Cannings, L., Hutton, C. W., Sorichetta, A., & Nilsen, K. (2024). Supplementary information for: Embodied emotional expressions for intuitive experience sampling methods: A demographic investigation Is the fulfilment of objective wellbeing reflected in subjective wellbeing? A case study of vulnerable communities in Volta Delta, Ghana. *International Journal of Wellbeing*, 14(2), 3149s, 1-16. https://doi.org/10.5502/ijw.v14i2.3149s

SUPPLEMENT

Supplementary information for: Is the fulfilment of objective wellbeing reflected in subjective wellbeing? A case study of vulnerable communities in Volta Delta, Ghana

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Supplementary Material 1

Information used to calculate absolute, equivalised, adjusted expenditure poverty. (a) Expenditure data types included (b) Regional cost-of-living indices (c) GSS calorie-based household equivalisation scale.

Table S1a. Expenditure types included in the calculation of the expenditure poverty measure. The mean percentage of household expenditure for each type is also reported.

Expenditure type	Mean % annual expenditure
Food	59%
Household essentials (inc. electricity & transport)	12%
Education	9%
Health	4%
Livelihood inputs (inc. fertilisers & equipment)	4%
Sporadic house costs (inc. home improvements & repairs)	2%
Non-essential household costs (inc. furniture & clothing)	1%
"Other" (inc. funerals & weddings)	1%
Insurance	<1%
Supporting migrants in hardship	<1%

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Table S1b. Indices are produced over the 12-month period of the Ghanaian Living Standards Survey No. 7 (2017) (produced with Greater Accra January 2017 as the reference point). Note, the indices for a region are calculated as the monthly average over a 12-month period; therefore explaining why the index for Greater Accra is not 1.0, despite being the reference location (GSS, 2018).

Region	Overall price index	Food index	Non-Food index
Western	1.02	1.00	1.04
Central	0.98	0.94	1.03
Greater Accra	**1.03**	**1.02**	**1.03**
Volta	**0.99**	**0.93**	**1.07**
Eastern	0.95	0.94	0.96
Ashanti	0.96	0.90	1.03
Brong Ahafo	0.93	0.91	0.97
Northern	0.97	0.98	0.97
Upper East	0.86	0.80	0.93
Upper West	0.92	0.90	0.96

Table S1c. Equivalation scale used by the GSS, based on dietary requirements of different ages and sexes - recorded by the National Research Council in 1989 (GSS, 2018; National Research Council, 1989).

Category	Age group (years)	Average energy allowance per day (kcal)	Equivalence scale
Infants	<1	650	0.22
Children	1 to 3	1,300	0.45
	4 to 6	1,800	0.62
	7 to 10	2,000	0.69
Adult males	11 to 14	2,500	0.86
	15 to 18	3,000	1.03
	19 to 25	2,900	1.00
	26 to 50	2,900	1.00
	51+	2,300	0.79
Adult females	11 to 14	2,200	0.76
	15 to 18	2,200	0.76
	19 to 25	2,200	0.76
	26 to 50	2,200	0.76
	51+	1,900	0.66

Supplementary Material 2

S2. Deprivation threshold descriptions (basic needs deprivation)

S2.1 Financial capital (employment, food expenditure & bank access)

Employment deprivation was categorised by whether a household had an unemployed member in the household. Unemployment is defined as those who are not employed, yet have actively sought after paid employment. The DECCMA dataset did not provide information on whether individuals were actively seeking work, therefore certain assumptions had to be made. In Ghana, the working population is defined as those aged 15 (Baah-Boateng, 2013) to a retirement age of 60 (Tawiah, 2011). However, occupation data was only collected for those aged 18+. Also, data showed a large proportion of over 60s to be still working. Therefore to avoid overestimating unemployment by assuming all those aged 60+ were not working, unemployment was looked at across all ages 18+. An individual was defined as unemployed if they reported themselves as unemployed and were aged 18+ years old, not a student, not retired and not an unpaid home carer. A household was seen to be deprived if there was at least one unemployed individual in the household. If no one in the household was of working age or economically active (retired, student or carer) then the household was deemed to be deprived also as there would be no incoming income channel. 48 households had all working age members unemployed, however this potential deprivation cut-off was deemed too constrictive, and would ignore the financial effort and burden that having an unemployed household member can have on the household as a whole (Kassa, 2012).

The second financial capital indicator captures households' proportion of expenditure on food; reflecting sensitivity to food price changes. This study uses a cut-off of 60% of total expenditure to define households as financially and nutritionally insecure; as defined by the World Food Programme and other food security and welfare studies (Junaedi, 2021; Lele et al., 2016; Rose et al., 2013). To ensure consistency with objective expenditure poverty, expenditure on loan repayments and housing/land rental were excluded from the calculation. Other studies suggested a threshold of 65-75% for high levels of insecurity and 50-65% for medium levels (Hjelm, Mathiassen, et al., 2016; World Food Programme, 2017). Nevertheless, 60% is selected in this study as the mean percent expenditure on food in the sample is approximately 60%; therefore a 60% threshold was deemed appropriate to identify those who spend a higher-than-average amount relative to the rest of Volta Delta, and are also classified as "insecure" by international guidelines.

Thirdly, Peachey & Roe (2004) state that access to financial services should be viewed as much of a basic need in LMICs as access to water, education and health services. Availability and access to financial institutions is also interpreted as a freedom essential for poor communities to protect themselves and achieve socio-economic development (Bayulgen, 2013; Pogge, 2005). Without financial services, it is "harder to build up reserves, let alone use credit, insurance and other complex formal financial tools", which can aid access to wider basic needs and services (World Bank, 2012). A household is defined as deprived if they have no access to banking services or loans. Therefore, if they stated that they had access to any of the following, then they were not deprived; microfinance organisations (including rural banks), informal money lenders, kinship loans or large formal banks.

S2.2 Human capital (education & health)

Basic education in Ghana is a combination of primary school and lower secondary school, with the latter starting at aged 12 and concluding after 3 years (UNESCO, 2012). Upper secondary school and higher education are deemed to be "additional education"; upper secondary starts at age 15 for 4 years, with higher education commonly starting at age 19. Each individual within each household, aged 15 or over, was deemed to be deprived in education if they had not completed lower secondary school (basic education). A household is deemed to be deprived in education if every household member aged 15 and over has not completed a basic education.

The second human capital indicator is "proximity to hospital". This measure was calculated as a contextual variable for each of the 50 enumeration areas, with the distance to a hospital taken from the central point of each enumeration area. Locations of hospitals were obtained directly from the Ghana Health Service (GHS). Using Google API, distances, based on car travel across the road network, from the community centroids to the nearest hospital were produced. The World Health Organisation (WHO) recommends that households should be within 5km of a health facility (Ashiagbor et al., 2020); therefore, a 5km cut-off was used to define households as having poor access to health facilities. Hospitals, rather than all primary/secondary health facilities, were selected due to greater data completeness, and an acknowledgement that hospitals provide a wider range of crucial health services, and are commonly provided with higher quality (Dotse-Gborgbortsi et al., 2023). Hospitals were also selected, over other health clinics and facilities, due to findings from qualitative fieldwork, where both communities and district planners primarily discussed hospitals when questioned on health service access.

S2.3 Social capital (cooperative membership & network size)

The first social metric is based on whether households had joined a community cooperative group in the last 5 years. If the respondent responded "no" then they are defined as deprived in objective social capital (Francesconi & Wouterse, 2011). The limitation of some households existing within a cooperative network before the 5-year timeframe is acknowledged. However, restricting the question to the last 5 years increases the probability that the cooperative networks are still being accessed.

The second social metric captures households' network size. This proxy sums the number of family members from outside the household (i.e., number of uncles/aunts, cousins, nieces/nephews, brothers/sisters-in-laws), and friends with migration experience. Many studies highlight the role of network size in positively influencing innovation, heightening exposure to diverse information/knowledge, reducing transaction costs, increasing new opportunities, mobilising greater communication and broadening worldviews (Abbasi et al., 2014; Rojas et al., 2011; Zheng, 2010). It is acknowledged that the size of the network does not necessarily reflect the density, quality or quantity of information/resources available; however, these limitations are accepted due to data availability (Knight & Yueh, 2008; Peng et al., 2021). It is assumed that as the network has migration experience, the probability of them being "redundant" relationships is mitigated. An absence of guidance regarding a network size "threshold" resulted in the threshold being constructed relatively. The mean number of family/friends outside the household is 5, the median is 4 and the mode is 3. Based on these summary statistics, a household is said to be deprived in social networks if the total number is below 3, which is also below the sample median. Access to training or NGO/governmental support, defined as a social capital measure by Gannon & Roberts (2020), could not be included due to high missing data.

S2.4 Physical capital (roof material, latrine type, drinking water, overcrowding, housing tenure)

Inadequate roofing is defined as one made of natural materials (Gordon, 2005) or lacking cement, slabs or tiling (Catalan, 2017). Within the DECCMA survey, a household was not deprived if the roof material was stone/brick/slate or cement/tiles/asbestos, whereas the household was recorded as deprived if the roof was constructed from tin/corrugate, hay/leaves/branches or "other".

WHO defines improved latrine sanitation as including private facilities which "separate human excreta from human contact" (WHO, 2022a). Respondents who recorded having either a flushing latrine, a pit latrine or a ventilated pit (KVIP) were deemed to have improved facilities; whereas those without a facility or primarily using a public toilet were recorded as deprived.

WHO defines an improved drinking water source as "piped water, public tap, borehole or pump, protected well, protected spring or rainwater" (WHO, 2022b). Based on the categories available in the DECCMA survey, households with piped water, standpipe or tubewell/borehole were defined as having an improved source. In contrast, those relying on dug wells, springs, rainwater, or surface water were deemed to be deprived. 199 households stated they used an "other" drinking water source that was not listed. 84% of these households stated that they were either moderately or very happy with their drinking water; therefore, it was assumed those that stated "other" were not deprived. For reference, a comparative 83% households with piped/standpipe/borehole water were moderately/very happy with their drinking water.

Overcrowding was incorporated within the GSS multiple deprivation study, defined as having 3+ people per room in a dwelling (GSS, 2020). However, the DECCMA dataset did not possess information on the number of rooms in the household. Therefore, to evaluate overcrowding, house size (m^2) was divided by the number of people in the household, to give a result of people per m^2 house space; a common measure used by the UN. A UN study in 2000 of 9 African countries stated the average floor space per person was 5-9m^2 (Ramalhete et al., 2018). A threshold for overcrowding was taken at 5m^2 and 9m^2 to test the measure's sensitivity. If using a 5m^2 threshold then only 2.7% of the sample would be deemed "overcrowded"; this is too restrictive and could be criticised for its lack of "specificity" (Rose et al., 2013). Contrastingly, when using a 9m^2 threshold, 16% of households were recorded as overcrowded. Selecting the 9m^2 threshold ensures that those defined as overcrowded have less floor space than the average household in the sampled African countries (Ramalhete et al., 2018).

The final physical capital indicator reflects home ownership and tenure security. Many multidimensional wellbeing measures emphasise the importance of secure tenure and ownership as a strategy to increase productivity and safety, remove poverty, "free up" capital for productive investments (Adarkwa, 2010), reduce health issues emerging from the uncertainty of having an "exclusive" place to call home (Luginaah et al., 2010), and ensure universally recognised basic living standards are met (Alkire & Santos, 2010; El-hadj et al., 2018; Lemanski, 2011; Santos & Villatoro, 2018). Households that outright owned their property were defined as non-deprived, whereas households that either rented, mortgaged, or squatted in their property were deemed to be deprived. Due to high rent/mortgage costs in urban areas, and preference for self-construction in poorer, rural areas (Cobbinah & Niminga-Beka, 2017; Decardi-Nelson et al., 2012; Parby et al., 2015), it is hypothesised that housing tenure will be less prevalent in more-affluent, peri-urban areas. However, "housing tenure" is incorporated as an indicator of "deprivation", not a reflection of monetary wealth.

Supplementary Material 3

Sensitivity testing the basic needs deprivation metric with different weightings and thresholds (Table S3). The impact of different second cut-off thresholds uses "nested" weighting as an example (Figure S3).

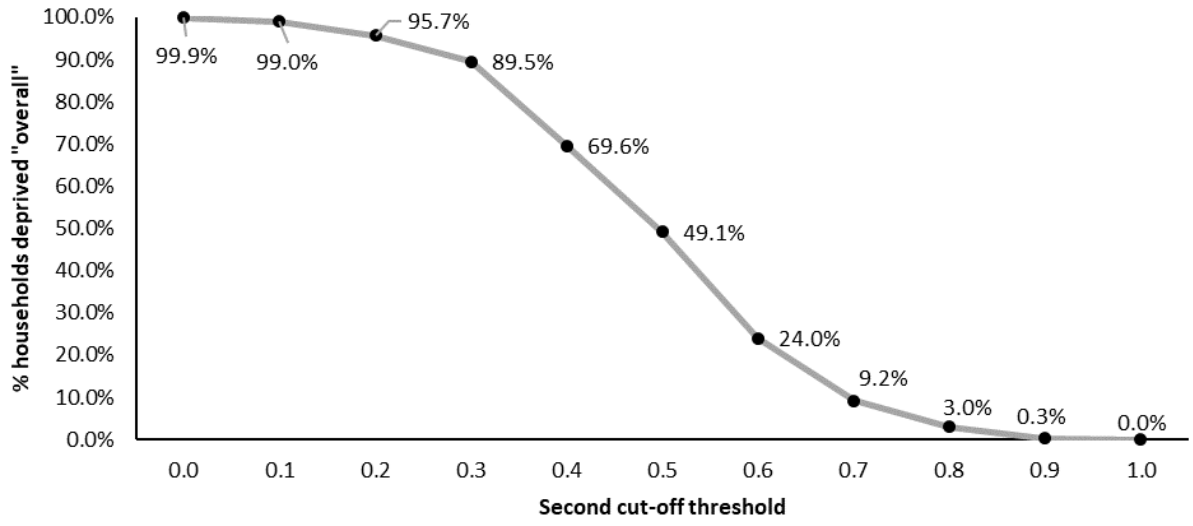
Weighting type (Decancq & Lugo, 2013):

- **Nested:** Individual measures are nested within overarching basic needs/capitals. Overarching basic needs/capitals are weighted equally.
- **Equal:** Each individual measure is weighted equally.
- **Frequency-based:** Less-common deprivations are weighted higher than widespread deprivations. For example, if 75% of households are deprived in food security, a 0.25 weight is applied. If 10% of households have unsafe sanitation, a weight of 0.90 is applied.
- **Statistical:** Principal components analysis (PCA) generates statistical loadings/weights based on the influence or correlation of each measure to the overall principal component - which explains the most variation in the different deprivation measures.

Table S3. Sensitivity of the overall rate of basic needs deprivation when utilising different weighting methods, and selecting different second cut-off thresholds

	% households deprived "overall"			
Second cut-off threshold	**Nested**	**Equal**	**Frequency-based**	**Statistical**
Union (1 or more measure)	99.9%	99.9%	99.9%	99.9%
1/4 (0.25)	93.7%	94.0%	72.2%	90.1%
1/3 (0.33)	84.5%	84.5%	48.0%	84.5%
1/2 (0.50)	49.1%	44.5%	13.0%	64.9%
Intersection (all measures)	0.0%	0.0%	0.0%	0.0%

Figure S3. Overall rates of basic needs deprivation when defining "overall" deprivation with different second cut-off thresholds. "Nested" weighting used in this example



There is no consensus on weighting, decisions should be made on a study-by-study basis, conditional on data availability, existing results and contextual information (Santos & Villatoro, 2018). Firstly, equal weighting was not selected because it potentially over-weighted physical capital due to the higher number of metrics (Ervin et al., 2018). Secondly, frequency-based weighting produces comparatively lower deprivation rates, potentially reflecting its unsuitability within an environment with widespread deprivation (Decancq & Lugo, 2013). Finally, statistical weighting is deemed inappropriate in this study due to low correlation among the majority of deprivation metrics (Alkire & Foster, 2011). Furthermore, assuming correlation reflects the importance of different deprivations fails to treat basic needs as ends in themselves (Brandolini, 2009; Joint Research Centre-European Commission, 2008).

Due to the measure's sensitivity, expert and community-preference weightings are recommended for future research to avoid assumptions or statistical decisions inaccurately classifying households' objective wellbeing. Nevertheless, the robustness of the "nested" approach is heightened by the similar overall rates to the "equal" approach across different thresholds.

Supplementary Material 4

Table S4. PCA loadings for individual domains in the life domains happiness index. All positively correlate with the first component.

Life Domain	First Principal Component loading
Happiness with food security	+0.6577
Happiness with housing	+0.6535
Happiness with economic security	+0.6397
Happiness with family interactions	+0.6367
Happiness with environment	+0.6310
Happiness with community interactions	+0.6207
Happiness with health	+0.5756
Happiness with drinking water	+0.4231

Supplementary Material 5

Crosstabulations and chi-square tests of association between general (global) happiness and happiness with community interactions (Table S5a) and economic security (Table S5b). The 5-point Likert scale was aggregated into a 3-point scale, with moderately/very unhappy, and moderately/very happy combined.

Table S5a. Happiness with community interactions

	Happiness with community interactions			
Happiness in general	Happy	Neutral	Unhappy	Total
Happy	830 (90%)	50 (5%)	43 (5%)	923
Neutral	94 (78%)	21 (17%)	6 (5%)	121
Unhappy	251 (78%)	27 (8%)	42 (13%)	320
Total	**1,175 (86%)**	**98 (7%)**	**91 (7%)**	**1,364**
Chi-square statistic	**52.989*** **			

Note. *** p < 0.01, ** p < 0.05, * p < 0.1

Table S5b. Happiness with economic security

	Happiness with economic security			
Happiness in general	Happy	Neutral	Unhappy	Total
Happy	471 (51%)	132 (14%)	320 (35%)	923
Neutral	30 (25%)	23 (19%)	68 (56%)	121
Unhappy	36 (11%)	18 (6%)	266 (83%)	320
Total	**537 (39%)**	**173 (13%)**	**654 (48%)**	**1,364**
Chi-square statistic	**239.208*** **			

Note. *** p < 0.01, ** p < 0.05, * p < 0.1

Supplementary Material 6

Table S6. Chi-square analysis, with test statistics and significance results, between individual components within the basic needs deprivation measure, and other objective and subjective outcomes. Non-significant associations (p>0.05) are "greyed-out".

	Objective wellbeing	**Subjective wellbeing**	
Basic needs component	**Expenditure poverty**	**Financial stress**	**Life domains unhappiness**
Employment			
Excess capital (food expenditure)	**26.847***** More-than-expected households expend >60% on food when **not in poverty.**		
Bank access	**23.805***** More-than-expected households without banking access when **in poverty.**		
Education			
Hospital access	**12.091***** More-than-expected households >5km from hospital when **in poverty.**	**5.626**** More-than-expected households >5km from hospital when **financially stressed.**	
Cooperative membership			
Network size	**3.972**** More-than-expected households with less-than 3 network size when **in poverty.**		**6.378**** More-than-expected households with less-than 3 network size when **not unhappy.**
Roof quality	**16.003***** More-than-expected households with low-quality roofing when **in poverty.**		

Latrine type		**4.019**** More-than-expected households with low-quality latrines when **financially stressed.**	
Drinking water	**41.594***** More-than-expected households with unprotected drinking water when **in poverty.**		**4.045**** More-than-expected households with unprotected drinking water when **unhappy.**
No crowding	**22.722***** More-than-expected overcrowded households when **in poverty.**	**9.973***** More-than-expected overcrowded households when **financially stressed.**	
Home ownership	**11.948***** More-than-expected non-homeowner households when **not in poverty.**	**5.401**** More-than-expected non-homeowner households when **not financially stressed.**	

Note. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Supplementary Material 7

Crosstabulations and chi-square tests of association[+] between the two objective and two subjective wellbeing measures. Table (S7a) includes associations between expenditure poverty, and the other three wellbeing measures; basic needs deprivation, financial stress and life domains unhappiness. Table (S7b) includes associations between basic needs deprivation, and the two subjective wellbeing measures; financial stress and life domains unhappiness. Table (S7c) includes associations between the two subjective wellbeing measures; financial stress and life domains unhappiness.

Note, different overall household counts for the different wellbeing measures are due to missing data.

Table S7a. Expenditure Poverty (objective)

	Expenditure Poverty (objective)		
Basic needs deprivation (objective)	**No**	**Yes**	**Total**
No	448 (65%)	242 (35%)	690
Yes	404 (61%)	263 (39%)	667
Total	852 (63%)	505 (37%)	1,357
Chi-square test statistic:	**2.757***		
Financial stress (subjective)	**No**	**Yes**	**Total**
No	130 (72%)	51 (28%)	181
Yes	724 (61%)	455 (39%)	1,179
Total	854 (63%)	506 (37%)	1,360
Chi-square test statistic:	**7.286*****		
Unhappiness (subjective)	**No**	**Yes**	**Total**
Happy	744 (64%)	415 (36%)	1,159
Unhappy	110 (55%)	91 (45%)	201
Total	854 (63%)	506 (37%)	1,360
Chi-square test statistic:	**6.571*****		

Note. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table S7b. Basic needs deprivation (objective)

	Basic needs deprivation (objective)		
Financial stress (subjective)	**No**	**Yes**	**Total**
No	99 (55%)	81 (45%)	180
Yes	591 (50%)	586 (50%)	1,177
Total	690 (51%)	667 (49%)	1,357
Chi-square test statistic:	**1.432**		
Unhappiness (subjective)	**No**	**Yes**	**Total**
Happy	586 (51%)	570 (49%)	1,156
Unhappy	104 (52%)	97 (48%)	201
Total	690 (51%)	667 (49%)	1,357
Chi-square test statistic:	**0.075**		

Table S7c. Financial stress (subjective)

	Financial stress (subjective)		
Unhappiness (subjective)	**No**	**Yes**	**Total**
Happy	177 (15%)	985 (85%)	1,162
Unhappy	5 (2%)	196 (98%)	201
Total	182 (13%)	1,181 (87%)	1,363
Chi-square test statistic:	**24.057*** **		

Note. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Supplementary Material 8

Chi-square analysis between expenditure poverty and life domains unhappiness, by region (Table S8a). Household livelihood cluster distribution by region also presented (Table S8b).

Table S8a. Subjective life domains unhappiness

		Subjective life domains unhappiness		
Region	**Objective expenditure poverty**	Happy	Unhappy	Total
Greater Accra	No	303 (90%)	35 (10%)	338
	Yes	115 (78%)	32 (22%)	147
	Total	418 (86%)	67 (14%)	485
	Chi-square test statistic	**11.209*** **		
Volta	No	441 (85%)	75 (15%)	516
	Yes	300 (84%)	59 (16%)	359
	Total	741 (85%)	134 (15%)	875
	Chi-square test statistic	**0.598**		

Note. *** p < 0.01, ** p < 0.05, * p < 0.1

Table S8b. Region

	Region		
Livelihood cluster	**Greater Accra**	**Volta**	**Total**
Crop farmer	93 (23%)	315 (77%)	408
Fisher/trade/transport/construction	293 (40%)	439 (60%)	732
Business owner/salaried employees	100 (45%)	125 (55%)	224
Total	486 (36%)	878 (64%)	1,364
Chi-square test statistic	**43.415*** **		

Note. *** p < 0.01, ** p < 0.05, * p < 0.1

Household livelihood cluster was constructed using Le Phan & Tortora's (2019) methodology. Firstly, each household was assigned eight binary values (0/1) based on whether the household had at least one: current migrant outside the household, crop/livestock farmer, fisher/shrimp farmer, construction/factory worker, salaried employee/business owner, trader/tailor/transport worker, other (inc. hawkers), and unemployed/unpaid carer/student/retiree. Next, multiple correspondence analysis (MCA) created uncorrelated, linear components explaining variability in livelihoods. The first four components, explaining 60% variance, were grouped into 3 optimum groups using k-means clustering. Based on the proportion of livelihoods incorporated within each cluster, the three groups were entitled: crop farmer, fishing/trade/transport/construction and business owner/salaried employees.

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Funding

The research leading to these results received funding from the ESRC South Coast Doctoral Training Partnership (SCDTP), under Grant Agreement No. ES/P000673/1

Competing interests

The authors have no relevant financial or non-financial interests to disclose, and no competing interests to declare that are relevant to the content of this article.

Ethical approval

Ethical approval for this study was received from the University of Southampton (ERGO ID: 67535).

Authorship

All authors contributed to the design and review of the paper. Laurence Cannings was responsible for the conceptualisation of the paper, data curation, formal analysis and writing the original draft. Craig Hutton, Alessandro Sorichetta and Kristine Nilsen supervised the project, and also reviewed and edited the final manuscript.

Acknowledgements

To Rebecca Russell for their continued support and encouragement. To Dr. Martin Watts for their guidance and assistance throughout the publication process. To Dr. Winfred Dotse-Gborgbortsi for providing invaluable contextual insights and support. To the South Coast Doctoral Training Partnership (Economic and Social Research Council) for funding LC's postgraduate research, during which this paper was produced.

Data deposition information

The DECCMA household survey dataset is openly available at Mendeley Data (https://data.mendeley.com/datasets/223z53kwnm/1).

The land cover classification data is also openly available at Delta-Portal (https://www.delta-portal.net/geonetwork/srv/eng/catalog.search;jsessionid=17A16671A3C85ABEA1519F9C670B57E4#/metadata/86b279b8-3cc9-4584-a8bd-9d4300a028df)

Publishing Timeline

Received 6 June 2023
Revised version received 5 February 2024
Accepted 13 February 2024
Published 21 May 2024