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RESEARCH ARTICLE

Exposure to climate shocks, poverty and household well-being

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Abstract
We evaluate the impact of climate shocks on the well-being of farmer households in a Small Island Developing State in the Pacific, the Solomon Islands. We find that both subjective (self-assessed exposure to climate shocks) and objective (number of past dry spells) indicators of environmental stress significantly reduce the quality of life among households. Household well-being is more severely affected for farmers living in poor dwellings (e.g., those with thatched roofs signaling shelters less resistant to environmental shocks), with below median income or durable assets, living in isolated areas and not being members of agricultural associations. Furthermore, households affected by climate shocks experience a significantly higher proportion of nutritional problems. These findings support the hypothesis of a strong correlation between climate shocks, household well-being and nutritional status, advocating for the relevance of global climate adaptation policies such as loss and damage funds, as well as prevention strategies.

Keywords: climate shock; nutrition; Small Island Developing State; subjective well-being

JEL classification: I31; Q01; Q20

1. Introduction

Evaluating the effects of climate threats on quality of life and the corresponding social challenges in poor and emerging countries is an underinvestigated issue of paramount importance in the current era of ecological transition and climate migration. From this point of view, the preferences of low-income individuals in small-scale island societies in the Pacific are particularly interesting, given the relatively high vulnerability to natural disasters, environmental degradation, and extreme climate events in this geographical area, along with challenges related to poor housing conditions and nutritional insecurity of its inhabitants (Briguglio, 1995; Nurse *et al.*, 2014; Scandurra *et al.*, 2018).

The current study aims to contribute to this research area by evaluating the impact of climate shocks on subjectively assessed household well-being on a sample of rural farmers living in the Solomon Islands. A related research hypothesis in our empirical analysis is whether isolation, poor income and wealth status are likely to amplify the negative climate shock effect, and thus whether there is a correlation between environmental and economic concerns.

The literature on the determinants of subjectively assessed well-being has grown significantly in the social sciences for several reasons. The first important reason is that it helped to identify variables that were not usually considered before by economists, such as relational goods (Becchetti *et al.*, 2008; Bruni and Stanca, 2008), expectations (Odermatt and Stutzer, 2019) and aspirations (Ferrante, 2009). A comprehensive understanding of subjectively assessed well-being therefore enables us to substantially broaden the scope of socioeconomic research since subjective well-being depends on a much wider range of factors beyond revealed preferences in observable consumption choices, such as perceived risks, procedural utility, the gap between expectations and realizations, mastery, intentionality, quality of relationships, and missed alternatives (Frey *et al.*, 2004; Frey and Stutzer, 2005). In addition, the relevance of subjective well-being indicators is demonstrated by the observed correlation between observed levels of well-being and objective outcomes (Kahneman *et al.*, 1993; Frijters, 2000; Shiv and Huber, 2000; Kaiser and Oswald, 2022), (e.g., job (un)satisfaction is a good predictor of resignations, health (un)satisfaction is a leading indicator of the insurgence of diseases or mortality Becchetti *et al.*, 2018).

The validity of the subjective well-being approach has also been confirmed by several additional factors, such as (1) the positive and significant nexus between life satisfaction and/or happiness and heart responses to stress (Shedler *et al.*, 1993), smiling attitudes, and other healthy physical reactions (Pavot *et al.*, 1991); (2) the observed choice to discontinue activities associated with low levels of well-being (Kahneman *et al.*, 1993; Frijters, 2000; Shiv and Huber, 2000); and (3) the correlation between happiness scores provided by family and friends with the respondent's own reports (Sandvik *et al.*, 1993; Diener and Lucas, 1999). Furthermore, self-declared life satisfaction has been shown to produce the same effect as positive feelings on physical measures of brain activity – higher alpha power in the left prefrontal cortex (Clark *et al.*, 2006).

Our research on the impact of climate shocks and droughts on household well-being in small island developing countries contributes to the more general literature on environmental goods and subjectively assessed well-being. This literature has a strong tradition of research evaluating the monetary equivalent impact of non-market environmental goods on subjective well-being, with valuable contributions related to climate parameters (Van de Vliert *et al.*, 2004; Rehdanz and Maddison, 2005; Maddison and Rehdanz, 2011; Murray *et al.*, 2013), air pollution (Welsch, 2006; Luechinger, 2010; Dolan and Laffan, 2016; Zhang *et al.*, 2017), airport noise (Van Praag and Baarsma, 2005; Fujiwara *et al.*, 2017) and environmental quality (Van Praag and Baarsma, 2005; Ferreira *et al.*, 2013), among others. By identifying further drivers of subjectively assessed household well-being, the current empirical study makes a contribution to this field of the literature measuring shadow values of non-market goods, beyond the existing conventional stated and revealed preference approaches.

Within this broader field, our research can be situated in the narrower and under-researched domain investigating the impact of climate risk and environmental disasters in poor or developing countries. In this direction, Rahman *et al.* (2022) show in a sample of Indonesians who experienced a climate disaster that rural residents are more severely affected than those living in urban areas and that low-income increases sensitivity to the shock. Alem and Colmer (2022) show that higher rainfall variability (used as a proxy of income uncertainty) has a significant and negative effect on farmers well-being in rural

Ethiopia and that the subjective well-being effect is larger than the negative impact of the same variable on consumption. Sapkota (2018) provides empirical evidence on the negative effects of subjective well-being of the 2015 Nepal earthquake, while Lohmann *et al.* (2019) evaluate the impact of environmental shocks on a sample of subsistence farmers living in an autonomous region of Papua New Guinea.

In a comparative perspective, similar environmental shocks in high-income countries seem to produce milder and short-lived effects, as shown for the case of hurricane Katrina (Kimball *et al.*, 2006), storm events in Germany between 2000 and 2011 (von Möllendorff and Hirschfeld, 2016) and droughts or weather-related climate shocks in Australia (Carroll *et al.*, 2009; Gunby and Coupé, 2023) (for a review of this literature see Berlemann and Eurich, 2022). This could depend on the higher capacity to transfer risk as shown by several research contributions. Luechinger and Raschky (2009) calculate the monetary value of the negative impact caused by floods on subjective well-being in 16 European countries and show that mandatory insurance mitigates the negative impact, while Ahmadiani and Ferreira (2021) show how natural disasters have a significant and negative effect on subjective well-being of US residents with an impact that peaks after six months. They find, however, that health care access, flood insurance and government assistance programs, as well as emotional and social support, help to attenuate the negative effect.

This comparative view therefore suggests that factors amplifying negative effects on subjective well-being are likely to be low-income, lack of insurance mechanisms and scarce adaptation opportunities that increase expected present and future negative effects of climate shocks on well-being.

Based on this literature, we argue that the field of climate shocks in poor and emerging countries requires further investigation, also to provide insights for the quantitative background for the determination of loss and damage funds in environmental disasters in poor and emerging countries (recently discussed at COP27) and for a better understanding and prediction of the phenomenon of climate migration which is ongoing and expected to grow in the future. The originality of our work, beyond the contribution to an under-researched field, is in testing specifically how fragility factors (isolation, low-income, poorer dwelling and durable asset stock) can amplify the effects of climate shocks on farmers' well-being. We further compare the effects of objectively and subjectively perceived climate shocks, and use a dependent variable where respondents are asked to evaluate household well-being and therefore called to a less self-centered evaluation of the impact of climate shocks on quality of life. We in fact expect standard self-centered life satisfaction to be much more driven by the respondent's idiosyncratic character traits, while her/his evaluation of the quality of life of household members is much less affected by them. This is the case if the respondent makes the effort to interpret their mood and if household members' idiosyncratic traits cancel out.

To our knowledge, the only study that examines the effect of climate shocks on subjective well-being in a small-scale island society is the abovementioned research of Lohmann *et al.*, 2019, based on a survey of 515 subsistence farmers conducted in 2014 in Papua New Guinea. Both their study and ours focus on small-scale island societies in the Pacific, examining the impacts of climate change on the well-being of the local populations. However, there are several key differences between the two studies. First, we test our hypothesis using not only the objective but also the subjective (self-assessed exposure to climate shocks) environmental stress indicator. Second, the two studies differ with regard to geographical location, sample size and year. Third, in Lohmann *et al.*

(2019), respondents' subsistence is based on farming, pig husbandry, fishing, hunting, and foraging, and the main commercial crops are cocoa and copra, while regular cash income does not exist for the majority of the population. In our study, the focus is on a group of cocoa and coconut farmers having as a main source of income the sale of their crops but including several other income sources arising from fishing, wages, and self-employment, in addition to private or government transfers. Lastly, our paper offers novel insights into evaluating how fragility factors (such as isolation, lower income and durable assets, and poor dwellings) enhance the effects of climate shocks on well-being.

Our findings identify a significant nexus between climate shocks and subjectively assessed household well-being when using both respondents' self-reported climate shocks and an objective proxy of droughts, such as the average number of 10-day dry spells per year in the last five years. In addition, we show that poor shelters, high altitude (proxying farmer isolation), below-median income and wealth measured in terms of durable good assets, and lack of membership in formal agricultural associations are crucial factors driving the negative nexus. The correlation between climate shocks and nutrition problems is confirmed when respondents who suffer from climate shocks report a significantly higher proportion of nutrition problems in their households in the same period.

2. Background and motivation

Small island developing states (SIDS) are a distinct group of developing countries that share common characteristics and challenges, including smallness (limited land area), remoteness (relative isolation and connectivity issues), low insularity (high sensitivity of the economy to external shocks), high risk of land area recession, and diminishing availability of freshwater for agricultural use. SIDS are constrained by structural economic, developmental, and environmental vulnerabilities, and their challenges are exacerbated by globalization and climate change.[1]

The geographical area under investigation is a small-scale island society in the Pacific, particularly vulnerable to the impact of climate change. Although vivid images are often portrayed through press conferences where prime ministers stand in the water to draw public attention to rising sea levels, the environmental vulnerability in these areas encompasses various other dimensions, including high exposure to tropical cyclones and storms, droughts due to longer dry spells, ocean acidification, and saltwater inundation (CSIRO, 2020; Leal Filho *et al.*, 2020). The Solomon Islands consist of 996 islands that span a distance of 1,450 km, with a land area of approximately 28,480 square km (Coleman and Kroenke, 1981). Currently, the Solomon Islands have a population of approximately 6,86,878 inhabitants, and the nominal GDP is estimated at approximately 1.546 billion USD (2,258.40 per capita USD) (World Bank, 2020). Extreme climate events such as tropical cyclones and associated storm surges (Fritz and Kalligeris, 2008), changing rainfall patterns, droughts, floods (Keen and McNeil, 2016), rising sea levels (Birk, 2012), salt water inundation (Birk and Rasmussen, 2014), heat stress, and ocean acidification affect all sectors of the country's economy (Lal *et al.*, 2009) and represent

[1]SIDS were first defined at the United Nations Conference on Environment and Development in June 1992 as follows: "Small Island Developing States, and islands supporting small communities are a special case both for environment and development. They are ecologically fragile and vulnerable. Their small size, limited resources, geographic dispersion and isolation from markets, place them at a disadvantage economically and prevent economies of scale" (Scandurra *et al.*, 2018).

a major threat to the socio-economic development and well-being of the country. For these reasons, the Solomon Islands are extremely vulnerable to the adverse impacts of climate change (Barnett, 2011) and are highly dependent on donors in development programs. Hence, the necessity for intervention through climate change adaptation measures is broadly agreed upon by scholars and scientists around the world and is strongly sustained by the local government (Leal Filho *et al.*, 2020).

3. Research hypotheses

The increase in the stock of greenhouse gases in the atmosphere is progressively leading to a rise in global temperature, in sea levels and the generation of an increasing number of extreme climatic events such as floods, droughts and heatwaves (see the IPCC Sixth Assessment Report; Lee *et al.*, 2023). If economic and social effects of climate shocks are significant even in high-income countries and non tropical latitudes, we expect them to have more severe effects on poor farmers in tropical countries and the specific environment of a small tropical island such as that of the Solomon Islands described in the previous section. Based on these considerations, we assume that the direct experience of climate shocks by local farmers in the past is going to significantly and negatively affect subjectively assessed household well-being for at least two reasons. First, experienced climate shocks has negative economic consequences on income, productive capacity and wealth of the household (crop loss in the case of droughts and floods, damage to durable assets in case of floods or atmospheric events such as cyclones). Second, their direct experience is likely to reduce expected future household well-being due to the fear of new adverse climatic events and the perception that the climate threat can get progressively worse due to global warming, ultimately leading to the extreme choice of climate migration in case living conditions become economically unsustainable.

Ho1: Subjectively assessed or objectively measured climate shocks negatively and significantly affect subjectively assessed household well-being.

We also assume that factors of fragility such as poor income, poor endowment of durable assets, lack of adequate dwelling and isolation, are going to reduce the capacity to adapt and cope with the shock and therefore exposure to these factors is going to make the impact of the two measures of climate shock on household well-being worse.

Ho2: The negative impact of (subjectively assessed or objectively measured) climate shocks on subjectively assessed household well-being is more severe with exposure to fragility factors such as low-income, poor endowment of durable assets, poor dwellings, and isolation.

4. Database construction and descriptive statistics

This study used data from a sample of 1,300 farmers located in three provinces of the Solomon Islands: Guadalcanal, Makira/Ulawa, and Malaita.[2] The data was collected between 9 July 9 and 3 October 2021, as part of the International Fund for Agricultural Development's (IFAD) Impact Assessment on the project "Rural Development Programme - Phase II (RDP II)". The IFAD database has been created for ex-post impact assessments of IFAD rural development projects. The methodology adopted to create it uses a mixed-method approach with both quantitative (statistical matching) and qualitative (stakeholder consultation) approaches employed to build the counterfactual

[2]The full list of wards and villages in our sample can be found in the online appendix, tables A5 and A6.

group. The focus is on cocoa and coconut agricultural partnerships. Control villages were selected if they met the eligibility criteria and were representative of the project locations. They were identified beyond a 5 km buffer around the villages covered by cocoa and coconut agricultural partnerships that exhibited characteristics similar to those covered by them. The number of observations at the household and village level is not always balanced at the province level. This is because, given the difficulty faced in finding treatment and control villages in the same province, the research group allowed control villages to be in another province from treatment villages. However, in such cases it was verified that the treatment and control villages were statistically similar in terms of geographical attributes, distance from infrastructures and services, transportation costs, and project staff and local stakeholders were consulted to ensure their similarities based on their local knowledge and familiarity with the project locations. Note, however, that our research is not an impact evaluation analysis and we therefore merely use the database as it provides a compelling sample of poor farmers in an area particularly affected by climate shocks.

The interviews were conducted during a difficult period, and more specifically, soon after the consequences of COVID-19 in the Solomon Islands were exacerbated by the contextual tropical cyclone (TC) Harold hit the country on 2 April 2020, two weeks after the pandemic was declared on 11 March 2020. TC Harold caused severe damage to crops, food gardens, housing, buildings, and roads across Honiara, Western Province, Guadalcanal, Makira/Ulawa, Rennell, and Bellona, therefore, some provinces in the RDP II study.

A legend of the variables is provided in table 1 while descriptive statistics of the sample are presented in table 2. Education levels were extremely low: approximately one-half of the respondents reported only six years of education corresponding to elementary school attendance; 20 per cent reported no education at all; only 20 per cent reported high school education, and 10 per cent reported education above the high school level. The average number of household members in the sample was 5.4, 80 per cent of the respondents were married, and a severe gender imbalance among the respondents (only 10 per cent women) was a result of the fact that household heads were mainly men due to local culture. The average age of the respondents was 46 years old. The gross yearly household income[3] was 24,099.00 Solomon Islands dollar, the local currency unit (LCU) (approximately 7.49 USD per day per household at the exchange rate of July 2021 of 8.06 LCU per USD), which corresponds to an individual income of 1.51 USD per day in PPP, which is 20 per cent below the per capita 1.90 USD per day, the International Poverty Line revisited by Ravallion *et al.* (2009).[4] The average official standard of living of the Solomon Islands was estimated in 2020 as 2.62 USD per day in PPP, confirming the aim of IFAD rural development projects to target the poorest farmers. However, what should be considered is that the survey occurred during the COVID-19 pandemic, which hindered farmers' access to the product market and consequently affected their sources of wage and self-employment income. Furthermore, the actual standard of living of the respondents is slightly higher when we assess the relevant share of cocoa, coconut, and fish at market prices that were self-consumed. After examining the farmers' income augmented by the market value of self-consumed products (using average sale prices per kilogram

[3]Experts administering the survey assisted in the measurement of yearly gross household income which was assumed to be the sum of the values of the different estimated sources of income.

[4]It is the headline poverty threshold and defines the World Bank's goal of ending global extreme poverty by 2030.

in the household market village), we estimated that the value of self-consumption adds approximately 10 per cent to the household income of all sources.

The dependent variable in this study is subjectively assessed household well-being, measured as the respondent's evaluation of the quality of life of their household. The question was asked only at the household level and formulated as follows: *"Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. Suppose we say that the top of the ladder represents the best possible life for you and your household and the bottom of the ladder represents the worst possible life for you and your household. On which step of the ladder would you say your household stands now?"*. This variable is different from the standard cognitive subjective well-being indicator used to measure life satisfaction.[5] Its distribution is also different - it is not right-skewed as are almost all the observed life satisfaction sampling distributions - it is closer to a normal distribution with a mode around the central value of five.

A crucial issue in our research is whether objective or subjective data on climate shocks is used. The available subjective measure is the response to whether the household suffered a climate shock in the previous year. Although there is no explicit question about it, some of the respondents may be likely to keep in mind TC Harold when answering this question. Subjective perceptions of exposure to climate shocks are helpful in this regard, as they provide much richer information than what is related to a specific objective climate shock, as the former is a comprehensive measure that includes different climate events such as floods, droughts and rising sea levels, along with perceptions of exposure to such climate shocks considering the given household's characteristics. Beyond capturing a much richer set of unobservable objective factors affecting the impact of climate shocks on the respondent, the subjective climate shock variable is also, by definition, more likely to affect household subjective well-being.

Moreover, to ensure that our findings were not biased by perceptions of the respondents, we created an objective climate indicator. More specifically, we used information on the geographical location of each respondent (longitude, latitude, and altitude) and selected local objective climate variables among available geolocalized indicators of drought spells, temperature change, and other measures of extreme climate events. However, given the relative geographical proximity of all our sample respondents, most of these data present limited cross-sectional variation, even though their time change is extremely useful for illustrating the climate scenario of the Solomon Islands.

The variable with sufficient cross-sectional variability was the average number of 10-day dry spells per year experienced by respondents in the last five years.[6] This is a variable of the Geographic Information System (GIS) in which a dry spell is defined as the number of consecutive days with no precipitation associated with the latitude and longitude of the respondent's household. In figure 1, we show a map of the geographical areas covered in our sample: darker regions are those more severely affected by drought periods.

[5]We expect that the standard individual life satisfaction is much more driven by idiosyncratic respondents' character traits than the subjective evaluation from an household member of the quality of life of the household we use in our paper, even though the latter maintains a broader scope than just what is captured by current income and wealth outcomes. The household well-being the respondent has in mind should therefore include non-income factors such as quality of relational resources (agricultural membership and the marital status) and exposure to (climate and non climate) shocks which will be tested in the econometric section that follows.

[6]As shown in table 2, the dry spell variable has a few missing observations due to a lack of data about latitude and longitude for a few interviewed households.

Table 1. Variable legend

Dependent variable	
Present HWB	Household well-being according to the household head respondent today (0–10 scale).
Subjective climate measure	
Climate shock	(0/1) dummy for households declaring they were affected by climate shocks (droughts/floods/sea level rise) in the last year.*
Objective climate measure	
Dry spells	Average number of 10-day (dekad) dry spell lengths per year in the last five years associated with the latitude and longitude of the respondent's household.
Dry above median	(0/1) dummy if the average number of 10-day dry spells per year in the last five years is higher than the median.
Household characteristics	
HH size	Number of household members.
Female headed	0/1 dummy for female household head.
Married	0/1 dummy for married status.
Age	Age of respondent.
Education years	Total number of respondent's education years (dummies = 0, = 6, = 13 and higher than 13).
Agricultural association member	0/1 dummy for membership in agricultural societies.
Agriculture and welfare	
Gross income	Gross yearly household income from crops, fishing, self-employment, transfers and other income in LCU.
Area	Land size of the household in ha.
No toilet	(0/1) dummy if the household has no access to a regular toilet.
Thatch roof	(0/1) dummy if the main material of the roof of the main dwelling is made of thatch.
Durable asset index	Durable assets index, PCA, normalized 0-1. The assets used to compute the durable good index include: regular mobile phone, smartphone, tv, refrigerator, bicycle, car.
Nutrition problem	(0/1) dummy where the respondent answered the question: "During last year, was there a time when anyone in your household was unable to eat healthy and nutritious/preferred foods because of a lack of money or other resources?
Non-climate shock	(0/1) dummy for households declaring they were affected by non-climate shocks and, more specifically, one among - Economic/financial shock (loss or reduction of income/ high input or food prices/low output prices) - Health shocks (death or illness of a household member) - Conflict/violence shocks (land disputes/domestic violence - in the last year
Low crop income	(0/1) dummy if the gross crop income is lower than the median of 2700.
Below median asset	(0/1) dummy if the durable index is lower than the median of 0.118.

Table 1. *Continued.*

Agriculture and welfare	
NUTRITION DUMMIES:	(0/1) dummies where the respondent answered the question: "During last year, was there a time when anyone in your household. . .
Nutrition 1: worried about food	. . . was worried about not having enough food to eat because of lack of money or other resources?
Nutrition 2: unhealthy food	. . . was unable to eat healthy and nutritious/preferred foods because of a lack of money or other resources?
Nutrition 3: few food	. . . ate only a few kinds of foods because of a lack of money or other resources?
Nutrition 4: skipped meals	. . . had to skip a meal because there was not enough money or other resources to get food?
Nutrition 5: ate less food than wanted	. . . ate less than you thought you should because of a lack of money or other resources?
Nutrition 6: run out of food	. . . ran out of food because of a lack of money or other resources?
Nutrition 7: hungry	. . . was hungry but did not eat because there was not enough money or other resources for food?
Nutrition 8: didn't eat for a whole day	. . . went without eating for a whole day because of a lack of money or other resources?
Fixed Effects	
Province	Categorical for the three provinces: Guadalcanal, Malaita, Makira/Ulawa.
Ward	Categorical for the 24 wards (see online appendix table A5 for ward list).
Village	Categorical for the 84 villages (see online appendix table A6 for village list).

Note: *The survey question was: During last year, did your household experience any of the following shocks? Climate shocks (droughts/floods/sea level rise).

Table 2. Summary statistics

Dependent variable	Mean	Std. Dev.	Min.	Max.	N
Present HWB	4.967	1.563	0	10	1274
Subjective climate measure					
Climate shock	0.476	0.5	0	1	1274
Objective climate measure					
Dry spells	12.9	5.2	0	21	1228
Household characteristics					
Household size	5.366	2.206	1	14	1274
Female headed	0.096	0.294	0	1	1274
Married	0.848	0.359	0	1	1274
Age	46.502	12.751	17	90	1274
Education years = 0	0.164	0.4	0	1	1274

Table 2. *Continued.*

Dependent variable	Mean	Std. Dev.	Min.	Max.	N
Education years = 6	0.513	0.500	0	1	1274
Education years = 13	0.228	0.420	0	1	1274
Education years higher than 13	0.094	0.292	0	1	1274
Agricultural association member	0.327	0.469	0	1	1274
Agriculture and welfare					
Total gross income (K)	23.782	67.224	0	1332.948	1274
Area of parcel (HA)	7.075	102.382	0	2500	1274
No toilet	0.553	0.497	0	1	1274
Thatch roof	0.441	0.497	0	1	1274
Non-climate shock	0.505	0.5	0	1	1274
Durable assets index	0.155	0.158	0	1	1274
Nutrition 1: worried about food	0.409	0.492	0	1	1274
Nutrition 2: healthy	0.470	0.499	0	1	1274
Nutrition 3: little food	0.517	0.500	0	1	1274
Nutrition 4: skipped meals	0.202	0.401	0	1	1274
Nutrition 5: ate less food than wanted	193	0.395	0	1	1274
Nutrition 6: ran out of food	0.110	0.313	0	1	1274
Nutrition 7: hungry	0.092	0.289	0	1	1274
Nutrition 8: didn't eat for a whole day	0.068	0.251	0	1	1274

4.1. Econometric findings

To examine the impact of climate shocks on subjectively assessed household well-being, we estimated the following OLS specification:[7]

$$\begin{aligned} HWB_{i,j,k,l} = {} & \alpha_0 + \alpha_1 Climate\ Shock_{i,j,k,l} + \alpha_2 Non\ Climate\ Shock_{i,j,k,l} \\ & + \alpha_3 HH\ Size_{i,j,k,l} + \alpha_4 Female\ Headed_{i,j,k,l} + \alpha_5 Married_{i,j,k,l} \\ & + \alpha_6 Age_{i,j,k,l} + \alpha_7 Age\ Squared_{i,j,k,l} + \alpha_8 Education\ Years = 0_{i,j,k,l} \\ & + \alpha_9 Education\ Years = 6_{i,j,k,l} + \alpha_{10} Education\ Years = 13_{i,j,k,l} \\ & + \alpha_{11} Agricultural\ Association\ Member_{i,j,k,l} + \alpha_{12} Gross\ Income_{i,j,k,l} \\ & + \alpha_{13} Area_{i,j,k,l} + \alpha_{14} No\ Toilet_{i,j,k,l} + \alpha_{15} Thatch\ Roof_{i,j,k,l} \\ & + \alpha_{16} Nutrition\ Problem_{i,j,k,l} + \eta_l + \epsilon_i \end{aligned}$$

[7] As it is standard and shown in the literature, estimating a model with the 0–10 well-being dependent using OLS instead of ordered logit has no substantial impact on empirical results (Ferrer-i Carbonell and Frijters, 2004). In the robustness checks that follow (see table A1 in appendix), we will show that this is also the case in our estimates with main findings robust when the benchmark equation is estimated with ordered logit.

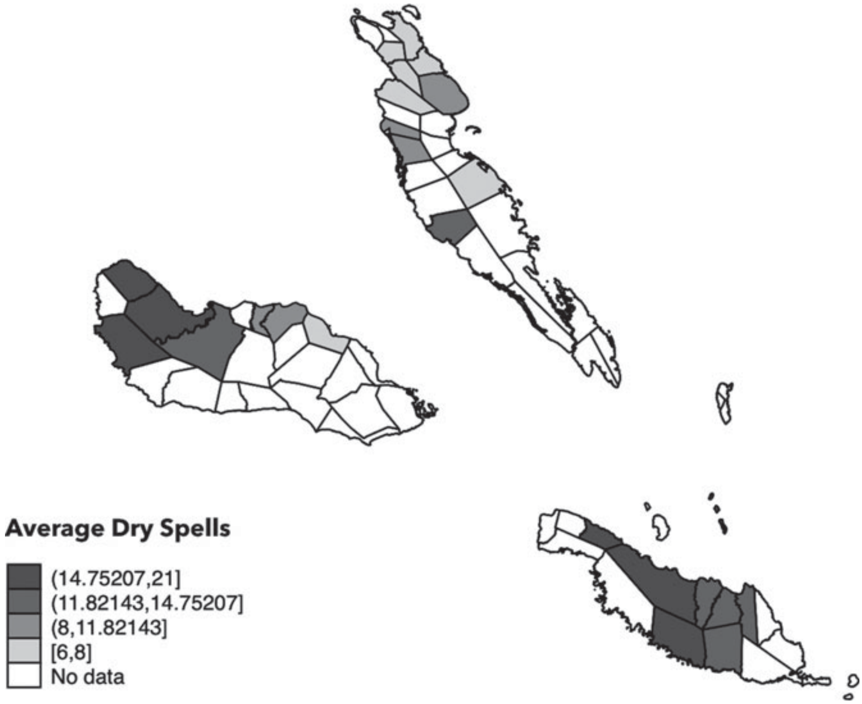

Figure 1. Dry spells in the Solomon Islands.

where the dependent variable is the subjective (0–10) assessment of the i-th farmer living in province j, ward k, and village l on the well-being of her/his household and the main regressor of interest (Climate Shock) is a dummy for respondents who report having suffered a climate shock in the last year. Controls include declared exposure to non-climate shocks and standard sociodemographic variables such as household size, a (0/1) dummy for female gender, a (0/1) dummy for marital status, age, and age squared to account for the potentially nonlinear impact of the variable on subjective well-being (see Blanchflower, 2021), three education dummies that capture three of the four education levels reported in the sample (0 years, 6 years, and 13 years), with more than 13 education years being the omitted benchmark, and a (0/1) dummy that identifies respondents who are members of formal agribusiness partnerships.[8]

The four variables representing economic factors are total gross income, a (0/1) dummy with unit value for households which responded that some members were unable to eat healthy and nutritious/preferred foods due to lack of money or other resources, and two proxy measures of the living conditions (absence of toilet and

[8]The RDP II project aims to develop agribusiness partnerships in order *"to strengthen the links between smallholder farm houses and markets"* and *"to assist farming households to engage in productive partnerships with commercial enterprises"*. Activities and input involve the provision of technical and financial support to commercial enterprises and farming households to enable them to form partnerships. This support targets farmers' households ("co-partners") and is provided through commercial enterprises ("lead partners").

thatched roofs). In a further robustness check we introduce a durable good index[9] and the total area of cultivated plantations in hectares, respectively. This broad set of flow and stock variables that measure economic conditions helps to identify the different dimensions of the economic structure, and the measurement of these indicators was assisted by the researchers administering the survey to account for the lack of numerical literacy of household respondents. This benchmark specification is progressively augmented with province, ward, and village fixed effects in columns 1–3 of table 3.

The estimated findings indicate that exposure to climate shocks is negatively and significantly correlated with household well-being. The goodness of fit of the estimates improves progressively up to the last fully augmented specification, including village fixed effects (column 3, table 3), where more than one-third of the variability of the dependent variable is explained. The findings related to the other control variables suggest that economic factors are strongly significant. Specifically, gross income, poor dwellings proxied by thatched roofs, and cultivated land extensions were significantly related to subjectively assessed household well-being. In addition, membership in formal agricultural associations is positive and significant as it is likely to enable services that can help members improve market access and bargaining power, reduce risks, and absorb shocks. This finding is consistent with the role of local associations (such as the most known Kastom Gaden Association) in providing technical assistance to farmers and supporting the continuity of the Food and Agriculture Organization (FAO) and the IFAD rural development projects.

Character traits (e.g., anxiety) can lead some respondents to judge events as climate shock events that are not considered as such by other respondents. An objective measure such as dry spells avoids the problem of disagreement in subjective measures of what a climate shock is. For this purpose, we use the latitude and longitude of each respondent in the sample to obtain objective climate indicators using GIS mapping data.[10] This allows us to include measures such as dry spells, which provide a standardized and unbiased representation of climate conditions.

The most relevant climate indicator for current research is related to the yearly number of dry spells, proxying one of the three main climate change factors (rise in sea levels, droughts, and storms) identified in the climate shock question that can adversely affect the inhabitants of the Solomon Islands. A dry spell is defined as the number of consecutive days without rain precipitation. The standard variable collected by IFAD in the GIS data is the average number of 10-day periods with dry days per year. To evaluate the effect of an objective climate variable, we therefore introduce the number of 10-day dry spells per year over the last five years before the interview as an explanatory variable. As explained in our sample description, all participants in the survey were coconut or cocoa farmers and drew a dominant share of their income from these two crops. We therefore expect the impact of this variable to be significant because long dry spells generated by climate warming have severe negative effects on the production of both crops due to the

[9]The assets used to compute the durable good index include regular mobile phone, smartphone, television, refrigerator, bicycle, car.

[10]IFAD GIS data used here come from different sources and mainly from CHIRPS (the Climate Hazards Group InfraRed Precipitation with Station data), based on a combination of NOAA (National Oceanic and Atmospheric Administration) data, terrestrial weather station data and ARC2 (the ARC2 -NOAA's African Rainfall Climatology version 2) data. Data on temperature come from the European Centre for Medium-Range Weather (ECMWF) ERA INTERIM reanalysis model.

Table 3. The effects of the subjective measure of climate shocks on current subjective well-being (OLS)

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Subjective measure			
Climate shock	−0.227 (0.082)	−0.250 (0.080)	−0.234 (0.082)
Household characteristics			
Household size	−0.010 (0.020)	−0.024 (0.020)	−0.035 (0.020)
Female headed	−0.332 (0.143)	−0.177 (0.133)	−0.224 (0.146)
Married	0.228 (0.129)	0.351 (0.125)	0.243 (0.133)
Age	0.007 (0.017)	0.013 (0.017)	0.019 (0.017)
Age^2	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Education years = 0	−0.188 (0.175)	−0.190 (0.169)	−0.285 (0.177)
Education years = 6	−0.158 (0.144)	−0.161 (0.143)	−0.172 (0.147)
Education years = 13	−0.121 (0.155)	−0.137 (0.156)	−0.090 (0.161)
Agricultural association member	0.219 (0.086)	0.199 (0.083)	0.306 (0.084)
Agriculture and welfare			
Gross income (K)	0.003 (0.001)	0.002 (0.001)	0.002 (0.001)
Area (HA)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
No toilet	−0.49 (0.086)	−0.153 (0.092)	−0.155 (0.092)
Thatch roof	−0.336 (0.084)	−0.415 (0.085)	−0.428 (0.089)
Nutrition problem	−0.425 (0.086)	−0.320 (0.091)	−0.402 (0.092)
Non-climate shock	−0.267 (0.083)	−0.391 (0.079)	−0.486 (0.081)
Fixed effects			
Province	YES	NO	NO
Ward	NO	YES	NO
Village	NO	NO	YES
Constant	5.364 (0.429)	4.719 (0.450)	5.692 (0.602)

Table 3. *Continued.*

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Observations	1274	1274	1274
R^2	0.216	0.294	0.352

Notes: The dependent variable is a (0–10) categorical variable answering the question: *"Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. Suppose we say that the top of the ladder represents the best possible life for you and your household, and the bottom of the ladder represents the worst possible life for you and your household. On which step of the ladder would you say your household stands now?".* See table 1 for regressors legend.
Robust standard errors in parentheses.

reduction in soil moisture and decreased soil fertility, which can lead to cocoa seedling mortality. In addition, droughts weaken plants and reduce coconuts yield and weight.

Consistent with our expectations, the dry spell variable is negative and significant when introduced in our benchmark specification (table 4). Dry spells are less likely to be affected by endogeneity.[11] Furthermore, the subjective climate variable (perceived exposure to climate shock) remains significant after this change. This finding suggests that cumulative dry spells, as expected, do not capture the entire impact of climate shocks on household well-being, consistent with the fact that the latter includes the effect of other extreme climate events. Additionally, subjective evaluation of climate shocks on subjective well-being can also include the perception of the impact of future climate risks and the idiosyncratic effect of past climate shocks on the specific respondent situation based on the characteristics of the respondent's land area, living conditions of household members, type of crops, and breakdown of sources of income creating further endogeneity problems.

In the estimates that follow, we examine the factors that can worsen and mitigate the impact of climate shocks on household well-being. For this purpose, we interact the climate shock variable with proxies of low housing quality (thatched roofs), unit dummies for membership in formal agricultural associations, altitude (a proxy of isolation and poorer market access), below-median values of income, and durable assets. Related findings indicate that the effect is stronger for people living at higher altitudes, with poor dwellings, income or wealth below the median, and not being members of formal agricultural associations (table 5).

The correlation between the disutility created by climate shocks and poorer income and/or wealth conditions confirms that environmental concerns do not arise only for high-income people. The rationale of our findings is that rural farmers have experienced climate shocks in the past and are aware of the economic consequences of climate shocks on their lives and economic activities. Therefore, they realize that if they are poor or more isolated, they have fewer opportunities to defend themselves effectively against climate risks. The rationale for the effect of poor housing quality is straightforward in that farmers' exposure to "environmental" shocks, including events such as the recent TC Harold, is perceived as more harmful for farmers who live in dwellings with a lower probability of resisting extreme meteorological events (the omitted benchmarks of thatched roofs are wood, not burnt, or burnt bricks).

[11] We cannot, however, exclude in principle that characteristics associated with dry areas also affect local farmer well-being, and association between location of poorer farmers and more marginal and less climate-friendly lands.

Table 4. Difference between subjective and objective measures of climate shocks on current subjective well-being (OLS)

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Objective measure			
Dry spells	−0.024 (0.009)	−0.024 (0.010)	−0.034 (0.014)
Subjective measure			
Climate shock	−0.242 (0.084)	−0.239 (0.082)	−0.241 (0.084)
Household characteristics			
Household size	−0.014 (0.021)	−0.027 (0.020)	−0.035 (0.021)
Female headed	−0.371 (0.142)	−0.218 (0.133)	−0.246 (0.148)
Married	0.259 (0.133)	0.379 (0.129)	0.275 (0.138)
Age	0.009 (0.018)	0.017 (0.017)	0.021 (0.018)
Age^2	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Education years = 0	−0.108 (0.178)	−0.109 (0.174)	−0.226 (0.181)
Education years = 6	−0.062 (0.149)	−0.085 (0.148)	−0.107 (0.151)
Education years = 13	−0.048 (0.158)	−0.068 (0.159)	−0.029 (0.164)
Agricultural association member	0.227 (0.089)	0.192 (0.085)	0.300 (0.087)
Agriculture and welfare			
Gross income (K)	0.003 (0.001)	0.002 (0.001)	0.002 (0.001)
Area (HA)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
No toilet	−0.041 (0.088)	−0.162 (0.096)	−0.178 (0.096)
Thatch roof	−0.320 (0.086)	−0.403 (0.086)	−0.420 (0.091)
Nutrition problem	−0.428 (0.088)	−0.312 (0.094)	−0.400 (0.096)
Non-climate shock	−0.270 (0.085)	−0.385 (0.080)	−0.476 (0.083)
Fixed effects			
Province	YES	NO	NO
Ward	NO	YES	NO
Village	NO	NO	YES

Table 4. *Continued.*

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Constant	5.769 (0.437)	5.121 (0.468)	6.248 (0.621)
Observations	1228	1228	1228
R^2	0.217	0.295	0.353

Notes: See notes for table 3.

Membership in formal agricultural societies is also shown to be relevant in reducing the impact of climate shocks on subjective well-being, and this finding is consistent with the roles, activities, and strategies of these societies. The current interpretation is confirmed by estimates indicating an interaction with the objective climate variable of above median dry spells (table 6).

To provide further evidence of the correlation between climate shocks and nutrition problems, we investigated the correlation between reported climate shocks and nutritional issues in the last year (table 7).[12] Our findings indicate that respondents exposed to climate shocks reported a significantly higher proportion (13 per cent compared to 6 per cent) of hunger for at least one member in their household, situations in which members ran out of food (13 per cent versus 9 per cent), ate less than wanted (23 per cent versus 16 per cent), or when members had to skip meals (23 per cent compared to 18 per cent).

5. Discussion and robustness checks

In a robustness check we introduce altitude among the regressors and find that the variable has no significant effects on household well-being. Therefore, it appears that the rise in sea level does not concern respondents or is not captured by the altitude variable. On the contrary, altitude proxies remoteness and distance from product markets and, therefore, significantly increases the impact of climate shocks on household well-being.

In a further robustness check, we rectify the total gross income with the market value of crops not sold but directly consumed in the household, evaluating them at the local village market price. In addition, we performed other robustness checks using log income and linear income augmented for self-consumption. Our main findings related to both the climate shock and the interaction between the thatched roof and the climate shocks are robust and do not change when using the modified specifications (tables A1 and A2 in the appendix replicate tables 3 and 4, respectively). In a final robustness check, we introduce the durable good index as a control and observe that our main findings for all the alternative specifications of tables 3 and 4 remain significant (see table A3 in the appendix).

Also note that the subjectively assessed climate shock variable captures additional effects different from those captured by dry spells. More specifically, as indicated by construction of the variable in the questionnaire, the variable can capture droughts,

[12] The table reports all sample observations including those dropped in the econometric estimates due to missing values in some regression variables. Findings are robust when calculated with the restricted sample and are available upon request.

Table 5. Subjective measure of climate shocks and subjective well-being: interaction effects

Household characteristics	(1) Present HWB	(2) Present HWB	(3) Present HWB	(4) Present HWB	(5) Present HWB
Household size	−0.035 (0.020)	−0.034 (0.020)	−0.036 (0.020)	−0.038 (0.020)	−0.035 (0.020)
Female headed	−0.221 (0.146)	−0.240 (0.148)	−0.213 (0.145)	−0.209 (0.145)	−0.223 (0.145)
Married	0.244 (0.133)	0.235 (0.135)	0.243 (0.133)	0.241 (0.132)	0.244 (0.133)
Age	0.020 (0.017)	0.019 (0.017)	0.021 (0.017)	0.019 (0.017)	0.019 (0.017)
Age^2	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Education years = 0	−0.282 (0.177)	−0.290 (0.177)	−0.289 (0.176)	−0.235 (0.177)	−0.286 (0.177)
Education years = 6	−0.168 (0.147)	−0.167 (0.147)	−0.171 (0.145)	−0.143 (0.145)	−0.171 (0.147)
Education years = 13	−0.089 (0.161)	−0.093 (0.160)	−0.082 (0.159)	−0.076 (0.159)	−0.089 (0.161)
Agricultural association member		0.314 (0.084)	0.305 (0.085)	0.280 (0.084)	0.307 (0.085)
Agriculture and welfare					
Gross income (K)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)
Area (HA)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
No toilet	−0.159 (0.092)	−0.172 (0.093)	−0.162 (0.093)	−0.131 (0.092)	−0.155 (0.092)
Thatch roof	−0.430 (0.089)	−0.414 (0.088)	−0.411 (0.089)	−0.383 (0.089)	
Nutrition problem	−0.398 (0.092)	−0.403 (0.091)	−0.409 (0.093)	−0.405 (0.092)	−0.400 (0.092)
Non-climate shock	−0.489 (0.081)	−0.479 (0.081)	−0.501 (0.081)	−0.477 (0.080)	−0.485 (0.081)
Subjective climate shock interaction effects					
Climate shock = 0× Association NO	*o.b.* (.)				
Climate shock = 0× Association YES	0.241 (0.112)				
Climate shock = 1× Association NO	−0.278 (0.098)				
Climate shock = 1× Association YES	0.107 (0.124)				
Climate shock = 0× High altitude = 0		*o.b.* (.)			
Climate shock = 0× High altitude = 1		−0.130 (0.108)			

Table 5. *Continued.*

Household characteristics	(1) Present HWB	(2) Present HWB	(3) Present HWB	(4) Present HWB	(5) Present HWB
Climate shock = 1× High altitude = 0		−0.186 (0.108)			
Climate shock = 1× High altitude = 1		−0.409 (0.120)			
Climate shock = 0× Low crop income = 0			*o.b.* (.)		
Climate shock = 0× Low crop income = 1			0.019 (0.113)		
Climate shock = 1× Low crop income = 0			−0.094 (0.117)		
Climate shock = 1× Low crop income = 1			−0.366 (0.122)		
Climate shock = 0× Below median asset = 0				*o.b.* (.)	
Climate shock = 0× Below median asset = 1				−0.265 (0.103)	
Climate shock = 1× Below median asset = 0				−0.231 (0.127)	
Climate shock = 1× Below median asset = 1				−0.509 (0.118)	
Climate shock = 0× Thatch roof = 0					0.*b.* (.)
Climate shock = 0× Thatch roof = 1					−0.386 (0.111)
Climate shock= 1× Thatch roof = 0					−0.196 (0.103)
Climate shock= 1× Thatch roof = 1					−0.667 (0.120)
Village FE	YES	YES	YES	YES	YES
Constant	5.979	5.993	5.884	6.017	5.957
	(0.589)	(0.593)	(0.595)	(0.587)	(0.587)
Observations	1274	1274	1274	1274	1274
R^2	0.352	0.354	0.355	0.358	0.352

Notes: o.b. denotes omitted benchmark. See notes for table 3.

floods or sea level rise. As a consequence, our data unfortunately does not allow us to fully disentangle the effect of dry spells from those of the other two climate shocks in the overall climate shock variable.

When the two variables are used together, part of the dry spell variable effect is captured by the climate shock variable. However, the significance of the climate shock

Table 6. Objective measures of climate shocks and subjective well-being: interaction effects

Subjective measure	(1) Present HWB	(2) Present HWB	(3) Present HWB	(4) Present HWB
Climate shock	−0.239 (0.082)	−0.238 (0.082)	−0.242 (0.081)	−0.242 (0.081)
Household characteristics				
Household size	−0.036 (0.020)	−0.035 (0.020)	−0.037 (0.020)	−0.039 (0.020)
Female headed	−0.242 (0.147)	−0.255 (0.148)	−0.236 (0.146)	−0.230 (0.146)
Married	0.253 (0.134)	0.249 (0.134)	0.251 (0.134)	0.251 (0.132)
Age	0.019 (0.017)	0.018 (0.017)	0.020 (0.017)	0.019 (0.017)
Age^2	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Education years = 0	−0.284 (0.178)	−0.287 (0.177)	−0.291 (0.177)	−0.232 (0.178)
Education years = 6	−0.165 (0.147)	−0.160 (0.147)	−0.165 (0.147)	−0.135 (0.146)
Education years = 13	−0.088 (0.161)	−0.093 (0.160)	−0.092 (0.161)	−0.074 (0.159)
Agricultural association member		0.305 (0.085)	0.306 (0.085)	0.271 (0.084)
Agriculture and welfare				
Gross income (K)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)	0.002 (0.001)
Area (HA)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
No toilet	−0.165 (0.092)	−0.182 (0.093)	−0.167 (0.092)	−0.142 (0.092)
Thatch roof	−0.428 (0.088)	−0.418 (0.088)	−0.425 (0.088)	−0.382 (0.089)
Nutrition problem	−0.421 (0.092)	−0.418 (0.092)	−0.412 (0.093)	−0.424 (0.092)
Non-climate shock	−0.481 (0.081)	−0.474 (0.081)	−0.491 (0.081)	−0.471 (0.080)
Objective climate shock interaction effects				
Dry above median = 0× Association NO	*o.b.* (.)			
Dry above median = 0× Association YES	0.292 (0.119)			
Dry above median = 1× Association NO	−0.443 (0.180)			
Dry above median = 1× Association YES	−0.139 (0.193)			

Table 6. *Continued.*

Subjective measure	(1) Present HWB	(2) Present HWB	(3) Present HWB	(4) Present HWB
Dry above median = 0× High altitude = 0		*o.b.* (.)		
Dry above median = 0× High altitude = 1		−0.134 (0.121)		
Dry above median = 1× High altitude = 0		−0.376 (0.190)		
Dry above median = 1× High altitude = 1		−0.568 (0.182)		
Dry above median = 0× Low crop income = 0			*o.b.* (.)	
Dry above median = 0× Low crop income = 1			−0.093 (0.120)	
Dry above median = 1× Low crop income = 0			−0.401 (0.188)	
Dry above median = 1× Low crop income = 1			−0.556 (0.184)	
Dry above median = 0 × Below median asset = 0				*o.b.* (.)
Dry above median = 0× Below median asset = 1				−0.296 (0.131)
Dry above median = 1× Below median asset = 0				−0.476 (0.189)
Dry above median = 1× Below median asset = 1				−0.733 (0.194)
Village FE	YES	YES	YES	YES
Constant	5.991 (0.586)	6.027 (0.588)	5.993 (0.587)	6.046 (0.585)
Observations	1274	1274	1274	1274
R^2	0.354	0.356	0.355	0.360

Notes: o.b. denotes omitted benchmark. See notes for table 3.

variable in the estimate where both variables are present tells us that there is something more than dry spells in the negative effect of climate shocks on the dependent variable. Therefore, we have one main reason for using both variables (showing that the negative impact of climate shocks on household well-being goes beyond the effect of dry spells). In addition, if we use only the dry spell variable we have an omitted variable bias if dry spells are correlated with the climate shock variable. However, we find that correlation is small (below .05). Therefore, we perform a robustness check using only the objective climate shock variable. More specifically, we reproduce estimates of table 3 with the dry spell variable replacing the climate shock variable, as shown in table A4 in the appendix. The results of the dry spell coefficient exhibit minimal variation with respect to the results of estimates where both regressors are present (as in table 4).

Table 7. Nutrition problem difference between groups experiencing or not climate shocks

Nutrition Variables	No climate shock group %	No climate shock group N. of obs.	Climate shock group %	Climate shock group N. of obs.	Diff. (T-C)	S.E.	T-stat
Nutrition 1: worried	41.0	680	41.9	620	−0.009	0.027	−0.3310
Nutrition 2: unhealthy food	48.7	680	0.45	620	0.037	0.028	1.3265
Nutrition 3: little food	50.3	680	53.0	620	−0.028	0.027	−0.9980
Nutrition 4: skipped meals	17.6	680	22.9	620	−0.052	0.022	−2.3629
Nutrition 5: ate less food than wanted	16.0	680	23.1	620	−0.070	0.022	−3.2151
Nutrition 6: ran out of food	9.1	680	12.7	620	−0.036	0.017	−2.1009
Nutrition 7: hungry	5.9	680	12.6	620	−0.067	0.016	−4.2244
Nutrition 8: didn't eat for a whole day	5.7	680	7.7	620	−0.020	0.013	−1.4462

Note: Results from t-test between the means of the two groups: those experiencing climate shocks and those not.

6. Conclusions and direction for future research

The global economic system has entered an era of strongly correlated and interdependent environmental and social shocks affecting a relevant part of its population. An investigation of the consequences of climate shocks is therefore of the utmost importance to understand their impact and design policies that can address the problem and reduce the exposure of rural farmers to such shocks. To contribute to the existing literature, we evaluate the impact of climate shocks on a sample of low-income farmers in the small-scale island society of the Solomon Islands. The focus of our investigation on low-income individuals, particularly those exposed to climate shocks, is extremely important for measuring the correlation between environmental and socioeconomic problems.

Our findings indicate that respondents' evaluation of their exposure to climate shocks significantly reduces their subjectively assessed well-being. Similar findings are obtained when using an objective measure (dry spells) that proxies for one of the climate shock dimensions (droughts) in the area. Additionally, we find a significant correlation between environmental shocks and economic problems since respondents with poorer homes (proxied by thatched roofs), below-median income, and fewer durable goods are more severely affected in terms of household well-being. This interaction is confirmed by the fact that those affected by climate shocks reported a significantly higher proportion of nutrition-related problems in the same period. Our findings suggest that the reported loss of household well-being finds correspondence with environmental and social problems.

One limitation of our analysis is in the impossibility of using a finer disaggregation in the comparison between the objective measure (droughts) and the subjectively assessed exposure to climate shocks including three possibilities (sea level rise, droughts, floods). We suggest on this point the development of more detailed data with disaggregation of subjective perception of climate shocks (foods, droughts, sea level rise) to understand their differential impact.

The significance of the objective climate measure used in this study, if interpreted in the sense of causality, suggests the relevance of climate adaptation policies – in particular, the adaptation of crops to drought and longer dry spells – for local farmers. The interdependence between our main findings and the role of housing, income, wealth, and membership in agricultural organizations provides additional policy suggestions related to factors of fragility that can make adaptation more difficult for local farmers. In addition, our findings on the nexus between climate shocks and subjective well-being of poor farmers provide strong evidence in favour of global policies such as the creation of loss and damage funds for vulnerable countries hit by climate disasters. On this point, it is therefore promising that the COP27 deliberated to go forward in this direction. Our findings, however, suggest in this context that we should not just dedicate financial resources to compensation for shocks that have already occurred (rehabilitation, recovery and reconstruction) but also to support for strategies of adaptation and prevention. In this respect, membership in agricultural associations can be an important direction since these associations often have forms of insurance, mutual aid and provision of various services, thus reducing farmer vulnerability to shocks. In addition, local agricultural organizations can play an important role in providing support services and acting as a bridge between FAO/IFAD rural development programs and local farmers, helping the latter to consolidate knowledge and innovation in their productive activities that reduce exposure to climate shocks.

Future research should examine whether similar effects of climate shocks on household well-being can be found for other low-income areas and populations and fill existing information gaps with the development of more detailed data. More research in this direction is urgently needed, as the literature evaluating the impact of climate shocks on subjective and household well-being is a first building block that can help to improve our knowledge on related objective outcomes such as the probability of climate migration. Future empirical research that directly reconnects evidence on disutility from climate shocks with climate migration choices (with proper data on this point thereby overcoming another limitation of this analysis) would be particularly important in this regard, in the same direction as what has been done in the literature that found clear relationships between "feelings integers and subsequent get-me-out-of-here actions" (Kaiser and Oswald, 2022), or the materialisation of objective outcomes, as in the case, among others, of the nexus between job satisfaction and quitting job, and self-assessed health and the onset of chronic diseases.

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Competing interest. The authors declare none.

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Appendix A:

Table A1. Alternative specifications estimates from table 3

Subjective climate shock on present SWB	(1)	(2)	(3)
Ordered probit regression with linear income			
Climate shock	−0.202 (0.060)	−0.225 (0.061)	−0.223 (0.063)
Thatch roof = 0 × Climate shock = 1	−0.133 (0.075)	−0.149 (0.078)	−0.184 (0.080)
Thatch roof = 1× Climate shock = 0	−0.190 (0.079)	−0.255 (0.082)	−0.317 (0.088)
Thatch roof = 1 × Climate shock = 0	−0.482 (0.089)	−0.575 (0.091)	−0.586 (0.095)
Linear regression with self consumption			
Climate shock	−0.259 (0.082)	−0.274 (0.080)	−0.260 (0.082)
Thatch roof = 0× Climate shock = 1	−0.172 (0.104)	−0.179 (0.103)	−0.214 (0.103)
Thatch roof = 1× Climate shock = 0	−0.247 (0.106)	−0.321 (0.106)	−0.393 (0.112)
Thatch roof = 1× Climate shock = 1	−0.621 (0.118)	−0.714 (0.118)	−0.707 (0.121)
Ordered probit regression with self consumption			
Climate shock	−0.203 (0.060)	−0.224 (0.061)	−0.221 (0.063)
Thatch roof = 0× Climate shock = 1	−0.131 (0.076)	−0.145 (0.078)	−0.178 (0.080)
Thatch roof = 1× Climate shock = 0	−0.187 (0.079)	−0.254 (0.083)	−0.317 (0.088)
Thatch roof = 1× Climate shock = 1	−0.483 (0.089)	−0.578 (0.091)	−0.590 (0.095)
Linear regression with log income			
Climate shock	−0.284 (0.083)	−0.288 (0.080)	−0.265 (0.083)
Thatch roof = 0× Climate shock = 1	−0.190 (0.105)	−0.190 (0.102)	−0.215 (0.103)
Thatch roof = 1× Climate shock = 0	−0.166 (0.106)	−0.244 (0.107)	−0.320 (0.113)
Thatch roof = 1× Climate shock = 1	−0.572 (0.119)	−0.655 (0.117)	−0.645 (0.120)
Ordered probit regression with log income			
Climate shock	−0.245 (0.061)	−0.256 (0.061)	−0.250 (0.064)
Thatch roof = 0× Climate shock = 1	−0.167 (0.076)	−0.173 (0.078)	−0.201 (0.081)

Table A1. *Continued.*

Subjective climate shock on present SWB	(1)	(2)	(3)
Thatch roof = 1× Climate shock = 0	−0.132 (0.079)	−0.196 (0.084)	−0.262 (0.090)
Thatch roof = 1× Climate shock = 1	−0.480 (0.089)	−0.558 (0.091)	−0.571 (0.096)
Province FE	YES	NO	NO
Ward FE	NO	YES	NO
Village FE	NO	NO	YES

Notes: The dependent variable is a (0–10) categorical variable answering the question: *"Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. Suppose we say that the top of the ladder represents the best possible life for you and your household, and the bottom of the ladder represents the worst possible life for you and your household. On which step of the ladder would you say your household stands now?"*. See table 1 for regressors legend.
For the interactions Thatch roof=0 × Climate shock=0 is the omitted benchmark.
Robust standard errors in parentheses.

Table A2. Alternative specifications estimates from table 4

Objective and subjective climate shock on present SWB	(1)	(2)	(3)
Ordered probit regression with linear income			
Dry spells	−0.016 (0.006)	−0.019 (0.007)	−0.029 (0.012)
Climate shock	−0.210 (0.061)	−0.214 (0.062)	−0.226 (0.064)
Thatch roof = 0× Climate shock = 1	−0.142 (0.077)	−0.137 (0.079)	−0.192 (0.081)
Thatch roof = 1× Climate shock = 0	−0.175 (0.081)	−0.242 (0.084)	−0.312 (0.090)
Thatch roof = 1× Climate shock = 1	−0.475 (0.090)	−0.553 (0.092)	−0.580 (0.096)
Linear regression with self consumption			
Dry spells	−0.025 (0.009)	−0.025 (0.010)	−0.034 (0.014)
Climate shock	−0.245 (0.084)	−0.238 (0.082)	−0.239 (0.084)
Thatch roof = 0× Climate shock = 1	−0.157 (0.107)	−0.140 (0.105)	−0.198 (0.105)
Thatch roof = 1× Climate shock = 0	−0.221 (0.109)	−0.298 (0.109)	−0.382 (0.115)
Thatch roof = 1× Climate shock = 1	−0.580 (0.121)	−0.659 (0.119)	−0.668 (0.123)
Ordered probit regression with self consumption			
Dry spells	−0.017 (0.006)	−0.020 (0.008)	−0.029 (0.012)
Climate shock	−0.212 (0.061)	−0.214 (0.062)	−0.224 (0.064)
Thatch roof = 0× Climate shock = 1	−0.141 (0.077)	−0.132 (0.079)	−0.186 (0.082)

Table A2. *Continued.*

Objective and subjective climate shock on present SWB	(1)	(2)	(3)
Thatch roof = 1× Climate shock = 0	−0.171 (0.081)	−0.240 (0.084)	−0.313 (0.090)
Thatch roof = 1× Climate shock = 1	−0.477 (0.090)	−0.556 (0.092)	−0.583 (0.096)
Linear regression with log income			
Dry spells	−0.024 (0.009)	−0.024 (0.010)	−0.031 (0.014)
Climate shock	−0.303 (0.085)	−0.283 (0.083)	−0.275 (0.086)
Thatch roof = 0× Climate shock = 1	−0.205 (0.107)	−0.178 (0.105)	−0.225 (0.106)
Thatch roof = 1× Climate shock = 0	−0.142 (0.110)	−0.219 (0.110)	−0.309 (0.116)
Thatch roof = 1× Climate shock = 1	−0.574 (0.121)	−0.632 (0.119)	−0.643 (0.123)
Ordered probit regression with log income			
Dry spells	−0.016 (0.006)	−0.019 (0.007)	−0.026 (0.011)
Climate shock	−0.257 (0.062)	−0.251 (0.063)	−0.256 (0.066)
Thatch roof = 0× Climate shock = 1	−0.178 (0.077)	−0.165 (0.079)	−0.211 (0.082)
Thatch roof = 1× Climate shock = 0	−0.115 (0.081)	−0.178 (0.085)	−0.254 (0.092)
Thatch roof = 1× Climate shock = 1	−0.475 (0.090)	−0.537 (0.092)	−0.565 (0.097)
Province FE	YES	NO	NO
Ward FE	NO	YES	NO
Village FE	NO	NO	YES

Notes: See notes for table A1.

Table A3. Durable index robustness (estimates from tables 3 and 4)

Subjective climate shock on present SWB	(1)	(2)	(3)
Linear regression			
Climate shock	−0.241 (0.081)	−0.256 (0.080)	−0.236 (0.081)
Durable assets index	1.434 (0.281)	1.325 (0.283)	1.007 (0.281)
Thatch roof = 0 × Climate shock = 1	−0.169 (0.104)	−0.180 (0.102)	−0.203 (0.103)
Thatch roof = 1 × Climate shock = 0	−0.176 (0.106)	−0.261 (0.106)	−0.337 (0.110)
Thatch roof = 1 × Climate shock = 1	−0.511 (0.117)	−0.612 (0.116)	−0.613 (0.119)

Table A3. *Continued.*

Subjective climate shock on present SWB	(1)	(2)	(3)
Ordered probit regression			
Climate shock	−0.215 (0.060)	−0.232 (0.061)	−0.226 (0.063)
Durable assets index	1.106 (0.205)	1.111 (0.214)	0.904 (0.220)
Thatch roof = 0 × Climate shock = 1	−0.152 (0.076)	−0.165 (0.078)	−0.191 (0.080)
Thatch roof = 1 × Climate shock = 0	−0.138 (0.079)	−0.209 (0.083)	−0.275 (0.088)
Thatch roof = 1 × Climate shock = 1	−0.436 (0.089)	−0.525 (0.091)	−0.543 (0.094)
Objective and subjective climate shock on present SWB			
Linear regression			
Dry spells	−0.022 (0.009)	−0.024 (0.010)	−0.035 (0.014)
Climate shock	−0.253 (0.083)	−0.242 (0.082)	−0.241 (0.084)
Durable assets index	1.446 (0.287)	1.382 (0.286)	1.050 (0.288)
Thatch roof = 0× Climate shock = 1	−0.178 (0.105)	−0.160 (0.105)	−0.210 (0.105)
Thatch roof = 1× Climate shock = 0	−0.157 (0.109)	−0.238 (0.109)	−0.327 (0.114)
Thatch roof = 1× Climate shock = 1	−0.506 (0.119)	−0.581 (0.118)	−0.605 (0.122)
Ordered probit regression			
Dry spells	−0.015 (0.006)	−0.020 (0.007)	−0.030 (0.011)
Climate shock	−0.221 (0.061)	−0.219 (0.063)	−0.228 (0.065)
Durable assets index	1.110 (0.209)	1.151 (0.217)	0.934 (0.224)
Thatch roof = 0× Climate shock = 1	−0.158 (0.077)	−0.150 (0.080)	−0.197 (0.082)
Thatch roof = 1× Climate shock = 0	−0.124 (0.082)	−0.193 (0.085)	−0.268 (0.090)
Thatch roof = 1× Climate shock = 1	−0.426 (0.090)	−0.498 (0.092)	−0.532 (0.096)
Province FE	YES	NO	NO
Ward FE	NO	YES	NO
Village FE	NO	NO	YES

Notes: See notes for table A1.

Table A4. The effects of objective measure of climate shocks on current subjective well-being (OLS)

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Objective measure			
Dry spells	−0.022 (0.009)	−0.026 (0.010)	−0.034 (0.013)
Household characteristics			
Household size	−0.012 (0.021)	−0.025 (0.020)	−0.034 (0.021)
Female headed	−0.384 (0.141)	−0.232 (0.132)	−0.271 (0.147)
Age	0.010 (0.018)	0.017 (0.017)	0.022 (0.018)
Age^2	−0.000 (0.000)	−0.000 (0.000)	−0.000 (0.000)
Married	0.232 (0.132)	0.353 (0.129)	0.244 (0.138)
Education years = 0	−0.090 (0.180)	−0.081 (0.175)	−0.197 (0.183)
Education years = 6	−0.050 (0.151)	−0.068 (0.149)	−0.090 (0.152)
Education years = 13	−0.014 (0.160)	−0.030 (0.161)	0.008 (0.166)
Agricultural association member	0.252 (0.089)	0.207 (0.086)	0.316 (0.088)
Agriculture and welfare			
Gross income (K)	0.003 (0.001)	0.002 (0.001)	0.002 (0.001)
Area (HA)	0.001 (0.000)	0.001 (0.000)	0.001 (0.000)
No toilet	−0.034 (0.088)	−0.145 (0.096)	−0.158 (0.096)
Thatch roof	−0.320 (0.086)	−0.397 (0.086)	−0.413 (0.091)
Nutrition problem	−0.429 (0.089)	−0.308 (0.094)	−0.391 (0.096)
Non-climate shock	−0.344 (0.080)	−0.455 (0.077)	−0.548 (0.078)
Fixed effects			
Province	YES	NO	NO
Ward	NO	YES	NO
Village	NO	NO	YES

Table A4. *Continued.*

	(1) Present HWB	(2) Present HWB	(3) Present HWB
Constant	5.637	5.029	6.072
	(0.438)	(0.468)	(0.626)
Observations	1228	1228	1228
R^2	0.212	0.290	0.348

Notes: The dependent variable is a (0–10) categorical variable answering the question: *“Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. Suppose we say that the top of the ladder represents the best possible life for you and your household, and the bottom of the ladder represents the worst possible life for you and your household. On which step of the ladder would you say your household stands now?”.* Robust standard errors in parentheses.