Prioritising Sustainable Development Goals, characterising interactions, and identifying solutions for local sustainability

Reihaneh Bandari[1, *], Enayat A. Moallemi[1], Rebecca E. Lester[2], David Downie[2], Brett A. Bryan[1]

[1] Centre for Integrative Ecology, School of Life & Environmental Sciences, Deakin University, Melbourne Burwood Campus, VIC, 3125, Australia.

[2] Centre for Regional and Rural Futures, Deakin University, Locked Bag 20000, Geelong, VIC, 3220, Australia.

* Corresponding author: Centre for Integrative Ecology, School of Life & Environmental Sciences, Deakin University, Melbourne Burwood Campus, VIC, 3125, Australia; rbandari@deakin.edu.au; (+614) 32 993 776

Abstract

The United Nations 2030 Agenda brings a holistic and multi-sectoral view on sustainability via the Sustainable Development Goals (SDGs). However, a successful implementation of this agenda is contingent on understanding the multiple, complex interactions among SDGs, including both synergies and trade-offs, for informing planning for sustainability at the local level. Using a case study of the Goulburn-Murray region in Victoria, Australia, we prioritised global goals and targets for the local context, characterised the interactions between them, analysed the main synergies and trade-offs, and finally identified potential policy solutions to achieve local sustainability. We identified the five highest priority SDGs for the region as clean water and sanitation (SDG 6), agricultural activities (SDG 2), economic growth (SDG 8), climate action (SDG 13), and life on land (SDG 15). Across these five priority SDGs and their 45 targets, we found 307 potential interactions, of which 126 (41%) were synergistic, 19 (6%) were trade-offs, and 162 (53%) were benign. We highlight the most salient trade-offs, particularly how unsustainable agricultural practices could negatively affect water resources, the environment, and sustainable economic growth. Also, critical ongoing uncertainties like climate change, local policies on environmental water recovery, international markets, and emerging new technologies could present risks for the future of agriculture and the economy. Our results provide important insights for local and regional sustainability policy and planning across multiple sectors, and our methodology is broadly applicable for prioritising SDGs and assessing their interactions at local scales, thereby supporting evidence-based policy-making for achieving the SDGs.

Keywords

Agriculture; water; local sustainability; SDG; synergy; trade-off.

1. Introduction

The United Nations Agenda 2030 for Sustainable Development, signed by all UN Member States, consists of 17 goals and 169 targets representing shared environmental, social, and economic aspirations commonly referred to as the Sustainable Development Goals (SDGs). The 2030 Agenda was adopted to tackle a wide range of challenges and risks for humanity to achieve prosperity and well-being for all (UN 2015). With less than one decade left to achieve the SDGs and implement the 2030 Agenda, the UN called this period the "decade of action" and committed to mobilise financing, enhance national implementation, and bolster local action (UN 2019). However, implementing this agenda strongly depends on capitalising on synergies and reducing trade-offs among SDGs (Kroll et al. 2019; Pradhan et al. 2017).

The 2030 Agenda is intended as an integrated 'indivisible whole' (UN 2015). Hence, it is essential to analyse interactions among priority SDGs to bring about opportunities for transformative action across sectors as evidence of complex SDG interaction mounts (Alcamo et al. 2020; Scharlemann et al. 2020). Analysing goals and targets in isolation and ignoring potential interactions can lead to adverse impacts on the overall fulfilment of the goals (Pradhan et al. 2017) and result in incoherent policies where adverse impacts of development policies in some sectors spill over to other sectors (Blanc et al. 2017). For example, using coal to ensure access to energy (SDG 7) in Asian nations can exacerbate climate change (SDG 13) and acidify the oceans (SDG 14) along with increasing air pollution (SDG 3) (Nilsson et al. 2016). Institutional barriers and the individual interests of each organisation, specifically around crucial topics such as food and agricultural activities, water, poverty, health, and energy, can impede collaborations among organisations when implementing the SDGs. Pan-institutional interventions and policies are needed to advance multiple SDGs and avoid the unintended consequences of isolated sustainability efforts.

Studies are increasingly focussing on assessing the interactions among specific SDGs (IGES 2017; Mainali et al. 2018; Van Soest et al. 2019; Weitz et al. 2014). A preliminary exploration was conducted by mapping interactions between SDG 14 (i.e., life below water) and other SDGs (Blanc et al. 2017; Singh et al. 2018). Fuso Nerini et al. (2017) undertook a qualitative study based on published evidence around interactions between SDG 7 (i.e., affordable and clean energy) and other SDGs. UN (2017) developed a comprehensive methodology to assess relationships between clean water and sanitation (SDG 6) and other SDGs using a systems thinking approach. A report by the International Council for Science (ICSU 2017) evaluated key interactions between the targets of SDG 2 (i.e., zero hunger), SDG 3 (i.e., good health and well-being), SDG 7, and SDG 14 with other SDGs using a seven-point scale, without accounting for geographical context. McCollum et al. (2018) conducted a systematic assessment between SDG 7

targets and other SDGs by reviewing energy-related literature and assessing context dependencies. In addition to these studies, Nilsson (2017) discussed SDG interactions between SDG 1 (i.e., no poverty), SDG 2, SDG 3, SDG 5 (i.e., gender equality), SDG 9 (i.e., industry, innovation and infrastructure), and SDG 14 with other SDG targets, focusing on important interactions between the targets of six selected goals rather than all interactions.

Some studies have taken a more comprehensive approach to assessing SDG interactions, focusing at the global (Pradhan et al. 2017) and national scales (Weitz et al. 2018). Weitz et al. (2018) analysed SDG interactions in a cross-impact matrix in Sweden and selected two targets per goal before applying network theory and systems analysis to determine the most influential targets. Pradhan et al. (2017) quantified synergies and trade-offs at global and national scales within and among goals by using SDG indicator data. Kroll et al. (2019) further analysed trends in future interactions among projected SDG indicators to 2030 by using global SDG indicators between and within the goals. Network analysis and SDG indicators at the national level were used to analyse interactions among some SDG targets (IGES 2017). Blanc (2015) analysed interactions among all SDGs at the global level using network analysis. Van Soest et al. (2019) showed how Integrated Assessment Models can assess synergies and trade-offs among SDGs at the global scale. Herrero et al. (2021) highlighted the potential trade-offs and unintended spatiotemporal consequences of agricultural and food system technologies on multiple the SDGs. Gao and Bryan (2017) used a detailed land-use model to assess the interactions between land-sector SDGs for Australia, finding that multiple SDGs were unlikely to be met due to the inherent trade-offs between socio-economic and environmental objectives.

Although the results of these studies are comprehensive in terms of SDG coverage, they have concentrated on global and national scale interactions, with few studies assessing the nature and characteristics of SDG interactions at the local level. Focusing on local scales is important, as the UN and the scientific community have emphasised that robust actions at the national level should emerge from effective local sustainable development frameworks (Patole 2018; UN 2015). Advocating a similar approach, Nilsson et al. (2016) discussed how “differences in geography, governance and technology make it dangerous to rely on generalised knowledge”, highlighting the need to interpret SDGs according to local and sub-national contexts. Moallemi et al. (2019) argued that bottom-up actions, supported by local stakeholders (e.g., local authorities, communities and cities), can pave the way for a *Local Agenda 2030* with the aim to align sub-national contexts with the global agenda and capture synergies and co-benefits between national (and even global) aspirations and the specific needs and priorities of local communities. Local grassroots initiatives could therefore provide opportunities to accelerate progress towards the SDGs (UN 2020). Given the diversity of local conditions

(Moallemi et al. 2020), limited budgets, and resource constraints in implementing the SDGs (ICSU 2017), governments and local authorities need to focus on those SDGs with the strongest effects on the prosperity and well-being of people and nature. The prioritisation of SDGs and assessment of their interactions needs to be tailored to the specific conditions of local areas.

In this study, we prioritised SDGs and assessed the interactions among their constituent targets at the local scale through an evidence-based and context-specific assessment of sustainability. As a case study, we analysed SDG interactions in the Goulburn-Murray region in Victoria, Australia, a nationally important area for agricultural production with implications for regional and national sustainability. SDGs were first prioritised using a contextual analysis of key local strategic documents and studies identified with stakeholders. We then conceptualised SDG interactions using a scoring methodology based on a set of evaluation criteria. We focussed on target-level SDG interactions to enable more specific interpretability for policy and planning. We identified positive interactions (i.e., synergies) among targets that can be capitalised upon to achieve the 2030 Agenda. We also identified negative interactions (i.e., trade-offs) indicating challenges in achieving the SDGs, which should be avoided and managed. We discussed potential for capturing synergies and mitigating trade-offs between SDGs via a range of specific management and policy solutions. This study provides a comprehensive view for local policy makers to understand the potentially multiplicitous impacts of specific policy solutions, to take advantage of potential synergies and avoid unintended consequences of sustainability solutions. Our results highlight how local authorities can give effect to the 2030 Agenda by implementing efficient policies and targeting limited budgets on local priority SDGs and their interactions and guiding local sustainability planning across sectors.

2. Methods

The methods included three stages: data collection; defining local priority SDGs, targets, and interactions; and interaction analysis (Figure 1). In the first stage, we collected relevant data for our case study through interviews with local stakeholders and through contextual analysis of key literature. In the second stage, we defined priority SDGs, targets, and identified the most relevant interactions via contextual analysis of documents. In the interaction analysis, we explored the nature of each interaction from the collected documents, evaluated the interactions, and highlighted how implementing specific goals and targets may affect other goals/targets by scoring the effects against semi-quantitative evaluation criteria. Finally, we synthesised the main synergies and trade-offs among priority interactions and discussed potential solutions to achieve local sustainability.

<Insert Figure 1 here>

2.1. Study area

We focused on the Goulburn-Murray region in Victoria, Australia, as a case study. The Goulburn-Murray region is located adjacent to the River Murray in the north of Victoria, covers six local government areas: Moira, Greater Shepparton, Loddon, Campaspe, Gannawarra, and Swan Hill (Figure 2). This region is regarded as Australia's food bowl with extensive cropping, livestock production, and horticulture (GMIDWL 2018). The region hosts the most extensive area of irrigated land in Australia and provides significant employment opportunities, generating more than 10,000 jobs and more than $6 billion worth of agricultural production value each year (GMW 2018; Goulburn-Murray Water 2018; VPA 2019). The main source of revenue in this region is irrigated dairy production. Agriculture and the economy of the Goulburn-Murray region have been significantly impacted by recent economic, policy, and environmental change including climate change, reduced commodity prices, water reform policy, highly variable water prices, drought and variation in water availability, and volatile international markets. The effect of these combined challenges to sustainability makes the region an ideal case study for downscaling and assessing SDG interactions at the local scale.

<Insert Figure 2 here>

2.2. Data Collection

2.2.1. Local contextual analysis

The contextual analysis aimed to capture tacit knowledge to derive interactions among priority SDGs and their targets using a combination of interviews with local stakeholders and a comprehensive review of locally relevant literature including published papers, reports, and policy documents.

We attended the Goulburn-Murray Region Action Working Group Meeting in Tatura in May 2019 to identify relevant documents through interactions with the panel of local experts. With the Working Group we assembled a list of published and unpublished historical information; strategic, policy and planning documents; and scenario framing activities. Working Group participants also provided information regarding other available resources related to the Goulburn-Murray area. Furthermore, we identified selected scientific and grey literature documents relevant to Goulburn-Murray through a snowball procedure. Our documents are mostly related to (1) sustainable

development (water, irrigation, agriculture, energy, health, education, gender equality, economic growth, employment, inequality, local community, sustainable consumption and production, climate change, environment, biodiversity, and land degradation), (2) planning (strategic, scenario, management), and (3) local context (e.g., Goulburn-Murray, Murray-Darling Basin, local councils).

These documents included 33 published papers and 93 reports and books (Table S1) by agencies and organisations in Victoria and Australia such as the Department of Environment, Land, Water and Planning (DELWP), the Murray Darling Basin Authority (MDBA), the Goulburn Broken Catchment Management Authority (GBCMA), the North Central Catchment Management Authority (NCCMA), Goulburn-Murray Water (GMW), the Department of Economic Development, Jobs, Transport and Resources (DEDJTR), the Department of the Environment, Water, Heritage and the Arts (DEWHA), and local shire councils.

2.2.2. Interviews with targeted local stakeholders

We conducted a series of 42 face-to-face semi-structured interviews with targeted local community members, stakeholders, business leaders, industry representatives, and representatives from government agencies in the Goulburn-Murray region (Table 1) to assess the local socio-economic and environmental situation, the relative competitive and comparative advantages of the region, and the possible future opportunities in the Goulburn-Murray. A list of potential participants was developed in collaboration with the Department of Environment, Land, Water and Planning (DELWP) and the Goulburn-Broken Catchment Management Authority (GBCMA), focusing mostly on individuals who had engaged in focus groups and community meetings regarding the need for adaptation and change in local industries and the economy. Additional participants were added via a snowball process as those from the initial list suggested others. Interviews were sought (unsuccessfully) with representatives of the indigenous communities and additional Members of Parliament. Ethics approval was acquired from Deakin University Faculty of Science, Engineering and Built Environment Faculty Human Ethics Advisory Group. Discussion was prompted via broad questions about the challenges to environmental and socio-economic sustainability in the region specifically around water resources, agriculture, and other industries; opportunities for enhancing future prosperity and wellbeing; and the timeframe, feasibility, and obstacles to the implementation of these opportunities. Participants' responses were collated anonymously and were synthesised to identify a short list of potential opportunities and challenges for sustainable development in the region.

<Insert Table 1 here>

225

226 **2.3. Defining local priority SDGs, targets, and interactions**

227 We prioritised SDGs and targets for the region by performing a computer-aided review
228 of the literature. For the contextual analysis, we assessed relevant literature with the
229 software package NVivo Pro 12 (QSR International Pty Ltd 2018). We identified
230 statements related to each SDG, then coded that content manually by assigning
231 statements to relevant SDGs. As a first stage, we searched abstracts to find statements
232 relevant to each of the 17 SDGs. Some statements were only associated with one SDG,
233 while others were related to multiple SDGs. For papers and reports where finding
234 statements related to the SDGs in abstracts and summaries was challenging, we
235 scrutinised other parts of the document (especially the conclusion) to find relevant
236 content. In the contextual analysis, priority SDGs were identified as those with the
237 highest number of coded documents per SDG. We complemented these results by
238 analysing word frequency (i.e., a text-mining method) in the same database of
239 documents to better understand SDG priorities. This provided an overview of the most
240 important priorities and concerns in the case study and validated the SDG prioritisation
241 obtained by manual coding.

242 Interactions among SDGs may be more meaningfully determined via targets as they tend
243 to be more specific than goals (Weitz et al. 2018). Therefore, we conducted the
244 contextual analysis first at the goal level, then at the target level. Relevant targets under
245 each SDG were selected using a screening process to reflect the importance of those
246 targets, their relevance to the Goulburn-Murray region and the level of concern
247 expressed in the literature about those targets. The results of this analysis were a set of
248 local priority SDGs and related targets. We then identified the most relevant interactions
249 for the study area and compiled evidence (i.e., collecting quotations) for each
250 interaction by assessing the relevant documents and evaluating the nature of SDG and
251 target interactions.

252 **2.4. Interaction analysis**

253 Interactions among SDG targets can be categorised as synergies (positive interactions)
254 or trade-offs (negative interactions). Synergies imply that progress in one target also
255 advances progress towards another target, while trade-offs imply that progress in one
256 target hinders progress in another target (Kroll et al. 2019). Nilsson et al. (2016)
257 introduced a seven-point scoring methodology to characterise interactions among SDG
258 targets, ranging from cancelling (-3), counteracting (-2) and constraining (-1) as negative
259 scores, to enabling (+1), reinforcing (+2) and indivisible (+3) as positive scores. A score
260 of consistent (0) is given when two targets do not interact with each other (Table 2). We
261 applied the Nilsson scoring methodology to assess all linkages between priority SDG
262 targets.

<Insert Table 2 here>

In addition to scoring interactions, we used two criteria, namely *evidence* and *confidence*, to evaluate our characterisation of interactions against the literature (Table 3). We provided supportive statements for scores derived in the contextual analysis as evidence and additionally brought in our own interpretation. These supportive statements were used as evidence and mostly obtained from policy reports and published papers. We analysed the effectiveness and validity of statements in the contextual analysis according to the quality, type, year of publication, and number of literature sources for each interaction. Evidence scores were 'limited', 'medium', and 'robust'. The relevance of information in each source depended on the type of document (e.g., published literature, grey literature, interviews with stakeholders, and internet content).

The confidence evaluation criterion reflected the extent that we believed that our subjective score for each interaction would remain the same if given by others ('low', 'medium', or 'high'). We checked the consistency between evidence and robustness of evidence, then characterised confidence in the scores assigned for each interaction. Then, to derive an integrated perspective, we mapped how priority SDG targets could interact and create synergies or trade-offs in the Goulburn-Murray region. We constructed a heat map of priority SDGs and targets according to the scores assigned to each interaction. We also represented the interactions among priority SDGs in a network diagram to synthesise the main synergies and trade-offs.

<Insert Table 3 here>

3. Results

3.1. Identifying local priority goals, targets, and interactions

The contextual analysis resulted in a shortlist of priority SDGs and sustainability concerns in the Goulburn-Murray region (Figure 3). The five most frequently coded SDGs across all documents were SDG 6 (i.e., clean water and sanitation; 103 documents), SDG 2 (i.e., agricultural activities; 80 documents), SDG 15 (i.e., life on land; 73 documents), SDG 8 (i.e., decent work and economic growth; 65 documents), and SDG 13 (i.e., climate action; 43 documents). Furthermore, the highest numbers of pairwise SDG interactions across all documents were between SDG 15 and SDG 6 (54 documents), SDG 8 and SDG

2 (49 documents), SDG 6 and SDG 2 (42 documents), SDG 13 and SDG 6 (23 documents), and SDG 8 and SDG 6 (20 documents).

<Insert Figure 3 here>

Word frequency analysis (Figure 4) corroborated the priorities identified from the manual literature coding, finding the priorities to be water management, rivers, catchment management, groundwater, and salinity (SDG 6); agriculture, irrigation, farming, and rural production (SDG 2); climate change, resilience, and adaptation (SDG 13); environmental risks, flood, ecosystems, forests, wetlands, and biodiversity (SDG 15); and economy, industry, and investments (SDG 8).

<Insert Figure 4 here>

From a total of 45 targets under these five goals, we refined our selection to 29 targets in the five priority SDGs for analysis (Table S2). In the context of the Goulburn-Murray, some SDGs or targets were not meaningful or showed minimal relevance compared to other SDGs. For example, the main issues in this region were increasing food production for export to other Australian regions or international markets, or the aim of increasing sustainable agricultural activities, rather than SDGs more relevant to developing countries such as ending hunger (target 2.1) or poverty (SDG 1), or sanitation and hygiene for all people (target 6.2). Given the geography of the region, target 15.4 (i.e., protection of mountain ecosystems) and SDG 14 "conserve and sustainably use the oceans, seas and marine resources for sustainable development" were also not relevant to our case study and were omitted from further consideration.

3.2. Evaluating interactions among Sustainable Development Goals

3.2.1 Target-level interactions

We found 841 interactions among targets (29 × 29), but we quantitatively scored 307 interactions and assessed the level of evidence and confidence in scores assigned for each interaction (Table S3). We identified 126 synergistic interactions (i.e., 41% of total interactions between priority targets), 19 trade-offs (6%), and 162 benign (53%) interactions among targets for the five priority SDGs (Figure 5). By assessing the robustness of evidence and identifying the lack of knowledge among all interactions, we found robust evidence for 51% of target interactions, medium evidence for 46%, and

limited evidence for 3%. Furthermore, high confidence was assigned to 42% of all target interactions, medium confidence to 54%, and low confidence to 4%.

<Insert Figure 5 here>

3.2.2 Goal-level interactions

To understand synergies and trade-offs among SDGs at the goal level, we visualised interactions from the heat map with a network of interactions between priority SDGs (Figure 6). Considering all interactions, our analysis indicates that synergistic interactions among the targets of the five priority SDGs outweigh trade-offs. We highlighted the main trade-off and synergy interactions for SDG implementation by identifying 20 synergies and eight trade-offs among the targets of the five priority SDG goals.

<Insert Figure 6 here>

We focused on the top seven interactions (i.e., three trade-offs and four synergies) among the SDG goals by contextualising them and bringing quotations from relevant documents (Table 4 and Table 5) to focus the main trade-offs and synergies in this region. Three trade-offs and four synergies among the five priority SDG goals were selected according to the highest count of trade-offs and synergies among their target interactions. A notable example is SDG 2 (Agricultural activities) which is associated with the highest count of trade-offs across SDGs 6 (Clean water and sanitation), 8 (Economic growth) and 15 (Life on land). In particular, we identified 4 trade-offs between SDG 2 (Agricultural activities) and SDG 6 (Clean water and sanitation), 5 trade-offs between SDG 2 (Agricultural activities) and SDG 15 (Life on land), and 4 trade-offs between SDG 2 (Agricultural activities) and SDG 8 (Economic growth) (Table 4). For example, implementing some of the targets of SDG 2 (Agricultural activities) is an impediment to implementing some of the targets of SDG 6 (Clean water and sanitation) and SDG 15 (Life on land).

In addition, our analysis indicates that top four synergies are mainly between SDG 6 (Clean water and sanitation) and SDG 15 (Life on land; 20 synergies), SDG 2 (Agricultural activities) and SDG 8 (Economic growth; 16 synergies), SDG 13 (Climate action) and SDG 6 (Clean water and sanitation; 13 synergies), and SDG 6 (Clean water and sanitation) and SDG 2 (Agricultural activities; 10 synergies) (Table 5). For example, SDG 6 is mainly correlated with synergistic co-benefits among other SDGs and implementing water

related SDG targets can benefit life on land (SDG 15), agricultural activities (SDG 2), and consequently bring economic development (SDG 8) for this region.

<Insert Table 4 here>

<Insert Table 5 here>

4. Discussion

We have presented a practical approach for prioritising, analysing, and contextualising SDG interactions at the local scale to inform sustainability policy and planning. Our results identified SDG interactions in the Goulburn-Murray region in Victoria, Australia, that can allow policy makers to evaluate the implications of single-sector actions and help develop multi-sector solutions to limit trade-offs and capture synergies among SDGs. We identified a shortlist of priority SDGs aligned with the needs and concerns of the Goulburn-Murray region, which was derived from relevant documents and interviews with targeted local stakeholders. We also uncovered the major trade-off and synergy interactions of primary importance to five priority SDGs. We analysed the nature of interactions between priority SDGs and targets using a scoring methodology and assessed them with two evaluation criteria (evidence and confidence), and mapped interactions to demonstrate trade-offs and synergies among sectors.

4.1. Priority goals and interactions in the Goulburn-Murray

In this research, the high number of synergies compared to the trade-offs indicates potential opportunities in the Goulburn-Murray region to leverage synergies and overcome trade-offs among SDGs for successful local implementation of the global 2030 Agenda. Here, we discuss these main interactions among the priority SDGs which are critical for achieving local sustainability. The Goulburn-Murray region has been prone to extreme climate and weather conditions and natural hazards such as bushfire, drought, and flooding (e.g., settlements located on floodplains include Shepparton, Tatura, Euroa, Nagambie, and Seymour (Aither 2019)), as well as long-term climatic warming and drying trends. The effects of climate change (SDG 13) have exacerbated uncertainty about water availability and quality (SDG 6), which can significantly constrain agricultural activities (SDG 2) and affect the environmental health of water-dependent ecosystems (SDG 15) (DELWP 2019).

Available water has declined by almost 50% over the last 20 years (RPG 2020). In addition to the effects of climate change, increased competition for water across the Murray-Darling Basin and water policy reforms by the Australian federal government

(i.e., shifting water from agricultural use to environmental use (SDG 15)); have affected water availability in the Goulburn-Murray region. Increasing agricultural production is strongly dependent on water. Hence, variability in water availability could be a threat to the economy of the region (SDG 8). Climate change could further trigger increases in salinity, turbidity, and nutrients. Extreme droughts may trigger toxicants and pathogens, with high risks for environmental uses (DELWP 2019). Strengthening resilience and capacity to adapt to climate change impacts (SDG 13) could mitigate related environmental issues (SDGs 15 and 6).

Another set of interactions was observed between agricultural activities (SDG 2) and their effects on clean water and sanitation (SDGs 6) and life on land (SDG 15). Boosting agricultural activities (SDG 2) may create potential trade-offs and affect water quantity and quality, changing the condition of water-related ecosystems (SDG 6) and triggering land and natural habitat degradation (SDG 15). Soil health (SDG 15) is a constraint on the region's agriculture (SDG 2). Increasingly intensive agriculture over the last 150 years has caused severe structural issues in soils, especially in the subsoil (NCCMA 2016). To meet the demands of domestic and global agricultural markets, it will be necessary to improve soil health and subsoil structure while increasing soil carbon, which has declined significantly in the region (NCCMA 2016).

The clearing of native vegetation to cultivate food crops and produce livestock (SDG 2) has also been a key contributor to the disruption of aquatic ecosystems, impacting the condition of water resources, salinity and degradation of both soil and water resources (SDG 6 and SDG 15), causing reductions in the productive capacity of crop yields throughout the region (Aither 2019). Pesticides and fertilisers applied in agricultural activities, organic livestock waste and other waste from plantation crops are major causes of groundwater and surface water contamination and damage to soil health (NCCMA 2016). Grazing animals and pasture production cause erosion and sediment transport, with negative impacts on water quality (Hubbard et al. 2004). Sustainable agricultural practices could mitigate trade-offs between agriculture (SDG 2), water (SDG 6) and environmental (SDG 15) sectors with improvement to soil health and water quality, thereby bringing long-term economic benefits (SDG 8) for the Goulburn-Murray region.

Balanced development is therefore necessary to increase agriculture while protecting and restoring ecosystems. SDG 2 (Agricultural activities) created influential interactions affecting native vegetation and biodiversity (SDG 15). Biodiversity condition (SDG 15), especially in forested areas, has been declining in this region. The native vegetation extent is a critical attribute of biodiversity and while there has been progress in improving the condition of biodiversity in this region, many species are at risk of extinction mainly because of a loss of habitat and ongoing threats (e.g., pest plants and

441 animals) (GBCMA 2016b). Also, recent trends have shown that the long-term target of
442 increasing native vegetation by 70,000 hectares is below what is needed to be achieved
443 by 2030 in the Goulburn Broken catchment (GBCMA 2016b).

444 Some SDGs showed interactions between their targets. For example, literature on the
445 region unanimously agreed that sustainable development in the agricultural sector
446 (target 2.4) requires significant water-use efficiency improvement (target 2.a). The Shire
447 of Moira in the north-east of Victoria is one example where there is a need to manage
448 threats to water security and meeting water demand through enhancing efficiency (MSC
449 2018). Using appropriate policies to enhance water-use efficiency can foster the synergy
450 between SDG 2 and SDG 6 and consequently bring long-term economic benefits with
451 effects on SDG 8.

452 Another interaction was observed between SDG 2 and SDG 8. The combination of lower-
453 value primary production in the form of dairy farming and high water prices resulted in
454 ongoing challenges for the region's economic sustainability. Dairy production costs have
455 increased in recent years, but financial returns have not changed much. High prices and
456 low allocations of water to dairy farms and pastures in 2019–2020 caused a negative
457 cash flow, affecting the agricultural (SDG 2) and economic (SDG 8) sectors. Many farmers
458 have a cultural attachment to dairy, rather than switching to higher-value agricultural
459 systems with improved water-use efficiency. Although dairy is a large industry in this
460 region, a shift to higher value production systems compatible with variable water
461 availability will be necessary to ensure financial profitability and economic sustainability.
462 High prices for agricultural land in the Goulburn-Murray compared to other regions
463 along with typically small farm sizes, policies reducing water availability, and legacy
464 assets deterring investors from investing capital led to subdued rates of economic return
465 and growth (Downie et al. 2019).

466 Over recent years, labour demand (SDG 8) and rural populations have been declining as
467 a result of expanding farm scales along with increasing automation and novel
468 technologies in agriculture (SDG 2) (RPG 2020). Another issue relating to agriculture in
469 the Goulburn-Murray is rural population ageing and a reduction in the number of
470 farmers from younger generations, which could threaten future food production
471 (GBCMA 2013). An ageing population and rural depopulation combined with stagnating
472 labour productivity and variability in available water (Aither 2019) along with reduced
473 commodity prices and periodic high water prices could have long-term impacts on
474 economic outputs (SDG 8). This could potentially have knock-on effects on the
475 agricultural sector, especially the dairy industry.

476 **4.2. Policy implications**

477 Lack of knowledge around SDG interactions has led to incoherent policies, side-effects
478 of development policies from one sector to others, missed opportunities for synergistic

co-benefits and diverging outcomes in achieving sustainable development (Blanc 2015; Mainali et al. 2018). The results of this study can benefit policy making and avoid inappropriate policies across sectors. Policy makers in Goulburn-Murray can use the results to trace potential synergies and trade-offs to improve policies by considering interactions. We also propose potential solutions which were mostly extracted from local interviews and other policy documents to foster these synergies, tackle trade-offs, and build resilience in the region and align with the global Agenda 2030.

Our results demonstrate how inappropriate policies for gaining economic benefits in the agricultural sector (SDG 2) can create trade-offs for water (SDG 6) and the environment (SDG 15). Sustainable agricultural practices could mitigate potential trade-offs with improvements to soil health and water quality by reducing pollution, thereby bringing long-term economic benefits (SDG 8) for the region. For example, potential solutions include improving soil health by using organic fertilisers or recycled organic materials to supplement inorganic fertilisers, enhancing the proportion of perennial species in pastures, minimising unnecessary cultivation via minimum tillage practices, and using appropriate grazing strategies (GBCMA 2016a). Also, another potential solution would be to fence and restore riparian buffer zones to reduce pollutants entering waterways, along with increasing habitat, biodiversity benefits, and waterway health (NCCMA 2018). As another example, focusing on value-add to agriculture or high value crops rather than broad-acre commodities might be a way to reduce land degradation from unsustainable agricultural practices and make the environmental and water related goals more achievable without affecting (or even improving) agricultural productivity and profitability.

Adopting policies to increase agricultural production without promoting agricultural technologies and developing research (e.g., new irrigation technologies and growing drought-resilient crops) could result in water competition and trade-offs between the water and agricultural sectors. Sustainable agricultural activities as an alternative policy could create a balance between the economic benefits of agriculture and protecting ecosystems (ICSU 2017). We acknowledge Goulburn-Murray Water's (GMW) $2 billion Connections Project which ensures the sustainable future of productive agriculture in this region and could mitigate the potential effects of climate change (SDG 13) on life on land (SDG 15), water (SDG 6) and agricultural (SDG 2) sectors. We recommend complementary approaches to water-use efficiency via different water-saving methods and new farming practices (Norman 2019) to achieve water saving targets in future.

Changing the traditional cropping pattern to high-value crops per hectare/mega-litre could be an effective policy for agriculture (SDG 2), water (SDG 6) and the economy (SDG 8). For example, the profitability of farming enterprises or products could be increased by cultivating crops with the opportunity to process raw products into oils or other niche

products. The Goulburn-Murray region currently accounts for the most valuable export dairy commodities which could be affected by domestic and international markets such as Asia (GVWRRG 2017). The region could also focus more on international market needs especially on demand for fresh fruit from Asia (NCCMA 2016), the production of high-value products, and post-processing of agricultural production to complement current industries and achieve SDG 2 and SDG 8. This would require the development of new product lines, supply-chain logistics, and reform of political relations between governments.

Other proposed solutions focus on the development of high-value production practices such as glasshouse production, protected cropping, and permanent fruit plantings such as the recent increase in planting new apple and pear varieties for export markets. Glasshouse production (SDG 2) is appropriate for improving water-use efficiency (SDG 6) but is dependent on technology and technical expertise. Glasshouse production could benefit market-driven exports and produce fruits and vegetables. There are opportunities for both fresh and processed products such as nuts, plums, olives, citrus, pears, prunes, and apricots. Suggested crops also include corn, grapes, tomatoes, brassicas, chillies, zucchini, eggplant, and broccoli (Downie et al. 2019). It is necessary to adopt appropriate policies and regulatory structures to encourage transformation in the Goulburn-Murray region to develop enterprises with high-value production, with benefits for SDG 2, 8, 6, and 15. Furthermore, developing policies to link the agricultural sector to agri-tourism or aquaculture production for animal feed could diversify farming incomes to maintain economic productivity (SDG 8). Tourism could bring significant income to the region and reduce reliance on agricultural activities (SDG 2).

Adopting incentive policies such as land aggregation and scaling to enhance the attractiveness of land parcels for large-scale investors and facilitate the investment process are most likely to be profitable ways to achieve SDG 8, SDG 2 and some targets under SDG 6 and SDG 15. Development of industry precinct(s) to coordinate investment in value-adding to agricultural/food/industrial produce could also contribute. By planning effectively and building social licence about the types and areas suitable for new development, costs for the agricultural sector could be decreased by sharing access to water, renewable and low-cost energy, high speed internet, and access to markets.

4.3. Innovation and contribution

Our work builds on existing studies by prioritising SDGs according to local area needs rather than focussing on global or national levels (Fuso Nerini et al. 2017; ICSU 2017; Mainali et al. 2018; Singh et al. 2018; UN 2017). Previous studies have presented a comprehensive quantitative assessment of SDG interactions using SDG indicators (Kroll et al. 20 19; Pradhan et al. 2017). We built on these assessments by assessing interactions between goals and targets tailored to a local context. This qualitative

555 richness includes characterising interactions at a finer level by collating multiple sources
556 of information for each interaction.

557 This approach can be broadly applied to other local areas as it allows for the
558 identification of priority SDGs and the main interactions using contextual analysis of
559 related literature and interview with local stakeholders. This approach can support
560 policy making with a high degree of confidence and transparency, leading to more
561 accurate results, and better implementation of the 2030 Agenda. Although our
562 outcomes are context dependent, our results among some SDG interactions enhanced
563 the knowledge base of SDG interactions and could help bring a common understanding
564 of interactions that is applicable to other areas.

565 **4.4. Limitations**

566 The Goulburn-Murray region is a strategic area for both state and federal governments
567 and it has been the subject of many planning, scientific, and strategic investigations,
568 creating a rich source of data and literature for the region. We did not undertake a
569 comprehensive assessment of all available documents via a systematic literature review
570 due to the vast amount of material involved. Instead, we used a local participatory
571 approach using local expertise to target those documents which are critically important
572 for the local stakeholders to achieve the best local results.

573 The vast number of documents assessed in this study have been read by only one person
574 and there is a possibility of potential bias in the scoring approach. Bias in scoring could
575 be reduced by having multiple people score the interactions rather than just one.
576 However, this was simply not possible this due to the very large amount of work involved
577 in scoring so many goals, targets, and interactions. This is a challenge when working with
578 interactions because they increase exponentially as additional SDGs and targets are
579 considered. However, we do not believe that this limitation would have had a material
580 effect on the results and conclusions because we also mitigated this bias and uncertainty
581 and made it explicit by scoring confidence levels.

582 There was often no clear-cut boundary between targets. SDG targets can be broad, span
583 different sectors and can overlap each other. For example, target 6.6 (“protect and
584 restore water-related ecosystems, including mountains, forests, wetlands, rivers,
585 aquifers and lakes”) and 15.1 (“ensure the conservation, restoration and sustainable use
586 of terrestrial and inland freshwater ecosystems and their services, in particular forests,
587 wetlands, mountains and drylands …”) significantly overlap each other. Although in most
588 of the interactions, the confidence criteria were directly affected by the evidence
589 criteria, in some cases there is uncertainty about the assigned scores. In addition, some
590 evidence was relevant to more than one interaction, but we generally looked to find the
591 most relevant interaction for allocating each evidence score.

5. Conclusion

The SDGs are highly interrelated, and local policy makers have encountered difficulties in implementing the 2030 Agenda and achieving progress across all dimensions of sustainable development. We prioritised SDGs at the local level and characterised their interactions for informing policy and planning as a critical step in achieving sustainability in the Goulburn-Murray study area. Our results highlighted SDG 6 (Clean water and sanitation), SDG 2 (Agricultural activities), SDG 8 (Economic growth), SDG 13 (Climate action), and SDG 15 (Life on land) as highest priorities. We found more synergies than trade-offs among priority SDGs and their constituent targets. We discussed policy solutions that leverage synergistic interactions and limit the trade-offs for the successful implementation of priority SDGs. Our results highlighted that the Goulburn-Murray region is subject to ongoing changes in climate, agricultural commodity prices, international markets, and water policy reforms that may impede the achievement of the SDGs. Most trade-offs related to SDG 2 (Agricultural activities) and SDG 8 (economic growth) were associated with unsustainable agricultural or economic activities. Our analysis indicated that SDG 13 (climate action) and SDG 15 (life on land) were linked to other SDGs with only synergistic co-benefits. SDG 6 (Clean water and sanitation) was also mostly related to others through synergistic co-benefits. Understanding interactions among SDGs and targets is essential for local policy makers to achieve policy coherence to fulfil multiple SDGs and to minimise side-effects. Although our results are context-dependent, our practical approach is transferable to other areas for assessing local sustainability though the lens of the SDGs and provides a simple and reproducible methodology for assessing SDG interactions.

Acknowledgments

We acknowledge the contributions of community members and stakeholders in the Goulburn-Murray Irrigation District project. The authors wish to thank Katrina Szetey for her valuable inputs and Nick Taylor from Local SDG project for collecting necessary documents of the literature review.

Funding sources

This project was funded by The Ian Potter Foundation, North Central Catchment Management Authority, and Deakin University. The authors declare no conflict of interest.

Supplementary material

Supplementary material associated with this article was provided for methods and results.

References

Aither 2019, *Goulburn Regional Profile: An analysis of regional strengths and challenges*, Infrastructure Victoria, A Report prepared for Infrastructure Victoria, www.infrastructurevictoria.com.au/wp-content/uploads/2019/04/Aither-Goulburn-Regional-Profile-March-2019.pdf.

Alcamo, J, Thompson, J, Alexander, A, Antoniades, A, Delabre, I, Dolley, J, Marshall, F, Menton, M, Middleton, J & Scharlemann, JPW 2020, 'Analysing interactions among the sustainable development goals: findings and emerging issues from local and global studies', *Sustain Sci*, pp. 1-12, DOI https://doi.org/10.1007/s11625-020-00875-x.

Alston, M, Clarke, J & Whittenbury, K 2018, 'Limits to adaptation: Reducing irrigation water in the Murray-Darling Basin dairy communities', *Journal of Rural Studies*, vol. 58, pp. 93-102, DOI https://doi.org/10.1016/j.jrurstud.2017.12.026.

Baral, H, Keenan, RJ, Sharma, SK, Stork, NE & Kasel, S 2014, 'Spatial assessment and mapping of biodiversity and conservation priorities in a heavily modified and fragmented production landscape in north-central Victoria, Australia', *Ecological Indicators*, vol. 36, pp. 552-62, DOI https://doi.org/10.1016/j.ecolind.2013.09.022.

Blanc, DL 2015, 'Towards Integration at Last? The Sustainable Development Goals as a Network of Targets', *Sustainable Development*, vol. 23, no. 3, pp. 176-87, DOI https://doi.org/10.1002/sd.1582.

Blanc, DL, Freire, C & Vierros, M 2017, 'Mapping the linkages between oceans and other Sustainable Development Goals: A preliminary exploration', *UN Department of Economic and Social Affairs (DESA) Working Papers*, no. 149, UN, New York, DOI https://doi.org/10.18356/3adc8369-en.

Bryan, BA, Hajkowicz, S, Marvanek, S & Young, MD 2008, 'Mapping Economic Returns to Agriculture for Informing Environmental Policy in the Murray–Darling Basin, Australia', *Environmental Modeling & Assessment*, vol. 14, no. 3, pp. 375-90, DOI https://doi.org/10.1007/s10666-008-9144-8.

Crossman, ND, Connor, JD, Bryan, BA, Summers, DM & Ginnivan, J 2010, 'Reconfiguring an irrigation landscape to improve provision of ecosystem services', *Ecological Economics*, no. 69, pp. 1031–42, DOI https://doi.org/10.1016/j.ecolecon.2009.11.020.

DELWP 2019, *Victoria's North and Murray Water Resource Plan, comprehensive report part 1*, Department of Environment, Land, Water and Planning, Victoria State Government, https://www.mdba.gov.au/sites/default/files/pubs/vic-victoria%20s-north-and-murray-comprehensive-report-part-1-30-april-2019.pdf.

Downie, D, Lester, RE, Bomm, A, Fraser, L & Halliwell, D 2019, *Enabling community adaptation in the Goulburn-Murray Irrigation District: Scoping study report*, Centre for Regional and Rural Futures.

Fuso Nerini, F, Tomei, J, To, LS, Bisaga, I, Parikh, P, Black, M, Borrion, A, Spataru, C, Castán Broto, V, Anandarajah, G, Milligan, B & Mulugetta, Y 2017, 'Mapping synergies and trade-offs between energy and the Sustainable Development Goals', *Nature Energy*, vol. 3, no. 1, pp. 10-5, DOI https://doi.org/10.1038/s41560-017-0036-5.

Gao, L & Bryan, BA 2017, 'Finding pathways to national-scale land-sector sustainability', *Nature 544*, pp. 217–22, DOI https://doi.org/10.1038/nature21694.

GBCMA 2013, *Goulburn Broken Regional Catchment Strategy 2013-2019*, Goulburn Broken Catchment Management Authority, https://www.gbcma.vic.gov.au/downloads/RegionalCatchmentStrategy/GBCMA_RCS_2013-19.pdf.

GBCMA 2016a, *Annual Report 2016-17*, Goulburn Broken Catchment Management Authority, https://www.gbcma.vic.gov.au/downloads/AnnualReports/Goulburn_Broken_CMA_Annual_Report_2016-17.pdf.

GBCMA 2016b, *Goulburn Broken Catchment Biodiversity Strategy 2016-2021*, Goulburn Broken Catchment Management Authority, https://www.gbcma.vic.gov.au/downloads/Biodiversity_Strategy/GBCMA_Biodiversity_Strategy_2016_-_2021.pdf.

GMIDWL 2018, *An Inquiry into the effectiveness of the implementation of the Basin Plan and water resource plan*, Goulburn Murray Irrigation District (GMID) Water Leadership, Productivity Commission Murray-Darling Basin Plan: Five-year Assessment, https://www.pc.gov.au/__data/assets/pdf_file/0020/227540/sub062-basin-plan.pdf.

Gupta, M & Hughes, N 2018, *Future scenarios for the southern Murray–Darling Basin water market*, Australian Bureau of Agricultural and Resource Economics and Sciences, https://www.agriculture.gov.au/sites/default/files/documents/abares-future-scenarios-for-southern-mdb.pdf.

GVWRRG 2017, *Goulburn Valley Waste and Resource Recovery Implementation Plan*, Goulburn Valley Waste and Resource Recovery Group, http://www.gvwrrg.vic.gov.au/wp-content/uploads/2017/07/GV-Implementation-Plan.pdf

Herrero, M, Thornton, PK, Mason-D'Croz, D, Palmer, J, Bodirsky, BL, Pradhan, P, Barrett, CB, Benton, TG, Hall, A, Pikaar, I., Bogard, JR, Bonnett, GD, Bryan, BA, Campbell, BM, Christensen, S, Clark, M, Fanzo, J, Godde, CM, Jarvis, A, Loboguerrero, AM, Mathys, A, McIntyre, CL, Naylor, RL, Nelson, R, Obersteiner, M, Parodi, A, Popp, A, Ricketts, K, Smith, P, Valin, H, Vermeulen, SJ, Vervoort, J, van Wijk, M, van Zanten, HHE, West, PC, Wood, SA & Rockström, J 2021, 'Articulating the impact of food systems innovation on the Sustainable Development Goals', *The Lancet: Planetary Health 5 (1)*, pp. e50 – e62, DOI https://doi.org/10.1016/S2542-5196(20)30277-1.

ICSU 2017, *A guide to SDG intercations: from science to implementation*, International Council for Science, https://council.science/wp-content/uploads/2017/05/SDGs-Guide-to-Interactions.pdf.

IGES 2017, *Sustainable Development Goals Interlinkages and Network Analysis: A practical tool for SDG integration and policy coherence*, Institute for Global Environmental Strategies, https://www.greengrowthknowledge.org/sites/default/files/downloads/resource/IGES%20Research%20Report.pdf.

709 Kroll, C, Warchold, A & Pradhan, P 2019, 'Sustainable Development Goals (SDGs): Are we
710 successful in turning trade-offs into synergies?', *Palgrave Communications*, vol. 5, no. 1, DOI
711 https://doi.org/10.1057/s41599-019-0335-5.

712 Mainali, B, Luukkanen, J, Silveira, S & Kaivo-oja, J 2018, 'Evaluating Synergies and Trade-Offs
713 among Sustainable Development Goals (SDGs): Explorative Analyses of Development Paths in
714 South Asia and Sub-Saharan Africa', *Sustainability, MDPI, Open Access Journal*, vol. 10, no. 3,
715 pp. 1-25, DOI https://doi.org/10.3390/su10030815.

716 McCollum, DL, Echeverri, LG, Busch, S, Pachauri, S, Parkinson, S, Rogelj, J, Krey, V, Minx, JC,
717 Nilsson, M, Stevance, A-S & Riahi, K 2018, 'Connecting the sustainable development goals by
718 their energy inter-linkages', *Environmental Research Letters*, vol. 13, no. 3, p. 033006, DOI
719 https://doi.org/10.1088/1748-9326/aaafe3.

720 Moallemi, EA, Malekpour, S, Hadjikakou, M, Raven, R, Szetey, K, Moghadam, MM, Bandari, R,
721 Lester, R & Bryan, BA 2019, 'Local Agenda 2030 for sustainable development', *The Lancet*
722 *Planetary Health*, vol. 3, no. 6, pp. e240-e1, DOI https://doi.org/10.1016/s2542-
723 5196(19)30087-7.

724 Moallemi, EA, Malekpour, S, Hadjikakou, M, Raven, R, Szetey, K, Ningrum, D, Dhiaulhaq, A &
725 Bryan, BA 2020, 'Achieving the Sustainable Development Goals Requires Transdisciplinary
726 Innovation at the Local Scale', *One Earth*, vol. 3, no. 3, pp. 300-13, DOI
727 https://doi.org/10.1016/j.oneear.2020.08.006.

728 MSC 2018, *Major Towns' Strategy Plan Review*, Moira Shire Council,
729 https://www.moira.vic.gov.au/Residents/Building-and-planning/Planning/Current-and-future-
730 planning/Strategic-Plans-and-Strategies/Major-Towns-Strategy.

731 NCCMA 2016, *North Central Victoria Regional Sustainable Agriculture Strategy*, North Central
732 Catchment Management Authority,
733 http://www.nccma.vic.gov.au/sites/default/files/publications/nccma_sustainable_agriculture_
734 strategy_2016_final_web.pdf.

735 NCCMA 2018, *Annual Report 2017/18*, North Central Catchment Management Authority,
736 http://www.nccma.vic.gov.au/sites/default/files/publications/2017-
737 18_north_central_cma_annual_report_.pdf.

738 Nilsson, M 2017, 'Important interactions among the Sustainable Development Goals under review
739 at the High-Level Political Forum 2017', *SEI Working Paper 2017-06, Stockholm Environment*
740 *Institute, Stockholm*, http://mediamanager.sei.org/documents/Publications/SEI-WP-2017-06-
741 Nilsson-SDG-interact-HLPF2017.pdf

742 Nilsson, M, Griggs, D & Visbeck, M 2016, 'Map the interactions between Sustainable Development
743 Goals', *Comment in Nature*, vol. 53, no. 7607, DOI
744 https://doi.org/10.1787/agr_outlook-2015-en.

745

746 Patole, M 2018, 'Localization of SDGs through Disaggregation of KPIs', *Economies*, vol. 6, no. 1, p.
747 17, DOI https://doi.org/10.3390/economies6010015.

748 Pradhan, P, Costa, L, Rybski, D, Lucht, W & Kropp, JP 2017, 'A Systematic Study of Sustainable
749 Development Goal (SDG) Interactions', *Earths Future*, vol. 5, no. 11, pp. 1169-79, DOI
750 https://doi.org/10.1002/2017ef000632.

QSR International Pty Ltd 2018, NVivo qualitative data analysis software.

RPG 2020, GMID Resilience Strategy, Regional Partnership Goulburn.

Scharlemann, JPW, Brock, RC, Balfour, N, Brown, C, Burgess, ND, Guth, MK, Ingram, DJ, Lane, R, Martin, JGC, Wicander, S & Kapos, V 2020, 'Towards understanding interactions between Sustainable Development Goals: the role of environment–human linkages', *Sustain Sci*, vol. 15, no. 6, pp. 1573-84, DOI https://doi.org/10.1007/s11625-020-00799-6.

Singh, GG, Cisneros-Montemayor, AM, Swartz, W, Cheung, W, Guy, JA, Kenny, T-A, McOwen, CJ, Asch, R, Geffert, JL, Wabnitz, CCC, Sumaila, R, Hanich, Q & Ota, Y 2018, 'A rapid assessment of co-benefits and trade-offs among Sustainable Development Goals', *Marine Policy*, vol. 93, pp. 223-31, DOI https://doi.org/10.1016/j.marpol.2017.05.030.

UN 2015, *Transforming our world: the 2030 Agenda for Sustainable Development*, A/RES/70/1. UN General Assembly, New York, https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf.

UN 2017, *Integrated Approaches for Sustainable Development Goals Planning*, United Nations, DOI https://doi.org/10.18356/0ca8f8ae-en.

UN 2019, *Annex: Gearing up for a decade of action and delivery for sustainable development: political declaration of the Sustainable Development Goals summit under the auspices of the United Nations General Assembly*, Resolution 74.4, adopted by the General Assembly on 15 October 2019, New York, https ://undoc s.org/en/A/RES/74/4.

UN 2020, *The Sustainable Development Goals Report 2020*, United Nations, https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf.

Van Soest, HL, Van Vuuren, DP, Hilaire, J, Minx, JC, Harmsen, MJHM, Krey, V, Popp, A, Riahi, K & Luderer, G 2019, 'Analysing interactions among Sustainable Development Goals with Integrated Assessment Models', *Global Transitions*, vol. 1, pp. 210-25, DOI https://doi.org/10.1016/j.glt.2019.10.004.

Walker, BH, Abel, N, Anderies, JM & Ryan, P 2009, 'Resilience, Adaptability and Transformability in the Goulburn-Broken catchment, Australia', *Ecology and Society*, vol. 14(1): 12, DOI https://doi.org/10.5751/ES-02824-140112.

Weitz, N, Carlsen, H, Nilsson, M & Skanberg, K 2018, 'Towards systemic and contextual priority setting for implementing the 2030 Agenda', *Sustain Sci*, vol. 13, no. 2, pp. 531-48, DOI https://doi.org/10.1007/s11625-017-0470-0.

Weitz, N, Nilsson, M & Davis, M 2014, 'A Nexus Approach to the Post-2015 Agenda: Formulating Integrated Water, Energy, and Food SDGs', *SAIS Review of International Affairs*, vol. 34, no. 2, pp. 37-50, DOI https://doi.org/10.1353/sais.2014.0022.

Tables

Table 1. Description of participant organisation representatives and individual interviewees.

Groups or individual participant
• Agribusiness executive
• Industry research and development representative
• Irrigation industry group representative
• Various industry group representatives including farming, dairy and fruit growing
• Farmers in the dairy, fruit growing and horticulture industries
• Regional consultants
• Regional partnership board member
• Government council board members from multiple jurisdictions
• Farmer advocacy group representative
• Representative of water services committee
• Financial and economic consultant
• Investment broker
• Corporate strategist
• Water provider representatives
• Business development manager
• Representative in the management of environmental water
• Local council/shire representatives (Victorian and NSW)
• Catchment management agency representatives (past and present)
• Water consultant
• Water trading consultant
• Media business representative
• Public service representatives – state (NSW, VIC) and federal
• Project manager
• Member of Parliament
• Higher education institution representative

798 **Table 2.** Seven-point ordinal scale used to characterise and score interactions among
799 Sustainable Development Goal (SDG) targets. This table is adapted from Nilsson (2016).
800 Numbers (e.g., 6.6) represent target numbers in the SDG framework as outlined in Table
801 S2.

Interaction	Score	Description	Example
Indivisible	+3	A robust form of positive interaction where the achievement of one target is inextricably linked to the achievement of another.	Protecting and restoring water-related ecosystems (6.6) is an indivisible form of conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems (15.1).
Reinforcing	+2	One target significantly and directly causes the achievement of another target.	Ensuring sustainable food production systems and implementing resilient agricultural practices (2.4) reinforces approaches to combating desertification and restoring degraded land and soil (15.3).
Enabling	+1	The achievement of one target enables to the achievement of another target.	Ensuring sustainable food production systems and implementing resilient agricultural practices (2.4) enables improvements in water quality by reducing pollution (6.3).
Consistent	0	No important positive or negative interaction between two targets.	Maintaining the genetic diversity of seeds and cultivated plants (2.5) is consistent with supporting and strengthening the participation of local communities in improving water and sanitation management (6.b).
Constraining	−1	The pursuit of one target constrains the achievement of another target.	Investment in rural infrastructure (2.a) combined with agricultural mechanisation and automation may constrain the achievement of full and productive employment and decent work for all women and men (8.5).
Counteracting	−2	The achievement of one target counteracts the achievement of another.	Doubling agricultural productivity (2.3) may counteract the achievement of adaptive capacity to climate-related disasters (13.1).
Cancelling	−3	The most negative interaction where the achievement of one target makes it impossible to achieve another target.	Developing infrastructure (9.1) negates attempts to reduce natural habitat degradation (15.5).

802

803

804 **Table 3.** Evaluation criteria for the assessment of evidence and validation of assigned
805 scores

Evaluation Criteria	Evidence ('limited', 'medium', and 'robust')	Confidence ('low', 'medium', and 'high')
Limited/ Low	Limited evidence meant that we did not find any relevant documents for characterising interactions, we may have found just one document of lower relevance and mostly relied upon our own judgement.	We assigned a 'low' confidence score if the evidence was 'limited' and our scores were not well supported by evidence, or if evidence relevancy was 'medium' but the author team was not confident in the scores assigned.
Medium	Medium evidence meant that we found one source with highly relevant information or two sources with moderately relevant information.	We assigned a 'medium' confidence score if our scores were supported by some elements of the literature, with the presence of disagreements, but the author team was confident in the score assigned.
Robust/ High	Robust evidence meant that we found more than one source with highly relevant information or a combination of highly and moderately relevant information sources for characterising interactions.	If we had robust evidence with high consistency among sources and our scores were supported by this evidence, the author team assigned 'high' as a confidence score.

806
807
808
809
810
811
812
813
814
815
816

817 **Table 4.** Contextualising the main trade-offs between Sustainable Development Goal 2
818 (i.e., zero hunger) and three other Sustainable Development Goals (SDGs) in the
819 Goulburn-Murray Region. The table summarises quotations from relevant documents.

Affecting SDGs	Affected SDGs	Number of trade-off target interactions	Interaction examples
SDG 2. Zero hunger	SDG 6. Clean water and sanitation	5	"…Land use changes include increased dairy production and increased cropping. These have the potential to increase sediment and nutrient loads in waterways and toxicant impacts on groundwater."(DELWP 2019) "Yet water security and water-dependent ecosystems in many irrigated areas are threatened by the increase in demand for water to meet food requirements of growing populations…"(Crossman et al. 2010) "…agriculture often has a cost in terms of the impact on land and water resources such as reduced environmental flows and water quality, biodiversity loss, soil erosion and degradation and other impacts." (Bryan et al. 2008)
SDG 2. Zero hunger	SDG 15. Life on land	4	"… generally speaking, salinity is an issue in the Goulburn region due to the widespread conversion of native vegetation land to agricultural land and a shallow water table. Salinity can be an issue in both dryland and irrigated areas due to changes in hydrology as a result of land use change. The spread of dryland salinity in Victoria slowed or receded in many areas during the dry period (known as the Millennium Drought) due to lower groundwater tables however, the area impacted by salinity is likely to increase with a return of wetter conditions"(Aither 2019) "Substantially modified land-cover types (generally associated with agriculture and irrigated pastures) had lower habitat quality and biodiversity value."(Baral et al. 2014) "Overgrazing – intensive grazing of pasture for extended periods or insufficient recovery time resulting in insufficient ground cover (dairy)."(NCCMA 2016)
SDG 2. Zero hunger	SDG 8. Decent work and economic growth	4	"Advances in decoupling economic growth from environmental degradation may be constrained by a focus limited to doubling agricultural productivity." (ICSU 2017) "In line with national trends, there are fewer and larger farms, with increasing production efficiency. Increasing scale, combined with mechanisation and automation, leads to reduced demand for labour and rural depopulation."(RPG 2020)

820

Table 5. Contextualising the main synergies among Sustainable Development Goals (SDGs) in the Goulburn-Murray Region with quotations from relevant documents.

Affecting SDGs	Affected SDGs	Number of synergy target interactions	Interaction examples
6. Clean water and sanitation	15. Life on land	20	"Large-scale water for the environment deliveries to rivers and wetlands, natural inflows and additional protection and restoration works build on 20 years of activity that is addressing historical degradation. It could causes conservation and restoration of terrestrial and fresh water ecosystem."(NCCMA 2018) "One of the effects of poor water quality or salinity is degradation of the environment and wildlife habitats."(Aither 2019)
2. Zero hunger	8. Decent work and economic growth	16	"This region (Goulburn-Murray) is characterised by a relatively high concentration of agriculture and food product manufacturing industries as well as construction associated with rapid population growth in the peri-urban fringe. Agriculture and food manufacturing are key exports for the region… Dairying is a major industry in the valley floodplains and the biggest contributor to the local economy, sheep grazing for wool and meat and beef cattle fattening are also important and dominate the foothills other agriculture includes wine grapes and niche crops."(DELWP 2019) "The trend for fresh fruit will continue due to higher values and a renewed interest in fresh fruit export. Expansion of annual horticulture is also occurring with vegetable production moving further from Melbourne." (RPG 2020)
13. Climate action	6. Clean water and sanitation	13	"Climate change was the only cause of risk that generated very high risks to water availability for environmental and consumptive uses. Extreme drought caused high risk to environmental and consumptive uses. As a result of climate change and extreme drought, adverse changes to the inflow of water to aquifers was identified as a common threat to the beneficial use of groundwater. Higher temperatures and extended periods of low rainfall can result in increased evapotranspiration and reduced infiltration, resulting in a decline in inflow to aquifers."(DELWP 2019) "The Goulburn-Murray region has been getting warmer and drier. The region can expect temperatures to continue to increase year round; more hot days and warm spells; fewer frosts; less rainfall in autumn, winter and spring; and more frequent and more intense downpours." (RPG 2020)
6. Clean water and sanitation	2. Zero hunger	10	"Over the last twenty years, there has been an almost 50% net decline in water resources. This is due to a combination of climate change, water recovery as part of the Murray Darling Basin Plan, changes to water policy and competition for water from outside the region. Living with variability in water availability is already a feature of agriculture in the Goulburn-Murray region. Supply and demand determine water price and competing industries buy or sell water at different price points." (RPG 2020) "During drought periods, water trading allows scarce water resources to be allocated to regions and industries in greatest need…Water trading and carryover also play a role in facilitating long-run adjustment. Water markets allow water allocations and entitlements to be traded into expanding industries and regions. Carryover rights give water users some control over the reliability of supply, allowing for adjustment in response to industry changes— such as increased reliability to support more horticultural activity." (Gupta & Hughes 2018) "Following a lengthy drought at the turn of the century concerns were raised about water quality and river health. This led successive governments to introduce policies to systematically reduce water available for irrigated agriculture. The Murray-Darling Basin Plan was developed by the Commonwealth government and is designed to secure water savings from irrigators and to direct those water savings to the stressed natural environment."(Alston et al. 2018) "Food price volatility is higher with insufficient water availability in agriculture."(ICSU 2017) "Past clearing of native vegetation has caused saline water tables to rise, threatening crop production. Groundwater pumping is necessary but leads to discharging salt into the Murray River at levels that can be unacceptable to downstream users."(Walker et al. 2009)

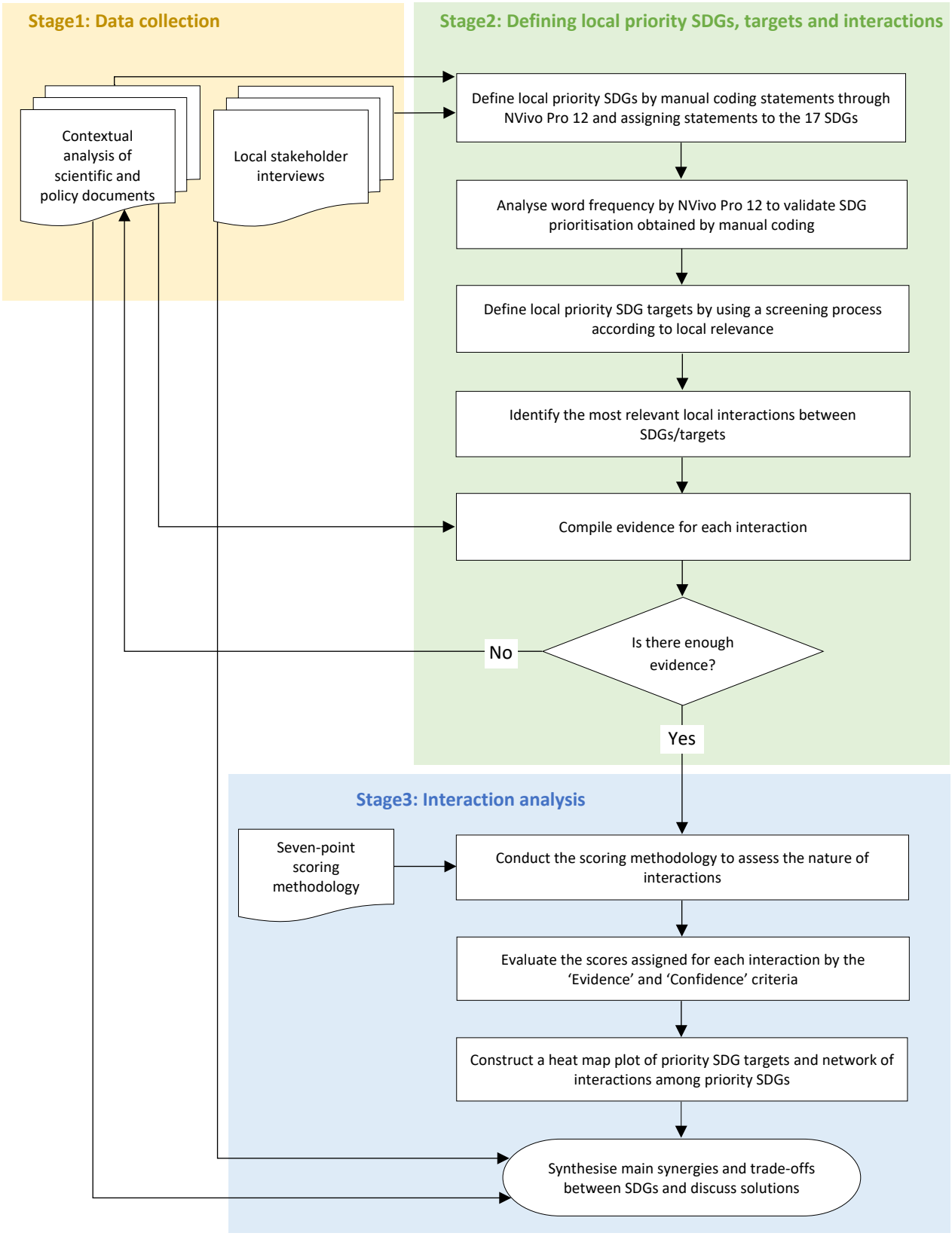

Figure 1. Overview of the methods used to prioritise and map interactions among local priority SDGs and targets.

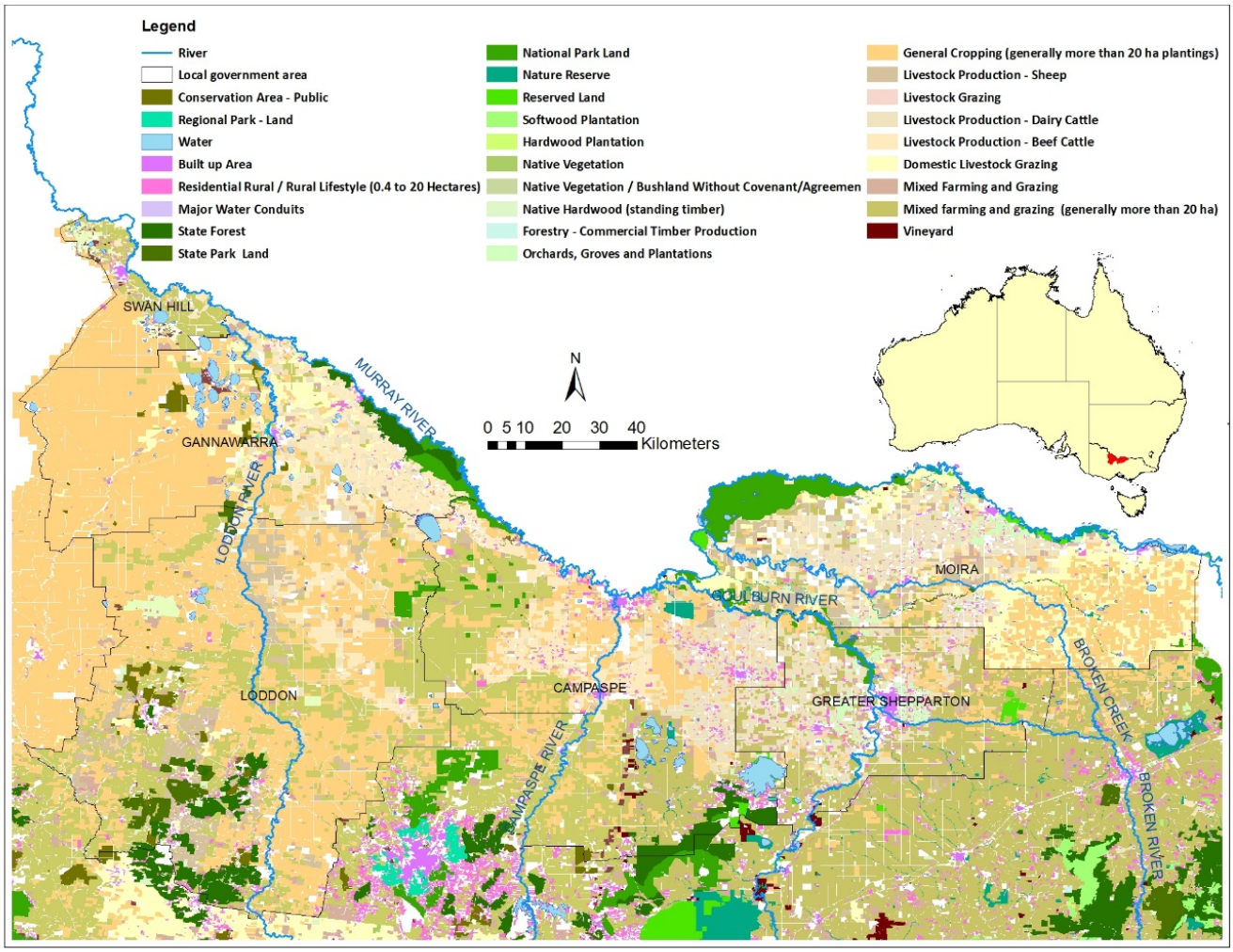

Figure 2. Map of land-use in the Goulburn-Murray in Victoria, Australia, (source of the land use shape file: land.vic.gov.au). Colours should be used for this figure in print.

SDGs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SDG 1: No Poverty	0																
SDG 2: Zero Hunger	0	80															
SDG 3: Good Health and Well-Bing	0	1	6														
SDG 4: Quality Education	0	1	1	5													
SDG 5: Gender Equality	0	0	0	0	2												
SDG 6: Clean Water and Sanitation	0	42	1	0	0	103											
SDG 7: Affordable and Clean Energy	0	0	0	0	0	1	4										
SDG 8:Decent work and economic growth	0	49	1	1	0	20	0	65									
SDG 9: Industry, Innovation and Infrastructure	0	6	0	0	0	6	0	8	23								
SDG 10: Reduced Inequalities	0	0	0	0	0	0	0	0	0	6							
SDG 11: Sustainable cities and communities	0	1	0	0	0	1	0	1	1	0	16						
SDG 12: Responsible Consumption & Production	0	3	1	0	0	10	2	1	0	0	0	21					
SDG 13: Climate Action	0	10	0	0	0	23	0	5	2	0	0	0	43				
SDG 14: Life below Water	0	0	0	0	0	0	0	0	0	0	0	0	0	1			
SDG 15: Life on Land	0	22	0	0	0	54	1	10	2	0	1	8	12	1	73		
SDG 16: Peace, Justice and Strong Institution	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	15	
SDG 17: Partnerships for the Goals	0	2	0	0	0	2	0	3	1	0	1	0	0	0	2	1	17

Figure 3. Heat map of the number of documents coded through contextual analysis for the 17 Sustainable Development Goals and their interactions. Colour scale from white (0, no documents) to dark green (103 documents). The diagonal of this matrix shows the number of documents relevant to only one SDG. Off-diagonal cells display the number of documents relevant to two SDGs. Colours should be used for this figure in print.

888

889 **Figure 4.** Word frequency analysis in the selected literature. Font size is indicative of
890 word frequency.

891

892

893

894

895

896

897

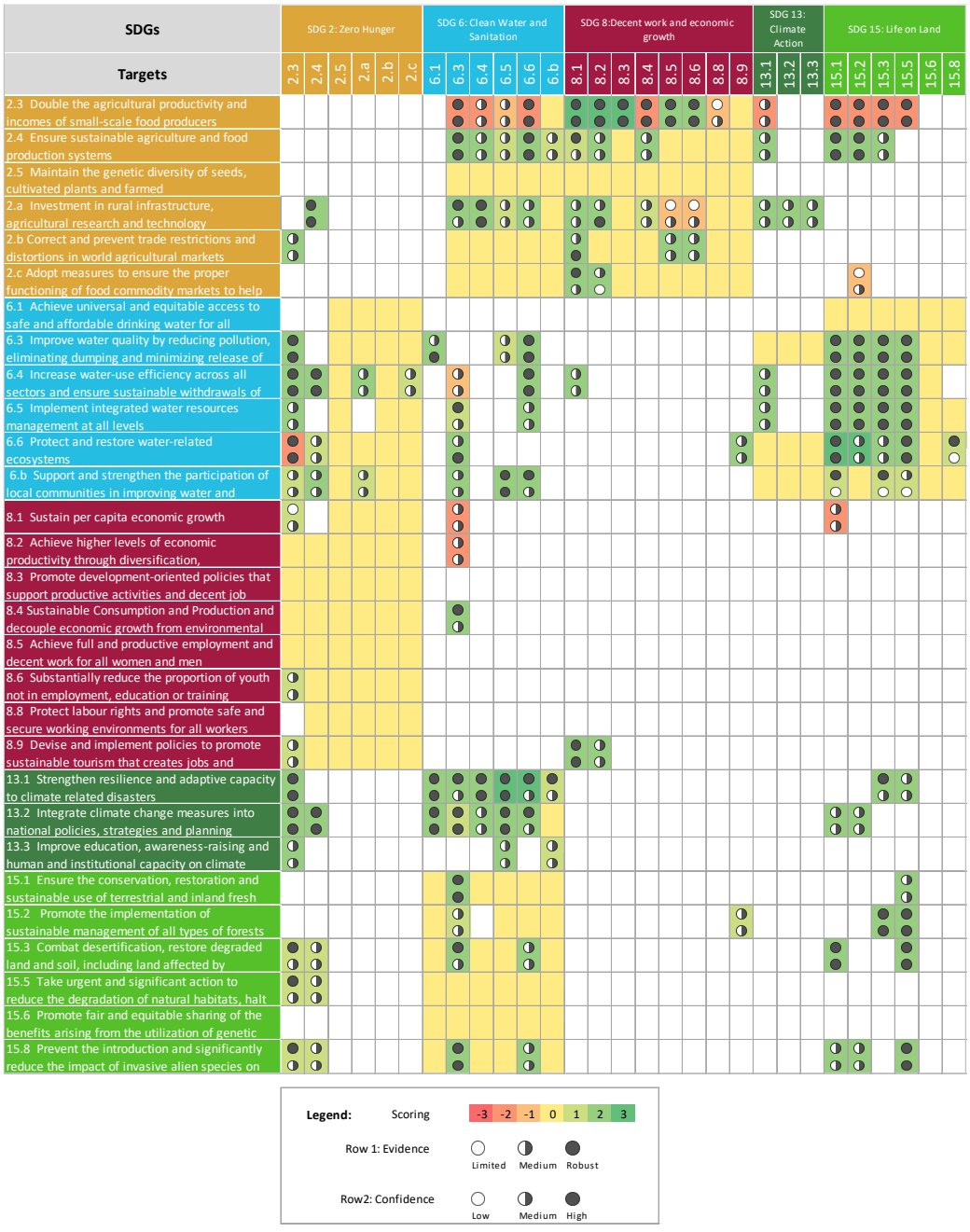

Figure 5. Heat map of 29 Sustainable Development Goals targets and their interactions in the Goulburn-Murray region. See Table S3 for a definition of interaction scores, here displayed with a colour scale and see Table S2 for description of each target. For each interaction, evidence is shown in the top circle and confidence in the bottom circle. Blank cells indicate interactions not assessed in this study. Note the matrix is not symmetrical along its diagonal. The heat map matrix is not symmetrical along the diagonal, as some interactions were unidirectional. For example, target 2.3 (doubling agricultural productivity) affected target 6.3 (water quality), and target 6.3 affected

target) 2.3 (i.e., bidirectional interaction). On the other hand, target 2.4 (Agricultural activities) affected target 6.3 but target 6.3 did not affect target 2.4 (i.e., unidirectional interaction). Colours should be used for this figure in print.

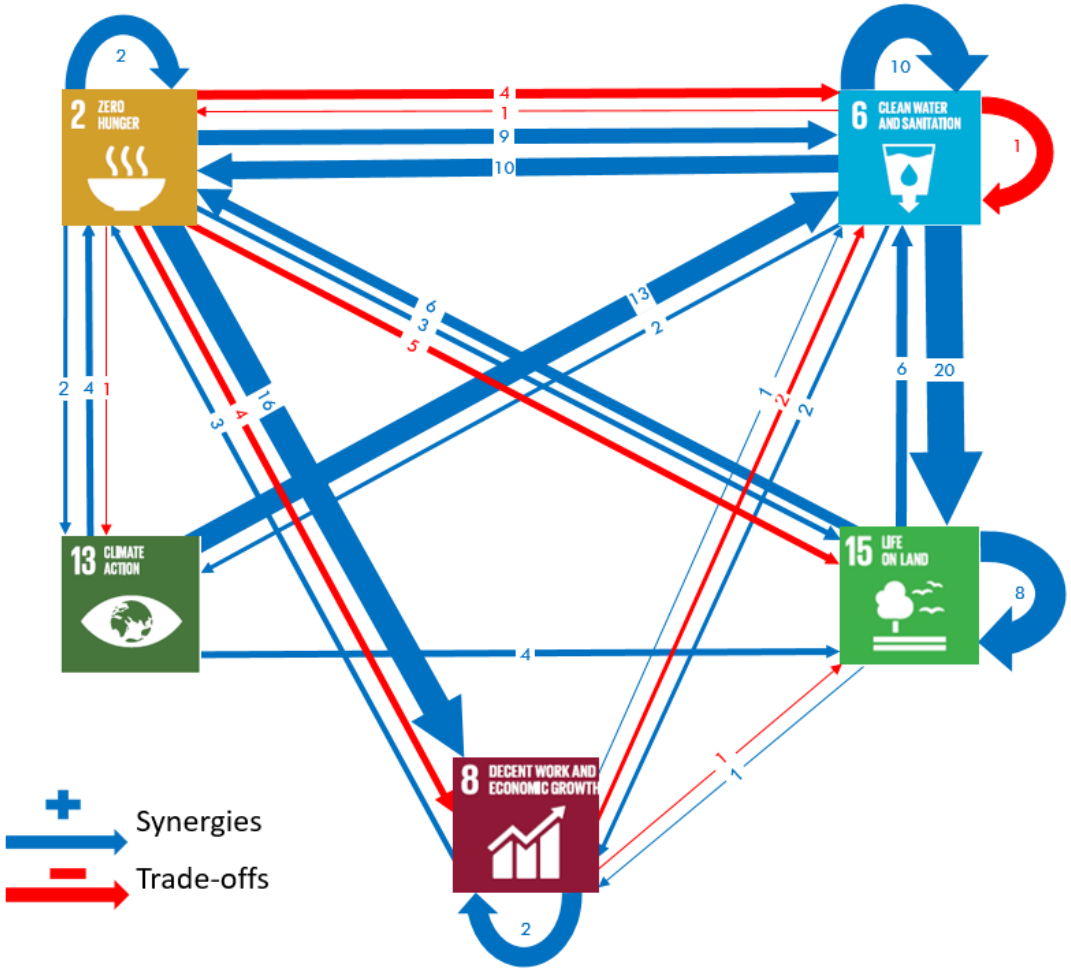

Figure 6. Network of interactions among priority Sustainable Development Goals (SDGs) in the Goulburn-Murray region. Each priority goal is a node that connects with other goals via blue (synergies) or red (trade-offs) arrows. Arrow thickness denotes the strength of links (i.e., number of target interactions) between two goals. Loop arrows show how one target can also (synergies or trade-offs) impact other targets under the same SDG. The SDGs icons are the courtesy of the UN SDGs communications material. Colours should be used for this figure in print.