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Modelling national transformations to achieve the SDGs within planetary boundaries in small island developing states

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Non-technical summary. The Sustainable Development Goals (SDGs) provide an integrated and ambitious roadmap for sustainable development by 2030. National implementation will be crucial and there is an urgent need to understand the scale and pace of transformations to achieve the goals. There is also concern that achieving socio-economic objectives will undermine longer-term environmental sustainability. This study uses modelling to explore how different policy and investment settings can enable the necessary transformations, adopting Fiji as a use-case. Modest investment over the coming decade can deliver improved performance. However, far more ambitious actions are needed to accelerate progress while managing long-term trade-offs with environmental objectives.

Technical summary. This paper presents the results from a national scenario modelling study for Fiji with broader relevance for other countries seeking to achieve the SDGs. We develop and simulate a business-as-usual and six alternative future scenarios using the integrated (*iSDG-Fiji*) system dynamics model and evaluate their performance on the SDGs in 2030 and global planetary boundaries (PBs) and the 'safe and just space' (SJS) framework in 2050. Modest investment over the coming decade through a 'sustainability transition' scenario accelerates SDG progress from 40% to 70% by 2030 but fails to meet all SJS thresholds. Greatly scaling up investment and ambition through an SDG transformation scenario highlights possibilities for Fiji to accelerate progress to 83% by 2030 while improving SJS performance. The scale of investment is highly ambitious and could not be delivered without scaled-up international support, but despite this investment progress still falls short. The analysis highlights where key trade-offs remain as well as options to address these, however closing the gap to 100% achievement will prove very challenging. The approach and findings are relevant to other countries with similar characteristics to increase the understanding of the transformations needed to achieve the SDGs within PBs in different country contexts.

Social media summary. How can countries accelerate progress on the SDGs by 2030 while ensuring longer-term coherence with climate and sustainability thresholds?

1. Introduction

The *2030 Agenda* and Sustainable Development Goals (SDGs) provide an integrated, ambitious and transformative global roadmap for achieving sustainable development by 2030 (UNGA, 2015). The challenge for achieving the SDGs is huge. Currently, no country meets the needs of its citizens at a globally sustainable level of resource use (O'Neill et al., 2018). Despite the need for global outcomes, most implementation measures will be developed at national or local levels and will rely upon ambitious commitments and action by countries (Allen et al., 2018; Stafford-Smith et al., 2018). However, very little is said in the *2030 Agenda* about its implementation (Randers et al., 2018) and the world is not on track to achieve most of the targets (Messerli et al., 2019b; Moyer & Hedden, 2020). There is a concern that achieving socio-economic targets will compromise our ability to achieve environmental targets (Hickel, 2019; Scherer et al., 2018; Spaiser et al., 2017; Spangenberg, 2017; Wackernagel et al., 2017). Efforts to achieve the SDGs may exceed global planetary boundaries (PBs) (Rockström et al., 2009; Steffen et al., 2015) and fail to deliver a 'safe and just space' (SJS) for humanity (Raworth, 2012, 2017).

Much more needs to happen in all countries to bring about the changes required to achieve the SDGs. Research is needed to understand and model national transitions and transformations in different country contexts (Messerli et al., 2019a; Randers et al., 2019; Sachs et al., 2019). Although national studies assessing interlinkages between the SDGs to support policy coherence are advancing (Breu et al., 2021; Weitz et al., 2017), there have been few national modelling studies published to date that provide practical guidance for the necessary transformations (Allen et al., 2019; Banerjee et al., 2017; Collste et al., 2017; Gao & Bryan, 2017; Pedercini et al., 2019b). Also, although global models have begun to address the critical link between the SDGs and PBs (Randers et al., 2019), the broader sustainability of SDG interventions beyond 2030 remains to be addressed in national modelling studies. Filling this gap is crucial as the national level is where many policy and investment decisions are made (Häyhä et al., 2016) and where the 'rubber hits the road' for implementing sustainable development (Bryan et al., 2019).

Small island developing states (SIDS) represent one-fifth of United Nations member states (UNDESA, 2019), and have many similar development challenges and priorities including small but growing populations and economies, comparatively low resource and carbon footprints, small administrations with limited resources, reliance on international trade and support, and very high vulnerability to climate change (United Nations Environment Programme, 2014). SIDS have strongly committed to achieving the SDGs (UN General Assembly, 2014) and are at the frontline of climate change impacts, but will depend upon international support and partnership to reach the SDGs. Understanding resource requirements to achieve the SDGs and harvesting synergies (Pedercini et al., 2019a) between climate action and SDG achievement will be critical for SIDS (Scobie, 2019).

This paper presents the results of a national-scale scenario modelling study undertaken for Fiji using the *iSDG-Fiji* integrated assessment model. Fiji is selected as a representative use-case of broad relevance to other SIDS and developing countries with similar characteristics as it has relatively good data availability as well as a comprehensive suite of recent national studies, strategies and targets (Government of Fiji, 2017a, 2017b, 2018a, 2018b). Fiji is an upper-middle income country with a robust long-term planning framework including a medium- and long-term National Development Plan (NDP) aligned with the SDGs (Government of Fiji, 2017c) which estimates additional investment needs of FJD50 billion over the period to 2036. Fiji is highly vulnerable to the effects of climate change (Government of Fiji, 2017a, 2018b) and addressing climate change and improving livelihoods and inequality are strategic priorities. Fiji has adopted ambitious climate change commitments including a vision for net zero emissions by 2050 (Government of Fiji, 2017b, 2018a). Additional background on Fiji and its SDG priorities is given in Supplementary Text SI.1. Our research explores how different policy and investment settings in Fiji can deliver coherent and improved performance on all 17 SDGs by 2030. We develop and simulate a business-as-usual (BAU) and six alternative future scenarios for Fiji and evaluate their performance on the SDGs by 2030 as well as their long-term coherence with PBs and the SJS framework in 2050. The research extends the scenario framework developed by Allen et al. (2019), nesting six alternative scenarios within the global shared socio-economic pathways (SSPs) for human development (Bauer et al., 2017; O'Neill et al., 2014, 2017; Riahi et al., 2017), each with a coherent set of assumptions, policy and investment settings.

2. Methods

2.1 Scenario framework, settings and targets

The SSPs comprise five different global pathways[i] which serve as reference scenarios for other studies (Bauer et al., 2017), with narratives for each pathway framed around future changes in key elements relating to demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources (O'Neill et al., 2017). However, the SSPs focus on challenges to climate change mitigation and adaptation and as such they do not address the majority of SDG targets quantitatively (Zimm et al., 2018). Given the focus of this study on the SDGs, these elements were further tailored based on recent literature on the main transformations needed to achieve the SDGs (Messerli et al., 2019b; Sachs et al., 2019). This provided six key 'entry points' or drivers that were used to structure and frame the different policy interventions, assumptions and investment settings across the alternative scenarios (Figure 1). These are considered to be important entry points in terms of driving changes in the model, either in terms of assumptions for key exogenous variables (e.g. for net migration or global temperature change) or for key interventions (e.g. expenditure in areas such as health and education, clean energy or environmental management). For each driver, a range of quantitative settings were developed for the calibration and parameterisation of the model, based on global integrated assessment model projections (Riahi et al., 2017), scientific literature, national and global time series data, and national modelling and projections undertaken across a range of sectors in Fiji (see sources in Supplementary Table SI.1).

Brief qualitative narratives for each of the six scenarios are provided in Table 1, along with aggregate investment and revenue settings, building on the scenario framework developed by the authors in Allen et al. (2019) (Figure 1). A BAU scenario provides the baseline for the analysis, with a continuation of existing trends and policy settings. The four foundation scenarios of 'Growth at all Costs' (GC), 'Green Economy' (GE), 'Inclusive Growth' (IG) and 'Sustainability Transition' (ST) are based on dominant development discourses of the past decade (Commission on Growth and Development, 2008; Gupta et al., 2015; UNEP, 2011; United Nations General Assembly, 2000). They use moderately ambitious and technically feasible settings, requiring only modest reallocation of government expenditure and private investment compared to the BAU scenario (on average from FJD430 million to FJD1 billion per annum to 2030, which corresponds to an average annual investment of 2.3% to 5.6% GDP) (Supplementary Table SI.1).

For this study, we expand on the 'ST' scenario with two additional scenarios: the high climate ambition ('ST_CLIMATE') scenario; and the high SDG ambition ('ST_SDG') scenario. Each of these scenarios relies on the 'ST' scenario narrative but incorporate significant investment along with more ambitious assumptions around climate or SDG action. These are exploratory scenarios that test the level of investment needed to deliver the rapid transformations at the scale and pace required for SDG achievement by 2030 and long-term sustainable development in 2050.

'ST_CLIMATE' represents a high-ambition climate action scenario which includes considerable expenditure and policy change to address climate change mitigation, targeting energy efficiency, renewable energy and electric vehicles (averaging FJD1.6 billion per annum to 2030, which corresponds to an average annual investment of 8.9% GDP) (Supplementary Table SI.1). 'ST_SDG' scenario represents a very high-ambition SDG transformation scenario combining deeper climate action measures with expenditure and settings in a range of other sectors including education, health, social transfers, taxation, transport, agriculture, protected areas, governance and gender equality (Supplementary Table SI.1) (averaging FJD4.2 billion per annum to 2030, which corresponds to an average annual investment of 21.7% GDP).

[i]SSP1: sustainability; SSP2: middle of the road; SSP3: regional rivalry; SSP4: inequality; SSP5: fossil-fuelled development.

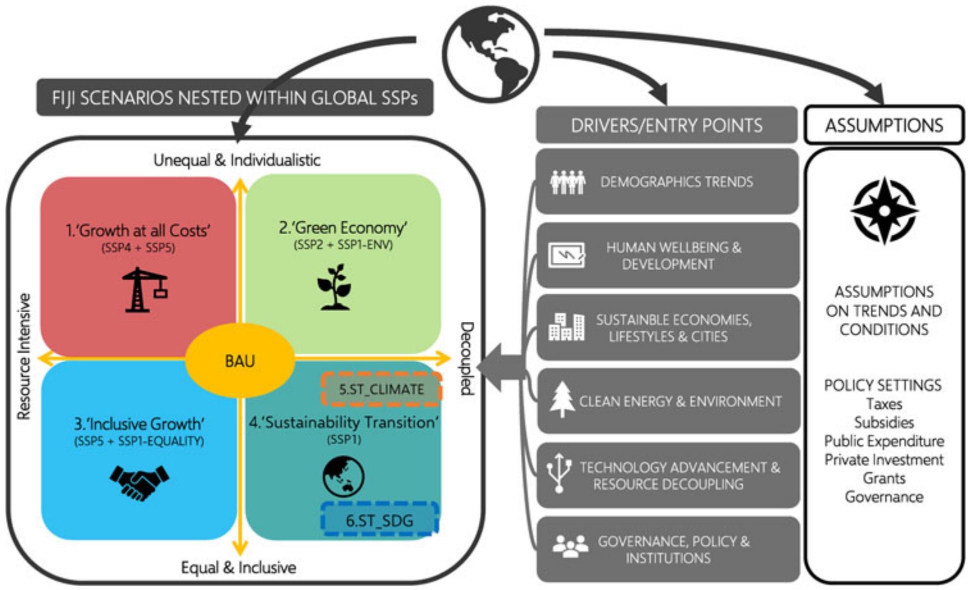

Fig. 1. Scenario framework used for the Fiji SDG modelling (adapted from Allen et al., 2019).

For each of the scenarios (Table 1), additional government expenditure (expressed as a share of GDP) is financed from revenue raised by increasing taxes (on income and profits, consumption or trade) or from international grants, with any shortfall financed through government borrowings (on which interest is paid). Any additional private investment in the scenarios is reallocated from private savings. The aggregate effect is that most of the 'additional' expenditure included the scenarios is the result of the reallocation of resources. As such, although the annual investment figures for the high-ambition scenarios are considerable and expressed as a share of GDP, they should not be interpreted as an annual percentage increase in GDP.

2.2 iSDG-Fiji *model structure, calibration and validation*

An overview of the *iSDG-Fiji* model is provided in Supplementary Text SI.2. Model selection was informed by prior research that found the *iSDG* simulation model to be well-suited for national SDG modelling (Allen et al., 2016). The base *iSDG* model has a stock and flow structure and is formulated as a system of differential equations comprising approximately 3000 variables organised across 30 sectors, covering key economic, social and environmental domains. The validation of the model involved both structural and behavioural validation using approximately 25 years of time series data for Fiji for the period 1990 to the most recent year (usually 2015–2018). Data were sourced from official national government sources (Fiji Bureau of Statistics and government administrative databases) and official data from international databases hosted by the UN, International Monetary Fund and World Bank (Supplementary Tables SI.1 and SI.2). The model implementation process is iterative, involving multiple rounds of calibration using multi-parametrical optimisation. Behaviour reproduction tests were used to evaluate the goodness-of-fit of simulated and actual data (Bennett et al., 2013; Sterman, 2000) (Supplementary Table SI.3).

Parameterisation of each of the alternative scenarios was based on the settings in Supplementary Table SI.1. The simulation period for the study was set as the remaining implementation period for the SDGs (beginning of 2020 to the end of 2030). For long-term projections, 2030 expenditure and revenue settings are held constant through until 2050.

Exploratory model-based approaches are highly suitable for supporting planning and decision-making under deep uncertainty (Weaver et al., 2013), and the development of multiple scenarios is a common approach (Maier et al., 2016; Walker et al., 2013). In the case of Fiji, key areas of uncertainty include global action on climate change and consequent impacts, costs associated with climate change adaptation, global trade and economic outlook for key sectors and commodities, the availability of international finance and support and political stability and governance. We employed sensitivity analysis to test the sensitivity of the results (SDG performance) to these key global assumptions used in the model. We followed the general workflow described in Pianosi et al. (2016), running Monte Carlo simulations (500 per analysis) in which model parameters are randomly adjusted within a predetermined range (min/max). Supplementary Table SI.4 describes the parameterisation for each sensitivity analysis. Where the BAU scenario results revealed sensitivity to assumptions, we ran subsequent sensitivity analysis on the 'ST', 'ST_CLIMATE' and 'ST_SDG' scenarios.

2.3 *Evaluation framework*

The SDG performance evaluation framework comprised of 17 goals, 51 targets and 80 indicators (Supplementary Table SI.2). Target values for each indicator were formulated drawing on a range of sources, including the official SDG targets, Fijian government plans and strategies (Government of Fiji, 2017c, 2018a), alternative international guidelines and benchmarks (e.g. WHO guidelines), and national data from peer countries (see sources in Supplementary Table SI.2). Each target was also defined as economic, social or environmental by interpreting the indicator descriptions and considering the nature of the datasets used to compile them and global reporting responsibilities (IAEG-SDGs, 2020; UNEP, 2017). In the *iSDG* model, projections simulate the proportional progress towards each SDG target over

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Table 1. Brief scenario narratives and aggregate settings*

Scenario	Narrative descriptor (SDG priorities)	Key policy and investment settings
Business-as-Usual (BAU) (SSP2)	BAU projection based on existing trends and policy settings with no changes to revenue or investment.	None.
1. Growth at all costs (GC) ● (SSP5, SSP4)	Fiji focuses primarily on economic growth as the fundamental development goal to the exclusion of social and environmental objectives. Emphasis is on free enterprise, and the role, size and expenditure of government is reduced somewhat over time, particularly in provision of social services, redistribution and environmental management.	Public investment declines by on average −2.7% GDP per annum (pa) below the BAU to 2030. Government revenue (tax) declines compared to the BAU by on average −3.8% GDP pa until 2030 and grants by on average 0.76% GDP pa until 2030.
2. Green Economy (GE) ● (SSP2, SSP1)	Fiji remains focused on achieving sufficient economic growth to support continuous job creation, while addressing goals related to sustainable consumption and production, resource efficiency, clean energy and climate change. Additional government and private investment targets environmental objectives of sustainable energy, transport, land and ocean management and adaptation. Reduced expenditure on social objectives (social transfers, health and education).	Public and private investment increase by on average 2.3% GDP pa above the BAU to 2030. Government revenue compared to the BAU includes reduced tax on trade and income/profits (−2.6% GDP pa), increased tax on consumption (+2.4% GDP pa) and increased grants (climate finance) of +0.5% GDP pa through until 2030.
3. Inclusive Growth (IG) ● (SSP5, SSP1)	Fiji is focused on achieving strong economic growth along with social goals relating to poverty, gender and income inequality. Larger investments are allocated to health, education, social inclusion, institutions and enhancing human and social capital. No additional investment in renewables and resource efficiency or environmental goals.	Public investment increases by on average 3.4% GDP pa above BAU to 2030. Government revenue compared to the BAU includes increased tax on trade (+2% GDP pa) and income/profits (+2% GDP pa), reduced tax on consumption (−1.6% GDP pa) and an increase in grants (inclusive finance) of +0.5% GDP pa through until 2030.
4. Sustainability Transition (ST) ● (SSP1)	Fiji shifts towards a more sustainable path, emphasising inclusive development within environmental thresholds. Public policy and public/private investment coherently addresses poverty and inequality, climate change and resource efficiency, environmental management and economic development and employment. A better-resourced and effective government plays a stronger role in steering the transition, with greater political stability.	Public and private investments increase by on average 5.6% GDP pa above BAU to 2030. Government revenue compared to the BAU includes increased taxes on trade (+1.9% GDP pa), income/profits (0.8% GDP pa) and consumption (+2.1% GDP pa) as well as international grants (+0.9% GDP pa) for climate and SDG finance through until 2030.
5. Sustainability Transition – Climate Action (ST_CLIMATE) ○	Same as ST with a more rapid and ambitious scale-up in public and private investments in decarbonisation, including clean energy, sustainable industry, electric vehicles and energy efficiency.	Public and private investments increase by on average 8.9% GDP pa above the BAU to 2030. Government revenue compared to the BAU includes increased taxes on trade (+2% GDP pa), income/profits (1.5% GDP pa) and consumption (+3.4% GDP pa) as well as international grants (+1.8% GDP pa) for climate and SDG finance through until 2030.
6. ST_SDG ○	Same as ST with a rapid and very ambitious scale-up in public and private investments to accelerate the SDG transformation, including in decarbonisation of energy and transport, resource efficiency, land management, biodiversity, ocean protection, education, health, social transfers, redistribution of wealth and gender equality.	Public and private investment increase by on average 21.7% GDP pa above the BAU to 2030. Government revenue compared to the BAU includes increased taxes on trade (+5.5% GDP pa), income/profits (+2.5% GDP pa) and consumption (+2.8% GDP pa) as well as international grants (+9.6% GDP pa) for climate and SDG finance through until 2030.

*Coloured dots in the table for each scenario are used to colour-code scenarios in Figures 1 and 2, and projections for each scenario presented in the Supplementary figures.

the period 2016–2030. A normalised scale (0–100) is used, whereby the baseline value for 2015 is considered the 'zero point' and the target value for 2030 is considered the final point (100% achievement). Where multiple indicators are included for a single target, the simple average performance across all indicators is calculated. Similarly, average performance for each of the 17 goals is calculated as the average performance across its targets. A single aggregate SDG performance score was also calculated as the average performance across all 17 goals.

For the SJS framework, we use a selection of per capita indicators as developed by O'Neill et al. (2018) and revised based on the capabilities of the *iSDG-Fiji* model. In total, six biophysical boundaries and nine social thresholds were selected (Table 2). Given the national scale of the model, biophysical boundaries are production-based or territorial metrics rather than the consumption-based metrics used in O'Neill et al. (2018). This is a noteworthy limitation as the indicators do not account for international trade. The exception is material footprint which is simulated by the *iSDG-Fiji* model. The nutrient flow metrics (nitrogen and phosphorus) correspond to territorial consumption of fertiliser, whereas CO_2 corresponds to territorial fossil fuel and cement emissions. The metric used for land system change is per capita land converted to crops which is drawn from the original PBs framework (Rockström et al., 2009).

For the social foundation thresholds, we use 'population without malnutrition' as the nutrition metric and the World Bank's

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Table 2. National biophysical boundaries and social thresholds and baselines for Fiji

Indicator	Unit	Desired threshold value	Fiji baseline 2015
Biophysical boundaries			
Per capita CO_2 emissions	$t\ CO_2\ year^{-1}$	1.61	2.6
Per capita phosphorus consumption	$kg\ P\ year^{-1}$	0.89	0.72
Per capita nitrogen consumption	$kg\ N\ year^{-1}$	8.9	6.6
Per capita water consumption	$m^3\ year^{-1}$	574	100.1
Per capita material footprint	$t\ year^{-1}$	7.2	7.4
Land converted to crops	Ha	0.3	0.3
Social thresholds			
Average life expectancy	Years	65	67
Population without malnutrition	%	95	93
Access to improved sanitation	%	95	93
Income – above $1.90 per day	%	95	97
Access to energy	%	95	95
Education: enrolment in secondary	%	95	83
Average governance index	Index	0.8	0.5
Equality (1-Gini coefficient)	Index	0.7	0.63
Employment	%	94	94

governance indicators (Kaufman & Kraay, 2016) converted to an aggregate normalised index in place of the democratic quality score used by O'Neill et al. (2018). For each scenario, simulated values for each of the 15 indicators in Table 2 were normalised and benchmarked against the desired threshold values to determine consistency with PBs and the SJS in 2050.

3. Results

3.1 Overall scenario performance on all SDGs by 2030

Aggregate progress of each scenario towards all 17 SDGs shows that under a BAU scenario, Fiji is expected to fall well-short of the SDGs by 2030 (BAU: 40.5% progress). Although none of the alternative scenarios deliver 100% progress, most scenarios bring improvements in SDG performance by 2030 compared to the BAU, with the exception being 'GC' which observes slower progress (34.0%). Both 'IG' (50.7%) and 'GE' (57.0%) observe moderate improvements; however, the 'ST' outperforms the other foundation scenarios reaching nearly 70% progress by 2030. The high-ambition scenarios push this performance further, with the 'ST_CLIMATE' and 'ST_SDG' scenarios reaching 75.8% and 83.4%, respectively.

Delivering enhanced performance towards the SDGs comes at a cost. We calculate the cost of each percentage point increase in SDG progress delivered under each scenario (dividing total additional public and private investments as a proportion of GDP over the decade by the percentage improvement in SDG progress above the BAU scenario in 2030); we call this the 'cost-to-progress ratio' (Figure 2). This reveals that the gains made by the 'GE' scenario come at the least cost at around 1.6% GDP per percentage point (or FJD4.5 billion total additional investment over the decade), followed by 'ST' at 2.1% GDP; whereas 'ST_SDG' has the highest cost at 5.6% GDP.

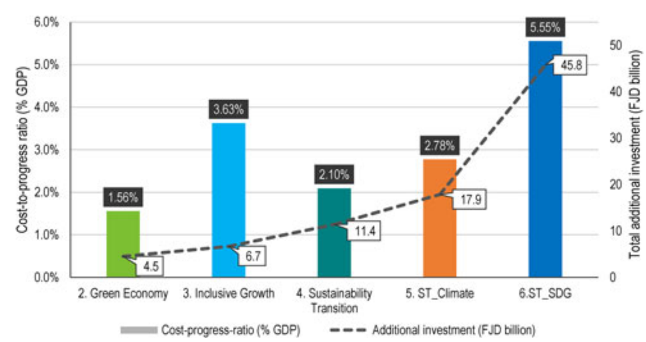

Fig. 2. Total additional investment (FJD billion, right axis) for each scenario and cost-to-progress ratio as % GDP (market prices) per percentage point additional improvement in SDG progress score above BAU scenario (left axis). A cost-to-progress ratio is not calculated for the 'GC' scenario as performance declines slightly on the BAU along with a reduction in investment of FJD −4.7 billion over the decade.

3.2 Progress on each of the 17 SDGs

The performance of the scenarios on each of the 17 goals is presented in Figure 3. For each goal, the BAU projections for 2030 are represented by dotted lines, whereas the projections for each foundation scenario are represented by coloured bars (scale: 0–100%). Results for the high-ambition scenarios ('ST_CLIMATE' and 'ST_SDG') are given in boxes in the outer ring of the chart, with arrows representing additional gains above the 'ST' scenario.

At the goal level, Fiji's performance under the BAU scenario is higher for water (Goal 6), education (Goal 4) and poverty (Goal 1) (Figure 3). Goals that lag behind include means of implementation (Goal 17), climate action (Goal 13), oceans (Goal 14), governance (Goal 16), terrestrial biodiversity (Goal 15) and gender equality (Goal 5).

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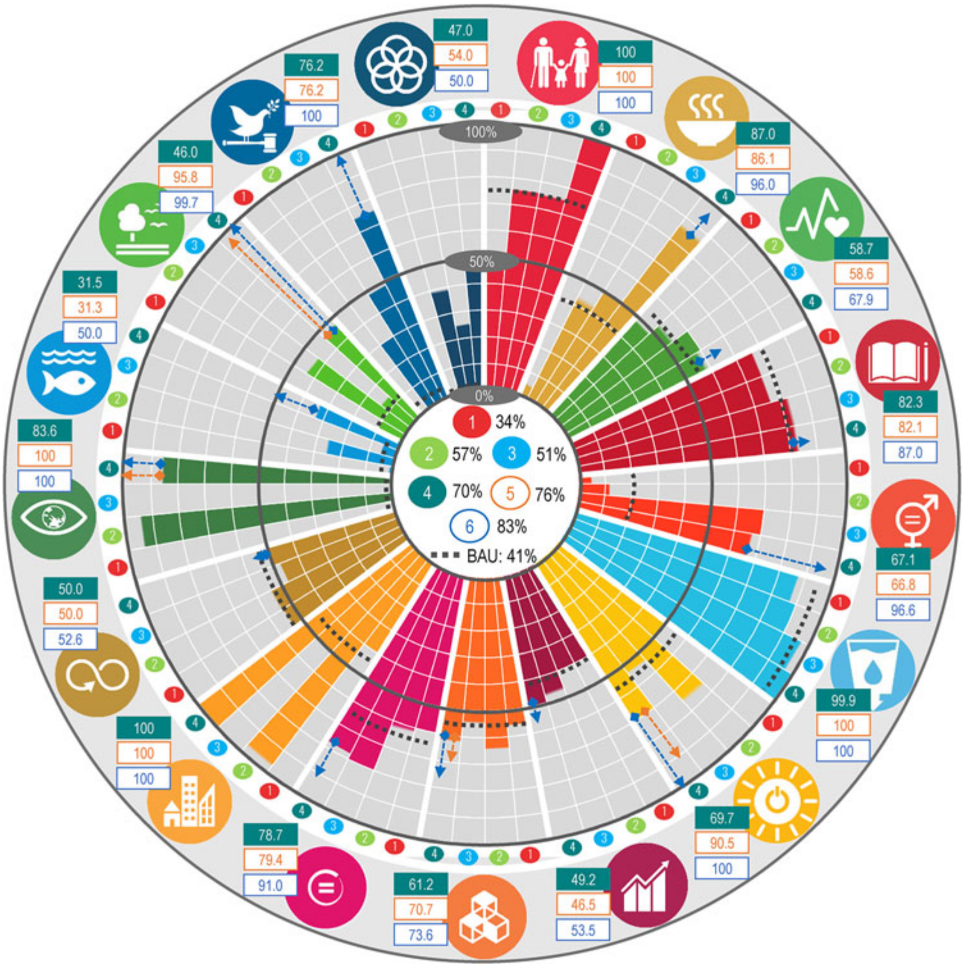

Fig. 3. Projected performance of each scenario on each of the 17 SDGs in 2030. Reading from the outside of the diagram inwards, goal icons for each of the 17 goals are in the outer circle using official UN logos (United Nations, 2016) starting with 'Goal 1. No Poverty' at the top centre-right and then proceeding clockwise. Coloured numbers (1–4) in the next circle represent each of the four alternative scenarios as listed in centre (1 = 'growth at all costs'; 2 = 'green economy'; 3 = 'inclusive growth'; 4= 'sustainability transition'); moving inwards, the coloured bars show the projected average progress on each goal across all of its SDG targets in 2030, on an index scale of 0% (no progress) through to 100% (full achievement). These percentages reflect proportional progress towards all targets (from 0 to 100), rather than the percentage of targets achieved. Dotted black lines show the level of achievement projected for the BAU scenario for comparison. Dotted blue and orange arrows represent additional progress made by the ST_CLIMATE and ST_SDG scenarios, whereas boxes in the outer ring present projected goal progress for each of the ST scenarios (ST, ST_CLIMATE and ST_SDG). Total average progress for each scenario towards all 51 targets is listed in the centre of the diagram (5 = ST_CLIMATE; 6 = ST_SDG).

Variations in performance for the alternative scenarios are driven largely by the different public and private expenditure and revenue settings introduced into the model (Table 1). Changes to these settings (Supplementary Figure SI.1) affect various sectors and result in dynamic changes to key economic indicators such as GDP, employment and income (Supplementary Figure SI.2), social indicators such as poverty, inequality, education and health (Supplementary Figure SI.3) and environmental indicators such as greenhouse gas (GHG) emissions, renewable energy and forest cover (Supplementary Figure SI.4). In all scenarios, population is projected to reach over 900,000 by 2030 (Supplementary Figure SI.1), whereas GDP continues to grow to between FJD10.7 and 12.9 billion by 2030 (Supplementary Figure SI.2).

Compared to the BAU, the 'GC' scenario projection results in a small reduction or no change in progress on most goals (Figure 3). For the 'GE' scenario, modest additional green investment results in improvements on environmental targets relating to cities (Goal 11), climate action (Goal 13), oceans (Goal 14), biodiversity (Goal 15) and energy (Goal 7) (Figure 3). Carbon dioxide emissions and net GHG emissions decline well below the BAU, whereas forest cover and biodiversity protection increase (Supplementary Figures SI.4a to 4f). For the 'IG' scenario, larger investments in social transfers and more progressive taxation and subsidies observe improved performance in social goals including health (Goal 3), education (Goal 4), gender equality (Goal 5), inequality (Goal 10) and governance (Goal 16). The 'ST' foundation scenario combines settings from 'GE' and 'IG' and projects improved performance across almost all goals (16 out of 17), although improvements are very marginal for health (Goal 3), education (Goal 4) and water (Goal 6) (Figure 3).

When compared against 'ST', the 'ST_CLIMATE' projections result in improved performance on energy (Goal 7), sustainable infrastructure (Goal 9), climate change (Goal 13) and terrestrial biodiversity (Goal 15) (Figure 3). Overall, GDP growth drops below 'ST' as additional private investment in energy infrastructure draws down on the resources available to other sectors (Supplementary Figure SI.2). The proportion of electricity from renewable energy increases to over 75% by 2030

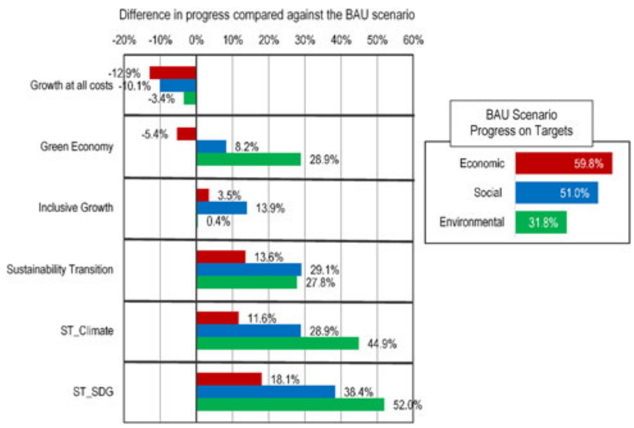

Fig. 4. Performance of each scenario on economic, social and environmental SDG targets when compared against the BAU. Coloured bars in the main figure represent the difference in progress achieved by each scenario on groupings of economic, social and environmental targets when compared against the BAU (inset small chart on right). This is calculated by subtracting the BAU progress scores averaged for economic, social and environmental targets from the progress scores for each scenario. Positive scores represent achievement levels for each group of targets that are better than the BAU scenario, whereas negative values represent the levels of achievement worse than the BAU. Supplementary Table SI.2 specifies the targets allocated to each category (economic, social or environmental).

(Supplementary Figure SI.4). Carbon dioxide emissions begin to decouple from economic growth, whereas net GHG emissions including reforestation observe a strong reduction to around 50% of the 2015 baseline value (Supplementary Figure SI.4).

Finally, the ‘ST_SDG’ scenario projection observes equal or improved performance on all 17 goals compared to the ‘ST’ scenario (Figure 3). Again, the largest improvements can be observed on environmental targets relating to biodiversity (Goals 14 and 15), climate action (Goal 13), sustainable industry and infrastructure (Goal 9) and energy (Goal 7), as well as social goals including gender equality (Goal 5), income equality (Goal 10), food and nutrition (Goal 2), health (Goal 3) and education (Goal 4). However, goals where progress overall remains restrained include economy and jobs (Goal 8), sustainable consumption and production (Goal 12), oceans (Goal 14) and means of implementation (Goal 17). Not surprisingly, the massive additional investment initially results in more rapid GDP growth; however, the rate of growth slows towards 2030 due to higher resource efficiency targets which affect industry productivity (Supplementary Figure SI.2a). Real GDP per capita is higher than for any other scenario (Supplementary Figure SI.2b) however per capita disposable income is lower than some scenarios as a result of higher taxes (Supplementary Figure SI.2c). Performance is improved across almost all key social (Supplementary Figures SI.3) and environmental indicators (Supplementary Figures SI.4).

3.3 Economic, social and environmental coherence

Overall, the BAU scenario performs better on social targets (51.0% progress) and economic targets (59.8% progress) than it does on environmental targets (31.8% progress), highlighting that environmental performance lags furthest behind for Fiji. Figure 4 compares the performance of each alternative scenario on economic, social and environmental targets when compared against the BAU scenario. Additional green investment in the ‘GE’ scenario observes greater progress on environmental targets as well as synergies for social targets and trade-offs for economic targets. Extra socio-economic investment in ‘IG’ delivers greater progress in social and economic targets, with little change in environmental targets. The ‘ST’ foundation and high-ambition scenarios improve progress across all three domains. For ‘ST_CLIMATE’, the increased advancement on environmental targets comes at the expense of progress on economic targets. Under the ‘ST_SDG’ scenario, these trade-offs are managed; however, final performance on economic targets (approximately 77.9% progress) lags behind environmental (83.7%) and social targets (89.4% progress).

The synthesis of results (Figure 3) is an index-based assessment of progress towards the SDG targets (0% to 100%) rather than assessing the actual achievement of target levels. Figure 5 presents the total percentage of SDG targets assessed as ‘achieved’ (≥95% progress) or with ‘very limited progress’ (<10% progress) across each of the scenarios. The performance of the scenarios is lower using this metric compared with the index-based assessment of progress. The most ambitious ‘ST_SDG’ scenario achieves 72.5% of all SDG targets, which is close to double the ‘ST’ scenario (Figure 5a). Only 8% of targets under ‘ST_SDG’ have very limited progress (Figure 5b).

3.4 Long-term projections and performance on the SJS framework in 2050

Long-term model projections for 2050 reveal that GDP growth is projected to stall from 2040 under the ‘BAU’ and ‘GC’ scenarios, and slow considerably for ‘IG’, partly due to worsening effects of climate change (Supplementary Figure SI.5a). Slower growth in global average temperatures and increased adaptation expenditure under ‘GE’ and ‘ST’ ameliorate these effects to some degree. Despite this, the rate of GDP growth is projected to slow across all scenarios, even the high-ambition scenarios, which highlights that adaptation costs continue to increase beyond 2030, exceeding expenditure.

For the ‘ST_CLIMATE’ and ‘ST_SDG’ scenarios, total net GHG emissions including reforestation are projected to fall to <30% of the 2015 baseline levels by 2050 (Supplementary Figure SI.5b). However, the best-case scenario for per capita carbon dioxide emissions is 2 t CO_2 per person by 2050 (Supplementary Figure SI.5c). With the share of renewables in electricity reaching 100% by 2050 under the ST_SDG scenario, the majority of remaining CO_2 emissions is associated with oil consumption in the industry sector and, to a lesser degree, the transport and residential sectors. Overall progress on the SDGs also slows beyond 2030 across all scenarios, reaching a maximum of 87.1% progress under the ‘ST_SDG’ scenario in 2050 (Supplementary Figure SI.5d).

When benchmarked against the SJS framework, Fiji performs moderately well overall in meeting social foundations within PBs (Figure 6). For social foundations (inner ring of chart), progress is generally above 90% for all scenarios and indicators except for governance while all foundations are achieved for ‘ST_SDG’ (Figure 6). For the PBs (outer ring of chart), two boundaries (carbon dioxide emissions and material footprint) are exceeded across all scenarios but to a lesser degree for the two high-ambition scenarios, and a third boundary (phosphorus) is exceeded under the ‘GC’ and ‘IG’ scenarios.

3.5 Sensitivity analysis on key model assumptions

Results from the sensitivity analysis are provided in Supplementary Figures SI.6 (BAU scenario), SI.7 (‘ST’ scenario),

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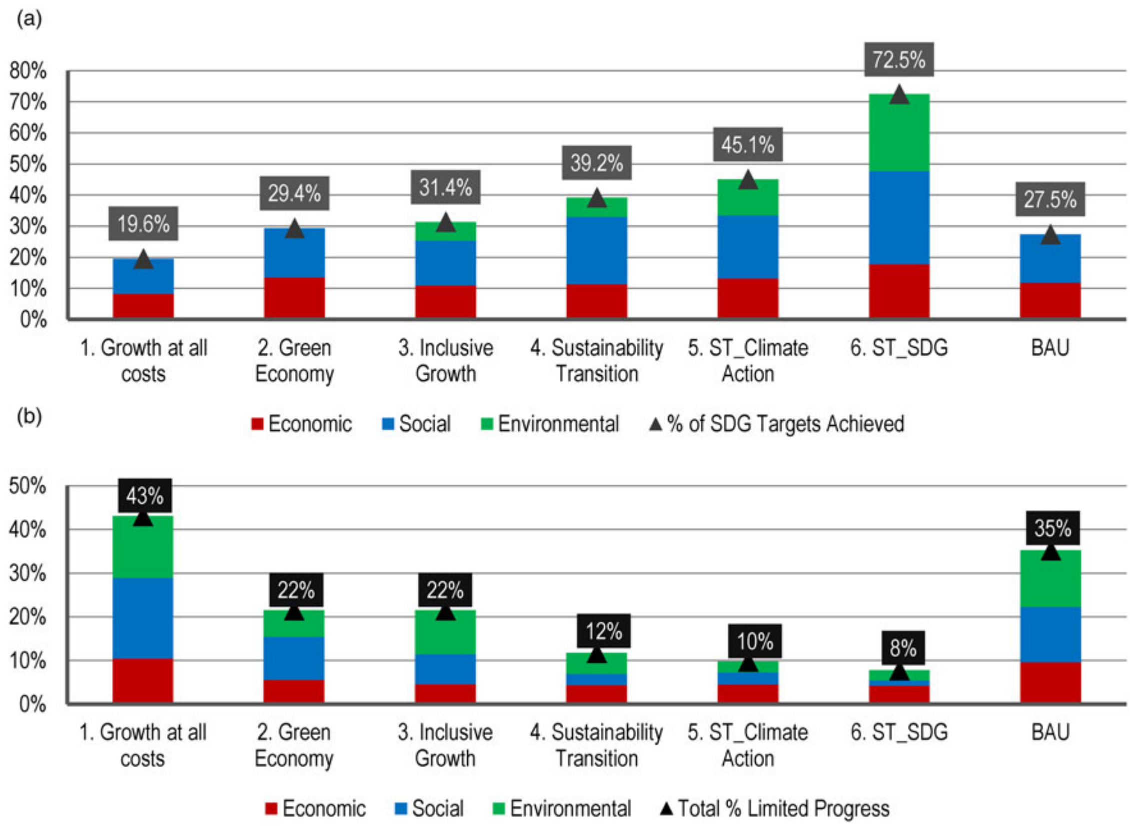

Fig. 5. Proportion of SDG targets assessed as 'achieved' or 'very limited progress' under different scenarios. (a) Proportion of SDG targets assessed as 'achieved' (≥95% achievement of target value) for all goals and for each scenario, and the share of achieved targets for each scenario that are economic, social or environmental targets. For example, for the ST scenario, 56.9% of targets are assessed as 'achieved' with the majority being social targets (blue), followed by environmental (green) then economic (red) targets. (b) Proportion of SDG targets assessed as 'very limited progress' (≤10% progress towards target value).

SI.8 ('ST_CLIMATE') and SI.9 ('ST_SDG'). The results show limited sensitivity of overall SDG performance for the different assumptions tested (up to ±15%). Sensitivity to very low values in the estimated cost of adaptation was evident for goals that included climate change vulnerability targets (Goals 1, 11 and 13). The sensitivity of model projections to the magnitude of grants was higher for Goal 17 (means of implementation) and Goal 8 (economy and jobs) as well as for some environmental targets reliant upon additional investment.

4. Discussion

4.1 Performance of the foundation scenarios on the SDGs and SJS

The 'GC' scenario projection shows the limited scope for Fiji to reduce taxation and government expenditure to stimulate private investment without undermining economic and social objectives by 2030, and the lack of investment in climate change results in an economic downturn by 2050 (Supplementary Figure SI.5a). The 'GE' scenario addresses Fiji's poor baseline performance on environmental targets, providing an opportunity for the country to invest modestly in the environment and deliver quick gains on the SDGs at the lowest 'cost-to-progress ratio' of any scenario (Figure 2); however, trade-offs with economic targets are apparent (Figure 4). Gains made on social targets and the SDGs under the 'IG' scenario are modest overall and come at a much higher cost, but without diminishing economic or environmental performance.

The 'ST' scenario results reveal that coherent progress towards all SDGs is feasible for Fiji, advancing total progress to 70% by 2030 (Figure 3). The scenario out-performs the other foundation scenarios and delivers relatively balanced additional progress on environmental and socio-economic targets (Figure 4) at a comparatively low cost-to-progress ratio (Figure 2). This is achieved without compromising GDP growth, income or employment; however, carbon dioxide emissions continue rise above 2015 levels by 2030 (Supplementary Figure SI.4a). In terms of the SJS framework, the scenario meets most social foundations (8 from 9) and four of the six biophysical thresholds, reaching over twice the per capita carbon dioxide threshold by 2050. The scenario therefore fails in terms of achieving long-term sustainability objectives, and it provides minimal improvements beyond the BAU.

These findings are likely to be transferable to other SIDS or small developing countries which face resource and capacity constraints and high climate change vulnerability. Modest additional public and private investment partly financed through international assistance and grants can have a considerable positive impact for the economy, livelihoods and environment by 2030. However, a large gap in progress towards the SDGs (~30%) is projected to remain, and the challenge to decarbonise the economy and achieve longer-term sustainability should not be underestimated. Faster and deeper transformations will be needed to achieve the SDGs within PBs.

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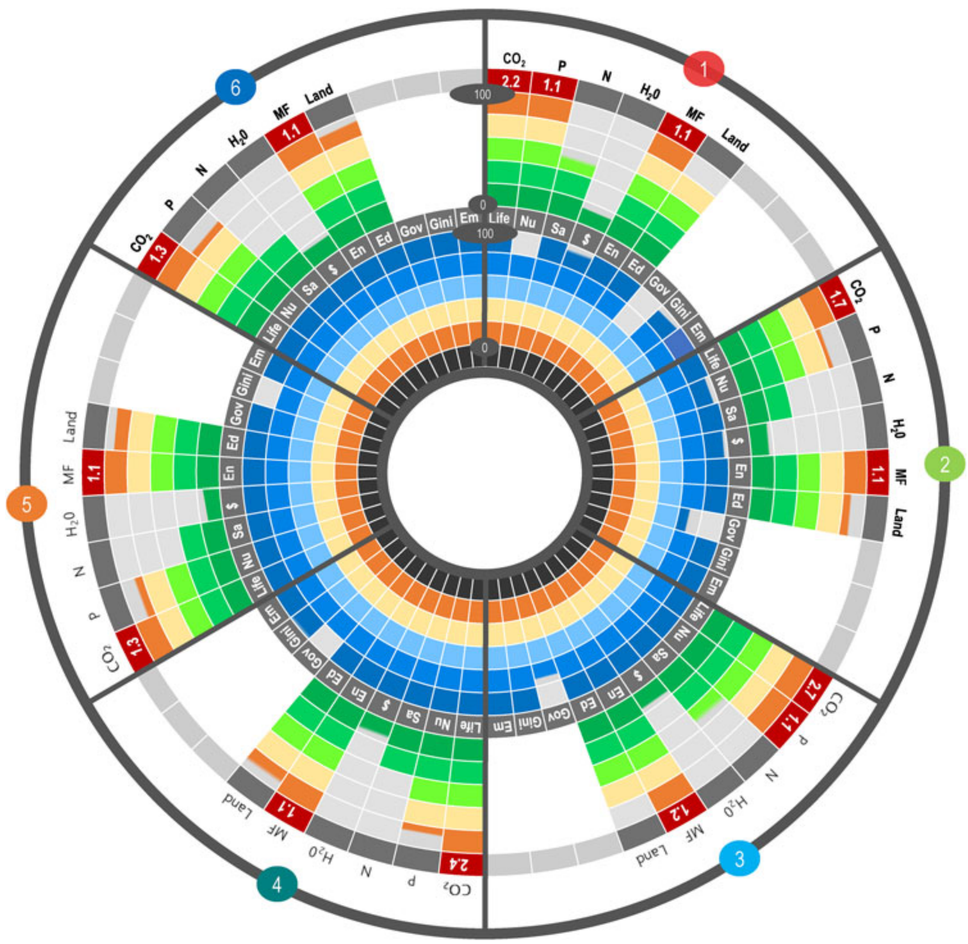

Fig. 6. Performance of each scenario on the 'SJS' framework in 2050. Reading from the outside in, numbers in coloured circles represent the scenarios: (1) growth at all costs; (2) green economy; (3) inclusive growth; (4) sustainability transition; (5) ST_CLIMATE and (6) ST_SDG. Coloured bars in the outer ring (green to red) represent normalised scores on biophysical indicators aligning with PBs (Table 2). Threshold boundaries are represented by a normalised score of '100'; progress below the threshold is desirable whereas progress beyond the threshold is considered unsustainable (red). Numbers in red boxes represent exceedance factors (e.g. 1.3 = 1.3 times the threshold level, or 30% above). CO_2, carbon dioxide emissions; P, phosphorus; N, nitrogen; H_2O, water; MF, material footprint; land, land converted to crops. Coloured bars in the inner ring (orange to blue) represent social foundations (Table 2). Normalised scores of '100' mean that a social foundation threshold has been met; values that are below this threshold are less desirable. Life, life expectancy; Nu, nutrition; Sa, sanitation; $, income; En, energy access; Ed, education; Gov, governance; Gini, inequality; Em, employment.

4.2 Performance of the high-ambition transformation scenarios on the SDGs and SJS

The 'ST_CLIMATE' scenario rapidly scales up investment to transform energy and transport systems and decarbonise Fiji's economy. Additional investment in climate mitigation reaches FJD6.5 billion above the 'ST' scenario, similar to costings from Fiji's NDC Implementation Roadmap of FJD6.3 billion (Government of Fiji, 2017b), which drives increased share of renewables in electricity to 77% by 2030 and 90% by 2050. The transition to renewables is slightly faster in the ST_SDG scenario, reaching 81% in 2030 and 94% by 2050. The transition to renewables along with additional investments in energy efficiency for households, industry and vehicles, a shift to 100% share of electric vehicles in new sales by 2050, and ambitious reforestation efforts deliver a reduction in net GHG emissions by around 70% by 2050 (Supplementary Figure SI.5b). Although significant, this clearly falls short of the Government's target of net zero emissions and global efforts to stabilise the climate, which undermines the long-term sustainability of these scenarios. To achieve net zero, the analysis highlights that additional measures will be needed to target remaining emissions. We identify priority measures to include substitution of oil in the industry sector (e.g. electrification and biofuels), full electrification of the built environment, an early phase out of remaining fossil-fuel baseload electricity generation and internal combustion vehicles, reducing or replacing cement in construction (e.g. sustainable cement and timber structures), and reducing emissions from livestock (e.g. shifting diets away from meat and feed alternatives).

The highly ambitious 'ST_SDG' scenario accelerates progress on the SDGs to 83% with relatively balanced performance across economic (77.9% progress), social (89.4%) and environmental (83.7%) targets (Figure 4). The costs of these additional gains are significant, with total additional investment of FJD45.8 billion roughly in-line with the estimated FJD50 billion investment envisaged in Fiji's NDP (Government of Fiji, 2017c). The scale of investment is highly ambitious and perhaps unrealistic as it could not be delivered without greatly scaled-up international financial support as well as improvements in governance, as highlighted in the sensitivity analysis (Supplementary Figure SI.9).

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The ST_SDG scenario is structured around key entry points (Figure 1) for action on the SDGs, each of which incorporates a range of interventions that accelerate progress on the SDGs (Supplementary Table SI.1). For the entry point on human well-being and development, key interventions include additional expenditure on education and access to healthcare, increasing subsidies and transfers with redistribution in favour of low-income earners, and increased gender equality targets. For sustainable economy and lifestyles, these include increased taxes on consumption, income and profits and international trade, shifting the tax burden to high-income earners, increased material efficiency targets and additional investment in sustainable transport, climate change adaptation and sustainable biomass. For clean energy and environment, these include additional investment in solar, hydro and biomass energy, additional energy efficiency expenditure for households, industry and vehicles, a rapid transition to electric vehicles and additional expenditure on reforestation, sustainable agriculture and marine and terrestrial-protected areas. These interventions are also accompanied by improvements in government effectiveness, regulatory quality, control of corruption, political stability and voice and accountability, whereas population growth is slightly below existing trends. However, despite the broad range of interventions and considerable additional investment, a gap of 17% in overall SDG achievement remains by 2030, closing to 13% by 2050.

Several pockets of resistance are observed which highlight potential areas for further action to close the remaining gap in SDG performance. Targets with very limited progress (<10%) include road fatalities (Target 3.6), labour productivity (8.2), sustainable fish stocks (14.4) and public debt (17.4), whereas other targets that lag behind (<50% progress) include non-communicable diseases (3.4), sustainable industry (9.2) and domestic resource mobilisation (17.1). Within these, there may be 'low-hanging fruit' where progress could be made without notable trade-offs with other sectors – for example, introducing measures to better enforce road regulations (3.6) or encouraging healthy lifestyles (3.4). However, for many targets, even with additional measures, it may prove impossible to overcome persistent trade-offs which are observed between increasing industrial output and jobs (Goals 8 and 9) while reducing material consumption (Goals 12 and 8), increasing agricultural output and nutrition (Goals 2 and 8) while ensuring sustainable fish stocks (Goal 14), raising revenue while reducing tax burden (Goal 17), increasing incomes and consumption (Goal 8) while reducing non-communicable diseases (Goal 3), and increasing overall SDG expenditure while reducing public debt (Goal 17).

A challenge across all scenarios is that progress towards the SDGs increases rapidly from 2020 and then begins to plateau, suggesting diminishing returns from investment as progress gains momentum. For example, the additional 7% progress on the SDGs achieved by the 'ST_SDG' scenario compared to 'ST_CLIMATE' requires over double the total investment (Figure 2). Even when projections are continued through until 2050, the 'ST_SDG' scenario rises slowly to 87.1% SDG progress (Supplementary Figure SI.5d). This 'last mile' challenge is in-line with our previous findings from modelling in Australia (Allen et al., 2019) and results from several factors, including that climate change effects increase exponentially over time, that some remaining trade-offs between SDG targets cannot be overcome, that additional investment needs to be complemented with other measures such as regulation and incentives that target behaviour change, that target levels set for some indicators may be overly ambitious and that the *iSDG-Fiji* model lacks adequate structure or feedback dynamics in some sectors.

The results for the ST_SDG scenario suggest that the increased progress on the SDGs by 2030 can also advance on the SJS framework. However, it is notable that Fiji's baseline performance on the SJS framework is relatively strong and as such the improvements are minimal. Although all social foundations are achieved, two of the biophysical thresholds remain transgressed by a small margin (per capita CO_2 and material footprint). Based on global frameworks for evaluating SDG interlinkages (Nilsson et al., 2016), this suggests that progress on the SDGs in Fiji 'enables' progress towards longer-term social foundations of the SJS framework, but has limited enabling effects on achieving longer-term biophysical boundaries. However, these biophysical thresholds may be within reach with additional measures in Fiji to mitigate remaining emissions (as suggested above) and with moderately more ambitious material efficiency targets. However, it is likely that such measures to address carbon and material footprints will result in trade-offs. For example, increasing resource efficiency and replacing oil in the industry sector may reduce productivity, which would have implications for performance on socio-economic targets of the SDGs. These aspects warrant further investigation.

Overall, the results from the modelling have wider relevance for other SIDS and countries – that is, although considerable progress can be made, achieving all of the SDGs by 2030, or even 2050, will be extremely challenging. In our attempts to achieve the SDGs, we should also consider longer-term coherence with sustainability objectives and planetary thresholds to ensure that global boundaries are not transgressed. Although the SDG targets were designed to have equal importance, ultimately, it seems likely that decisions will need to be made considering national priorities. This issue has received some attention in the recent literature in the context of the recovery from COVID-19 (Naidoo & Fisher, 2020; Sachs et al., 2020). Placing the SDGs in the context of longer-term sustainability thresholds may assist with such prioritisation. For example, by weighting or prioritising interventions that accelerate progress on the SDGs by 2030 while also advancing the SJS framework by 2050. The modelling approach and evaluation framework applied in this study may support such decisions.

4.3 Study caveats and limitations

There are some important caveats in interpreting the study results and their broader relevance for other countries. First, we acknowledge that uncertainty is an inevitable part of long-term decision-making and modelling, including future changes in climate, technological, socio-economic and political situations. This is clearly highlighted by the recent coronavirus pandemic, which we did not factor into this modelling. In this study, we model only a selection of future scenarios and apply sensitivity analysis to evaluate the effect of key assumptions on the results. However, uncertainty remains and the results from this exploratory study should be interpreted as 'what–if' projections rather than future predictions.

Second, every country is different and national context is critical for the assessment of policy interventions. Fiji is a small country in population and economic terms and the scale of additional investment included in the high-ambition scenarios is significant as a proportion of GDP; most of which is government expenditure and drives more rapid economic growth. This investment can only be sustained in the long-term through generous assumptions

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around international grants. Fiji's per capita CO_2 emissions and material footprint are also low by international standards. This provides a very different starting point for Fiji compared to, for example, a resource-intensive developed nation. For Fiji, the challenge is to moderately reduce these footprints over time, whereas for a large, developed country a much greater transformation would be needed to bring them in-line with global thresholds. This would have very different implications for economic growth and SDG performance, as shown by Allen et al. (2019) for Australia. The results for Fiji highlight that although environmental sustainability outcomes are achieved with higher GDP growth, this does not necessarily mean that increasing GDP is the primary mechanism for delivering environmental outcomes. Further discussion on study caveats, limitations and results is provided in the Supplementary Discussion.

Another important caveat is that the PBs thresholds used in the SJS framework for this study rely primarily on territorial or production-based metrics. As such they do not include consumption associated with international trade which have been used in other global studies (O'Neill et al., 2018) and which are important for assessing absolute sustainability. In addition, we acknowledge that the study evaluates only a selection of downscaled PBs, excluding important aspects such as biosphere integrity and aerosol loading, for example. An area for further model development is to convert territorial metrics to consumption-based metrics and factor in additional boundaries, which could be achieved by coupling the *iSDG* system dynamics model with multi-regional input–output models.

5. Conclusions

This study has explored how different approaches to development – and levels of ambition and their associated policy and investment settings – enable the transformations needed to achieve the SDGs by 2030 and the SJS framework by 2050, adopting Fiji as a use-case. The results show that coherent progress towards all SDGs is feasible for Fiji while also reaping longer-term benefits. Modest investment over the coming decade through an ST scenario would accelerate SDG progress to 70% but would fail to address longer-term risks associated with climate change. Significantly scaling up the level of investment and ambition through an SDG transformation scenario highlights the possibilities for Fiji to further accelerate SDG progress to 83% by 2030 while improving long-term performance on the SJS framework.

However, even with highly ambitious investment, Fiji is projected to fall short on achieving either framework. We suggest areas where Fiji could prioritise action to further close the gap, including lagging SDG targets and net zero emissions. However, it may prove impossible to overcome all trade-offs inherent in the SDGs while also delivering on longer-term sustainability objectives. The scale of investment projected is also extremely ambitious and could not be delivered without greatly scaled-up international financial support and partnership. The findings for Fiji are likely transferable to other SIDS and small developing countries with similar characteristics, and the scenario and modelling framework developed for study demonstrates an approach that is flexible and could be used more broadly to increase understanding of the transformations needed to achieve the SDGs within PBs in different country contexts.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/sus.2021.13.

Data. The datasets collected and analysed during the current study are available from the corresponding author on reasonable request. Sources for data are provided in Supplementary Tables SI.1 and SI.2. The *iSDG* simulation model can be made available from the Millennium Institute on reasonable request.

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Author contributions. CA led the research including data collection, model calibration for *iSDG-Fiji*, model adjustments, scenario development and simulations. MP developed the *iSDG* base model and provided advice and guidance on data, model calibration and adjustment. GM and TW provided overall study supervision, advice and guidance regarding research framing, scenario development, methods and data sources. CA wrote the paper with inputs from GM, TW and MP.

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