in partnership with BoM, has provided climate change science capability - including a contemporary (CMIP5) suite of regionally specific projections for each partner country along with various aspects of scientific understanding of climate change and large-scale climate processes impacting current and future climate, to each of the 15 partner countries. As a result, the PICs and Timor-Leste now have an improved understanding of the current and future climate for their countries and the science-based evidence to inform adaptation and disaster risk management policy, planning and associated decision-making.

As part of the PACCSAP program, examples of outcomes for adaptation planning involving the direct application of the science included fine spatial scale analysis of future climate impacts on:

— the location and design specifications of the new Australian Government funded parliamentary building complex in the Samoa capital of Apia, noting the previous building was destroyed by storm damage and the location was subject to rising sea level and risk of storm surges[14]

— vulnerability of Pacific regional groundwater resources from the risk of salinisation from sea level rise/wave over-topping (e.g. the Bonriki lens on the capital island of Tarawa, Kiribati, noting this is the primary fresh water supply for the Kiribati population)[15]

— design criteria for the engineering specifications of upgraded drainage system for Pt Vila, Vanuatu as part of the ADB-funded $30 million upgrade of Pt Vila urban infrastructure

— high resolution modelling of tropical cyclone induced storm tides in the Nadi Flood plain, Fiji to mitigate climate change flood and storm damage risk.

Since the completion of PACCSAP, many partner PICs have developed new/updated National/Sub-national (Climate Change) Adaptation Plans or Action/Resilience Plans which have incorporated (often for the first time) evidence-based analysis of climate change risk for their country informed by the science. Examples include the *Honiara Urban Resilience and Climate Adaptation Plan (2016)* for Solomon Islands and the *Pt Vila Urban Resilience and Climate Adaptation Plan (2017)* for Pt Vila in Vanuatu.

[12] CSIRO internal document; 2017: Climate Change in Australia Survey Results: Comparison between 2016 & 2017 Results
[13] The survey posed a series of questions/statements and asked respondents to rate them from "strongly disagree" to "strongly agree"
[14] https://coastadapt.com.au/climate-scientists-help-protect-democracy-samoa
[15] http://www.ga.gov.au/about/projects/water/pacific-island-groundwater-and-future-climates-first-pass-regional-vulnerability-assessment

3.5 Adoption

Climate Change in Australia - Resource Management Project

The NRM Clusters (and through them the 56 NRM organisations) are the principal users of CSIRO's climate change projection and adaptation work. The CCiA-RM project has enabled all the 56 NRM organisations to update their regional NRM plans to address climate change impacts on the natural resources in their regions – delivering a full national coverage. Many regions have taken this a step further to help local communities prepare for change. For example, actions in the Strathbogie Ranges area in Victoria illustrate the type of action in which CSIRO is now engaged to drive adoption of the CCiA-RM work (see **Box 1**).

BOX 1 PLANNING FOR CHANGE - STRATHBOGIE RANGES, VICTORIA

The Goulburn Broken Catchment Management Authority, RMIT University and CSIRO, are helping regional communities in the Strathbogie Ranges adapt to climate change and build farmer resilience. They are working with the local communities through engagement workshops to identify critical opportunities to prepare both the people and the environment for climate change.

There may be one or multiple pathways to reach the community's preferred future destination and plans for possible future scenarios must be flexible enough to respond to the unknown or unforeseen. Planning for an uncertain future includes:

- identifying the main aspects that make up the identity of an area
- determining which of these aspects are critical to maintain an area's identity ('critical attributes')
- working with scientists to determine the thresholds around each critical attribute to identify possible tipping points that would result in a change in identity.
- making robust decisions about which critical attributes to respond to now and which ones can be left for later.
- planning for multiple pathways and unforeseen changes.
- analysing the costs and benefits of each pathway.
- monitoring the critical attributes while being flexible enough to adapt as other aspects may become important in the future.
- implementing and monitoring actions that maintain the identity or result in positive adaptation to change.

SOURCE: NRM WEBSITE: BUILDING CLIMATE CHANGE RESILIENCE IN VICTORIA'S STRATHBOGIE RANGES; HTTP://NRMREGIONSAUSTRALIA.COM.AU/BUILDING-CLIMATE-CHANGE-RESILIENCE-IN-VICTORIAS-STRATHBOGIE-RANGES/

The project has now been adopted by a far broader community of users, particularly state and local government, for an array of planning purposes. Key applications currently relate to:

— coastal planning and adaptation

— heat waves and appropriate responses/preparations

— drought planning (to a lesser extent)

— agriculture and food production – to address the potential decline in productivity due to climate change and identify opportunities to address this decline through improvements in productivity from applied research and development.

Given that the data sets for heat and sea level changes are more robust and can be extracted at little additional cost, this effectively delineates the 'low hanging fruit' in terms of early adoption. To build on this momentum, CSIRO provides a consistent and robust approach to planning for climate change for local, regional and national organisations by supporting:

— NRM organisations to share climate change information with land managers in their regions

— investment by local communities/land managers in building soil resilience including improved productivity and soil carbon, management of soil vulnerable to extreme events and reinstatement of perennial vegetation on vulnerable soils

— investment by local communities/land managers in landscape connectivity including bio-links; protection of drought refugia; and reducing pressures on the condition of natural resources that are projected to be affected by climate change

— the protection of Aboriginal Cultural Heritage sites vulnerable to climate change and facilitating the use of biocultural Indigenous knowledge

— protection of carbon rich 'blue carbon' coastal and freshwater systems

— investment in research needs identified through the *Regional NRM Climate Change Adaptation Plans* to increase the likelihood of science being applied on the ground.

Pacific-Australia Climate Change Science and Adaptation Planning Project

The set of climate projections for the Pacific delivered under the PACCSAP project have been used by:

— the PICs and their agencies, especially those directly involved in adaptation planning and the development of climate science at the country level (e.g. the meteorological bureaus)

— regional planning and coordination agencies, in particular SPREP and the Secretariat to the Pacific Community (SPC)

— NGOs and the broader regional community that engage in climate planning and adaptation work

— climate scientists and the broader science community involved in the South Pacific

— Australian climate scientists given:

- the very strong affinity between the western Pacific and Australian climate drivers
- that the learnings from the project have direct application with regard to CCiA-RM (and vice versa)

— the client Department/agencies for the purposes of building international relations/aid capacity

— potential use by commercial providers and consultants operating in the South Pacific.

The Pacific Climate Change Science and Services Outreach Project (2016–18) was specifically designed to facilitate uptake of the PACCSAP climate science knowledge products by sectors in partner Pacific Island countries, with an emphasis on targeted communication, capacity development and coordination via national meteorological services. Adoption of the project products is encouraged and facilitated through the provision of training materials/tools and workshop facilitation.

The targeted outreach delivered under the Science and Services Outreach phase has extended the reach of the project to new sectoral stakeholders in the South Pacific. The *Preliminary case study assessment of climate change impacts and risks for cocoa farming in Guadalcanal Plain, Solomon Islands*[16] with its three goals of awareness raising; providing decision makers with a preliminary assessment of climate change impacts; and in motivating mitigation/adaptation responses is illustrative of the projects undertaken under Outreach phase of the project. A further national case study designed to demonstrate the use of new guidance materials for development climate related risk assessments in the fisheries sector is underway in Samoa through collaboration with SPREP, the Samoa National met Service and the Samoa fisheries sector.

3.6 Impacts

The anticipated impacts of global warming are well documented – an increase in average annual temperatures with noticeable changes in the number of 'extreme heat' days; sea level rise and related increases in storm surge levels; an increase in rainfall intensity and variations in average annual rainfall (up or down depending on location); and changes in the intensity and frequency of extreme events (cyclones, drought, local flooding, extreme winds) etc. The implications of these changes (for agricultural production, land use planning, health, infrastructure, biodiversity etc) are also well documented.

Furthermore, there is a growing body of reputable work detailing the economics of adaptation (i.e. the International Panel on Climate Change (IPCC) Climate Change 2014: Impacts, Adaptation, and Vulnerability Report; Chapter 17: Economics of Adaptation[17]), as well as the costs associated with climate change (financial, social and ecological) (i.e. Climate Council Report – Counting the Costs: Climate Change and Coastal Flooding[18]).

[16] SIMS, SPREP and CSIRO (2018): *A preliminary case study assessment of climate change impacts and risks for cocoa farming in Guadalcanal Plain, Solomon Islands*. CSIRO, Melbourne, Australia https://www.pacificclimatechangescience.org/publications/developing-climate-change-information/

[17] http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap17_FINAL.pdf

[18] *Counting the Costs: Climate Change and Coastal Flooding* by Will Steffen, John Hunter and Lesley Hughes (Climate Council of Australia), 2014

CSIRO's CCA work delivers greater certainty around issues relating to the planning and implementation of climate change adaptation measures. However, the long time horizons involved, and the relatively early stage of implementation make it difficult to assess the full impact of the projects. Nevertheless, the use of CCA as set out at Section 3.5 clearly points to the significant role the climate projections play in assisting NRMs and partner countries to assess options for climate adaptation measures.

The impact and benefits of the CCA work extend well beyond the client (Australian Government) and the direct stakeholders (NRM Clusters and partner countries). Others to benefit include regional organisations, State and local governments, businesses, land holders, interest groups, local communities and the public. CSIRO's CCA work has delivered significant benefits.

The PACCSAP science established a new benchmark for IPCC Working Group 1 (physical climate) science in the western tropical Pacific. The large suite of new peer-reviewed publications generated by PCCSP/PACCSAP point to the robustness and credibility of science. New and highly productive science networks have been established across the region involving partner PIC metrological offices, regional organisations, CSIRO, BoM and other partners. It has been variously used at regional, national and sub-national levels in partner PICs to inform sectoral planning and to raise community awareness of climate impacts. It has also informed various national governments as part of the international negotiations under the UNFCCC process. Most importantly, this new benchmark has informed and is aligned with the most recent IPCC 5th Assessment Report, thereby providing a critical knowledge resource for partner PICs to draw on as part of the ongoing international negotiations through the UNFCCC process.

The impacts of the CCA work and the CCiA RM and the PACSAPP projects include:

Targeted adaptation actions based on robust climate projections

The climate projections and web tools allow governments, resource management and planning agencies, businesses and the broader community to more accurately identify areas of climate change impact and risk and to design adaptation strategies/works that are both proportional to the level of threat and which offer the best return on investment. Such adaptation measures can partially offset/counter the social, economic and ecological costs of the deleterious impacts of climate change.

Assessing and incorporating adaptation measures to address the physical impacts of climate change (and extreme weather events) is vital for the long-term sustainable growth of a business. For instance, Adelaide Airport Ltd (AAL) the airport lessee and operating company for Adelaide Airport has stated that it:

> *recognises its responsibility to ensure that its assets are designed and maintained to withstand future climatic conditions, so that the organisation can continue to deliver excellence in service into the future. …. AAL has used the latest available climate science and projections from the Intergovernmental Panel on Climate Change (IPCC) and the Australian Government's national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It has identified key climate risks and, where the existing comprehensive controls and operational plans required additional mitigation actions, these have been specified and will be integrated into key business documents and guidance.*[19]

A key achievement of the PACCSAP science component was development of new climate projections for individual partner PICs for the 21st century based on CMIP5, incorporating components that were not present in the previous generation of CMIP3 models. The core components of the CMIP5 models have also undergone some development, meaning that some can be used for new purposes such as examining ocean chemistry reactions. These projections are aligned with IPCC AR5 (IPCC 2013) emissions scenarios and include analysis, interpretation and communication of the projected changes in key atmospheric variables (including mean temperature and rainfall, and extreme temperature and rainfall and drought). The results have been published as discrete, individual 'country climate' chapters in *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports*[20] and standalone country brochures (available at www.pacificclimatechangescience.org).

The work evaluated how well CMIP5 models simulated seasonal and annual mean and extreme climatology compared with observations. This enabled analysis of the key drivers of projected change and assessment of confidence (based on expert judgement) in the projections; research into the simulation of climate processes by models; and the use of this evaluation to convert raw model outputs into tools for future planning.

[19] Commonwealth of Australia, *'National Climate Resilience and Adaptation Strategy'* 2015
[20] Op.cit

Global climate models have relatively coarse spatial resolution, meaning that there may be considerable deviation from such large-scale projections at smaller scales due to island topography and associated micro-climates. Using dynamical downscaling techniques, detailed spatial information of the climate change signal was able to be incorporated into the updated projections for relevant partner PICs.

Targeted resilience preparations to protect against extreme events

Deloitte Access Economics has recently completed an assessment of the cost of natural disasters in Australia, highlighting the need building resilience to natural disasters[21]. Their report found that:

> *…. the total economic cost of natural disasters is growing and will reach $39 billion per year by 2050. These costs include significant, and often long-term, social impacts, including death and injury and impacts on employment, education, community networks, health and wellbeing.*

The report went on to note that:

> *Further investment in disaster resilience is essential to lessen the forecast increase in costs. This includes physical measures, such as resilient infrastructure, and community measures, such as preparedness programs.*

While not all natural disasters are linked to climate change (i.e. earthquakes, volcanic eruptions) many are, especially in Australia and the South Pacific. The climate projections and web tools are an invaluable source of information in helping both governments and communities reach informed decisions around investment in resilient infrastructure and preparedness programs. These can potentially:

— reduce the direct (such as reduced damage to property and infrastructure) and indirect (such as disruptions to business) costs of natural disasters

— reduce the intangible costs of impacts on health and wellbeing, employment and community connectedness (these are estimated to be as great, or greater than, tangible costs - but are difficult to price)

Enhanced planning decisions

Informed planning decision making (at all levels) is facilitated by access to the climate projections and web tools. Better planning decisions (in relation to coasts; cities and the built environment; agriculture, forestry and fisheries; water resources; natural ecosystems; health and wellbeing; and disaster risk management) will result in significant economic gains in terms of costs avoided. These costs can be tied to international analysis (i.e. IPCC).

Adaptation captures a wide range of possible planning policies and regulations, actions and choices (such as building codes; environmental protection legislation; strategic investment in built infrastructure (i.e. seawalls); protection of natural infrastructure (i.e. sand dunes); education and information that change behaviour or adjustment of market prices (i.e. insurance premiums); and changes in business management practices (i.e. shifting planting dates).

The valuable role climate projections can play in planning decisions is exemplified in the study undertaken as part of *the Green Climate Fund Readiness and Preparatory Support (Activity Area 4) for Vanuatu (Readiness Grant Agreement VUT-RS-001)*[22]. The approach was to adopt and modify the use of well-established methodologies for socio-economic benefit analysis in relation to planning decisions to incorporate climate information services. While the project focussed on initial application in Vanuatu, there is potential for application more broadly within partner PICs.

The importance of better informed planning and decision making is exemplified by coastal zone planning. The impact of climate change is likely to be more tangible and immediate in coastal areas (see **Box 2**) and the potential scope for cost savings through relatively simple planning decisions is significant.

[21] Deloitte Access Economics; The Australian Business Roundtable for Disaster Resilience & Safer Communities Building resilience to natural disasters in our states and territories; November 2017

[22] New th D, Gunasekera D and Gooley G. (2017) *Framework for Undertaking Socio-Economic Cost-Benefit Analysis for Climate Information Services in the Western Tropical Pacific. Report to the Green Climate Fund Readiness and Preparatory Support (Activity Area 4) for Vanuatu (Readiness Grant Agreement VUT-RS-001).* Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

BOX 2 COASTAL PLANNING CONSIDERATIONS

Coastal assets include both built and natural assets.

- built assets include residential and commercial buildings; ship terminals, ports and harbours; bridges; beach protection works such as groynes and jetties; artificial reefs; and navigational channels
- natural assets/resources (e.g. landforms, flora, fauna, waterways, wetlands) which produce goods and services.

Climate change exacerbates the existing risks to coastal areas which are exposed to sea-level fluctuations, coastal inundation and river flooding from extreme weather events. This exacerbates the risk to households and settlements; businesses; infrastructure and essential services; and industry such as fishing and tourism. The climate projections facilitate effective planning and adaptation measures to counter:

- rising sea levels which increase the risk of damage caused by storm surges, exacerbating coastal erosion, with the risk of damage to coastal infrastructure, removal of sediment from beaches and loss of land
- increased flooding and inundation of low-lying coastal settlements
- risks arising from other variables and hazards, such as ocean acidification, warmer sea surface temperatures, bushfires, increased wind speeds, and the increased frequency and intensity of heatwaves

SOURCE: FROM DEPARTMENT OF ENVIRONMENT WEBSITE HTTP://WWW.ENVIRONMENT.GOV.AU/CLIMATE-CHANGE/CLIMATE-SCIENCE-DATA/CLIMATE-SCIENCE/IMPACTS

Impact linkages

Table 2 shows the linkages between impacts realised by the projects to date and CSIRO's impact categorisation framework. The categories of impact are:

- **Economic impact** - National economic performance; Trade and competitiveness; Productivity and efficiency; Management of risk and uncertainty; Policies and programs; New services, products, experiences and market niches; Animal health and prosperity; Securing and protecting existing markets
- **Environmental Impact** - Air quality; Ecosystem health and integrity (natural capital); Climate; Natural hazards mitigation; Energy generation and consumption; Land quality; Aquatic environments; Built environments
- **Social Impact** - Health and wellbeing; Access to resources, services and opportunities; Quality of life (material security and livelihoods); Safety; Security (e.g. cyber, biological, civil and military); Resilience; Indigenous culture and heritage; Innovation and human capital (creativity and invention); Social cohesion (social inclusion, social capital and social mobility).

TABLE 2 IMPACT ALIGNMENT WITH CSIRO CATEGORISATION

Outcomes/impacts	Economic impact	Environmental Impact	Social Impact
Better targeted adaptation actions	◑	◑	◔
Reduced economic losses	●	◔	◑
Better targeted resilience to extreme events	●	◔	◑
Enhanced planning decisions	◑	◑	◑
Reduced health/social costs	◑	○	●
Reduced infrastructure losses	●	◑	◑
Improved use of resources	●	◔	●

○ = NO IMPACT ◔ = MINIMALL IMPACT ◑ = SIGNIFICANT IMPACT ● = MAJOR IMPACT

SOURCE: ACIL ALLEN CONSULTING

3.7 Potential future impacts

The impacts arising from both projects will take time to become manifest given the long-term planning horizons involved with climate adaptation. Furthermore, it is difficult to predict how long it will take before the tangible benefits appear – CSIRO and BoM worked for 27 years on the creation of climate knowledge and only shifted focus to the overt application of knowledge in 2016. However, the science is being drawn on increasingly to inform various climate adaptation planning and associated decision-making and there is some evidence that the projections data is beginning to be 'mainstreamed' into community, government and business decision making. For example, NRM relationships continue to strengthen and grow, with NRMs driving further and more detailed use of data sets at the local level. This includes:

— outreach with landholders using climate projections to communicate with landholders in a way that facilitates a conversation with climate sceptics to address issues around '*what your farm might look like in the future*'

— specific *Climate Projections Training* workshops to enable regional practitioners to use climate projections across many applications. One participant noted that:

> *…. incredible opportunity for practitioners to learn how to do climate projections. …. we had representatives from key agencies tackling climate change issues such as planning for drought water resources, water resource planning, impact on catchments and estuaries, fire management and risk, city sustainability, sea level rise, potential impacts on agricultural industries in our region, and impacts on crop yields and pasture production (including policy level).*[23]

PICs are incorporating the projections into their coastal planning approaches through targeted training activities which draw upon PACCSAP data (i.e. the *Climate Resilient Tonga professional development program*[24]). Local governments in Australia are using the projections to inform coastal zone planning and development decision making. For example, the *Hobsons Bay City Council Climate Change Adaptation Plan*[25] draws on the CSIRO's work in framing the implementation actions in its plan. In addition, the scientific knowledge generated by the PACCSAP project is informing research directly relevant to Australia's national interest, given both the western tropical Pacific and Australia for the most part share the same climate system.

PACCSAP outcomes have provided the impetus to move to the development of new resources to provide guidance materials for sectors as to how to develop and apply climate change science data and information for climate vulnerability and risk assessments. This was in part facilitated by CSIRO stepping to breach the gap in aid funding from 2014 to 2016 and deploying its discretionary resources to drive outreach and application of the projections. Based on the success of CSIRO's efforts, the 'business model' for delivering Australian overseas development aid shifted profoundly from generating scientific knowledge to towards building trusted partnerships and collaborative relationships focussed on application of the projections at the national/sub-national/sectoral levels.

PACCSAP capability and learnings have generated new business opportunities such as an ADB project to develop a Regional Climate Consortium and data portal for Asia-Pacific. This project was initially based on case studies in three pilot countries - Thailand, Indonesia and The Philippines. It was successfully completed to the point that a consortium across the three partner countries was established, along with a prototype portal, which integrated inter-active functions linking regional climate projections data via tailored guidance materials for sectoral risk assessment applications.

The Commonwealth Government (Environment Department) is developing 'climate risk master classes' to incorporate greater consideration of climate change projections and adaptation strategies into public/government policy making processes. The financial and broader business sector is showing interest in the use of data sets to 'test' the robustness of investment decisions and long-term profitability, particularly as 'triple bottom line reporting' becomes more prevalent in the business sector. In addition, the Association of Chartered Certified Accountants (ACCA) and actuaries are urging consideration of climate issues/risk in investment decisions and accounting as an important step towards the better allocation of capital[26].

The above examples clearly show the potential for CSIRO's CCA work to be 'mainstreamed' and illustrate the scope for CSIRO to develop a significant market/business opportunity around the provision of tools and services in this area. CSIRO is better placed to capture this market (in terms of background IP, expertise, better understanding of the climate projections and adaptation tools) and to deliver a more comprehensive product than its potential competitors. CSIRO's success in capturing work (at cost) internationally in Malaysia, Vietnam, and the Philippines points to the esteem with which the work is held and to the market potential.

[23] Kay Iene Parker, Southcoast NRM: in relation to Climate Projections Training workshop, Albany, June 2018
[24] https://coastadapt.com.au/sites/default/files/case_studies/CS87_Resilient_Tonga.pdf
[25] http://www.hobsonsbay.vic.gov.au/files/assets/public/documents/pdfs/council/have-your-say/sustainability-framework/climate_change_adaptation_plan_15_april_13.pdf
[26] https://www.cfoinnovation.com/accounting-compliance/acca-companies-must-be-aware-financial-impact-climate-related-risk

4. Counterfactual and Attribution

4.1 Counterfactual

There are no other research groups in Australia with the capability and data access to undertake the full range of research and development essential to delivering the two CCA projects considered in this case study.

State governments could undertake this work at a local level; but:

— inconsistency and patchiness issues would prevent aggregation to national level

— their coverage and capacities would not result in comprehensive products

— climate issues don't respect jurisdictional boundaries (thus the focus on NRM Clusters).

At the international level there are 'competitors' including the UK Met Office and the US National Centre for Atmospheric Research (NCAR) with the capacity to undertake the South Pacific work, but they have:

— limited expertise in the region

— limited history in working with PICs

— are not necessarily party to regional alliances or integrated with the relevant regional organisations.

However, the work is very much a collective effort - the outcomes reflect the joint efforts of CSIRO and its partners and stakeholders.

CSIRO is best positioned to deliver a comprehensive, robust and 'fit for purpose' product that fully meets user' needs.

Furthermore, the holistic outcomes from both projects were highly dependent on CSIRO's capacity to act as a 'trusted advisor' with the capacity to deliver independent, quality controlled work that is consistent (both spatially and temporally) at both the scope and scale required. It is unlikely that there would be climate projections for the PICs and some parts of regional Australia if CSIRO had not undertaken this work.

4.2 Attribution

Climate change adaptation work involves at long-term planning horizons (5, 10 and 20 year timelines/horizons) and impacts will take time to emerge. While the benefits from CSIRO's work are clearly significant, it is difficult to quantify those benefits which can be directly attributed to the CCA projects. In the absence of other data, one approach might be to adopt the ratio of the value of CSIRO inputs against total inputs – that would give an attribution of around 11 per cent to CSIRO.

However, given the nature of the projects and the work undertaken, this is not considered an accurate reflection (especially in relation PACCSAP). There are several factors that need to be considered:

— BoM was a key partner and contributed key inputs to the project (BoM funding and co-contributions not included in **Table 1.1**)

— stakeholders, in particular the NRM Clusters and PIC agencies, made significant contributions, especially in the latter stages of the work

— the projections and adaptation models from both projects reflect heavily applied science and CSIRO has value added to many of inputs i.e. the datasets

In the absence of concrete data, ACIL Allen believes it reasonable to attribute 30 per cent of the benefits from the two projects to CSIRO.

5. Evaluating the Impacts

Modelling the economic consequences of climate change is complex and hampered by limited current knowledge base for the impacts. Recent work[27] by The Organisation for Economic Co-operation and Development (OECD) concludes that it is only possible to model a subset of these potential impacts and capture some of the relevant uncertainties. The OECD found that GDP losses in 2060 for the selected impacts covered in the analysis are projected to amount to almost 1 per cent for Australia[28].

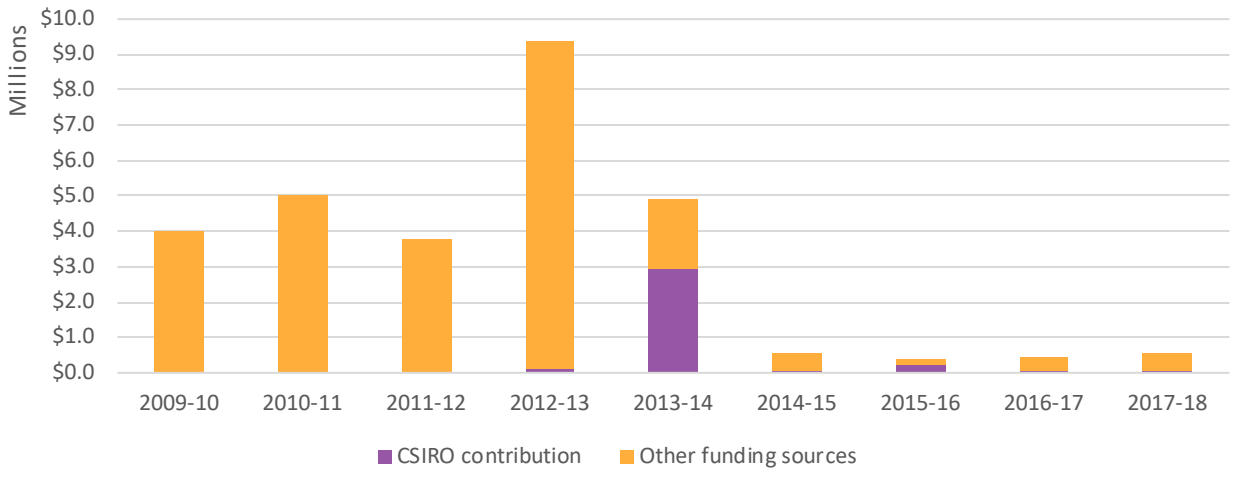
The Deloitte Access Economics cited above found that the total economic cost of natural disasters will grow from is grow from $18.2 billion to $39 billion per year by 2050 (2016 figures). The intensity and cost of many of these natural disasters will be exacerbated by climate change (and potentially ameliorated by adaptation measures).

5.1 Cost-Benefit Analysis

Costs

R&D Costs: The costs of CCA projects considered were shown previously at **Table 1.** CSIRO made an in kind co contribution of $3.455 million (11 per cent) towards the total CCA project budget of $29.103 million. Costs associated with the CCiA-RM project totalled $4.281 million, while those for the PACCSAP project were $21.517 million. The year-by-year combined R&D costs of the CCA projects are shown in **Figure 2**.

FIGURE 2 CLIMATE CHANGE ADAPTATION PROJECT R&D COSTS, 2009-10 TO 2017-18



SOURCE: CSIRO

Adaptation costs: For simplicity, in the cost-benefit analysis it is assumed that the cost of adaptation measures that will be implemented by NRM groups or others in Australia will be the same with or without the CCiA-RM project. However, as is explained below, it is assumed that the adaptation measures will be more effective in reducing the economic costs of climate change with the CCiA-RM project than without the project.

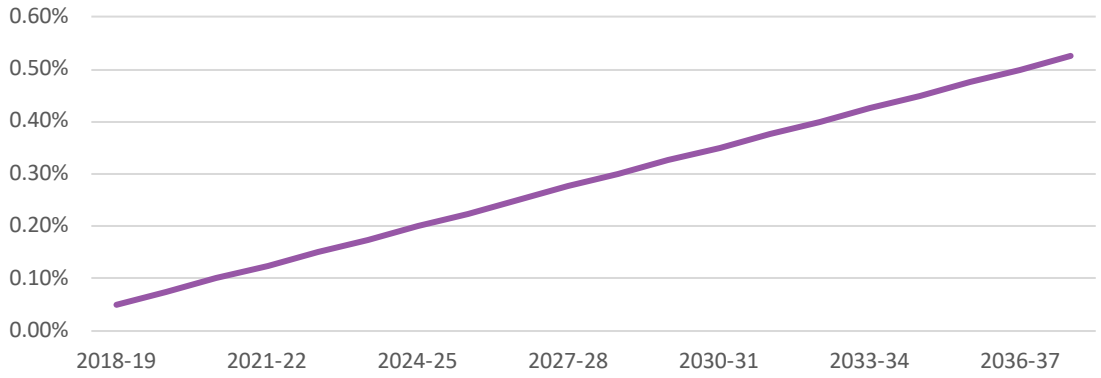
[27] OECD (2015), The Economic Consequences of Climate Change, OECD Publishing, Paris, https://doi.org/10.1787/9789264235410-en.
[28] Sectors included - Agriculture; Coastal zones; Extreme events; Health; Energy demand; Tourism demand; Water stress; Human security

Benefits

ACIL Allen has estimated the benefits of the CCiA-RM project to Australia over the next 20 years (that is, from 2018-19 to 2037-38). The analysis period was chosen after considering the duration over which the project's outputs and findings will likely influence the design and implementation of NRM adaptation activities and the persistence of the benefits that flow from these activities.

As discussed previously at Section 5, according to the 2015 OECD report *The Economic Consequences of Climate Change: The damages from selected climate change impacts to 2060*[29], damages from selected climate change impacts are likely to reduce Australia's GDP by approximately 0.9 per cent in 2060. The OECD's estimates (more recent) are more conservative in comparison to earlier work (i.e. work by Garnaut or Stern). In the cost-benefit analysis, for simplicity a linear relationship between time and the magnitude of climate change GDP impacts is assumed (see **Figure 3**).

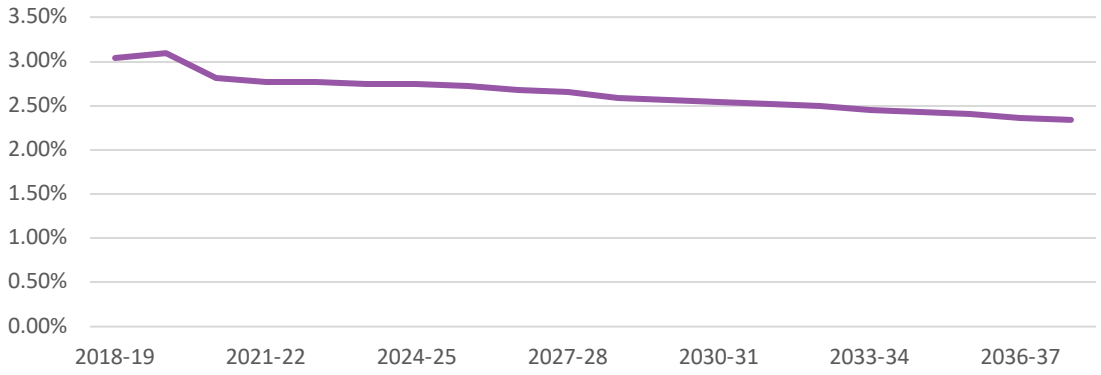
FIGURE 3 REDUCTION IN AUSTRALIA'S REAL GDP DUE TO CLIMATE CHANGE, 2018-19 TO 2037-38



SOURCE: ACIL ALLEN CONSULTING

In 2016-17 (the latest financial year for which data is available), Australia's real GDP was approximately $1.694 trillion. Projected Australian real GDP growth to 2037-38, according to ACIL Allen's macroeconomic modelling, is shown in Figure 4.

FIGURE 4 PROJECTED AUSTRALIAN ANNUAL REAL GDP GROWTH, 2018-19 TO 2037-38

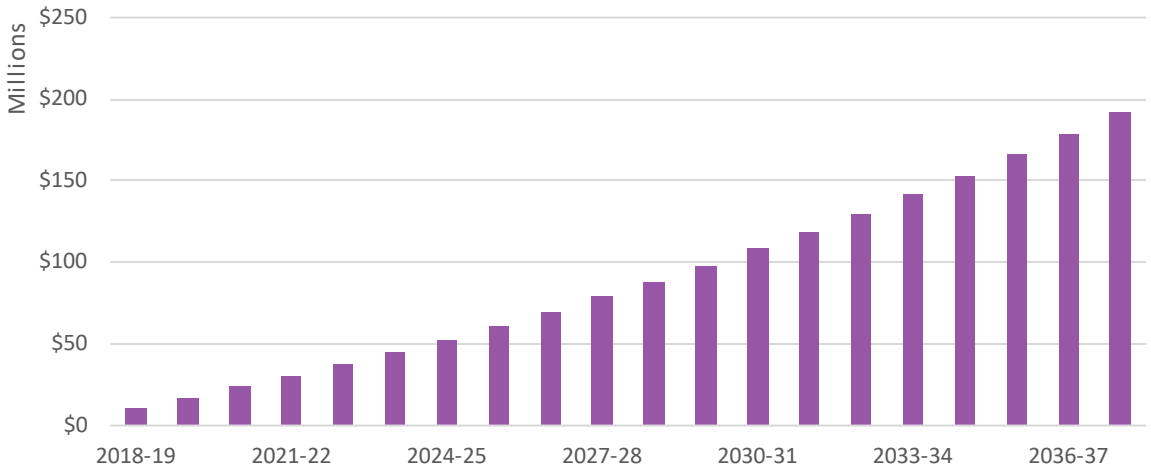


SOURCE: ACIL ALLEN CONSULTING

[29] Op cit

In the cost-benefit analysis, it is assumed that 25 per cent of the economic costs of climate change can be reduced by adaptation. It is also assumed the CCiA RM project results in a 5 per cent increase, relative to counterfactual position, in the effectiveness of adaptation activities to ameliorate the economic costs of climate change in Australia. That is while adaptation would have occurred, it would have been less effective, less timely and more expensive **Figure 5** shows the benefits of the CCiA-RM project in terms of the projected reduction in the economic costs of climate change in Australia from more effective adaptation, based on the assumptions set out above[30].

FIGURE 5 REDUCTION IN THE ECONOMIC COSTS OF CLIMATE CHANGE IN AUSTRALIA DUE TO CSIRO'S CCIA-RM PROJECT, 2018-19 TO 2037-38



SOURCE: ACIL ALLEN CONSULTING

As discussed previously in Section 4.2, 30 per cent of the benefits of the CCiA-RM project are attributed to CSIRO.

For the purposes of the cost-benefit analysis, the PACCSAP project benefits have not been included as these accrue almost exclusively to the PICs, and not directly to the Australian economy.[31] The benefits to Australia are primarily intangible – enabling the client Department/agencies to build their international relations/aid capacity; and possibly enhancing CSIRO's capacity to market its expertise in this area.

In addition, ACIL Allen has not quantified the social and environmental benefits of the CCiA-RM and PACCSAP projects due to the lack of robust supporting data.

Assessment of benefits against costs

Under a 7 per cent real discount rate, the present value (PV) of total R&D costs across the CCiA-RM and PACCSAP projects is $48.7 million in 2018-19 dollars. The PV of CSIRO R&D costs across both projects is $4.9 million in 2018-19 dollars.

The PV of total project benefits to Australia under the same discount rate is projected to be approximately $739.6 million in 2018-19 dollars, while the PV of project benefits attributable to CSIRO is projected to be approximately $221.9 million in 2018-19 dollars.

The combined net present value (NPV) of the two projects is therefore projected to be $691 million in 2018-19 dollars, while the benefit-cost ratio (BCR) is estimated to be 15.19. The former is obtained by subtracting the present value of total R&D costs from the present value of total project benefits, while the latter is obtained by dividing the present value of total project benefits by the present value of total R&D costs.

[30] The estimated 25 per cent reduction in economic costs, and 5 per cent increase in effectiveness err on the conservative – for instance the 2010 review of the Climate Adaptation Flagship (Assessment of CSIRO Impact & Value: Report prepared as input to CSIRO's Lapsing Program Review; ACIL Tasman) uses figures of up to 50 per cent and 10 per respectively for these parameters.

[31] There are potentially indirect benefits to Australia. For example, if a lack of climate information for the Pacific led to poor adaptation decisions in PICs, then this could lead more severe future crises that Australia might need to contribute to.

From CSIRO's perspective, the net benefit-investment ratio (NBIR) of the two projects – calculated by dividing the present value of benefits attributable to CSIRO by the present value of CSIRO's R&D costs – is estimated to be 45.54.

Sensitivity analysis

In the central case of the cost-benefit analysis, it is assumed that 25 per cent of the economic costs of climate change can be reduced by adaptation. If this proportion is 40 per cent, the BCR will increase from 15.19 to 24.30, while the NBIR will increase from 45.54 to 72.86. Conversely, if this proportion is 10 per cent, the BCR will decrease to 6.08, while the NBIR will decrease to 18.21.

In the central case of the cost-benefit analysis, it is assumed that the CCiA-RM project results in a 5 per cent increase in the effectiveness of adaptation activities to ameliorate the economic costs of climate change in Australia. If this proportion is 10 per cent, the BCR will increase from 15.19 to 30.38, while the NBIR will increase from 45.54 to 91.07. Conversely, if this proportion is only 3 per cent, the BCR will decrease to 9.11, while the NBIR will decrease to 27.32.

In the central case of the cost-benefit analysis, a 7 per cent real discount rate was used. Under a 4 per cent real discount rate, the BCR will increase from 15.19 to 25.61, while the NBIR will increase from 45.54 to 72.71. Conversely, under a 10 per cent real discount rate, the BCR will decrease to 9.32, while the NBIR will decrease to 29.49.

In the central case of the cost-benefit analysis, it is assumed that 30 per cent of project benefits is attributable to CSIRO. With a 50 per cent attribution rate, the NBIR will increase from 45.54 to 75.89. Conversely, the NBIR will decrease to 30.36 with a 20 per cent attribution rate.

5.2 Externalities or other flow-on effects on non-users

Positive externalities will accrue to the broader community through application the projections developed for guiding adaptation measures to counter the deleterious impacts of climate change. The social economic and environmental impact of climate change is significant and affects both government and the broader community at all levels. Both projects generate significant externalities that accrue to the broader community.