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Supplemental information

Social media data for environmental sustainability: A critical review of opportunities, threats, and ethical use

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Table S1. Classification of the 415 studies in the database based on application and related Sustainable Development Goal target

SDG	SDG target	Application	Focus of supporting studies
	Sustainable agriculture (2.4)	• Assess cultural significance of agricultural landscapes	• In Tuscany, Italy[1–3] and Europe[4] • Mountain agriculture in Trento, Italy[5]
		• Map and monitor urban farming	• Four world metropolises[6]
	Sustainable development education (4.7)	• Explore meaning-making about environment and sustainability	• Young adults in Sweden[7] • Empathy expression in New York[8]
	Safe drinking water (6.1)	• Gauge public attitude toward management	• Shutdown of water supply due to pollution in USA[9] • Water charges in Ireland[10] • Analyze water discourses[11]
		• Inform operation of supply systems	• Catchment hydrology in Italian Alps[12]
	Water quality (6.3)	• Promote sustainable sanitation	• Benefits of nature-based solutions[13,14]
		• Value benefits of quality improvement	• Recreation in Minnesota lakes[15]
	Water-related ecosystems (6.6)	• Inform ecosystem restoration	• Great Lakes, USA[16,17] • Tourism in a Ramsar wetland in India[18]
		• Assess provision of cultural ecosystem services	• Wetlands in South Korea[19,20], India[21], France[22], Canada[23], China[24] • Danube[25], Ebro[26,27] river deltas • Rivers in Idaho[28], the Netherlands[29] • Lakes in the USA[30], globally[31]
		• Monitor environmental change	• Water level in a Saudi Arabian cave[32]
	Access to energy services (7.1)	• Explore public perception of energy	• Energy utilities merger in the Carolinas[33] • Nuclear energy risk communication in the USA[34]

		supply and energy projects	• Coal seam gas project in Alaska[35] • Debate concerning Keystone XL pipeline[36] • Hydraulic fracturing[37] • Communication by anti-coal activist movements[38]
	Share of renewable energy (7.2)	• Understand public opinion on renewable energy	• Three Gorges Dam hydroelectricity project[39] • Preferences for energy policies in Spain and UK[40] • Local opposition to wind power project in Germany[41]
	Sustainable tourism (8.9)	• Characterize spatial-temporal patterns of tourist visits	• Tourism in China[42], Shenzhen[43], Hong Kong[44,45], Beijing[46–48], Qingdao[49], Huangshan[50], Cilento, Italy[51], Tokyo[52], NE Portugal[53], India[54], Europe[55], worldwide[56,57] • Hotspots in Nepal[58], European cities[59,60] • Areas of Interest in six world metropolises[61]
		• Analyze tourist movements and choices	• Tourism routes in New York City[62,63] • Tourists' behavior in California[64,65] • Visitors perceptions of lake tourism[66]
	Sustainable and clean industries (9.4)	• Analyze sustainability marketing communication	• Environmental disclosure of Brazilian companies[67] • Fortune 500 enterprises[68]
	Inclusion (social, economic and political) (10.2)	• Address inequality in access to natural areas	• Green gentrification in Barcelona[69] • Visitation and access in New York City's parks[70] • Inequality in access to protected areas in Chile[71]
	Public transport systems (11.2)	• Analyze cycling infrastructure and their use	• Path networks in Belgium[72], Amsterdam and Osnabrueck[73] • Investment in cycling infrastructure in Glasgow[74] • Exposure of cyclists to air pollution in Glasgow[75] • Cycling behavior in Glasgow[76]
		• Plan and improve public transport systems	• Sentiment of transportation-related tweets during London Olympics[77] • Human mobility in Chicago[78] • Public opinion about transport system[79]

Inclusive and sustainable urbanization (11.3)	• Characterize visual quality of urban landscape	• City of Livorno, Italy[80], Province of Barcelona[81], various cities[82] • Public open spaces in Munich[83]
	• Map urban functions and urban land use	• Amsterdam[84], London[85,86], Turku, Finland[87], Guangzhou, China[88–90], Beijing[91], Shanghai[92], Edinburgh[93], Dakar[94], St. Petersburg[95], Sapporo[96], Chicago[97], Shenzhen[98], multiple cities[99,100] • Monitor urbanization and urban sprawl[101]
Cultural and natural heritage (11.4)	• Examine use and management of heritage sites	• Visitor flows worldwide[102] • Tourist movement in Cuzco and Machu Picchu[103] • UNESCO World Heritage sites in conflict areas[104] • Historic urban landscape of Tripoli, Lebanon[105] • Communication about Marine World Heritage sites[106]
Resilience to disasters (11.5)	• Detect and characterize flood extent and severity	• Flood extent maps in UK[107–109], Germany[110,111], US[112,113], Philippines and Pakistan[114], China[115] • Prediction of flood events[116,117] • Flood velocity and streamflow estimation[118,119] • Flooding thresholds in the US East Coast[120] • Prioritization of flood response[121]
	• Social sensing of natural hazards for footprint and damage assessment	• Earthquakes[122,123] • Hurricanes[124–126] • Wildfires[127–129] • High winds[130] • Heavy precipitation[131]
	• Enhance preparedness, response and recovery	• Typhoon Haiyan[132] • Hurricane Sandy[133–137] • Wildfires[138,139] • Crisis development, refugee flows after Arab Spring[140] • Multiple disasters, including Hurricane Sandy[141] • Monitor community mood to enhance resilience[142] • Severe weather risk communication[143]

			• Winter storms[144] • Drought risk management[145] • Post-disaster (earthquake) recovery[146]
	Urban green and public spaces (11.7)	• Assess ecosystem services of urban parks and green infrastructure	• Green spaces in cities in Turkey[147,148], China[149–157], Germany[158,159], USA[160], Canada[161], Denmark[162], Finland[163,164], Spain[165], Australia[166], Singapore[167–170], UK[171,172] • Places of importance for local urban residents[173]
		• Evaluate well-being benefits from exposure to nature	• Nanjing residents during COVID-19 pandemic[174] • Cities of Szeged, Hungary[175], San Francisco[176], Boston[177] • Urban parks in New York City[178], USA cities[179]
		• Understand public opinion, perceptions and satisfaction	• Green spaces in Dublin[180], London[181,182], Shenzhen[183], Beijing[184–186], Birmingham[187,188], Seoul[189,190], New York City[191,192], Zurich[193]
	Management of chemicals and wastes (12.4)	• Monitor solid waste management	• Odors from landfills in China[194] • Impact of litter on wildlife[195]
		• Infer urban air pollution levels and inform air pollution debate	• Power relations in communication about air pollution in China[196] • Predict particulate matter concentration in Beijing[197] • Atmospheric air quality and health effects, globally[198] • Air quality index for Chinese cities[199]
	Corporate sustainable practices (12.6)	• Inform corporate sustainability practices	• Spillover effects of environmental regulation in China[200] • Information from social media as input to decision-makers[201] • Assessment of supply chain risks and uncertainty[202]
		• Assess impacts on business performance	• Effect of social activism on stock market performance of Spanish banks[203]
	Sustainable development awareness (12.8)	• Uncover public perspectives on sustainability topics	• Sentiment of sustainability-related tweets[204] • Discourses on sustainability and consumption[205] • Debate about seal hunting in Canada[206] • Conceptions of health and sustainability in beverage consumption[207] • Global debate about land grabbing[208]

		• Understand perceptions of nature	• Testing the biophilia hypothesis[209] • Classifying public opinions on nature[210] • Discourse and dissemination around nature-deficit disorder[211]
		• Explore spread of sustainability information	• Effectiveness of science communication in Italy[212] • Circulation of environmental information[213] • Biodiversity conservation awareness[214] • Communication about natural capital concept[215], conservation science[216], Deepwater Horizon oil spill[217]
		• Analyze communication on environmental politics	• Greens party in Australia[218] • UKIP party in UK[219]
	Resilience and adaptive capacity (13.1)	• Identify mismatches in socio-ecological systems	• Wildflower phenology and human visitation in Mount Rainier National Park[220], green areas in Beijing[221] • Public response to heat waves[222]
		• Assess impacts on nature-based recreation	• National parks in the USA[223]
	Climate change policies (13.2)	• Explore perception of impacts and policies	• Low-carbon cities in China[224] • Remarkability of temperature anomalies[225]
	Climate change awareness (13.3)	• Analyze online discussions on climate change	• Discussions on COP21[226], 2013 IPCC report[227] • Gender differences[228] and social network effects[229,230] in climate change communication • Discourses of climate change skeptics or deniers[231–234] • Climate change-related discussions in China[235], and globally[236–238] • Effect of weather events on climate change discussion[239–242] • Climate change science learning and environmentally friendly behavior[243]
	Marine and coastal ecosystems (14.2)	• Assess coastal and marine ecosystem services	• Whale watching in Sri Lanka[244] • Recreation in NW Portugal[245], Gold Coast, Australia[246], Azov Sea shores[247], beaches in Indonesia[248] • Eco-tourism in Great Barrier Reef [249,250], Seychelles[251] • Recreational fisheries[252,253]

			• Global coral reef tourism[254] • Multiple cultural ecosystem services in Lithuania[255], Mexico[256], Turkey[257], the Netherlands[258]
		• Map human interactions with marine species and disturbance to ecosystems	• Cetacean occurrences in Italian Mediterranean Sea[259] • Human interactions with Hawaiian monk seal[260] • Environmental impacts from tourism in Iceland[261] • Environmental monitoring in Great Barrier Reef[262,263] • Occurrence of jellyfish in Malta[264]
	Conservation of coastal areas (14.5)	• Assess benefits of marine protected areas	• Multiple marine protected areas worldwide[265,266] • Tarutao National Marine Park, Thailand[267,268] • Coral Coast in Brazil[269]
	Terrestrial and freshwater ecosystems (15.1)	• Map land use/land cover or geomorphometry	• Land use/land cover in urban green areas in London[270], San Diego county, USA[271] • Landscape variation and folksonomies in Switzerland[272] • Geomorphometry in UK[273]
		• Analyze public perception and benefits of terrestrial protected areas	• Nature-based tourism and recreation in Spain[274–276], South Africa[277–280], Finland[277,280–282], Israel[283], USA[284–289], Australia[290,291], UK[292], Germany[293,294], and globally[295–297] • Landscape aesthetics in Yorkshire Dales National Park, UK[298] • Public perceptions of national parks in Nepal[299], South Africa[300] • Mountain biking in Sintra-Cascais Natural Park, Portugal[301] • Multiple cultural ecosystem services of protected areas in Portugal[302,303], Spain[304,305], Argentina[306], Finland[307], Brazil[308] • Tourism pressure in Korean national parks[309] • Attractors for eco-tourists in sub-Saharan protected areas[310–312] • Discourses about controversial environmental management issues in Australia[313]
		• Investigate human-nature conflicts	• Cattle grazing in Californian rangelands[314] • Hunting in British Columbia[315] • Unwanted visitors' behavior in South African national park[316]

	• Assess cultural ecosystem services	• Nature-based tourism and recreation in New Zealand[317], South Korea[318], UK[319], Florida[320], Estonia[321], Switzerland[322], the Netherlands[322,323], Israel[324], Costa Rica[325], Argentina[326], China[327], Norway[328], Europe[329,330], Arctic[331,332], Canada[333], USA[334–336] • Wildlife watching in the USA[337], Scotland[338] • Cultural ecosystem services in Germany[339], multiple sites in Europe[340], of native and non-native trees in Spain[341,342] • Experience tranquility[343,344]
	• Quantify landscape aesthetic values	• Visitors' perceptions in the UK[345,346], Spain[347], USA[348–350], Switzerland[351,352], Turkey[353], Estonia[354], Slovenia[355], Europe[356], Japan[357]
	• Complement traditional monitoring	• Species distribution, climate data, land use / land cover in Europe[358–361] • Population distribution[362,363] • Occurrence of landslides[364] • Vegetation phenology[365] • Index of environmental quality[366] • Seasonal color change in the environment[367]
	• Evaluate environmental protection policies	• Benefits of investments in Public Land Acquisition[368]
Sustainable forest management (15.2)	• Assess cultural ecosystem services of urban vegetation	• Mangroves in Singapore[369,370] • Forests in Warsaw agglomeration[371]
	• Assess cultural ecosystem services of forests	• Forests in Tuscany, Italy[372] • Mount Baker-Snoqualmie National Forest[373] • Gariwangsan and Yeoninsan forests in South Korea[374] • Forests on conserved lands in Vermont, USA[375]
Conservation of mountain ecosystems (15.4)	• Assess benefits of mountain eco-tourism	• Indian Himalayan Region[376,377] • Berchtesgaden National park in Germany[378] • Dolomites UNESCO World Heritage Site[379]

		• Highest mountain in Australia[380,381] • European Alps[382] • Mount Etna[383]
	• Assess mountain cultural ecosystem services	• Dolomites UNESCO World Heritage Site[384] • Aesthetic values in Austria[385], France[386] • 'Quatre montagnes' in the French Alps[387]
Loss of biodiversity (15.5)	• Collect information on species ecology and behavior	• Spatial variation in species traits in Japan[388] • Species determination in digital media[389] • Ecology and behavior of shrikes[390] • Winged ant emergence, autumnal house spider sightings, and starling murmurations across the UK[391] • Behavior of red and grey squirrels in Europe[392] • Trophic interactions[393]
	• Map species distribution	• Flowering plants in the UK[394] • Monarch butterfly and snowy owl[395] • Bees and flowering plants in Australia[396] • Iberian Argiope spider species in Spain[397]
	• Characterize human-wildlife interactions	• African painted dog[398] • Giant panda in China[399] • Iconic terrestrial vertebrates in French alpine national parks[400] • Birds in Chicago, IL, USA[401] • Tourism pressure in grizzly bear recovery areas[402] • Grouse species during winter recreational activities[403]
	• Monitor and respond to illegal activities	• Illegal sport hunting in Brazil[404] • Conservation-related violence toward poachers[405]
	• Analyze perceptions of biodiversity and endangered species	• Sentiment toward iconic species[406] • Global Important Bird and Biodiversity Areas[407] • Public perception of slow lorises[408] • Public engagement with endangered species[409]

	Protected species trafficking (15.7)	• Monitor online wildlife trade	• Indonesian songbirds[410] • Orchids[411] • Slow loris trade in Turkey[412]
	Invasive alien species (15.8)	• Monitor spread of non-native species	• Freshwater turtles in the UK[413] • Oak processionary in Europe[414] • Oak processionary moth, emerald ash borer, eastern grey squirrel[415]

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