Supplementary Information for

Unravelling the mechanisms linking cultural ecosystem services and human wellbeing

Table S1: Coding for meta-data extraction

Variable	Details	Options	Comments
General study characteristics: Code by paper			
Geography	Geographical focus of the reported studies?		Longitude and latitude of the studied sites, extracted by Google Map
Type of ecosystem*	What type of ecosystem is discussed in the document?	1 = Forest & woodland 2 = Mediterranean 3 = Arctic & mountain tundra 4 = Grassland 5 = Desserts and scrublands 6 = wetlands 7 = Inland water 8 = Ocean & marine 9 = Urban & semi-urban 10 = Cultivated areas 11 = Aquaculture 12 = Coastal areas 13 = General landscape 14 = Other	Follow classification of ecosystem of IPBES evaluation assessment report
Research type	What is the research type?	1 = Qualitative 2 = Quantitative 3 = Mixed method	
Research objective	What is the research objective?	1 = Assessment 2 = Design and intervene for resource management 3 = Policy design 4 = Perceptional study 5 = Mapping services 6. Other	
Participants role	What is the role of the participants?	1 = Information provider 2 = Consultation 3 = Co-designing 4 = Not applicable 5 = Other	
Temporal scale	What is the temporal scale of the research?	1 = Cross-sectional study 2 = Longitudinal 3 = Mixed	
Spatial Scale	What is the geographical scale of the research?	1 = Local 2 = Regional 3 = Regional 4 = Global	
Stakeholder engagement	What kind of stakeholders are engaged in the discussion	1 = Local communities 2 = Private sector 3 = Government 4 = NGOs 5 = Tourists 6 = Experts and Researchers 7 = Indigenous communities	

		8 = International organisation
Data collection	What is the method for data collection?	Open text
Data analysis	What is the method for data analysis?	Open text
Framework	What is the theoretical framework?	Open text
Discipline	From what academic discipline the paper belongs to	Open text
Contribution of CES to human well-being (code by observation)		
Type of cultural ecosystem service*	What type of CES does the paper mention?	1 = Recreational and tourism 2 = Aesthetic value 3 = Cultural heritage/cultural diversity 4 = Spiritual value 5 = Social relations 6 = Sense of place 7 = Educational value 8 = Knowledge system 9 = Inspiration 10 = Other
State of CES	What is the change in CES?	1 = Significant degradation 2 = Moderate degradation 3 = Remain the same 4 = Moderate improvement 5 = Significant improvement 6 = Not mentioned
	What is the reason for the change?	Describe in text
Beneficiary*	What is the affected group?	1 = Local community 2 = Farmers & fisheries 3 = Private sector 4 = Government 5 = Tourists 6 = Indigenous community 7 = Researchers and students 8 = Other
Well-being*	Which constituent of human well-being that CES contribute to?	1 = Economic well-being 2 = Mental health 3 = Physical health 4 = Spirituality 5 = Learning & capability 6 = Inspiration & fulfilment of imagination 7 = Certainty, sense of control and security 8 = Identity & autonomy 9 = Connectedness & belonging 10 = Cultural fulfilment 11 = Subjective well-being
Channels of interaction*	What channel of human interaction with nature?	1 = Cultural practices 2 = Form 3 = Intellectual practices 4 = Spiritual practices
Type of mechanism*	What type of mechanism?	1 = Cognitive 2 = Creative 3 = Intuitive 4 = Retrospective 5 = Regenerative 6 = Communicative

		7 = Evolutive 8 = Formative 9 = Transcendentive 10 = Satisfactive 11 = Cohesive 12 = Remunerative 13 = Transactive 14 = Destructive 15 = Irritative 16 = Apprehensive
	Describe mechanism in text?	
Direction of impact*	What is the direction of impact on human well-being	1 = Negative impact 2 = two-way impact 3 = Positive impact 4 = Can't conclude
Magnitude of impact*	What is the magnitude of impact on human well-being?	1. Low 2. High 3. Can't conclude
Outcome of impact	What is the outcome of impact on human well-being	1 = Current state 2 = Future state

Note: * are the variables that were used for Latent Class Analysis.

Table S2: Definition of terminology in this review (followed definition of Millennium Ecosystem Assessment Framework)

Type of CES	Definition
Recreation & tourism service	Ecosystems and nature provide places where people can come for relaxation, recreation, enjoyment and tourism activities
Aesthetic value	Nature provides a great source of aesthetic pleasure for human. People find beauty in nature as reflected in many aspects of human behaviour such as their choice for housing location, their use of flowers for decoration, or their support for scenic views.
Cultural heritage value	Ecological phenomena are entangled in processes of human identities formation. Ecosystem plays an important role in forming the way people understand themselves and the relationship they have with the world around them. Interactions with ecosystem exist in people past memories, form their lifestyles, and shape their value system and cultural heritage
Spiritual value	Some people feel something greater than themselves in nature and search for spiritual connection to their environment. Ecosystem is often closed attached with this orientation in time and space in which spiritual values are placed on certain landscape (landfall and mountains) and species (sacred plants and animals).
Social relations	Nature provides a setting where people engage with each other and establish different forms of social relations.
Sense of place	The close relationship people have with nature consequently develops feeling of attachment and belonging associated with the place
Educational value	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
Knowledge system	Ecosystems and nature influence the types of knowledge systems developed by different cultures.
Inspiration	Nature inspires unlimited range of artistic and cultural expressions including music, books, folklore, national symbol and architecture
Other	Bequest, intrinsic and existence value Authentic wilderness

Table S3. Quality criteria for reviewed studies, adopted from Mupepele et al.

Quality checklist question	Score Yes=1, No=0
INTERNAL VALIDITY	
Research aim	
1. Does the study address a clearly focused question?	
2. Does the question match the answer?	
Data collection	
3. Was the population/area of interest defined in space, time and size?	
4. Selection bias: Was the sample area representative for the population defined?	
5. Was the sample size appropriate?	
6. Was probability/random sampling used for constructing the sample?	
7. If secondary data were used, did an evaluation of the original data take place?	
8. If data collection took place in form of a questionnaire, was it pre-tested/piloted?	
9. Were the data collection methods described in sufficient detail to permit replication?	
Analysis	
10. Were the statistical/analytical methods described in sufficient detail to permit replication?	
11. Is the choice of statistical/analytical methods appropriate and/or justified?	
12. Was uncertainty assessed and reported?	
Results and Conclusions	
13. Do the data support the outcome?	
14. Magnitude of effect: Is the effect large, significant and/or without large uncertainty?	
15. Are all variables and statistical measures reported?	
16. Attrition bias: Are non-response/drop-outs given and is their impact discussed?	
DESIGN-SPECIFIC ASPECTS	
Review	
17. Is there a low probability of publication bias?	
18. Is the review based on several strong-evidence individual studies?	
19. Do the studies included respond to the same question?	
20. Are results between individual studies consistent and homogeneous?	
21. Was the literature searched in a systematic and comprehensive way?	
22. Was a meta-analysis included?	
23. Were appropriate a priori study inclusion/exclusion criteria defined?	
24. Did at least two people select studies and extract data?	
FOCUS-SPECIFIC ASPECTS	
Quantification	
25. Is the unit of the quantification measurement appropriate?	
26. Was temporal change (e.g. annual or long-term) of quantities measured (e.g. species abundance or an ecosystem service) discussed?	
Valuation	
27. If discounting of future costs and outcomes is necessary, was it performed correctly?	
28. If aggregate economic values for a population were estimated, was this estimation consistent with the sampling and the definition of the population?	

Note: For each criterion answered with a 'yes' the study receives one point, else it receives zero points. If a question is not applicable for the specific study it may be left out, especially for design-specific and focus-specific aspects. Based on the aggregate score studies are characterized as having (a) Weak evidence if score is <24%; (b) Moderate evidence if score is 25%-49%; (c) Strong evidence if score is 50%-74%; and (d) Very strong evidence if score >75%.

Table S4: Summary of the characteristics and foci of reviewed studies

	Total (Number of studies)	Percentage (%)
Type of ecosystem		
Forest & woodland	61	20.2
Mediterranean	3	1
Arctic & mountain tundra	1	0.3
Grassland	5	1.6
Desserts and scrublands	2	0.7
wetlands	10	3.3
Inland water	37	12.3
Ocean & marine	23	7.6
Urban & semi-urban	79	26.2
Cultivated areas	19	6.3
Aquaculture	5	1.6
Coastal areas	27	8.9
General landscape	20	6.6
Other	9	2.3
Research type		
Qualitative	60	20
Quantitative	126	41.8
Mixed method	115	38.2
Research objective		
Assessment	118	39.2
Design and intervene for resource management	24	8
Policy design	10	3.3
Perceptional study	109	36.2
Mapping services	33	11
Other	7	2.3
Temporal scale		
Cross-sectional study	231	76.8
Longitudinal	70	23.1
Mixed	0	0
Spatial scale		
Local	246	82.8
Regional	25	8.3
Regional	19	6.3
Global	11	3.6

Table S5: List of countries for the study sites

Country	Number	Percentage
Argentina	2	0.7
Australia	14	5.1
Austria	3	1.1
Bangladesh	2	0.7
Benin	1	0.4
Bhutan	3	1.1
Brazil	5	1.8
Burkina Faso	1	0.4
Cambodia	1	0.4
Canada	7	2.5
Chile	5	1.8
China	19	6.9
Colombia	3	1.1
Cuba	1	0.4
Egypt	1	0.4
Findland	6	2.2
France	2	0.7
Germany	13	4.7
Ghana	1	0.4
Greece	3	1.1
Hawaii	7	2.5
Hongkong	1	0.4
Hungary	4	1.4
India	7	2.5
Indonesia	1	0.4
Iran	3	1.1
Ireland	1	0.4
Italy	10	3.6
Japan	8	2.9
Lebanon	1	0.4
Lithuania	1	0.4
Kenya	1	0.4
Madagasca	1	0.4
Malaysia	6	2.2
Mexico	3	1.1
Mozambique	1	0.4
Myanmar	2	0.7
Nepal	1	0.4
Netherlands	2	0.7
Nigeria	1	0.4

Norway	5	1.8
Papua New Guinea	1	0.4
Peru	1	0.4
Philippines	1	0.4
Poland	3	1.1
Portugal	3	1.1
Romania	2	0.7
Serbia	1	0.4
Singapore	1	0.4
Slovakia	4	1.4
South Africa	7	2.5
Spain	16	5.8
Sweden	5	1.8
Switzeland	2	0.7
Taiwan	1	0.4
Thailand	1	0.4
Turkey	2	0.7
United Kingdom	28	10.1
United States	34	12.3
Venezuela	1	0.4
Zimbabwe	1	0.4
Vietnam	1	0.4

Table S6: Academic disciplines in which the paper belongs to

Discipline	2000 - 2005	2006 - 2010	2011 - 2015	2016 - 2020	Total
Environmental psychology	1		9	49	59
Agriculture science			2	5	7
Anthropology		2	2	3	7
Architecture			1	0	1
Biodiversity Conservation	1		4	7	12
Biology	1				1
Cultural studies				1	1
Development studies	1		2	2	5
Ecology	2		8	19	29
Economics	1	1	3	4	9
Education		1			1
Energy & Fuel Sciences				1	1
Engineering			1	2	3
Entimonology			1		1
Environmental sciences	2	3	24	70	99
Environmental policy			4	14	18
Environmental Studies	2	6	16	82	106
Forestry			1	34	35
Geography	1	2	5	14	22
Geosciences		1	1	4	6
Green, sustainable science & technology	1		1	20	22
Health	1	1			2
hospitality, leisure, sport & tourism			2	5	7
International relations			2	2	4
Management of Natural resource			8	27	35
Marine & Freshwater biology			4	9	13
Medicines			1		1
Multidisciplinarity		2	4	29	35
Pharmacology & Pharmacy			2	1	3
Plant Sciences		1	2	1	4
Psychology		1	1	3	5
Public, Environmental & occupational health			4	6	10
Regional & Urban planning	2	1	5	12	20
Remote sensing		1			1
Sociology	1	2	3	5	11
Urban studies	1	1	3	28	33
Water resources			2	4	6
Agronomy			1		1
Oceanography			2	4	6

Table S7: Data collection and data analysis

	Number of studies	Percentage(%)
Data collection tool		
Interview	74	24.6
Survey	145	48.2
Observation	8	2.7
Workshop	13	4.3
Participatory mapping	13	4.3
Focus group discussion	16	5.3
Social media-based	13	4.3
Secondary data	55	18.3
Geospatial data	32	10.6
Ethnographic study	2	0.7
Health experiments	2	0.7
Photovoice	1	0.3
Data analysis tool		
Narrative	119	39.5
Descriptive statistics	22	7.3
Inferential statistics	163	54.2
Case study	9	3
Grounded theory	2	0.7
Economic evaluation techniques	25	8.3
GIS analysis	4	1.3
Ethnographic analysis	12	4
Historical analysis	4	1.3
Scenario planning	5	1.7

Table S8: Relative impacts on individual constituent of human well-being

Constituents of human well-being	Mean (Negative)	Standard Error (Negative)	Mean (Positive)	Standard Error (Positive)
Certainty, Sense of Control and Security	-1.88	0.44	1.86	0.072
Connectedness and belonging	-1.83	0.17	1.92	0.03
Cultural fulfillment	-1.62	0.31	1.83	0.08
Economic well-being	-1.96	0.08	1.88	0.09
Identity & autonomy	-1.80	0.06	1.84	0.042
Inspiration & Fulfillment of Imagination	-1.5	0.32	1.72	0.03
Learning & capability	-1.75	0.25	1.91	0.044
Mental health	-1.98	0.02	1.99	0.014
Physical health	-1.98	0.02	1.97	0.02
Spirituality	-1.94	0.056	1.79	0.05
Subjective well-being	-1.83	0.075	1.71	0.34

Table S9: Relative impact of individual mechanism to human well-being

Mechanism	Mean	SE	Mechanism	Mean	SE	Mechanism	Mean	SE
Apprehensive	-1.881	0.120	Destructive	-1.925	0.031	Regenerative	1.953	0.018
Cognitive	1.490	0.310	Evolutive	1.936	0.023	Renumerative	1.725	0.117
Cohesive	1.975	0.030	Formative	1.802	0.110	Retrospective	1.897	0.043
Communicative	1.912	0.050	Intiutive	1.942	0.024	satisfactive	1.824	0.088
Creative	1.802	0.098	Irritative	-1.667	0.154	Transactive	1.500	0.500
						Transcendentive	1.952	0.048

Table S10: Latent Class Analysis fitness tests

	Fit for 2 classes	Fit for 3 classes	Fit for 4 classes	Fit for 5 classes
Maximum log-likelihood	-12450.7	-11837.17	-11630	-11104.02
AIC	25155.41	24056.34	23770	22846.05
BIC	25795.11	25018.41	25054.44	24452.86
Estimated class shares	Class 1: 41% Class 2: 59%	Class 1: 27% Class 2: 46% Class 3: 37%	Class 1: 28% Class 2: 29% Class 3: 14% Class 4: 29%	Class 1: 11% Class 2: 12% Class 3: 35% Class 4: 15% Class 5: 27%
Predicted class membership	Class 1: 41% Class 2: 59%	Class 1: 28% Class: 46% Class 3: 36%	Class 1: 44% Class 2: 13% Class 3: 12% Class 4: 31%	Class 1: 11% Class 2: 12% Class 3: 35% Class 4: 15% Class 5: 27%

Table S11: The magnitude of impact (high, low) is defined in three dimensions: depth, scale and speed. Any observation which reflects the impact that can meet one of the conditions for high depth/scope/speed is classified as high magnitude impact.

Dimension of impacts	**Extent of impacts**
Depth	**Degree to which the impact of CESs on human well-being reflects something new, novel, impressive, and different from the current state**
High	- Associated with transformative and transcendental changes. - May involve radically changing how people perceive their happiness, values, frames, logic, health, and conditions of their well-being. - Interaction with nature may create deep internal reform, a complete change in perception and spiritual value, radical shifts in mind set, identity and relationships, significant impacts on health or economic assets.
Low	- Reflects incremental and transient impact with limited degree difference in which interaction with nature affects the perceived well-being, underlying values, health, economic assets, or norms.
Scope	**Scale of change – geographic or institutional**
High	- Large-scale changes that involve a large area or large population. - May be multi-dimensional, multi-scale or multi-institution. - May lead to a change in perceived well-being, a shift in underlying norms or behaviour an impact on health or economic condition across an entire population.
Low	- Impacts that occurred to an individual or a particular small stakeholder group.
Speed	**Time frame in which the impacts occur**
High	- Interaction with nature that creates immediate and instant impacts on people's perceived well-being, health, perception, values, and economic conditions.
Low	- Interaction with nature that creates impacts on human well-being that are largely slow or take a long time to see the result.

SUPPLEMENTARY MATERIAL – 70 pathways linking cultural ecosystem services and human well-being

TABLE S12: CULTURAL ECOSYSTEM SERVICES

CULTURAL ECOSYSTEM SERVICES							
	No	**Interaction with ecosystem through**	**Cultural ecosystem service**	**Constituent of well-being**	**Mechanism**	**Mechanism explained in detail**	**Direction of impact**
I. ES contribute to Economic well-being	**1**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Economic well-being (collective scale)	**Remunerative**	The development of nature-based tourism activities can directly or indirectly contribute to the economic growth of the local communities. Examples of the direct contributions are generating revenue by activities such as accommodations, transportation, tour operations, and food and beverage. Indirect contributions could be tourism contributes to reducing poverty, creating jobs, and promoting justice (Salem and El-Shimy, 2012; Rahman, Jiang and Irvine, 2018). Ecosystem service supply and demand, quality and quantity of ecosystem, visitors' environmental perception and their demographics can influence this mechanism.	Positive
	2	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic	Economic well-being (collective scale)	**Remunerative**	Beautiful nature and distinct landscape can contribute to the local iconic brand and the important symbol of the region. Economic activities of the local community can be based around this concept. Example: apart from tourism-related activities, the local iconic brand also give values to other local products/investment associated with this symbolism(Khakzad and Griffith, 2016). Local iconic brand, landscape types and characteristics can influence this mechanism	Positive

	3	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Economic well-being (individual/ household scale)	**Remunerative**	Many households and business owners earn their main (or additional) source income from nature-based tourism and recreational activities. Example: Money can play an important contributor to poverty alleviation. Increasing household income can be seen as a mechanism to enhance well-being through the capacity to purchase necessary commodities, enhancing education for children, and access healthcare(Dai *et al.*, 2015) Household livelihood and the level of income influence this mechanism. There is also distinct gender roles in the tourism sector. Women tend to be present in the tourism sector in a limited number of roles, always as an employee rather than as an owner of an enterprise.	Positive
	4	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Cultural heritage value	Economic well-being (individual/ household scale)	**Transactive**	For indigenous communities, particular species carries a special cultural heritage value. Species can be utilised as a products suited for exchanges and trades among kins. Example: Yalke (bush onion) is associated with the origins and continuity of Kaytetye people to the north of Arrernte country. Yalke is often traded among kins to sustain the reciprocal relationships essential to the functioning of desert Aboriginal groups(Walsh, Dobson and Douglas, 2013).	Positive

	5	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Knowledge system	Economic well-being (individual/ household scale)	**Remunerative**	Livelihood practices based on knowledge system mobility can contribute to promoting the economic well-being of the indigenous households. Example: traditional practices of multiple cropping, rain fed agriculture, crop varieties according to native soil conditions and micro climate can tolerate better to various natural stresses. Traditional land use adaptation in the vulnerable and inaccessible mountain slopes has been potential livelihood support to the farmers, ecological health, social and economic well-being of the indigenous community in the Central Himalaya region(Samal, Palni and Agrawal, 2003). Household livelihood can influence this mechanism.	Positive
II. CES contribute to Physical health	**6**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Physical health	**Regenerative**	Ecosystems promote physical health by offering opportunities for physical exercises and fitness activities, and by different recreational activities. Example: Benefits to physical health through interaction with nature include lower body mass index, reduced disease, reduced obesity more vitality, lower somatization level, decreased cognitive decline, reduced blood pressure, heart rate and muscle tensions, improved immune system, increased restoration and healing, and lower mortality risk(Russell *et al.*, 2013). ES characteristics (quantity and quality), time spent in nature, value and perception on environmental supportiveness, demographic background of people (age, income, gender, education level, ethnicity), accessibility, resource management and policy can influence this mechanism.	Positive

	7	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic	Physical health	**Regenerative**	The beauty of nature perceived by visual and other sensory experiences can contribute to increasing physical health of people. Example: Viewing beautiful landscapes can lower heat rates, aid recovery and benefit physical health via the mechanism of promoting physical exercises and fitness activities(Smith and Ram, 2017). ES characteristics (quantity and quality), time spent in nature, value and perception on environmental supportiveness, demographic background of people (age, income, gender, education level, ethnicity), accessibility, resource management and policy can influence this mechanism.	Positive
	8	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Biophilia Knowledge system	Physical health	**Regenerative**	Gardening improve healthy eating style and the nutrients of everyday meals because people can cultivate their vegetables in their yard. Knowledge of animals and plants regarding where, which, what, when and how to eat can also contribute to a better diet and ultimately contribute to good health. Biodiversity around where people live may contribute to greater immunological tolerances. Example: People living in the areas with more green space and gardens tend to report better health(Cox *et al.*, 2018). Demographic background of people, accessibility to nature, ES characteristics (quantity & quality) can influence this mechanism.	Positive

III. CES contribute to Mental health	**9**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Mental health (stress reduction)	**Regenerative**	Interaction with nature can help to reduce anxiety, stress and depression, decrease their visits to psychologists, and the intake of antidepressants and sedatives, increase sleeping quality and vitality, decrease cognitive decline, increased ability of recovery and healing from crisis, and reduce mental fatigue and illness. Nature-based therapy and treatment can also be effective to deal with mental issues. Example: Many studies indicate that interaction with nature via recreational activities can improve the mood states, such as reducing anxiety, anger, depression, dejection, hostility, confusion, and fatigue(Russell *et al.*, 2013; Pittman *et al.*, 2019). Characteristics of ecosystem, demographic background of people, environmental perception & values, accessibility, proximity to nature, ma-made facilities, resource management & policy can influence this mechanism.	Positive
	10	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic	Mental health (relaxation, tranquillity)	**Regenerative**	The beauty of nature perceived by visual and other sensory experiences can help to achieve peacefulness, calm, tranquility, restfulness, and escapism. Example: Simply interacting with nature creates a feel good factor on people, reduce the negativity of normal life, and improve human mental wellbeing(Egerer *et al.*, 2019). Characteristics of ecosystem, demographic background of people, environmental perception & values, accessibility, proximity to nature, man-made facilities, resource management & policy can influence this mechanism.	Positive

	11	**Spiritual practice**: Nature provides opportunity for spiritual/religious related matters	Spiritual Social relation Sense of place	Mental health (life meaning & value)	**Evolutive**	Spiritual fulfilment as a result of interacting with nature can positively contribute to mental health by giving meanings and values to people lives, a sense of purpose, a sense of wholeness and connectedness and a search of hope. Example: acknowledgement of a sense of belonging or knowledge of something greater than oneself via interaction with nature could contribute to positive psychological benefits. Natural places can be extraordinary and associated with identity, beliefs, values, thoughts, remembrance and beyond everyday problems. People can feel a sense of harmony and connectedness to the natural place, consequently loaded with positive attitudes during their visits to nature(Graymore and McBride, 2013; Völker and Kistemann, 2013). People's perception, values and belied system can influence this mechanism	Positive
	12	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Inspiration	Mental health	**Creative**	Nature is a source of inspiration for artworks, music, architecture and culture. Engaging in art and creation can improve mental health. Example: inspiration for artworks help relieve stress, add recovery, increase relaxation, gain new perspectives in life, boost confidence and resilient of people(Bieling *et al.*, 2014; Dou *et al.*, 2020). Ethnicity, cultural background, age, landscape features can influence this mechanism.	Positive

IV. CES contribute to Spiritualit y	**13**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Spirituality - transcendenta l experiences	**Transcendenti ve**	Recreational activities in nature setting such as camping, hiking, walking are, at least in part, transcendent experiences which change something from within for many people. Example: Nature-based tourism in the dessert in Oman provided opportunities for people to have an 'embodied immersion' – a transformative experience of mythical space through solitude. The mutual observation of the Sun and the experience of waiting for the sun to set can be perceived as a transcendental journey of a transformation of self(Gutberlet, 2019). The perception, values, and beliefs of people can influence this mechanism. The spiritual connectedness is mediated via the aesthetic and physical scenery and the interaction between people and nature.	Positive

	14	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic value Cultural heritage Knowledge system	Spirituality - meanings & values	**Intuitive**	Many types of ecosystems are richly symbolic environments, which are associated with the physical expression of some spiritual meanings, values and purposes in life, and some of these are directly linked to people's spirituality and religion. Example: In African religions, there are many links between the religious heritage and the Universe's visible and invisible creation. The presence of the Creators can be found in the moon, sun, starts, cloud, rain, wind, lightning, mists, storms, animals, plants, water, and land(Amenga-Etego, 2016). In the mountains in Argentina and Italy, people find meanings from the time they are born to the time they die, as they grow from the Earth and become the Earth again. The spirituality attached to nature brings belief, faith, hope, and empowerment to the people(Steinhäuser, 2020). The perception, values, and beliefs of people can influence this mechanism.	Positive

	15	**Spiritual practice**: Nature provides opportunity for spiritual/religious related matters	Spiritual value Cultural heritage Knowledge system	Spirituality - religion	**Transcendentive**	Nature provides sacred spaces for people to carry spiritual and religious practices such as customary rituals, pray to the Creator and worship ancestors. Example: "In Kenya, Individuals or groups conduct 'pilgrimage', which is a journey of spiritual or religious fulfilment to a sacred and salutary place to seek a transcendental encounter with a spiritual entity for acquiring physical, mental, or spiritual healing or benefits(Wangai *et al.*, 2017). Spiritual benefits offered by nature are not only limited to indigenous communities. Modern Western communities also express varied and deep spiritual connections to ecosystems. Landscape features, the perception, values, and beliefs of people can influence this mechanism.	Positive
	16	**Spiritual practice**: Nature provides opportunity for spiritual/religious related matters	Spiritual value	Spirituality - connectedness	**Formative**	People experience ecosystem-inspired feelings related to "entities larger than themselves". Being in harmony with nature is a way to cherish human connections to the Universe. Example, a study about two cases in Canada and the UK indicates that the nature inspires people to reflect on being a tiny speck in the Universe and connect to something more powerful than ourselves. Nonetheless, Interactions with nature can enhance the spiritual relationship of people to their Creator and make them feel they being cared for and close with the Creator(Pike *et al.*, 2015). Landscape features, the perception, values, and beliefs of people can influence this mechanism.	Positive

V. CES contribute to Learning & capability	**17**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Learning & capacity	**Evolutive**	Recreation in nature has positive effects on personal growth and development. Example: Nature can contribute to gradually transforming people to more playful, friendly, elated, and affectionate and develop useful skills in life(Pike *et al.*, 2015). In a study about home garden in Canada, many interviewees shared that home gardening was gratifying, satisfying and promote their self-esteem, self-appreciation, and courage(Raymond *et al.*, 2019).	
	18	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism Cultural heritage	Learning & capacity	**Communicative**	Eco-cultural tourism combined together ecological and cultural aspects of a landscape can create many benefits such as exposing tourists to the indigenous and traditional knowledge, local customs and practices, the history and the local cultural heritage related to the landscape. This type of tourism is also a tool for the local and indigenous communities to keep the traditions and knowledge alive and support the conservation of both ecosystems and cultural heritage. Example: fishing villages in North Carolina promoted heritage and cultural tourism associated with long traditional activities in the areas can help promote local livelihood, educational purposes and awareness rising(Khakzad and Griffith, 2016). Tourists' perception and knowledge, local customs & practice, history and social life can affect this mechanism.	Positive

	19	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic value	Learning & capacity	**Regenerative**	Exposure to natural systems enhances learning, even of unrelated material. Example: Learning in nature can enhance concentration, cognitive benefits, effectiveness and problem solving and attention restoration. Learning in a nature can be more enjoyable, enhance motivation, and contribute to personal development, consequently increasing overall educational performance(Pike *et al.*, 2015).	Positive
	20	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetics value Cultural heritage value Knowledge system	Learning & capacity	**Communicative**	Culturally important landscape features and species, various associated practices and language affect cultural behaviours, the ways people think, the choices they make and their capacity to sustain their livelihood. Example: in the indigenous Sami community in Northern Norway, cultural knowledge and the ecological practices associated with their livelihood are part of the people' capacity. Cultural knowledge and the knowledge transmission strengthen people's sense of self-determination and self-worth(Nystad, Spein and Ingstad, 2014).	Positive

	21	**Intellectual practices**: interactions with nature provide an environment for learning and gaining new information and knowledge	Education value Cultural heritage value	Learning & capacity	**Cognitive**	Interaction with nature can develop knowledge and understanding of the world. The natural environment is the source of our learning about history, culture, social relationships and human-nature relationships. Nature provides opportunities for scientific development, nature-related education, learning from previous generations. Outdoor education can inspire people to have a more caring relationship with nature. Educating children in the natural setting inspires a sense wonder and attachment for the world around them(Raymond *et al.*, 2019). Knowledge transmission (place-based, observational, formal, informal, etc.), people's perception and demographic characteristics, childhood experiences with nature, landscape characteristics can influence this mechanism.	

	22	**Intellectual practices**: interactions with nature provide an environment for learning and gaining new information and knowledge	Knowledge system	Learning & capacity	**Communicative**	Local and traditional ecological knowledge plays important role in the development at both personal and community level. Practices based on local knowledge are passed down from generation to generation. For example, In West Hawaii, traditional knowledge includes language and/or culture encoded knowledge such as rain and other meteorological phenomena or plant/animal behaviour and characteristics; species or natural processes that are associated with the cycles of another plant/animal species, landscape-specific practices. There are possibilities for co-construction of knowledge that incorporate local nature-encoded knowledge capital and scientific expertise for appropriate management interventions for the ecosystems(Leong *et al.*, 2019). Knowledge transmission (place-based, observational, formal, informal, etc.), people's perception and demographic characteristics, childhood experiences with nature, landscape characteristics can influence this mechanism.	Positive

	23	**Form**: Physical, tangible or measurable aspects of ecosystem	Spiritual value Sense of place Inspiration	Learning & capacity	**Retrospective**	The sense of 'untouched' and 'natural' that the place has inspires the imagination, a sense of perspective, reflection and judgement. The childhood memories with the places, previous land-uses, the changes in the ecosystems through time, the origins of the landscapes, local identity, people in the past, etc. shape the way people think, their perspective and capability in lives. Example: A study on coastal landscape indicates that a particular landscape can inspire a sense of reflection and encourage people to put things into perspective. For some respondents, this reflection was inspired by the physical form of cliffs which was linked with the eternity of nature compared with the shortness of human lives(Willis, 2015).	
	24	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Social relations Recreation & tourism	Learning & capacity	**Cohesive**	Social interactions and activities in natural setting form an important part in social structures, principles of reciprocity, and important for personal development. Example: Resources generated from social relations in nature are categorised into four different kinds of social capital: 'political and financial skills social capital, prestige and education-associated social capital, personal skills social capital, and personal support social capital'. These social capitals are important in building resilience at both personal and community level(Kamiyama *et al.*, 2016).	Positive

VI. CES contribute to Certainty, sense of control and security	**25**	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic value Sense of place	Certainty, sense of control and security	**Formative**	The shape, beauty, suitability of the natural places can make people feel safe. Example: In a study about woodland in England, interviewees mentioned the physical characteristics of the woodland canopy and the ways they create a sense of safety, security, and protection(O'Brien, Morris and Stewart, 2014). Cultural and demographic background, landscape features and people's perception and values can influence this mechanism	Positive
	26	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Sense of place Recreation & tourism Aesthetic	Certainty, sense of control and security	**Retrospective**	The close relationship people have with nature consequently develops feeling of security and belonging associated with the place. Example: a study about Genheyuan National Wetland Park found that 94.7% of the respondents feel safest in the wetlands where they are in the familiar places in which they have many memorable experiences(Dou *et al.*, 2020).	Positive
VII. CES contribute to Inspiration, Fulfilment of imagination	**27**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring,	Recreation & tourism Educational value Sense of place Cultural heritage value	Inspiration & Fulfilment of imagination	**Evolutive**	Recreational activities in natural areas are positively associated with pro-environmental behaviours and stewardship, support for environmental protection, and fundraising. Our interaction with nature can inspire people to care more about nature, increase environmental literacy and environmental awareness(Hunter, 2011). Education level and demographic background of people can influence this mechanism.	Positive

		gathering and consuming					
	28	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism Aesthetic value Cultural heritage value	Inspiration & Fulfilment of imagination	**Creative**	Interaction with nature can inspire people and help people to live a life with positive experiences and creation. Example: In a study about lowland and grassland in Southern England, respondents stated that nature offers them original and new experiences that inspire aesthetic appreciation, artistic expression, creativity, and freedom. Nature inspires them to write, draw, paint, photograph, be active and positive, protect, conserve, discover, explore, walk, exercise, and think about things(King *et al.*, 2017).	Positive
	29	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Social relations Recreation & tourism	Inspiration & Fulfilment of imagination	**Cohesive**	Social interactions and activities in natural setting can strengthen ties, reinforce fundamental values and inspire respect, culture, and responsibility, solidarity and caring for the communities and the environment. Example: In Balcarce County, agricultural landscape inspires local traditional cuisines, cultural practices and social gatherings, social cohesion, culture values or, the "authentic rural lifestyles"(Auer, Maceira and Nahuelhual, 2017). People's perception, belief and values and demographic characteristics can influence this mechanism	Positive

VIII. CES contribute to Identity & autonomy	**30**	**Form**: Physical, tangible or measurable aspects of ecosystem	Spiritual value	Identity & autonomy (individual identity)	**Intuitive**	Plants and landscapes can metamorphose to spirit person or ancestral character. Natural environment in the place people born and grow up reflect in their individual and collective identity, cultural and historical significance. The identity-landscape connection exists in many indigenous communities, and this connection manifests significantly via people's interaction with the landscape. Example: “Ecocentric identity”—is that identity encompasses human, animal, and material. Many indigenous people such as Inuit have this form of identity(Russell *et al.*, 2013). The connection between nature and identity can also be mediated by particular species.	Positive
	31	**Form**: Physical, tangible or measurable aspects of ecosystem	Cultural heritage value	Identity & autonomy (collective identity)	**Intuitive**	Ecosystems within communal lands are associated with cultural value, forming an important part of local culture and identity. Specific species can have totemic value, and encode certain customary laws or codes of conduct. Example: In central Australian Aboriginal communities, the history of a family and certain social cohorts are associated with how species are named and classified. Long-standing institutional arrangements, cultural and social practices and norms revolving around communal lands significantly contribute to local cultural identity. Some ecosystem is a symbol of the community and reflect a way of life and identity of the people(Walsh, Dobson and Douglas, 2013). Cultural identity was strongly attached to place and time, and relating to biocultural	Positive

						diversity, effects of nature on lifestyle and built heritage	
	32	**Form**: Physical, tangible or measurable aspects of ecosystem	Sense of place Aesthetic value	Identity & autonomy	**Retrospective**	People form emotional and cognitive bonds with the natural landscapes. Ecosystems are part of their personal and collective memory, their childhood and their life-story. Example: A study in Swedish mountain indicates that the strength of the attachment (emotional component of place identity) between people and the natural places is positively linked with the level of well-being they perceived when they are at these places. Similarly, the level of thinking, rememberance, and mental travel (cognitive component of place identity) people direct to the natural places is also positively associated with the level of well-being people perceive at the places(Knez and Eliasson, 2017)	Positive
	33	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism	Identity & autonomy	**Retrospective**	Recreational experiences in natural setting form part of people's memories and their identity. Individual identities are intricately intertwined with the surroundings and the interactions and experiences in childhood. Example: recreational activities in agricultural landscapes in Balcarce County give people satisfaction and caress for the heart, forming important part of their childhood memories(Auer, Maceira and Nahuelhual, 2017). Personal relational value, place attachment, childhood experience with nature, exposure to nature and environmental attributes can influence this mechanism	Positive

	34	**Form**: Physical, tangible or measurable aspects of ecosystem	Aesthetic value	Identity & autonomy (individual autonomy)	**Formative**	Ecosystems offer spaces for individuals to be enabled to express their personal distinctiveness and identity without feeling constrained by external factors such as the norms and values imposed by society. Naturalness enable the mechanism of achieving a personal sense of freedom and escapism from the social boundaries created by extrinsic factors of society. The sense of freedom and autonomy inspired by wild nature can allow individuals to strengthen their own intrinsic values and beliefs and to feel they can be free and make their own choices in lives(Bentley Brymer *et al.*, 2020). Personal relational value, place attachment, childhood experience with nature, exposure to nature and environmental attributes can influence this mechanism	
	35	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Knowledge system	Identity & autonomy (collective autonomy)	**Cognitive**	Landscapes often associated with people's livelihoods and their autonomy level. These landscapes are linked with the local ecological knowledge. Example: in the timber towns in the Inland Northwest, livelihood and work history, with the knowledge system can shape identities for both individual and collective scale. These are important predictors of the level of community autonomy(Russell and Harris, 2001).	

IX. CES contribute to Connectedness and belonging	**36**	**Form**: Physical, tangible or measurable aspects of ecosystem	Sense of place Social relation Cultural heritage value	Connectedness & belonging (Place attachment)	**Cohesive**	Nature can create a sense of belonging by representing the symbol connections between individuals and their ancestors or cultures. Place belonging and attachment can reinforce social capital, creating collective benefits, such as more collaborative collective actions. Example: A place of attachment can inspire connections to past events and people. Recurring social events can be hosted in the places where people have a great sense of attachment and contribute to enhancing their social relationships and community cohesion(King *et al.*, 2017).	Positive
	37	**Cultural practic**e: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Sense of place Recreation & tourism Aesthetic	Connectedness & belonging (Place attachment)	**Intuitive**	Interaction with nature can create place dependence. People feel a sense of belonging when they are in a familiar places. The value of a natural place is associated with its capacity to fulfill the needs or behavioural purposes of an individual or group. Example, ecosystems can closely be linked with people's livelihood and way of life and, create a sense of belonging to people(Adams and Neil Adger, 2013).	Positive

	38	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Social relations Recreation & tourism	Connectedness & belonging (personal relationship)	**Cohesive**	People can develop the bonds with family and friends through interaction with nature. Particular landscape can strengthen the bonds with family history, linked with family memories or symbolise a continuation of life over generations. Example: In a study about Florida National Scenic Trail hikers, on a personal level, "good social relation", "family", "friends", "neighbours" and "kinship" are mentioned by the majority respondents when talking about the social benefits they obtain from these hiking activities(Kil *et al.*, 2012). Landscape features, exposure to nature, time spent in nature, demographic factors, the perception, values, and beliefs of people can influence this mechanism.	Positive

	39	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Inspiration Social relation	Connectedness & belonging (social cohesion via environmental stewardship)	**Cohesive**	Interaction with nature can foster social cohesion via environmental awareness, socially beneficial behaviours and stewardship. As a form of social participation, stewardship enable interactions among diverse groups, creates favourable environment for developing relationships and expanding social networks. Example: Studies have consistently found that the social bonding formed in nature can create networks that emerge beyond the physical boundary of the sites, enhancing stewardship and reinforce the existing relationship at both personal and collective levels(Parlee, Berkes and Gwich'In, 2005; McMillen *et al.*, 2016). Landscape features, exposure to nature, time spent in nature, demographic factors, the perception, values, and beliefs of people can influence this mechanism.	Positive
	40	**Intellectual practices**: interactions with nature provide an environment for learning and gaining new information and knowledge	Education value Social relations	Connectedness (social cohesion via education)	**Cognitive**	Outdoor education can bring people closer to each other. Children who have many experiences in nature and learn how to protect it tend to become more active citizens when they grow up; interact more in their community and engage better in a democratic society. Family bonds can be improved through teaching children to interact with nature. Knowledge transferred across generations is critical to conserve cultural knowledge of local resources and the continuation of cultural practices(Pike *et al.*, 2015). Landscape features, exposure to nature, time spent in nature, demographic factors, the	Positive

						perception, values, and beliefs of people can influence this mechanism.	
	41	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Social relations	Connectedness (via communication)	**Communicative**	Ecosystems offer opportunity for socializing, expanding networks, and increasing social integration. People perceived natural landscape as spaces for socialisation with neighbours; where they can strengthen the relations of solidarity and mutual support. Example: Berry picking activities in Northern Canada are the events where people get together and socialise. Participants mentioned the benefits of working together and socialise in the land with their neighbours. They also talked about the benefits of sharing either information, materials or experiences during these occasions(Parlee, Berkes and Gwich'In, 2005).	Positive
X. CES contribute to cultural fulfilment	**42**	Cultural practice: Nature provides opportunity for playing and	Cultural heritage value	Cultural fulfilment	**Satisfactive**	Particular landscape can be associated with people's livelihood and way of life, and represent the local history and culture. Engaging in cultural events in such landscapes can fulfil people's cultural needs and instil	Positive

		exercising, creating and expressing, producing and caring, gathering and consuming				feelings of satisfaction(Adams and Neil Adger, 2013).	
XI. CES contribute to subjective wellbeing	**43**	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism Aesthetic value Social relations Inspiration	Subjective well-being: experiential well-being	**Satisfactive**	Positive and Negative hedonic or experiential wellbeing is defined as the emotions of pleasure (e.g. happiness) and pain (e.g. anxiety) people experience. Interaction with and socialising in nature and the beauty of nature can fulfil leisure needs and imagination associated with positive feelings. People feel enlightened, novelty, compatibility, fascination, timelessness, cultural satisfaction, connectivity to the past and union when they are in nature, which increase their subjective experiential well-being. Research constantly find that the level of exposure to natural settings is positively associated with level of subjective satisfaction and happiness(Lindberg, Swearingen and White, 2020). Perceived site level biodiversity per se, and site satisfaction and feeling connected to nature, nature dose and self-estimated mental health can influence this mechanism.	Positive

	44	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism Aesthetic value Social relations Inspiration	Subjective well-being: eudaimonic well-being	**Formative**	Eudaimonic wellbeing is associated with how meaningful/worthwhile individuals think their behaviours/activities are. Interaction with and socialising in nature can offer significant benefits to their personal development and social relationship and give people meanings and purposes in life. All of these experiences make people feel their lives are meaningful and worthwhile at the particular moment and increase their eudaimonic well-being. Perceived site level biodiversity per se, and site satisfaction and feeling connected to nature, nature dose and self-estimated mental health can influence this mechanism.	Positive
	45	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Recreation & tourism Aesthetic value Social relations Inspiration	Subjective well-being: evaluative well-being	**Formative**	Evaluative wellbeing is associated with how well individuals think their life is going overall. Interaction with nature can create more positive feeling, promote mental and physical health and increase the level of life satisfaction overall(Lindberg, Swearingen and White, 2020).	Positive

TABLE S13: CULTURAL ECOSYSTEM DISSERVICES

CULTURAL ECOSYSTEM DISSERVICES							
No	**Interaction with ecosystem through**	**State of provision of ecosystem**	**Cultural ecosystem service**	**Constituent of well-being**	**Mechanism type**	**Mechanism explained in detail**	**Direction of impact**
1	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Physical health	**Irritative**	People were most concern about the health problems associated with their local environment(Shackleton *et al.*, 2016). For example, people are concerned about the local environment that impacts their health, such as unwanted pests, allergies from pollens, vector-spread diseases, noises from wildlife, scary natural landscapes, etc(Bolund and Hunhammar, 1999; Larson *et al.*, 2019). People's perception of ES, their socio-cultural value, knowledge and use of ecosystems (can influence this mechanism.	Negative
2	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Mental health	**Irritative**	Ecosystem disservices cause negative feelings (anxiety and discomfort) and affect mental health of people. Example: Noise generated from wildlife, movements and the presence of some pests causing a disordered impression, plant litter or animal wastes causing disgust(Lyytimäki *et al.*, 2008), jumping insects(Hussain *et al.*, 2019)	Negative

3	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Mental health	**Apprehensive**	Natural resource loss can be associated with fear and create some dramatic impacts on mental health. For example, biodiversity loss was revealed to be the contributor to generalised mental suffering and post-traumatic stress(Russell *et al.*, 2013).	Negative
4	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Certainty, sense of control and security	**Apprehensive**	The common concern when people are in natural setting is the fear of safety. Crime rate is high in the natural areas where there is higher tree cover. Example: The high tree cover areas or wild areas offer favourable for people to do 'inappropriate things' such as drinking or drugs. The high crime rate in these areas may create a sense of fear for the surrounding people(Sonti *et al.*, 2020).	Negative

5	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Certainty, sense of control and security	**Apprehensive**	The common concern people have is the fear of safety which is directly associated with perceiving natural elements. Obsessive fear can be created when people encounter natural features via visual (or sometimes auditory) interactions, such as scary animals, dangerous predators, animal blood, dark high tree-covered areas, etc.(Russell *et al.*, 2013; Hussain *et al.*, 2019; Sonti *et al.*, 2020). Many people have a limited frame of reference for recognising and construing such unfamiliar sensory experiences, and may develop a sense of overwhelming "cognitive chaos" and alienation towards nature(Russell *et al.*, 2013) People's demographic background and childhood interaction with nature can influence this mechanism	Negative
6	**Cultural practice**: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Static	Recreation & tourism	Certainty, sense of control and security	**Irritative**	Human-wildlife conflicts affect the safety of millions of people globally. Some behaviours of species can be perceived to be dangerous to people and trigger human–avian conflict. These behaviours include aggression towards humans, threatening, jeopardising infrastructures or causing mess, or destroying behaviours. Example: Some indigenous people in Sahelian wetlands develop a sense of fear toward the wildlife due to the crop destruction associated with wildlife	Negative

						in the areas(Ezealor and Giles, 1997).	
7	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Subjective well-being	**Destructive**	Many sites are neglected, abused, damaged, or unpleasant and disturbingly noisy, affecting subjective well-being of people. Example: in a studies about green roofs in Chicago and Toronto, many respondents indicated that the prairie 'messy, unkempt, and too wild looking. It seems not very well maintained, not very well landscaped'(Loder, 2014). Landscape features, land cover forms and perception can influence this mechanism.	Negative

8	**Form**: Physical, tangible or measurable aspects of ecosystem	Static	Aesthetic value	Economic well-being	**Destructive**	Ecosystem disservices can increase the direct cost for repairs and maintenance, control or remove unwanted species. Financial loss to physical structures can be caused by, e.g., microbial community causing decomposition of wood for construction, tree roots and branches breaking up manmade infrastructure or animals destroying the construction. Harmful animals or plants can harm garden plants or pets (herbivorous species harm crops, pests, fungi). Many maintenance problems of buildings are associated with tall trees. Shading vegetation can also provide cover for burglars(Lyytimäki *et al.*, 2008).	Negative

TABLE S14: NEGATIVE CONTRIBUTION OF CES DUE TO EXTERNAL DRIVERS

In describing these pathways, the authors have chosen to avoid repetitions by focusing on the pathways where the impacts on well-being are not simply the reduction of the services (opposite effects of the counterpart positive pathways) but an additional reaction to the loss of services or trade-offs or underlying factors manifest these circumstances.

No	Interaction with ecosystem through	State/drivers of provision of ecosystem	Cultural ecosystem service	Constituent of well-being	Mechanism	Mechanism explained in detail	Direction of impact
1	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Drivers: environmental pollution and degradation Climate change	Recreation & tourism	Economic well-being	Remunerative	Environmental degradation and climate change greatly impact tourism industry, especially those rely heavily on nature such as winter sport, water-related activities, etc. This significantly reduces the tourism revenue, damaged local reputation, decreased incomes and employment loss. Indirect costs associated with environmental degradation includes human health, safety costs, restoration costs and reduced investments in the region(Schultz *et al.*, 2016; Schirpke *et al.*, 2018). Environmental quality, weather and the livelihood of people can affect this mechanism.	Negative

2	Form: Physical, tangible or measurable aspects of ecosystem	Degrade Drivers: environmental pollution and degradation	Aesthetic value	Economic well-being	Remunerative	Degradation of natural resources can reduce the amenity of the living environment, resulting in a decrease of the property price in the area. Fluctuation in the property market can negatively influence the local economy(Phaneuf *et al.*, 2008; Liebelt, Bartke and Schwarz, 2018). Environmental quality, visibility and proximity to the ecosystem can affect this mechanism.	Negative
3	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade, trade-offs Drivers: tourism development	Recreation & tourism	Economic well-being	Destructive	Nature-based tourism development can create enormous benefits to the local economy, however, it also triggers many risks and conflicts to the society and the environment. Unlike regulating or provisioning ESs, cultural ESs are not always positively associated to health of ecosystems. To most places, the increasing tourism revenue reflects the increasing values of cultural ESs for now, but this does not necessarily mean maintain or developing tourism is desirable in the long-term. Environmental degradation associated with extensive tourism development, risks associated	Negative

						with changing employment structure in the community and the conflicts among different stakeholders using the resource can influence the economic security and social resilience of the local people(Chen, 2020).	
4	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: Environmental pollution	Recreation & tourism	Physical health	Destructive	Environmental degradation can pose significant impacts on physical health when people come in contact with the polluted source through recreational activities in nature. For example, People report many problems in skins when coming in contact with contaminated water and/or inhaling aerosolized biotoxins through recreational activities(Willis, 2015). Biodiversity degradation also reduce the benefits ecosystems provide to health and wellbeing, such as nature-based activities and exercising in nature(Johns *et al.*, 2014). Demographic background of people, accessibility to nature, ES characteristics (quantity & quality) can influence this mechanism.	Negative

5	Form: Physical, tangible or measurable aspects of ecosystem	Degrade Driver: Environmental pollution	Aesthetic value	Mental health Subjective well-being	Destructive	Environmental degradation has significant impact on people's mental health and subjective well-being. Exposure to polluted areas affects negatively on people's mood and stress level. Biodiversity degradation also reduces opportunities to enjoy the mental health wellbeing benefits offered by nature(Johns *et al.*, 2014).	Negative
6	Spiritual practice: Nature provides opportunity for spiritual/religious related matters	Degrade Driver: modernisation	Spiritual value	Spirituality	Destructive	Ritual and religious activities are gradually lost due to environmental degradation and modernisation. As ritual activities are becoming uncommon, the spiritual values associated with specific landscapes and plants are known as a lesser extent. Example: Mining operation in Limpopo Province, South Africa results in loss of communal land and spiritual values associated with it(Shackleton, 2020).	Negative

7	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Trade-offs Driver: Tourism development	Recreation & tourism	Spirituality	Destructive	Ecosystems and natural places can invoke spiritual experiences in people(Pike *et al.*, 2015; Wangai *et al.*, 2017). In many indigenous communities, the Earth and its elements are living entities and valued for their own sake. Tourism and recreational activities which provide leisure opportunities for improving health and subjective happiness are perceived as violating sacred places. The tourism sector, in some cases, sacrifices spiritual and intrinsic values for the instrumental benefits of its offerings(Winter, 2007)	

8	Intellectual practices: interactions with nature provide an environment for learning and gaining new information and knowledge	Trade-offs Driver: Scientific development	Educational value	Spirituality Identity & autonomy	Irritative	Traditional and indigenous people are often against the research potential and educational value in the sacred or spiritually important areas. Researchers are viewed with skepticism by many indigenous people as extensive studies have been conducted in their regions but appear to have little impact on their well-being. The large number of research conducted in the areas creates dissatisfaction of the local people and a reduction in spirituality fulfilment(Cochran *et al.*, 2008). There are complex issues and multiple barriers (technical, perception, communication, etc.) and different values at place that have alienated the active engagement of indigenous communities in ES management plans(Cochran *et al.*, 2008; Barnes-Mauthe *et al.*, 2015; Hiwasaki *et al.*, 2015).	

9	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: biodiversity loss, urbanisation	Knowledge system	Learning & capability	Destructive	With the loss in biodiversity, local people perceive a significant loss in traditional knowledge and skills. This happens through the mechanism of decrease in the supply of the ecosystem services due to biodiversity loss and the decrease in the demand for the services (young people are not interested in traditional and local knowledge and practices)(Castonguay *et al.*, 2016).	Negative
10	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: climate change	Knowledge system	Learning & capability	Destructive	With the changing climate, the knowledge system becomes somehow unreliable and the farming practices are less productive. In response, many people reported that they had lost confidence in their farming skills and in their ability to predict future weather(Ellis and Albrecht, 2017). The physical condition of the land and seasonal weather conditions can influence this mechanism.	Negative

11	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: biodiversity conservation	Knowledge system	Learning & capability	Destructive	There are conflicts between externally initiated biodiversity and natural resource conservation and local traditional practices, leading to a sense of 'madness' to local community. For example, local people perceive that modern conservation management limits their access to resources, hinders their traditional livelihoods, brings bureaucracy, and broadens the gaps between decision-makers and users. Local people feel the modern practices lessen the value of local ecological knowledge and traditional concepts of sustainability, which have developed through centuries of adapting life(Arabi and Nahman, 2020).	Negative
12	Form: Physical, tangible or measurable aspects of ecosystem	Degrade Driver: environmental degradation	Aesthetic value	Certainty, sense of control and security	Destructive	There is a sense of fear and insecurity emerged from seeing abrupt and unpredictable social–ecological changes. With the decrease in aesthetic values associated with biodiversity loss and natural disaster, the crime rate and level of insecurity in the local communities increase(Takase, Hadi and Furuya, 2019). People's demographic background and childhood	Negative

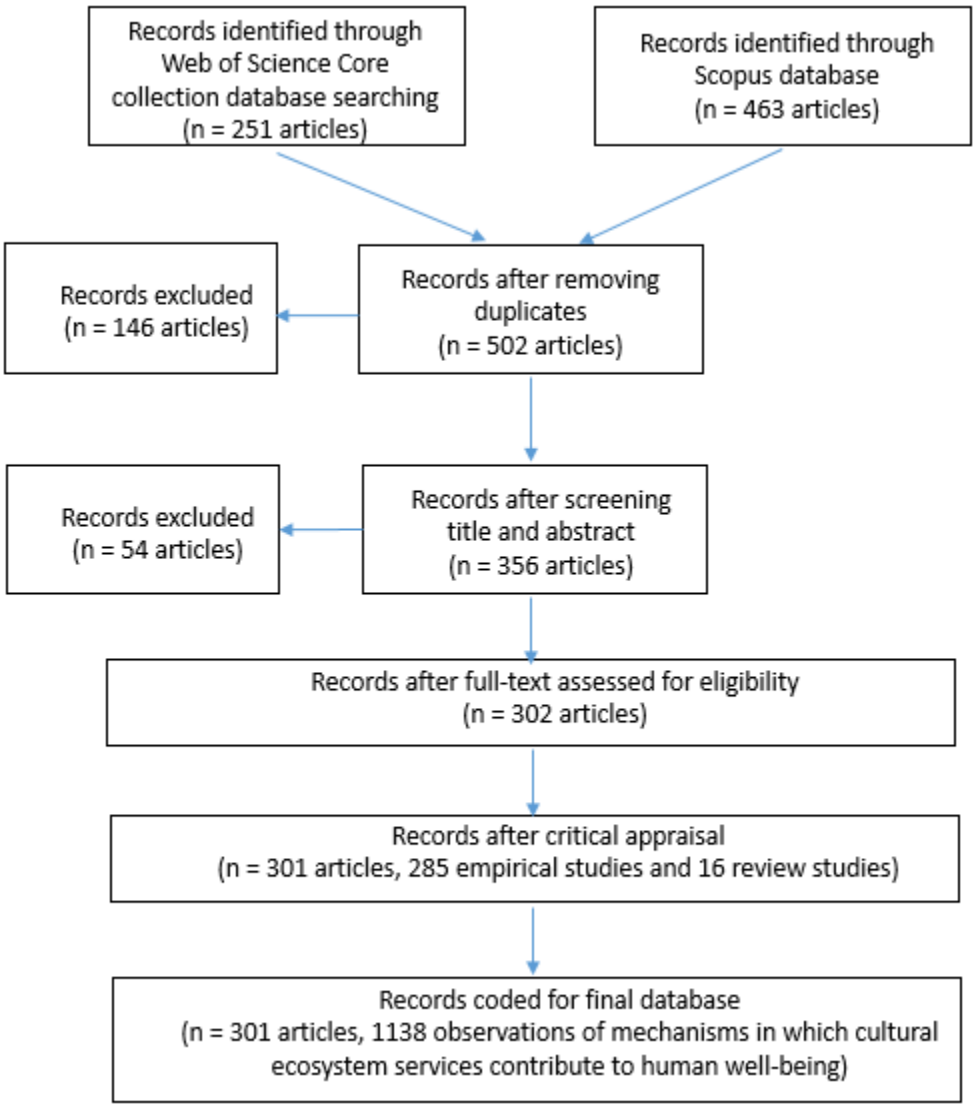
						interaction with nature can influence this mechanism	
13	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: Social value and belief system	Sense of place	Connectedness & belonging (place attachment)	Destructive	Place attachment is generally perceived as a positive factor and should be promoted to contribute to overall wellbeing. However, in some circumstances, it might also have undesirable and unintended consequences. Extremely high levels of place attachment, place dependency, and local identity might trigger extreme attitudes towards managing ecosystems, in turn hindering the effectiveness of ecosystem management. This may create conflicts in society and negatively impact social relationships(Leviston *et al.*, 2018).	Negative
14	Form: Physical, tangible or measurable aspects of ecosystem	Degrade Driver: environmental degradation	Sense of place	Connectedness & belonging (place attachment)	Destructive	When disrupted, place attachment can negatively impact well-being; relocation through forced or voluntary form can make people suffer from separation from significantly important place. Broken or "stretched" place bonds due to environmental degradation are linked with health issues, lower educational performance, sorrow, longing, alienation, disconnectedness and	Negative

						disorientation(Leviston *et al.*, 2018).	
15	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: environmental degradation, climate change	Social relation	Connectedness & belonging	Destructive	Degradation of natural resources and climate change can have effects on social relations. The reduction in participant number in the events in natural setting can hinder culturally/socially meaningful activities where people establish and sustained social relationship, support and cohesion(Leslie *et al.*, 2018).	Negative
16	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: Environmental degradation, modernisation	Cultural heritage value	Subjective well-being Cultural fulfilment	Destructive	With modernisation and environmental degradation, people feel less attach to the ecosystems. This is associated with a significant reduction in the cultural practices, cultural values, social norms associated with the ecosystems. The decrease in these cultural values leads to a decrease in eudaimonic and experiential wellbeing.(Chou, Huang and Mair, 2018)	

17	Cultural practice: Nature provides opportunity for playing and exercising, creating and expressing, producing and caring, gathering and consuming	Degrade Driver: decline in traditional knowledge	Knowledge system	Identity & autonomy	Destructive	Traditional knowledge is developed and preserved by the communication and transmission of knowledge between individuals and generations. Decline in traditional knowledge due to external drivers can diminish the collective identity of the whole community. Upon abandoning their traditional knowledge and livelihood practices, people perceive a lack of autonomy, question their capacity and struggle to adapt to the new socio-economic conditions(Cetinkaya, 2009).	Negative

Note: In describing these pathways, we have chosen to avoid repetitions by focusing on the pathways where the impacts on well-being are not simply the reduction of the services (opposite effects of the counterpart positive pathways) but an additional reaction to the loss of services or trade-offs or underlying factors manifest these circumstances.

Figure S1: Flowchart of the methodology including article search, inclusion and critical appraisal for the literature review



Keywords search:
("Ecosystem*" OR "Ecosystem service*" OR "social-ecological system*" OR "Nature's contribution*") AND ("cultural ecosystem service*" OR "aesthetic*" OR "recreation*" OR "spiritual*" OR "inspiration*" OR "place attachment" OR "social relation*" OR "knowledge system" OR "sense of place" OR "educational value* OR "Non-material nature's contribution*") AND ("Quality of life" OR "wellbeing" OR "human needs" OR "well-being")

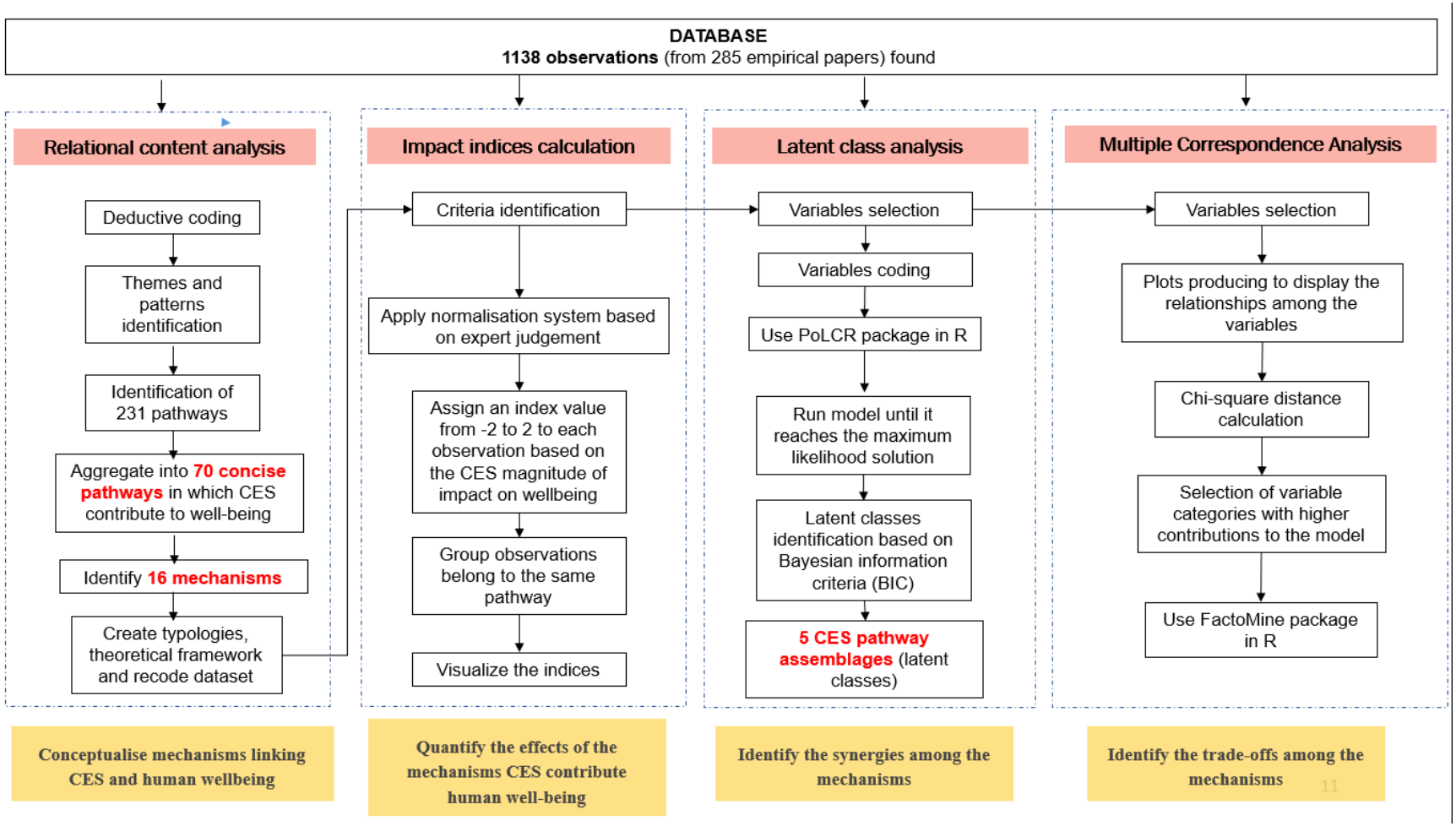


Figure S2: Flowchart of data analysis, from elicitation of mechanisms linking CES and human wellbeing, quantifying the effects of different mechanisms, Latent Class Analysis, and Multiple Correspondence Analysis.

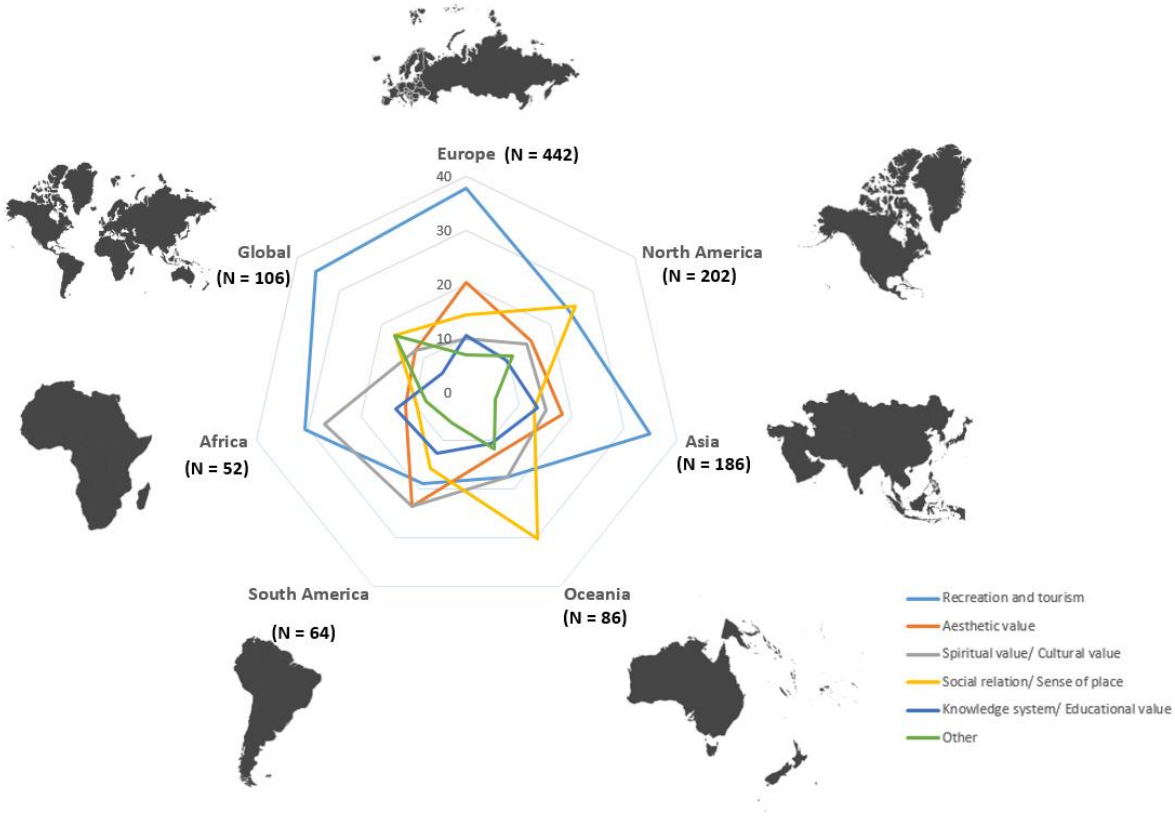


Figure S3: Geographical distribution of the observations for the mechanisms in which cultural ecosystem services contribute to human well-being. Radar axes reflect the percentage of observations reflecting each type of CES over the total number of observations for that region.

Among 301 reviewed studies, the authors found 1138 observations of the mechanisms in which CES contribute to human well-being. Different continents have different interests in CES research (Figure 2). The vast majority of CES documented in the academic literature globally are recreation, tourism, and aesthetic value and are mostly found in Europe and Asia. In Oceania and North America, with the large number of indigenous communities, sense of place and social relations are more represented than other services in the research landscape. The identity-landscape connections that refer to the natural environment's impacts on people's identity, cultural and historical development, and relationships with the broader communities are well-known in these regions(Pajak, 2004; Loder, 2014; Sangha and Russell-Smith, 2017). In contrast, spiritual value and cultural heritage value attract more attention in the academic literature in Africa and South America. In these regions, many types of ecosystems that are rich in symbolic expressions often link to people's religion and cultural heritage(de Lacy and Shackleton, 2017; Masterson, Mahajan and Tengö, 2018).

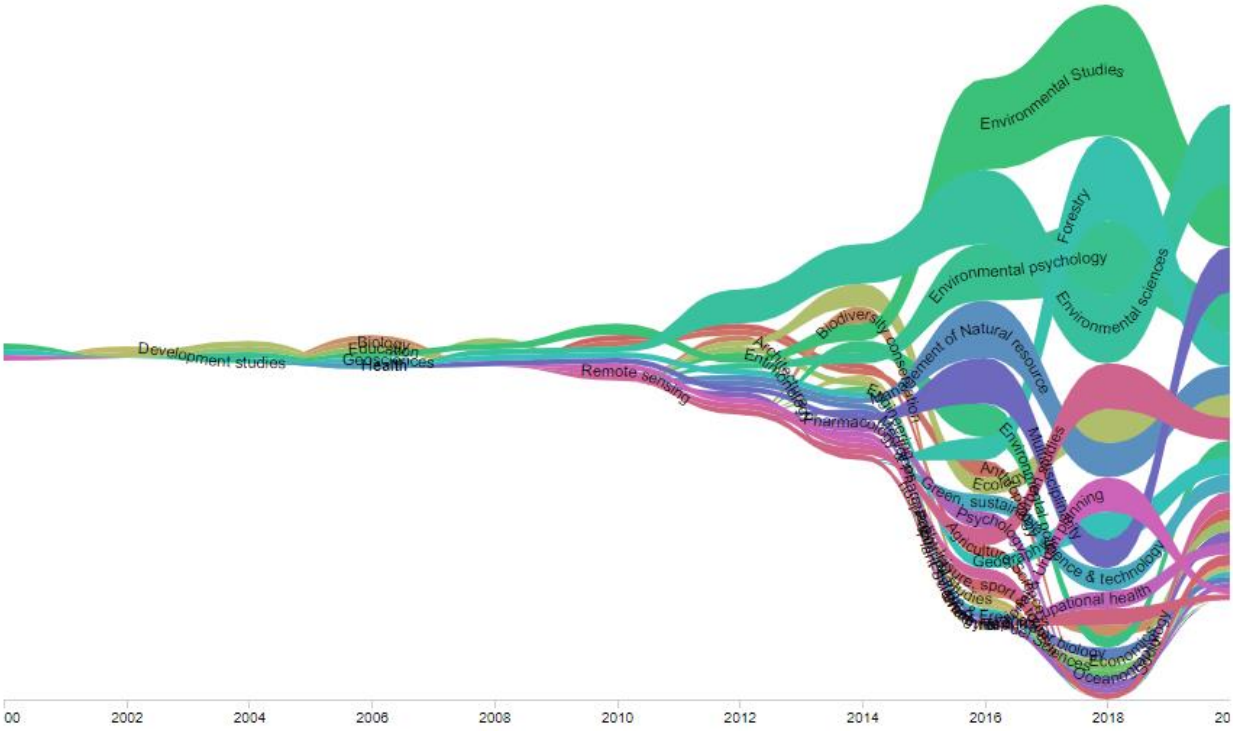


Figure S4: Interdisciplinary – Evolution of the main academic disciplines represented in the reviewed study.

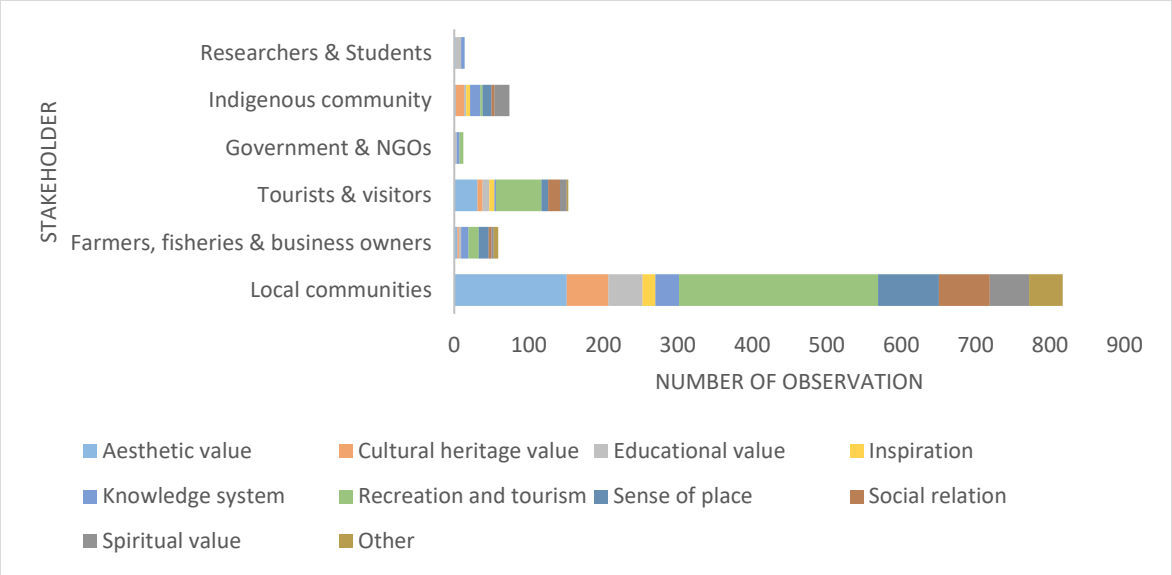


Figure S5: Number of observation of each cultural ecosystem service type based on different types of stakeholder

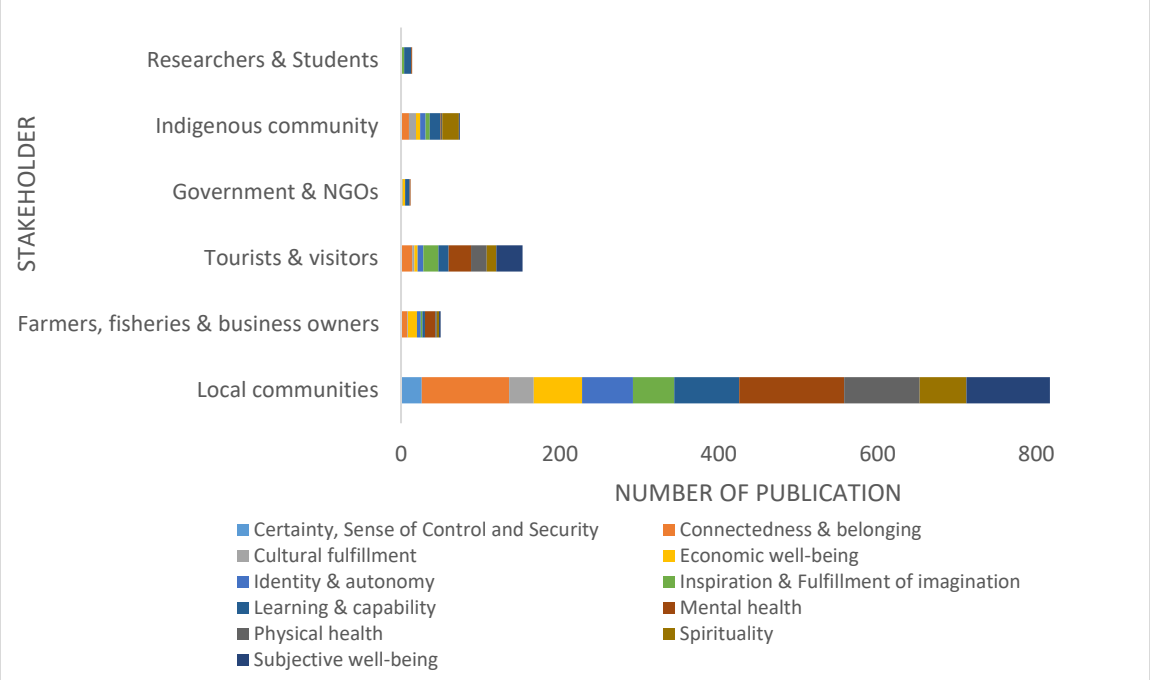


Figure S6: Number of observation of each constituent of human well-being based on different types of stakeholder

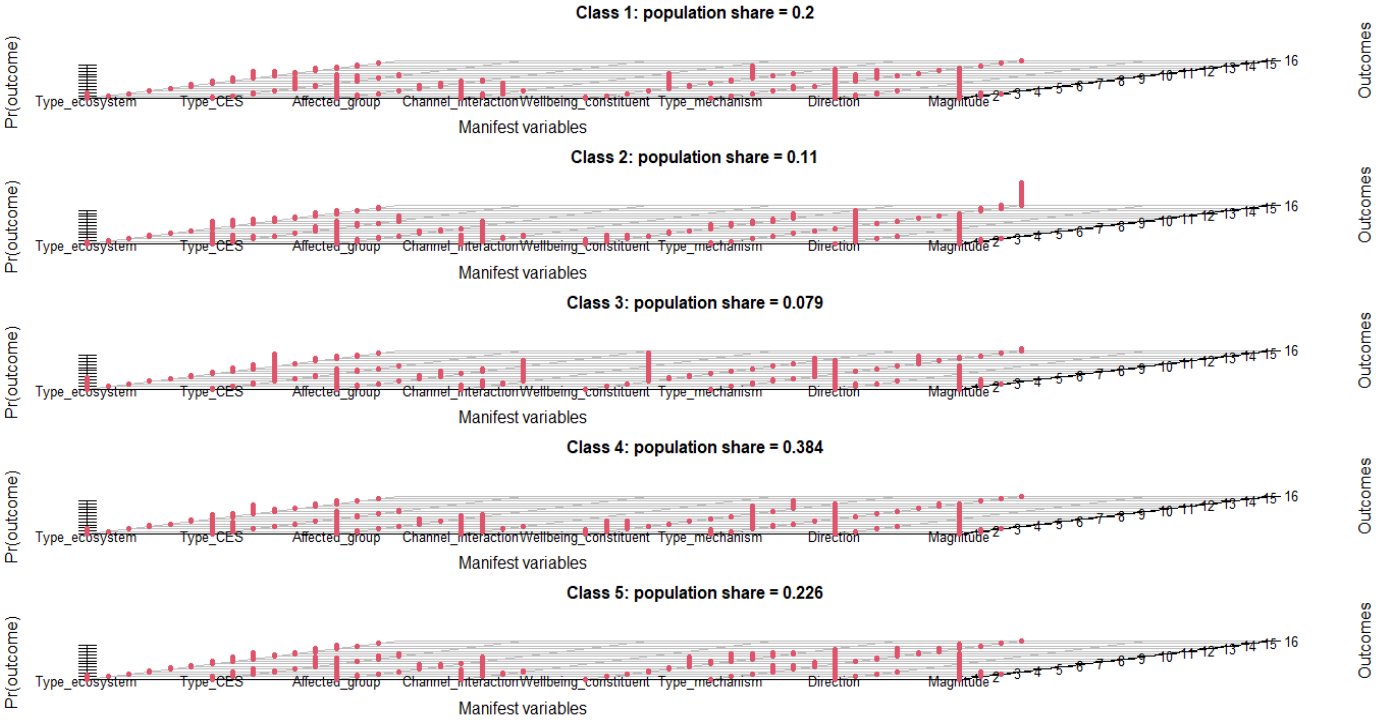


Figure S7: Likelihood for all variables by latent classes

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