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A conceptual framework for adoption of conservation agriculture in South Pacific Island countries

O.E. Juttner-Melland[1,2], D.L. Antille[1,3,*], M. Monjardino[4], S.A.T. Fulton[1,5], J. Palmer[6], F. Tacconi[6], P.A. Misiewicz[1,3] and R. Barboza da Silva[7]

[1]CSIRO Agriculture and Food, Canberra, Australian Capital Territory 2601, Australia
[2]Australian National University, Research School of Biology, Canberra, Australian Capital Territory 2601, Australia
[3]Harper Adams University, Engineering Department, Newport, Shropshire TF10 8NB, United Kingdom
[4]CSIRO Agriculture and Food, Adelaide, South Australia 5064, Australia
[5]University of Tasmania, Tasmanian Institute of Agriculture, Burnie, Tasmania 7320, Australia
[6]CSIRO Agriculture and Food, Brisbane, Queensland 4067, Australia
[7]Universidade Estadual Paulista, Faculdade de Ciências Agrárias do Vale do Ribeira, Departamento de Agronomia e Recursos Naturais, Registro, São Paulo 11900-000, Brazil
[*]Correspondence: Dio.Antille@csiro.au

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Abstract. There is an opportunity, and an urgent need, for transformational change of the current farming systems in South Pacific Island countries (SPIC) to improve soil security, and therefore food, nutrition and income security, and to better adapt to climate change. Tillage-based systems are dominant across some SPIC and reliance on tillage may increase if the use of broad-spectrum herbicides is banned. Increased reliance on tillage, or its inappropriate use in fragile soils, may exacerbate soil degradation processes and lead to increased food insecurity in the region. A potential solution to addressing these problems is conservation agriculture (CA), a regenerative and sustainable farming system that promotes minimum soil disturbance, the maintenance of permanent soil cover and diversification of crop species, and soil conservation. The drivers for and barriers against uptake of CA in SPIC are not fully understood nor are they well documented, which makes it difficult for policymakers to devise effective measures and implement strategies for increased adoption. A conceptual framework to represent CA adoption in the SPIC context is proposed. The framework combined the ADOPT modelling tool (which predicted the time taken to adopt CA and the peak adoption level) with a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis (which synthetised present state and future potential based on expert knowledge and a literature review of CA). ADOPT modelling predicted that 45% peak adoption of CA would be reached after 23 years; however, removing key barriers to adoption could increase uptake to 62% and accelerate it by 13.2 years, reducing the timeframe to fewer than 10 years. Hence, the importance of developing policymakers and leaders' awareness and understanding of the benefits of CA to facilitate capacity building and drive CA adoption. The developed framework can be tailored for specific target audiences, including policymakers, and research and extension officers, to inform a pathway for long-term CA adoption.

Key words: agricultural development; climate change adaptation; farming systems resilience; sustainable intensification; technology adoption; smallholder ADOPT; SWOT analysis.

Used abbreviations:

ACIAR	Australian Centre for International Agricultural Research (Australian Government)
ADOPT	Adoption and Diffusion Outcome Prediction Tool
CA	Conservation Agriculture
CAAAP	Conservation Agriculture Alliance for Asia-Pacific
CREA	Consorcios Regionales de Experimentación Agrícola
DFAT	Department of Foreign Affairs and Trade (Australian Government)
FNU	Fiji National University
GM	Genetically Modified
SPIC	South Pacific Island Countries
SWOT	Strengths, Weaknesses, Opportunities, and Threats
USP	The University of the South Pacific

INTRODUCTION

Food and nutrition security are increasingly important issues in South Pacific Island countries (SPIC) as production demands increase and the effects of climate change on food systems and soil sustainability become more prominent. The South Pacific is a diverse, developing region, with a strong reliance on subsistence agriculture to provide for their island communities (Georgeou et al., 2022). Current methods of farming in mechanised or semi-mechanised systems in SPIC rely on conventional tillage (Mrema et al., 2015), and this reliance is expected to increase in response to a push from SPIC governments towards herbicide-free agricultural production (Hicks, 2000). The use of conventional tillage, which involves primary and secondary tillage operations for crop establishment, can exacerbate soil degradation due to erosion and other processes (e.g., driven by the effect of soil compaction), the decline of soil fertility and soil carbon through oxidation of soil organic matter (Kayombo & Lal, 1993; Mrema et al., 2015; Lal, 2015; Dang et al., 2018). Given the vital link between soil quality, production system resilience, and food and nutrition security (Susumu et al., 2022), there is an urgent need for transformational change of the current farming systems in SPIC. A faster transition to sustainable intensification, climate-smart farming, and in some circumstances nature-based solutions, is required for improved systems' resilience and efficiency (Lal, 2015; Friedrich & Kassam, 2016). This transition should ensure that a linkage between sustainable farming and soil management is maintained with the United Nations Sustainable Development Goals (https://sdgs.un.org/goals; accessed 22 July 2025). Soil protection is an important consideration for climate change mitigation (FAO, 2015; Amelung et al., 2020). Therefore, sustainable methods of farming need to be explored to advance the social, economic, and environmental security of this region. Whilst South Pacific indigenous knowledge of agriculture includes sustainability and the preservation of food systems (Spencer et al., 2020), the extent to which this body of knowledge is used in present days varies between areas and countries, but it is not very significant on a broad Pacific scale (Mrema et al., 2015).

An approach which has the potential to intensify under-performing agricultural systems and can be integrated with indigenous practices to combat soil degradation is conservation agriculture (CA). Conservation agriculture is a regenerative and sustainable approach to cropping, implemented in all continents (Kassam et al., 2009; Kassam et al., 2022), albeit with various degrees of success (Giller et al., 2009; Tittonell et al., 2009; Erenstein et al., 2012; Brown et al., 2017; Corbeels et al., 2020; Descheemaeker, 2020). This method of farming is based on the three interlinked principles of minimising, and where possible avoiding, soil disturbance by reducing tillage and machinery traffic, maintaining year-round soil cover, and practicing crop rotations following best management practices (FAO, 2017). When properly implemented, and in suitable contexts, CA practices can significantly reduce soil erosion and runoff, improve soil condition and soil functions, and increase crop yields (Friedrich & Kassam, 2012). Adoption of such practices is known to promote cost savings from increased labour- and energy-use efficiencies, as shown by research and on-farm experience when shifting from conventional systems to CA (Descheemaeker, 2020; Govaerts et al., 2005; Verhulst et al., 2012; Pittelkow et al., 2015; Sun et al., 2020¸ Kassam et al., 2022). On the downside, CA may rely on the use of herbicides to greater extent compared with conventional tillage systems (Friedrich & Kassam, 2012). However, management approaches (e.g., Friedrich, 1996) and technological developments such as machine vision for real-time weed recognition for spot-spraying, precision inter- and intra-row hoeing, and precision tillage are becoming available, and they have potential to avoid such impacts on the environment (O'Dogherty et al., 2007; Melland et al., 2016; Baillie et al., 2018; Andrade-Sanchez et al., 2019).

On a broader scale, and within the South Pacific context, CA has potential to co-deliver food and economic security, and improved nutrition across the region by narrowing yield gaps of staple crops, and by increasing farming systems profitability and resilience. However, this remains largely unquantified, with some exceptions (e.g., Antille et al., 2023; Meier et al., 2023; De Kock et al., 2026). Adoption of CA in the South Pacific is almost non-existent (Mrema et al., 2015; Antille et al., 2022), and the reasons for such low rate of adoption are not fully understood, especially in the region's context. Possible reasons may be the extent of mechanisation adoption, access to technology and technical advice, the size of farming enterprises and land tenure systems, biophysical characteristics such as soil type and landscape, and cropping systems (Ullah & Anad, 2007), and agricultural support policies and institutions that, through intervention (e.g., subsidies), may distort the farm sector's resource use (Anderson, 2024). For example, such distortion has been highlighted as a key factor in Fiji, where a significant proportion of resources are employed by the sugar and livestock producers at the expense of other farmers and producers of non-farm products (Anderson, 2024). Agricultural systems vary across SPIC from root and tuber crop-based systems to vegetable, tree and other plantation crops (e.g., coconut, bananas, coffee), and legumes, rice, and sugarcane (mainly in Fiji). Livestock and forestry also play an important role in South Pacific Island countries (FAO, 1998; Reddy, 2007; SPC, 2011).

Overall, there is heavy reliance on management practices perceived as unsustainable (e.g., soil tillage, poor soil cover, crop residue burning, including burning of plant cane prior to harvest, limited or no crop rotation, and insufficient soil nutrient replenishment through application of fertilisers or organic amendments, and lime) (Antille et al., 2022; Meier et al., 2023; Susumu et al., 2022; Antille et al., 2026).

Specifically for Samoa, clearance of natural forest for cultivation of root or tuber crops is common; the land is first cleared, and it may be cultivated for about five consecutive seasons after which it may be set-a-side to let the forest regrow over a similar period. Whilst during such period the land remains under vegetation cover, the vegetation structure and composition is often rather different from those of the original forest, with the associated loss of habitat and biodiversity. Such practice could be avoided if the existing arable land was appropriately managed and soil fertility and soil carbon rundown were prevented. An overview of key characteristics of typical agricultural systems in SPIC is provided as Supplemental Material S1 (Table 1S). We argue that the potential benefits of CA in the South Pacific region are time sensitive, and that cropping land may degrade to an unrecoverable extent if adoption of CA was delayed for too long. Such delay in the adoption of practices under the CA umbrella can have adverse effects on the farming systems resilience and long-term food security.

The objectives of the work reported in this article were to: (1) identify the drivers and barriers for CA adoption and reasons conducive to dis-adopting CA by employing Smallholder ADOPT; (2) formulate informed solutions to the barriers identified through a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis; and (3) encapsulate the broad understanding of present state and potential future of CA in the South Pacific in a conservation agriculture adoption framework, underpinned by expert knowledge, in-country consultation and literature review of CA in the SPIC context.

MATERIALS AND METHODS

Framework development

Existing literature both in the South Pacific and foreign contexts was reviewed, and a preliminary list of drivers, barriers, solutions and disadoption factors was created. Feedback was then sought through consultations with CA experts in the smallholder and semi-commercial growers' contexts, and with experience in the Pacific and other developing nations. The framework was screened through experts' consultation and subsequently refined by corroboration with established literature and accepted by the experts. The initial consultation process involved 48 participants from Fiji and Samoa and involved 18 academic, research and extension, intergovernmental and farmers-led organisations, government agencies, growers and machinery dealers. The subsequent screening process was undertaken with 11 Australia-based experts with career long (>30 years) experience in international agriculture for development in Africa, South Asia, South America and the Pacific, and who represented academic and research, and non-profit international organisations, independent consultants and government agencies. All of these organisations (academic, research and extension, intergovernmental and non-profit international institutions) operate globally and have significant presence across 27 countries and territories in the Pacific region. The information derived from this extensive consultation process was used to guide parametrization of the Smallholder ADOPT model as well as informing the SWOT analysis and the CA adoption framework.

Adoption prediction

This study applied the Adoption and Diffusion Outcome Prediction Tool (henceforth ADOPT, https://adopt.csiro.au/, accessed 23 July 2025), a scenario-based modelling tool used to estimate both the likely peak level of adoption of an innovation and the time required to reach peak adoption (Kuehne et al., 2017). The Smallholder ADOPT beta version (Brown et al., 2016) was used in this study to reflect the dominance of smallholder farming systems across the South Pacific (Sherzad, 2018).

Smallholder ADOPT operationalises adoption dynamics using 22 multiple-choice questions with stepwise response categories (e.g., from 'almost none' to 'almost all') (Supplemental Material S1, Table 1S). These questions characterise four domains, as illustrated in Fig. 1: the relative advantage of a given innovation, the relative advantage for the population, the learnability characteristics of the innovation, and population-specific influences on the ability to learn about the innovation. Learnability-related domains influence the time to peak adoption, while relative advantage domains influence both time to peak and peak adoption level. Responses are internally translated into numeric values and combined through predefined functional relationships to generate outputs: years to near-peak adoption, peak adoption (%), and an S-shaped cumulative adoption curve.

Model parameterisation followed standard ADOPT practice using discussion-based expert elicitation, typically through collaborative workshops where participants reached consensus responses for a defined target population. To assess the effect of addressing adoption barriers, a *status-quo* scenario was first defined, followed by 'barrier removed' scenarios in which selected barrier-related questions were adjusted and subsequently correlated with one or two questions; however, not all barriers were represented in the model. The removal of barriers was then simulated by answering the questions identically to the status quo, except for assigned 'barrier questions', which were answered as if there was no barrier present. ADOPT was used here as a semi-quantitative, exploratory tool informed by expert judgement rather than primary empirical data; therefore, results represent plausible adoption trajectories rather than predictive estimates.

SWOT analysis

A Strengths, Weaknesses, Opportunities, and Threats (henceforth 'SWOT') analysis was undertaken by synthesising the information derived from the proposed framework and the ADOPT modelling. Experts were also consulted in the production of the SWOT, but less extensively than for the development of the framework, as the SWOT drawn information from the framework. Generally, the SWOT analysis should give farmers (stakeholders) the essential assurance that moving from conventional cropping management to a sustainably intensified conservation (or regenerative) approach could be a financial 'no regrets' strategy. The CA literature review suggests that in a three to five-year period it is possible to have identifiable improvements in soil natural capital and cropping system resilience showing a trend that should continue over a longer time.

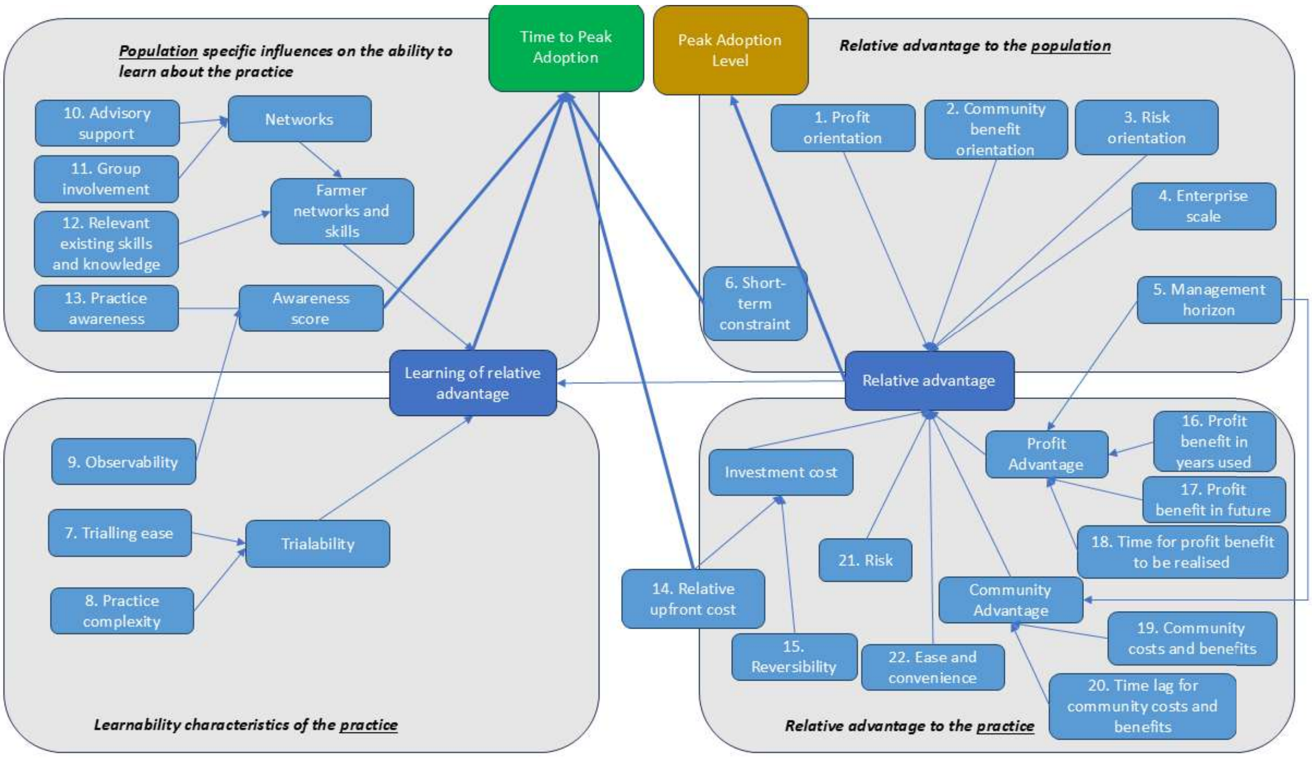

Figure 1. Underlying principles that inform the ADOPT model: Adoption and Diffusion Outcome Prediction Tool (available at: https://adopt.csiro.au/, accessed 23 July 2025), and their influence on model outputs, specifically, Time to Peak Adoption and Peak Adoption Level.

RESULTS AND DISCUSSION

Conservation agriculture adoption framework

The present state of CA in the South Pacific, as well as potential futures of CA, which depend on interventions taken to motivate farmers to adopt CA, is presented in Fig. 2. The graphical information derived from ADOPT is also available as Supplemental Material S2 (ADOPT Results). Disadoption is the situation in which farmers adopt a given technology or practice, but subsequently revert to the pre-adoption condition. Such situation may occur, for example, when financial, technical or logistical, and institutional support provided to farmers during the adoption phase is interrupted or completely removed, and true capacity has not been built during that initial phase. The barriers, solutions and factors leading to disadoption are complex, multifaceted and often inter-related, and as such, they have been briefly elaborated below.

Barriers to adoption

Technology settings. For some cropping systems, adoption of CA may require specialised machinery and operators. Investment may therefore be required for machinery acquisition and for upskilling labour, and potentially for new inputs. Experience of CA adoption elsewhere has shown that agronomic, economic, and environmental benefits almost always outweighed costs and therefore adoption can be justified. The financial impact associated with acquisition of new equipment can be buffered if the investment was to be incorporated into the machinery replacement programme. This means that older machinery that is due for retirement is progressively replaced by specialised machinery that is better fit for purpose. Some examples of new inputs may be the use of genetically modified (GM) plant material that facilitate weed control and provide additional protection against pests and diseases. From an agronomic perspective, this may be regarded as desirable given that poor weed management is a key factor underlying the significant yield gap that is evident in most crops (e.g., Antille et al., 2023; Meier et al., 2023). However, in the South Pacific context, GM technology is not yet available or has not been approved by government and biosecurity agencies (Shigaki, 2014).

Limited or no access to credit. Whilst conversion to CA can be perceived as costly, many farmers have no access to credit. For example, only half of Fijian farmers have a savings bank account and about 90% of farmers who do are men (Fiji MOA and FAO, 2020). Furthermore, much agricultural land in the South Pacific is held in trust; for example, 80% of Samoan farmland is held in trust (Malaki & Ullah, 2001), preventing it from being sold. Two consequences arise from this situation; firstly, farmers are encouraged to disregard the well-being of farmland, the protection of soil and other resources (e.g., natural forests), and exploit it. Secondly, even those farmers who want to reinvest into the property may not be able to, as the farmland may be unable to be used as collateral.

Non-commercial farmers mindset. Subsistence farmers often have a purely subsistence mindset, without the view to maximising production for the sake of profit to reinvest into the farm or to benefit their families outside the need to secure food (e.g., access to higher education). As such, this group of farmers do not necessarily consider ways of maximising long-term efficiency, timeliness of field operations, and sustainability outcomes.

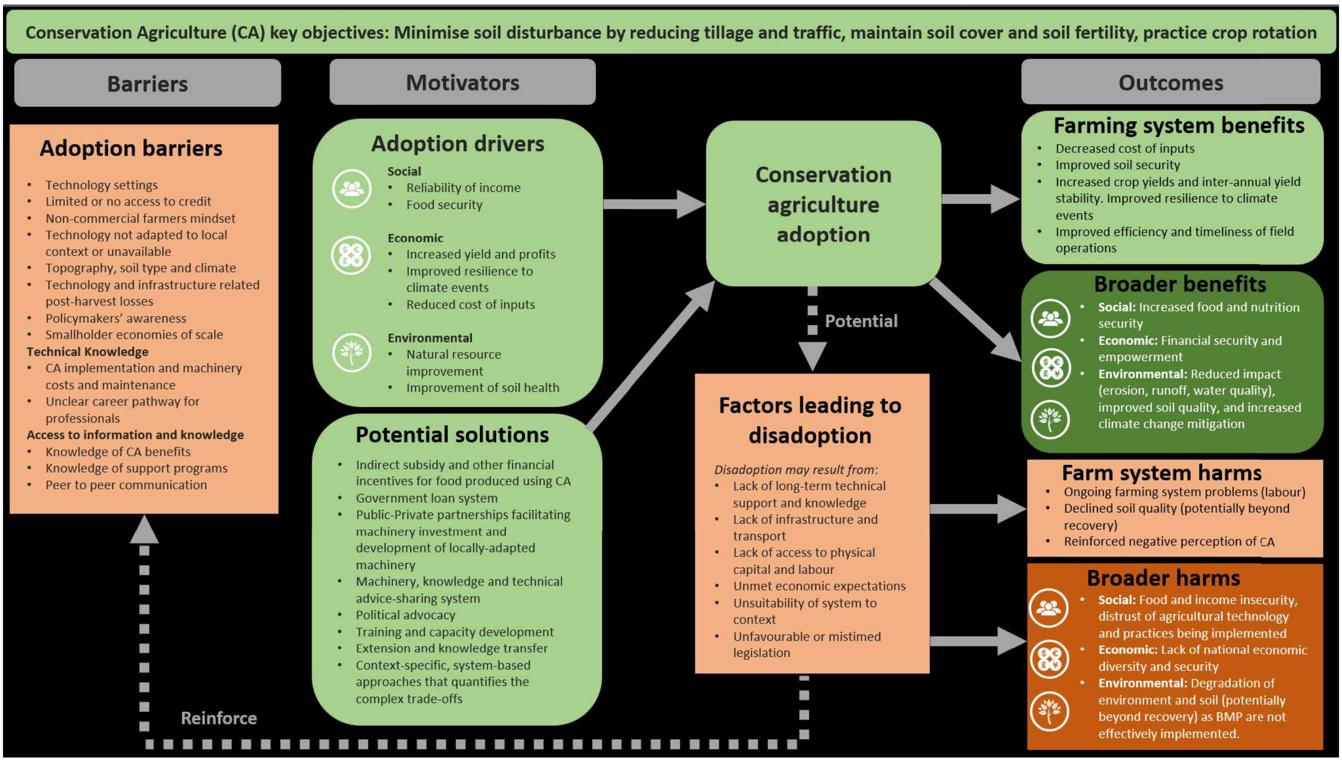

Figure 2. A conservation agriculture (CA) adoption framework. The framework shows barriers, motivators, and outcomes of CA adoption relevant to farming systems in South Pacific Island countries. Elements and factors within boxes are not listed in terms of importance. BMP: best management practices.

Technology not available or not adapted to local context

Current CA technology available elsewhere is not adequately adapted to South Pacific agriculture, and previous attempts to encourage machinery adoption have failed as a result. There is often a mismatch between the scale of the farming enterprise and the size of machinery; for example, some tractors introduced to SPIC were far too large for the small fields or type of implements used, rendering them inadequate. In cases such as taro and cassava cropping, its cultivation is mostly non-mechanised (Howeler et al., 1993; Nauluvula et al., 2025; Awuah et al., 2023); except for land preparation in some countries where production systems are commercial or semi-commercial (e.g., Fiji, Tonga). In other countries (e.g., Samoa), planting, crop protection, fertiliser application and harvesting are performed by hand (Steel et al., 2026). Mechanisation of the planting and harvesting operations for this as well as other root/tuber crops is possible, as shown by the Australian experience in the wet tropics of northern Queensland (Lemin, 2006), and as documented in the scientific literature (e.g., Howeler et al., 1993; Awuah et al., 2023, 2024). However, machinery manufactured outside SPIC may need to be adapted, and most likely downsized, if it was to be used in South Pacific systems. Development of locally suitable tools and equipment, and availability of after-market service and repair, and parts supply, need to be promoted and supported (e.g., Sims & Kienzle, 2015), but this can prove challenging given the size of the SPIC market.

Topography, soil type, and climate

Available CA-compatible equipment may not be readily used in certain South Pacific soils and landscapes (the reader is referred to the Pacific Soils Portal jointly developed by Landcare Research New Zealand and CSIRO: https://psp.landcareresearch.co.nz/, accessed 12 July 2025), which therefore requires research to adapt it to this environment. Furthermore, regular adverse weather events could make farmers avoid investment in equipment and alternative crops or cropping systems for CA if they perceive it as being too risky.

Technology and infrastructure related post-harvest losses

Lack of adequate technology and infrastructure to support agriculture can increase crop losses whether before or after harvest. Examples of this are the quality or state of roads that may prevent farmers from accessing remote sites in a timely manner or transport the produce to markets ensuring mechanical damage is avoided. Farmers do not always have proper means of transporting their harvest to markets (e.g., packaging and cooling) or have access to technology to keep their produce cool and fresh when they are at the market. These factors combined can often lead to loss of production or quality, and therefore revenue. Post-harvest losses in some horticultural crops can be as high as 30% or greater depending on the crop. Consequently, farmers may dissuade themselves from adopting if they feel that the economic benefits of CA would be negated by post-harvest losses. Similarly, farmers with capital to invest may have higher investment priorities such as in on-farm infrastructure (e.g., fencing, tracks for field access), land clearance, and soil de-stoning to name a few.

Policymaker awareness

Policymakers may be unaware of the severity of the threat that soil degradation possesses to food security in SPIC. Lack of understanding of CA, and the barriers preventing adoption and science-based approaches to remove them means that policymakers may implement policy and legislation with off-target negative effects on CA. Examples of this can be seen in the push towards eliminating the use of agrochemicals, instead of devising mechanisms (e.g., training, education and extension) to ensure best management practices are implemented. As CA may rely on herbicide use, legislation, and policy to avoid herbicide use can prevent farmers from adopting CA.

Complexity and resource trade-offs

Assessing the full impact of CA is challenging given the complex, context-specific and multi-dimensional nature of the innovation, and the systems in which farmers implement it (McCoy & Graves, 2010). For example, changes in crop yield will affect the amount of biomass in stubble (that is, plant residue after harvest), which can be used for multiple purposes depending on factors such as stubble quantity, quality, and value (Monjardino et al., 2021). Crop stubble can be sold as fodder or retained. In the latter case, it may be incorporated in the soil, used as ground cover, fed to livestock, or burned. Moreover, the role of crop residues or stubble can change, as they may be a better source of income than the produce in dry years, but not in wet years, potentially making the long-term adoption of CA rather cumbersome. The fate of crop stubble can be further influenced by crop choice. All these factors and actions have consequences in terms of resource trade-offs and the allocation of farm inputs, feed, labour, machinery, capital, and sometimes water and land.

Technical knowledge of conservation agriculture

There is a technical knowledge gap in farm mechanisation and applied agricultural engineering for CA as this subject area is not covered by agricultural and soil science courses, including graduate and postgraduate degrees, available at local universities (Antille & Stockmann, 2024). Consequently, extension officers and land managers are not trained in applied agricultural engineering, which prevents the effective implementation of CA. Specialised knowledge of and expertise in machinery maintenance is also lacking as manufacturers and suppliers are not based in South Pacific countries. These factors combined create a barrier to adoption of innovations as extension officers and farm advisers lack the knowledge necessary to support farmers in implanting CA. There is also a need to adapt machinery to enable implementation of alternative cropping practices such as intercropping and to develop farming systems knowledge that allows for mechanisation. This includes, for example, the need to optimise crop row spacing and intra-row plant spacing to allow for mechanisation (e.g., mechanical inter- and intra-row weed control) without compromising crop productivity. Such optimisation process can be informed by farming system modelling that incorporates climate datasets to simulate the agronomic performance of the system under historical and future climate scenarios.

Machinery available second-hand in SPIC does not come with after-sales support, so when it breaks down, farmers are unable to repair the machines, rendering them useless. Another knowledge gap is in agricultural research for CA development as CA systems are foreign to South Pacific farmers and as such need to be adapted and optimised for the specific local context. Overall crop and soil husbandry (e.g., crop protection, weed control, crop nutrition, irrigation, timing of planting and harvesting, crop configuration) are all examples of areas where research needs to be undertaken to develop cropping system-specific best management practices. A time-lag between research and adoption exists, research does not start until farmers adopt, but during the process of adoption and short-term post adoption period is when system-specific knowledge is most needed. Lastly, there is a disconnect between practical and applied research on-farm and higher-level research conducted at local universities and research stations, which underpins the farm-level research. This disconnect creates inefficiency, and delays the time taken adaptations and improvements to be made in CA systems.

Access to technical information and knowledge of conservation agriculture

Knowledge of the existence or benefits of conservation agriculture practices

Farmers may not be aware of the importance of soil health and the threat to soil security brought about by progressive land degradation and loss of soil fertility in the South Pacific region (Susumu et al., 2022). Almost no farmers are aware of CA and therefore the agronomic, environmental and food security benefits CA has potential to provide are not well understood. Knowledge of management practices with potential to co-deliver food security, climate change mitigation and adaptation, while addressing land degradation appears to be lacking (Smith et al., 2019).

Knowledge of support programmes

While most households access agri-services in some form (2020 Fiji Agriculture Census by Fiji MAW, 2020), few are aware of the relevant support and extension services available to them. Overall, 19% of households received an extension visit between 2019 and 2020, and only ~4% attended training or a workshop.

Peer-to-peer communication

Very few farmers are involved in groups discussing farming practices, and there is a general lack of communication infrastructure available for knowledge sharing. As a result, farmers do not have the networks established to communicate about how to adapt CA to their specific context, which in the Australian context was a cornerstone of successful CA adoption (Desbiolles et al., 2019). However, there is communication between farmers in the immediate local region, which often negatively influences CA adoption, as farmers discuss reasons to not change from the status quo. There is strong peer pressure against changing farming systems to new practices or technologies as farmers may face disapproval and social questioning for implementing practices not accepted by the community. An exception to this is the Samoan Farmers Association (https://pacificfarmers.com/listing/samoan-farmers-association/, accessed 2 June 2025), which has been active in the promotion and on-farm implementation of alternative farming practices through engagement in externally funded projects (e.g., through the SciTech4Climate Programme funded by the Australian Government's Department of Foreign Affairs and Trade led by CSIRO Agriculture and Food; available at: https://research.csiro.au/pcra/, accessed 23 July 2025). However, the continuation of their work has been limited to the extent of the projects they are or have been involved in (typically 3–5 years) and not necessarily sustained in the longer term once those projects are completed and funding interrupted.

Potential solutions to the barriers to adoption of conservation agriculture

Indirect subsidy and other financial incentives for food produced using conservation agriculture

To incentivise CA adoption and decrease the payback period on CA machinery and inputs, an indirect subsidy can be implemented, whereby a farmer will receive a rebate from the government based on product sold at market using a CA system. For this, a traceability system may need to be implemented (Gasparin et al., 2007; Peets et al., 2009). Other financial incentives may also be appropriate: tax relief, lower interest rates and access to foreign markets with a minimum sustainability threshold are examples. Financial incentives are useful to drive adoption in situations where a direct increase in yield and profit may not be immediately realised (Landers et al., 2001), but implementation of CA is still desirable due to environmental reasons, including (and importantly) soil protection (Thierfelder & Mhlanga, 2022). Experience of CA adoption in Australia has shown that growers are often in favour of regulation that requires best management practices to be performed when adoption of those practices is attached, for example, to tax incentives or financial offsets (Guerin & Gerin, 1994; Guerin, 1999). Incentives of that nature, provided as a mean to encourage conversion of conventionally managed land to conservation agriculture, can be justified in recognition of commitment by farmers to delivering a wide range of environmental benefits (Antille et al., 2016; Soane et al., 2012; Antille & Moody, 2021; El Bakali et al., 2023a-b). Commonly recognised environmental benefits resulting from CA adoption (and allied practices) include reduced risk of erosion and runoff (and associated reduction in nutrient and sediment transport to watercourses), reduced flood risk (and fewer requirements in terms of engineering infrastructure to manage excess runoff), reduced energy (fuel) use, and reduced oxidation of soil organic matter due to mechanical soil disturbance (e.g., through tillage) (Botta et al., 2022). Lastly, as sustainability becomes increasingly valued by society, goods produced using CA will have increased market acceptability, and with effective branding, will likely be able to fetch a premium price as a premium good.

Government loan system

There are existing government loan systems in some SPIC, for example, the Ministry of Agriculture grants in Fiji and the Fiji Development Bank Agriculture Family Loan Facility (https://www.fdb.com.fj/11490-2/, accessed 19 July 2025). These programmes should be expanded into more SPIC countries, and awareness of their existence raised. Programmes such as these provide opportunities for farmers who are not able to access credit through traditional means (for example, due to a lack of collateral if land is held in trust). As CA systems often require an initial investment in machinery and inputs, government loan programmes can provide farmers with access to credit to be able to make these investments.

Public-private partnerships facilitating investment and development of locally adapted machinery

To overcome the lack of properly adapted (or complete absence of) technology, SPIC governments should encourage foreign investment by an established machinery manufacturer to create locally adapted machinery. The South Pacific market is likely not sufficiently large to support the creation of new companies to manufacture machinery for the region. However, it may be sizeable for an established company to invest in the region (which has previously happened in the Fijian sugarcane industry with the production of harvesters). This would also help to overcome the lack of support for machinery maintenance and other problems that are common when buying second hand equipment, as the local arm of the machinery producer would be able to provide the required technical assistance for repair and after-market service (Prasad et al., 2021).

Machinery, knowledge, and technical advice-sharing system

The creation of a cooperativist machinery and knowledge-sharing company may be considered to help overcome economies of scale problems associated with purchasing farm equipment and the provision of technical support. Similar organisations exist in other countries, and they have been successful in driving adoption of sustainability-oriented activities and production-efficient practices in the agricultural sector (Rostami & Salehi, 2024). For example, the well-established 'Consorcios Regionales de Experimentación Agrícola' (known as 'CREA' Groups) in Argentina (https://www.crea.org.ar/, accessed 17 July 2025). In the CREA model, local farmers (typically, a group of 8–12 farmers who have a similar type and size of farming enterprise and are located in the same region) in an area all pay a membership fee in return for agronomic advice offered to group members who also benefit from on-farm experimentation, training, knowledge sharing and technology transfer. A shared machinery system within members of the CREA Group may also exist. Importantly, farmers members of the group, under the advice of a common agronomist, conduct on-farm research that enables them to adapt technology and practices to meet specific needs of their farming systems. Other successful institutional and organisational arrangements have been reported (e.g., Landers et al., 2001; Mitchell et al., 2025; Landers et al., 2021), which have facilitated widespread and rapid adoption of zero-tillage in Brazil.

Policy advocacy

For effective policy to be implemented, advocacy should occur so that policymakers and institutional leaders are aware of and understand the importance of CA in terms of the significant economic, social, and environmental benefits that such system offers, and are therefore able to take science-based action into implementing the solutions suggested (El Bakali et al., 2023b). Such shift towards CA requires sustained policy and institutional support that provides both incentives and motivations to encourage farmers to adopt CA practices and become the 'experts' who can improve them over time (Kassam et al., 2014). Policy advocacy also brings awareness to the negative off target effects of policies such as anti-herbicide measures and interventions (e.g., subsidies; Anderson, 2024), so that policymakers consider the implications of such policies on soil health and food security, and the overall long-term sustainability of the farming sector.

Training and capacity development

Training for extension officers should be provided using proven communication methods for capacity building (e.g., Acunzo et al., 2014) so these officers can, more effectively, encourage and support CA implementation. Communication networks between research and extension organisations should be developed, so that extension officers are able to provide the most accurate and up-to-date information possible. Furthermore, communication between on-farm, and higher-level university-based research should be developed, so that co-operation is encouraged, and research efficiency and context specificity is maximised. A clear career pathway should be created for technical professions in agriculture, to incentivise students to study agricultural science, agricultural engineering, and allied disciplines linked to the farming sector, build technical support, and academic, research and extension capacity (and be an attractive proposition so that the workforce remains in the sector). Local universities such as The University of the South Pacific (https://www.usp.ac.fj/, accessed 30 June 2025), The Fiji National University (https://www.fnu.ac.fj/, accessed 30 June 2025) and Tonga National University (https://tnu.edu.to/, accessed 24 July 2025) have a role to play in making study accessible to students (an example of which can be found with the ACIAR Capacity Building Programmes, https://www.aciar.gov.au/CapacityBuilding, accessed 28 June 2025), while local government policies should be aimed at ensuring career development pathways exist for those who graduate from university.

Extension and knowledge transfer

A robust system of extension and knowledge transfer should be developed and established to raise farmers awareness of the existence and benefits of CA and provide the required technical support on the ground for effective implementation. Workshops and field days may form the core of extension work, but availability and benefit of these activities should be communicated to farmers to encourage participation. In Fiji, radio is the most used form of media by farmers, used by c.a.50% of farming households (Fiji MOA and FAO, 2020), and therefore may be an effective way of advertising the benefits of CA and the available extension activities. Other knowledge transfer interventions could include regular CA conferences (e.g., biannual) to encourage effective peer-to-peer communication (Prager & Creaney, 2017), and the creation of a regional centre for CA. Such a centre could act as a CA hub to facilitate research and knowledge transfer to farmers, farm advisers, and extension officers. Similar proposals were highlighted in earlier studies (e.g., Antille et al., 2022; Antille & Stockmann, 2024), albeit focused on soil science and agricultural engineering research, and they may therefore consider CA as part of their purpose and scope of work.

Context-specific, system-based approaches that quantify the complex interactions and trade-offs

There is a need for quantitative analyses that demonstrate the potential to learn from where benefits may be greatest, and from where risk and uncertainty can most readily be mitigated. Higher volatility in terms of seasonal rainfall and commodity prices, lower availability of capital and farm labour, reduced market access, and threatened food security are examples of where uncertainty can be mitigated. The complex interplay of these and other socio-economic and biophysical factors has a crucial role in determining the economic value of the various components of CA and their likelihood of being adopted, together and separately (Monjardino et al., 2021). Often, prioritising livestock and stubble management, and developing a strategy for mechanisation adoption, along with the gradual implementation of best management practices, would likely maximise the value from investments in CA.

Factors leading to disadoption of conservation agriculture

Limited technical knowledge and lack of long-term technical support

Technical knowledge and extension activities must continue after foreign programmes (which usually last for three to five years) are finished, otherwise once technical support is withdrawn, farmers may revert to non-CA practices (Razafimahatratra et al., 2021). If technical capacity has not been built in the region, then disadoption is inevitable, as a gap of technical knowledge will exist. Furthermore, even if long term CA research and extension are established, there must be effective communication between the two to ensure up to date knowledge transfer to farmers.

Lack of infrastructure and transport

In a similar manner to how infrastructure and transport acts as a barrier to CA adoption, it can also be a motivating factor for disadoption. If farmers perceive that the effort required to implement CA is not worthwhile given the likely post-harvest losses they will likely incur, this can motivate disadoption. Similarly, there may be insufficient transport for CA inputs; for example, Habanyati et al. (2019) showed that the most cited factor leading to disadoption was 'lack of transport for manure', which 31% of farmers indicated as a reason for disadoption.

Lack of access to physical capital

If access to physical capital (money, inputs, machinery, labour) is impeded once a farmer has adopted CA, they will likely be forced to disadopt CA. Yield and profit increases often take three or more years to be realised when switching to a CA system. Therefore, unless the farmer has adopted CA for longer, they will likely not have the ability to continue to purchase CA inputs, forcing disadoption. Some farmers in Africa have reported an increase in labour requirements when practicing CA (Habanyati et al., 2019; Thierfelder et al. (2016), which may present a challenge in parts of the South Pacific where labour is scarce, especially, as economies develop and migration to urban areas increase.

Unmet economic expectations

When training is provided to farmers about the benefits of CA, too much focus can be given to increases in crop yield and profits, especially in the short-term. Many farmers report a decrease in the short-term following CA adoption, when systems and practices are still novel and not yet optimised (Razafimahatratra et al., 2021). This is often a reflection of the learning process that farmers must go through until experience in managing a 'new' system is gained. If farmers perceive that CA adoption will lead to immediate yield and profit increases, they may disadopt in the first few years when they are disappointed with results produced by CA. It is therefore important to emphasise the other benefits of CA: sustainability (mitigating degradation and rejuvenating soils), crop and soil resiliency to climate events and timeliness, as well as creating realistic expectation about timelines to achieve yield and profits improvements.

Unsuitability of system to context

Similar to the aforementioned barrier, if CA systems are not adapted to the local context, farmers will likely disadopt as practicing CA may be too burdensome and may not deliver the expected yield benefits. This further highlights the importance of on-farm research to adapt and optimise CA practices to the local context.

Unfavourable and untimely legislation

If poorly timed legislation, such as the anti-herbicide or pro-organic (e.g., free from manufactured fertilisers or GM crops) policy is implemented, then farmers may be forced to disadopt CA as it will not work as well without some level of key inputs (e.g., as part of an integrated weed management strategy, balanced nutrition, crop tolerance to herbicides or insects).

ADOPT modelling

Conservation agriculture was predicted to reach 45% peak adoption over 23 years under *status quo* conditions (Supplemental Material S2, ADOPT Results). Notably, the adoption *S*-curve indicates a pronounced early-stage 'chasm', with only ~5% adoption after five years, reflecting low initial awareness, perceived risk, and limited advisory reach. Targeted early-stage awareness-building, demonstration activities, and advisory engagement could help bridge this chasm, accelerating early uptake and shifting the adoption curve forward in time. Fig. 3 shows little difference in peak adoption level between different barrier removed scenarios, with most scenarios demonstrating a peak adoption level of 45%. The exceptions were the 'all barriers removed' and 'non-commercial farmer mindset' scenarios (both with 62% peak adoption).

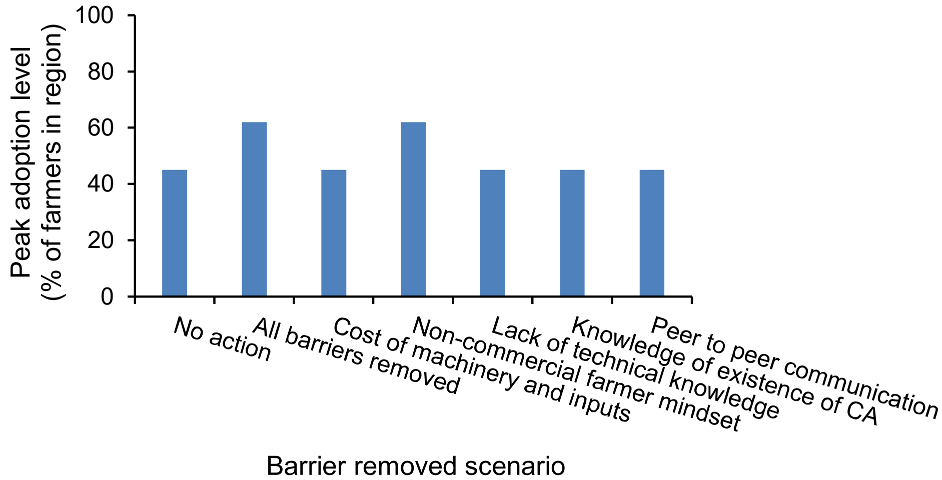

Figure 3. Peak adoption level as compared to barrier removed scenario. Results generated by Smallholder ADOPT model, based on responses to questions provided (please refer to Supplemental Materials S1 and S2). 'No action' refers to when all barriers are in place, representing the current status quo, and 'All barriers removed' when all the barriers that ADOPT incorporates are removed. CA: conservation agriculture.

The scenario removing the 'non-commercial farmer mindset' barrier (and as a result the 'all barrier removed scenario') was particularly affected by question 5 about the relative advantage of the innovation. The rest of the barriers were in relation to short-term constraints and learning of the relative advantage (e.g., Eq. 6), and as such only influenced time to peak adoption. Fig. 4 shows the difference in time to near peak adoption depending on the barriers to adoption present, providing useful information about which barriers effected adoption the most. This is especially true given the time sensitive nature of soil degradation, as minimising the time to CA adoption is crucial for realising its benefits. It is noted that subject to the differences in Fig. 3, the same time to peak adoption represents a much more rapid uptake of CA in the 62% peak adoption scenarios than the 45% ones. However, such predicted peak adoption rate was regarded as high compared with findings from other studies for smallholder farmers in Mexico, where peak adoption would reach 30%–35% after about 20 years following introduction of CA (Monjardino et al., 2021).

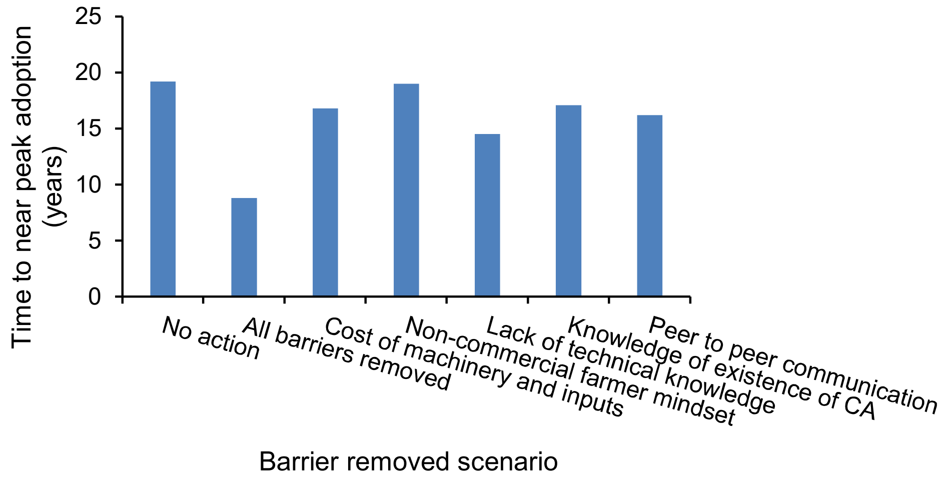

Figure 4. Time to near peak adoption level as compared to barrier removed scenario. Results generated by Smallholder ADOPT model, based on responses to questions provided (please refer to Supplemental Materials S1 and S2). Time to near peak adoption level is the time taken to reach 99% of the predicted peak adoption level, shown in Fig. 3. 'No action' refers to when all barriers are in place, representing the current status quo, and 'All barriers removed' when all the barriers that ADOPT incorporates are removed. CA: conservation agriculture.

As highlighted earlier, the model estimated that in the *status quo's* 'no action' scenario, it will take 23 years to reach near peak adoption, as compared with 9.8 years when all barriers were removed. However, not all barriers identified in the framework were encapsuled in the ADOPT model, and so the 'all barriers removed' estimate may be slightly less accurate than other scenarios. The experts consulted when developing the framework suggested that the most critical barrier to CA adoption was lack of technical knowledge and ongoing support after the innovation was introduced. This idea is supported by the results shown in Fig. 4, as the second greatest reduction in time (except when removing all barriers) was realised in the 'lack of technical knowledge' barrier removed scenario (~23 to 18.2 years), with 'knowledge of CA practices and benefits' being marginally more impactful (~23 to 18.1 years). Both these barriers had no impact on peak adoption (Fig. 3). The next most impactful barrier to remove was the lack of peer-to-peer communication (from ~23 to ~19.5 years), which is interlinked with a lack of technical knowledge as a part of farmer networks and skills (Fig. 1). The 'cost of machinery and inputs' barrier removed scenario also showed significant decreases in time to peak adoption of ~2.5 years. It has been reported that farmers' non-commercial mindset is often less of a barrier than South Pacific governments claim whereas other systemic or structural barriers are relatively more important (Toleafoa, 2014). This idea is supported by the ADOPT model, as removing the barrier of 'non-commercial grower mindset' decreased the time to peak adoption by only 0.2 years, but the peak adoption level increased from 45% to 62%.

Previous applications of Smallholder ADOPT have been for highly specific contexts, with a focus on well-defined geographic regions, farming systems, and target farmer populations. In the present case-study, answers to the model's questions were informed by deliberate generalisations across the broader SPIC agroecological region. Overall, the peak adoption component of the model was much more sensitive than time to peak adoption, as shown in the sensitivity analysis charts (Supplemental Material S2). Eight of the questions showed sensitivities greater than 10% in both directions; however, enterprise scale (Question 4) had the largest effect on peak adoption. This result is particularly relevant in the SPIC context, where customary land-tenure systems commonly result in fragmented holdings, shared access, and limited scope for land consolidation. These arrangements encourage diversified livelihoods and reduce household dependence on any single agricultural enterprise. Accordingly, the modelled response that 'about half of the target population depends highly on the enterprise' yielded a peak adoption of 45%. A step-down response − reflecting lower enterprise dependence associated with subsistence production or off-farm income − reduced peak adoption to 26%, while a step-up response increased peak adoption to 65%. This sensitivity highlights how tenure systems indirectly shape adoption potential by influencing enterprise scale, investment incentives, and risk tolerance.

Despite potential large variation, the assumption that at about half of smallholders across the SPIC depended on some level of CA and a peak adoption of 45% was somewhat consistent with previous ADOPT modelling for conservation agriculture. For example, Monjardino et al. (2021) estimated a lower peak adoption level of 31% for CA in the traditional smallholder context of central Mexico, although adoption increased to 47% when considering a simpler bundle of practices combining no-tillage and crop diversification. In contrast, Monjardino et al. (2020) projected that adoption of a cowpea legume crop within the traditional rice–cattle system of southern Laos would reach 54% within six years.

SWOT analysis

The findings of the framework and the ADOPT modelling were synthesised through a SWOT analysis to provide an integrated assessment of the key factors influencing CA in the South Pacific (Table 1). In conjunction with the framework, the ADOPT modelling primarily informed the strengths and weakness components of the SWOT, while parameters demonstrating high sensitivity to changes in conditions were used to identify potential opportunities and threats. This approach enabled systematic identification of the weakest elements of the adoption process requiring targeted intervention, while also highlighting areas of comparative strength and unrealised potential.

Table 1. Strength, Weaknesses, Opportunities, and Threats (SWOT) analysis for adoption of conservation agriculture (CA) in South Pacific Island countries

Strengths

- Increased resilience to adverse climate events, which leads to reduced production risk and improved reliability of income
- Increased yield and profits, and potentially reduced overall production costs
- Critically, CA improves soil health, which flows into a range of benefits, including better crop nutrition, improved water holding capacity, reduced power (energy) requirements, reduced potential for soil emissions of GHG, broader ecosystem benefits, and improved crop protection
- Improved timeliness allowing farmers to perform all field operations in a timely manner, importantly, crop establishment and harvest with potential to beat competitors to market
- Except for machinery costs (which can be circumvented with a machinery-sharing system), CA is reasonably easily triable and reversible, so farmers are able to 'try it out' before committing to farm-wide usage
- CA is easily observable to other farmers in the region, self-promoting further usage
- As sustainability becomes more socially important as a value, practicing CA leads to an improved social licence and likely increased market acceptability into the future

Weaknesses

- For some cropping systems, CA requires specialised machinery and operators, and potentially new inputs (e.g., increased reliance on herbicides, GMO plant material). In the context of Pacific agriculture, technology may be perceived as costly, and farmers may not have access to a line of credit
- An economics of scale problem may arise with purchasing CA-compatible machinery as smallholder subsistence farmers may not be able to afford it or may represent a sizeable financial risk
- Almost all (>90%) farmers in Pacific Island countries will need to gain new knowledge and skills to effectively implement CA
- Agricultural and applied engineering knowledge needs to be updated to a CA system. Overall crop and soil husbandry (e.g., crop protection, weed control, crop nutrition, irrigation, timing of planting and harvesting) are all examples of areas where research needs to be undertaken to develop cropping system-specific best management practices. This process is a dynamic and ongoing one, evolving with new practices and new knowledge. New recommendations must be effectively communicated to farmers to enable practice change where needed
- Current CA technology is not adapted to Pacific agriculture. Development of locally-suitable tools needs to be promoted. This can be a challenge given the size of the Pacific Island countries market

Opportunities

- Science based and well executed policy interventions are available to overcome the weaknesses and minimise the threats to CA:

✓ Financial support in the form of an indirect subsidy to cover cost of machinery investment can be provided for farmers. Other financial incentives such as tax relief and lower interest rates could be made available to ensure arable land is maintained in good agricultural and environmental conditions, and to mitigate unwanted, off-farm effects (e.g., sediment pollution of surface waters; flood mitigation; cost reduction in measures mitigate impacts off-farm).

Table 1 (continued)

- ✓ Financial support and incentives would also encourage CA uptake even when sizeable yield increases were not attained, particularly soon after CA adoption. However, the broader sustainability benefits and system's efficiency gains are still very desirable. A government loan system to provide a line of credit can also be implemented and promoted to ensure farmers are aware of the programme
- ✓ A cooperativist company can be created to provide shared machinery and technical support (in the form of a shared agronomist) for farmers in a region
- ✓ A clear career pathway should be created for technical professions in agriculture, to incentivise students to study agricultural science and engineering, and allied disciplines linked to the farming sector, build technical support, and research and extension capacity. Local universities such as USP and FNU have a role to play in making study accessible to students (an example of this can be found with the ACIAR PASS Programme, https://www.aciar.gov.au/scholarships/pass), while local government policies should be aimed at ensuring career development pathways exist for those who graduate
- ✓ Government engagement with machinery manufacturers to develop markets, facilitate access to customised technology (adapted for local systems), and the provision of after-market technical support (e.g., machinery servicing and parts). Expansion of CA will necessitate engagement of machinery manufacturers to: (i) promote CA and allied technology, (ii) develop close links with universities (e.g., USP, FNU), research and extension centres (e.g., SROS, MOA) and farmers-led organisations (e.g., The Samoan Farmers Association, Women in Business Development Inc., Pacific Islands Farmer Organizations Network) to drive innovation through (applied and on-farm) research and development
- ✓ A robust system of extension and knowledge transfer should be developed and implemented, educating farmers on the existence and benefits of CA, and providing technical support on the ground
- ✓ Extension activities such as workshops and field days are an opportunity to provide education and knowledge to female farmers who as a result of systemic barriers on average are less educated and have worse access to knowledge and agricultural best management practices

Threats

- There is currently lack of technical about CA in the Pacific, and a lack of technical capacity in the region. If a technical knowledge and research base is not built, then farmers will likely disadopt CA once foreign support programmes are discontinued
- Farmers have limited access to knowledge and information about the existence and benefits of CA. Most do not understand the importance of soil health and the harms of conventional tillage. Furthermore, many farmers are not aware of the support programmes available to them
- There is an absence of peer-to-peer communication about the positives of CA, but there is peer to peer communication about negative elements, which leads to peer pressure against CA adoption
- Most farmers have a non-commercial mindset, meaning that they do not make a profit, and have no capital to reinvest in production technologies such as CA
- If economic expectations about yield and income increases are not meet in the first few years of adoption (due need to relearn agricultural best practices), then farmers may feel that CA is a failure and disadopt, missing out on the real potential of CA
- Legislation can have off-target negative effects and dissuade farmers from adopting. Examples of this can be seen in the push towards eliminating herbicide use and producing 'organic' goods. As CA usually requires some herbicide usage, legislation and policy to minimise herbicide use can prevent farmers from adopting CA

The SWOT analysis indicates strong potential for CA to deliver a wide range of social, economic and environment benefits in the South Pacific. However, adoption of CA remains constrained by knowledge and technology gaps across multiple levels of the agricultural system, including farmer knowledge, extension capacity, research investment, inter-institutional communication, and policymaker awareness. Notably, the drivers of CA disadoption largely mirror the barriers to initial uptake, suggesting that many risks to sustained adoption are predictable and preventable. Addressing these constraints requires coordinated, long-term investment in training, extension, and knowledge-sharing systems that extend beyond short-term project cycles. Infrastructure, transport, and capital limitations could be mitigated through government loan schemes, targeted subsidies, and public–private partnerships that support locally adapted machinery and functional input and output supply chains. Furthermore, managing farmer expectations through extension that emphasises realistic transition timelines and system performance − alongside context-specific, systems-based approaches − can reduce the likelihood of early disadoption. Collectively, these findings underscore that sustained CA adoption in the South Pacific depends not only on farmer decision-making but also on coherent, scalable institutional, financial, and policy frameworks capable of supporting long-term system transformation.

CONCLUSIONS

The agronomic, economic, and environmental performance of conventionally managed cropping systems in the South Pacific could be improved if these systems were converted to conservation agriculture (CA). Whilst the costs of such shift remain largely unquantified in the SPIC context, on- and off-farm benefits appear to outweigh key risks of implementing CA, including financial. It is therefore anticipated that the cost of adopting CA may be affordable relative to the expected benefits that CA could deliver, especially, if incentives could be made available.

This study successfully identified drivers and barriers for CA adoption in the South Pacific. Key drivers identified included agronomic and environmental benefits due to likely improvements in soil quality and therefore soil security. It is expected that these benefits will translate into positive social and economic outcomes (through increased productivity and profitability), improved farming system resilience to climate events and reliability of income. Key barriers identified were the initial and ongoing investment that may be required for machinery acquisition, adaptation and maintenance, input unavailability of suitable and context-specific technology, insufficient technical knowledge and capacity leading to a lack of technical support for farmers. Farmers across the South Pacific region are unaware of CA and the multiple benefits it could deliver. Therefore, on-farm research coupled with extension and financial programmes need to be made available for effective implementation of CA.

A range of informed solutions were proposed, including the upskilling of farmers, research and extension officers and agronomic advisers, increased investment in on-farm research and development for adaptation of CA technology that meets specific needs of South Pacific agriculture, and stimulating a shift towards increased adoption of CA supported by agri-environmental stewardships. The latter needs to be actioned by a strong extension effort from local organisations, and supported and coordinated by international and regional agencies such as FAO, CAAAP (CA Alliance for Asia-

Pacific), ACIAR and DFAT (Australian Government). There is an opportunity to develop the next generation of CA experts for the South Pacific through better engagement of local universities in research programmes supported by foreign agencies, and the establishment of subject-specific academic programmes at the graduate, post-graduate, and post-doctoral levels.

Motivating factors for disadoption were identified, including insufficient long-term technical support and knowledge, a lack of access to capital and unmet economic expectations. The identified drivers, barriers, and factors leading to both adoption and disadoption were displayed and connected in a framework, to provide a broad view of CA in the South Pacific. Smallholder ADOPT was used to determine the most detrimental barriers to CA adoption. The most impactful barrier on time to near-peak adoption was a lack of technical knowledge, followed closely by limited peer-to-peer communication and the costs associated with specialised machinery and inputs. Crucially, addressing knowledge constraints implicitly requires a substantial shift in advisory support, from almost no producers accessing advisors to widespread use of advisory services. Achieving such a transition would represent a significant institutional and capacity-building challenge, necessitating major investment in advisory workforce development, funding mechanisms, and delivery models capable of reaching a broad and diverse farming population. The findings from this study were synthesised in a SWOT analysis to inform a plan for long-term CA adoption in the South Pacific.

Future research and development requirements

(i) The scope of research in this study was a broad, South Pacific-wide scale. Future research on country and farm system levels should be undertaken to better understand the specific barriers for individual populations and regions, and to be able to tailor appropriate solutions.

(ii) The research in the study can be adapted for non-academic audiences, such as farmers, extension officers and policymakers. For example, the framework can be simplified to focus on the objectives and benefits of CA for farmers, or adapted to focus on the benefits, barriers, and solutions for policymakers.

(iii) A more extensive and in-depth modelling may be performed by factoring in the cost to implement solutions as well as their impact, creating a thorough knowledge base to inform country-specific agricultural policy.

(iv) Future efforts to accelerate adoption should prioritise the development of scalable and realistic institutional support mechanisms. In particular, coordinated public–private extension strategies, investment in digital advisory platforms, and expanded group-based learning approaches are recommended to facilitate a major increase in advisory engagement. Such actions are necessary to ensure that adoption gains are supported not only by farmer-level decision-making but also by institutional arrangements capable of delivering near-universal technical support.

(v) The need to transition towards CA across Pacific nations is a consequence of the progressive decline in soil quality, which is having a dual effect on reduced agricultural productivity and compromised farming systems' resilience in the face of climate change. Any impact on soil quality due to poor management can have adverse effects on food security (not just the availability of food, but also the availability of food with adequate nutritional quality). These are important considerations for Pacific food systems given their exposure to climate effects-related and their limited capacity to quickly respond to environmental disasters that compromise (rather frequently) their entire food supply system. We consider that an important focus of the effort spent on building resilience across the Pacific needs to be based on managing agricultural systems such that soil quality is maintained (and where possible, enhanced). The identification and implementation of practices that protect the soil resource and increase productivity (and food quality) are pre-requisites for improving the overall resilience of the food production and supply systems.

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Supplemental Material S1

Table 1S. Responses to Smallholder ADOPT questions under different conditions. Questions left blank in the barrier removed column remain constant under all circumstances, and question responses were all changed to the 'barrier removed' answer for all barriers removed scenario. *Time to near-peak adoption level is the time taken to reach 99% of the predicted peak adoption level

	Question	*Status quo* answer	Barrier removed	Barrier removed answer
Relative advantage for population	1. Income/productivity orientation	A majority have maximising income/ productivity as a strong motivation.	-	-
	2. Local community benefit orientation	A majority have benefits to their community/village as a strong motivation.	-	-
	3. Risk orientation	Almost all have minimising production risk as a strong motivation.	-	-
	4. Enterprise scale	A majority of the target households depend highly on the enterprise(s).	-	-
	5. Management horizon	Almost none have a long-term management horizon.	Non-commercial grower mindset.	Almost all have a long-term management horizon.
	6. Short term constraints	A majority currently have a severe short-term financial constraint.	Cost of machinery and Inputs.	Almost none currently have a severe short-term financial constraint.
Learnability of innovation	7. Trialable	Moderately trialable.	-	-
	8. Innovation complexity	Somewhat difficult to evaluate effects of use due to complexity.	Knowledge of existence or benefits of CA practices.	Not at all difficult to evaluate effects of use due to complexity.
	9. Observability	Moderately observable.	Peer-to-peer communication.	Very easily observable.
Population ability to learn about innovation	10. Advisory support	Almost none use a relevant advisor.	Lack of technical knowledge.	Almost all use a relevant advisor.
	11. Group involvement	A minority are involved with a group that discusses new farming practices.	Peer-to-peer communication.	Almost all are involved with a group that discusses new farming practices.
	12. Relevant existing skills and knowledge	Almost all need new skills and knowledge.		
	13. Innovation awareness	A minority are aware that it has been used or trialled in their local area.	Knowledge of existence or benefits of CA practices.	Almost all are aware that it has been used or trialled in their local area.

Table S1 (continued)

Relative advantage of innovation	14. Relative upfront cost of innovation	Moderate initial investment.	-	-
	15. Reversibility of innovation	Easily reversed.	-	-
	16. Income/productivity benefit in years that it is used	Moderate income or productivity advantage in years that it is used.	-	-
	17. Future income or productivity benefit	Moderate income or productivity advantage in the future.	-	-
	18. Time until any future income or productivity benefits are likely to be realised	3–5 years.	-	-
	19. Local village/community costs and benefits	Moderate to large local community/village advantage.	-	-
	20. Time to local village or community benefit	3–5 years.	-	-
	21. Risk exposure	Moderate reduction in risk.	-	-
	22. Ease and convenience	Moderate increase in ease and convenience.	-	-
Predicted peak adoption level (%)		45%	-	62%
*Time to near-peak adoption (years)		23	-	9.8