

## Supplementary

### S1. Questionnaire design

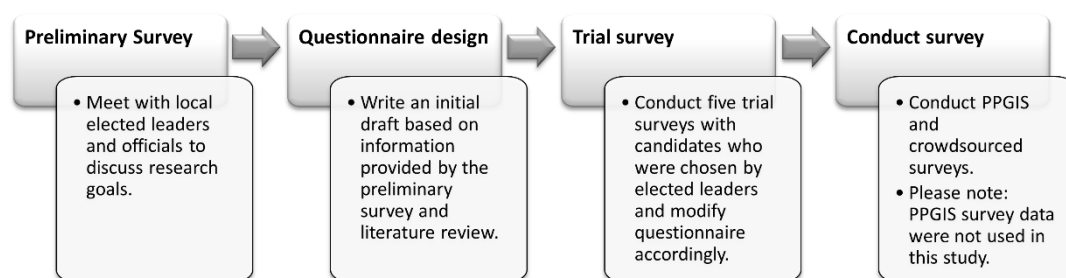
We used 11 of the 12 characterization methods and definitions of social values presented by Clement and Cheng [1] for forest ecosystems since the ecosystem and environment of our study area are similar (see Table S1). The one exception to this was the last social value 'therapeutic value', which we substituted with 'subsistence value'. In addition, the questionnaire included an assessment of public opinions on land use preferences, the familiarity of participants with the target areas, social value priorities, basic information, and the socioeconomic background. The questionnaire design process was based on the research methods presented by Fagerholm et al. [2].

**Table S1.** The definitions of 12 social values of ecosystem services taken from Clement and Cheng [1]

Values	Definitions
Aesthetic value	I value the Datuan Watershed because I enjoy the Datuan Watershed scenery, sights, sounds, smells, etc.
Biological diversity value	I value the Datuan Watershed because it provides a variety of fish, wildlife, plant life, etc.
Cultural value	I value the Datuan Watershed because it is a place for me to continue to pass down the wisdom and knowledge, traditions, and way of life of my ancestors.
Economic value	I value the Datuan Watershed because it provides fisheries, minerals, or tourism opportunities such as outfitting and guiding.
Future value	I value the Datuan Watershed because it allows future generations to know and experience the area as it is now.
Historic value	I value the Datuan Watershed because it has places and things of natural and human history that matter to others, the nation and me.
Intrinsic value	I value the Datuan Watershed in and of itself for its existence, no matter what I or others think about the forest.
Learning value	I value the Datuan Watershed because we can learn about the environment through scientific observation or experimentation.
Life sustaining value	I value the Datuan Watershed because it helps produce, preserve, clean, and renew air, soil and water.
Recreation value	I value the Datuan Watershed because it provides a place for my favorite outdoor recreational activities.
Spiritual value	I value the Datuan Watershed because it is a sacred, religious, or spiritually special place to me or because I feel

	reverence and respect for nature there.
Subsistence value	I value the Datuan Watershed because it provides necessary food and supplies to sustain my life.

With the research goal identified, we conducted a preliminary survey, and initiated communication with public officials and elected leaders of the area. The important information collected during this stage informed the questionnaire design process. After designing a pilot interview format, we then conducted a trial survey. This survey only included those 8 candidates whom had been identified during the preliminary survey by elected leaders. During the trial survey, respondents were given an introduction to the Datuan Stream, within the context of the Datuan Watershed's geographical, environmental, cultural, and historical background. We established ecosystem service definitions of the 12 social values, and 12 survey site types to maximize respondent participation. With the feedback collected from these selected candidates, we were also able to assess how intelligible the questionnaire was for the general public. After conducting five trial surveys, we finalized the questionnaire. Please see figure S1 for an overview of steps taken in the questionnaire design:



**Figure S1.** Overview of questionnaire design.

The final questionnaire was a crowdsourced online survey (see section S1.2) consisting of four sections as listed in Table S2. The first section introduced the background of the research area, focusing on the environment and anthropogenic historical background of the Datuan Watershed. In order to collect accurate results, this section also defined the 12 social values with simple illustrations. In the second section, we aimed to assess the public preferences of 12 types of survey sites of the Datuan Watershed. We accomplished this by allowing respondents to choose from a list proposed by each elected leader (Table S3). Additionally, participants had the option to specify an alternative survey site type if the types listed were not sufficient, although these responses were not considered in the current study. Respondents ranked survey site types using the Likert Scale categories of 1. Strongly Agree, 2. Agree, 3. No comment, 4. Disagree, and 5. Strongly Disagree. The third section quantified the ‘value index’ for the SolVES model by allowing respondents to quantify and prioritize 12 social values of each reference location [6]. The respondents first scored each social value on a scale from 0 to 10, then selected up to five locations that have the most social value for the respondent. Specifically, this section provides 29 reference location types, which corresponded to 46 representative location sites. The elected leaders identified each of the reference location types and representative sites during the preliminary survey. We later quantified the results of this section, which then served as input values for the social value model of ecosystem services (SolVES) to facilitate spatial analysis and modeling of the social values. Finally, the last section consisted of questions about basic demographic information, such as sex, age, number of people per household, educational level, income,

occupation, and residential address. Other questions included time residing in the Datuan Watershed, average annual duration and reason for residing in the Datuan Watershed, the connection between income and productive activities related to the Datuan Watershed, and the amount of food consumed from the Datuan Watershed. The last five questions in this section include questions about the interest level of participants in the future development of Datuan Watershed in the next 10 to 15 years, ecosystem understanding, history and culture, community activities, and economic activities in the Datuan Watershed. The results of the fourth section are depicted in Figures S2 (a-q).

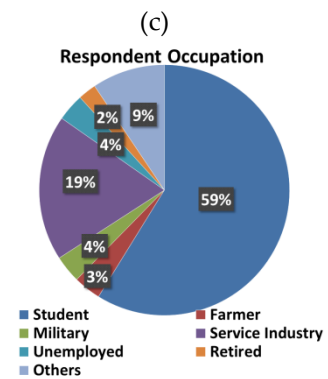
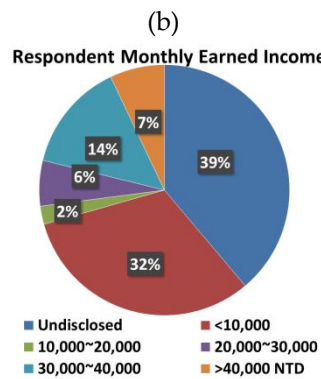
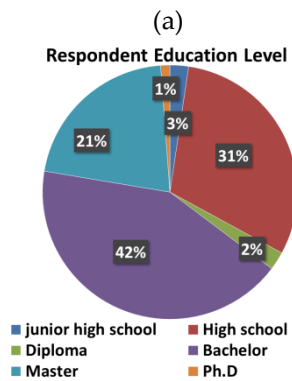
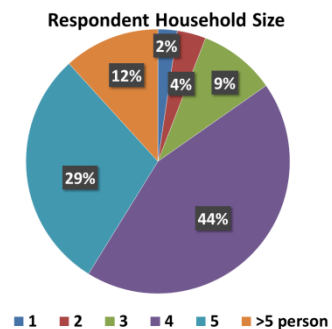
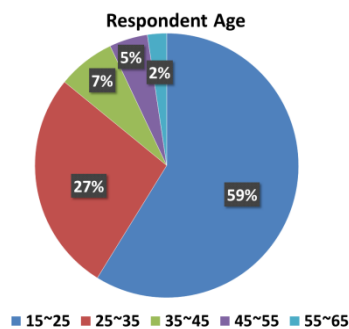
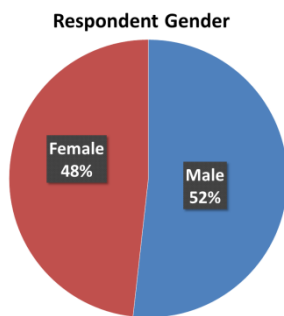
**Table S2.** Questions and contents of the questionnaire

Item assessed	Content
First Section: Background information of research area	Background of geographical environment and anthropogenic history of Datuan Stream
	Definitions and illustrations of 12 social values
Second Section: Survey site preferences assessment	12 types of survey sites including: recreational tourist farming, riparian fishing, coastal fishing, cultivation of crops, cultivation of ornamental plants, industrial and commercial land uses, fallow ground, bird sighting, the National parks or conservation area, cemetery, historical heritage, and construction; with 5 ranking options: Strongly Agree, Agree, No comment, Disagree, Strongly Disagree.
Third Section: Quantification of social values and selection of high value survey sites	Evaluation of 12 social values Prioritization of 12 social values and selection of respective representative locations
Fourth Section: Investigation of demographic statistics and familiarity of research area	Personal information Residential address and the familiarity with the Datuan Watershed

**Table S3.** Type of survey sites considered in the research area

No.	Survey Site Type	Description
1	Recreational tourist farm	Agricultural farm area that supplies agricultural products and serves a recreational, educational, social and environmental

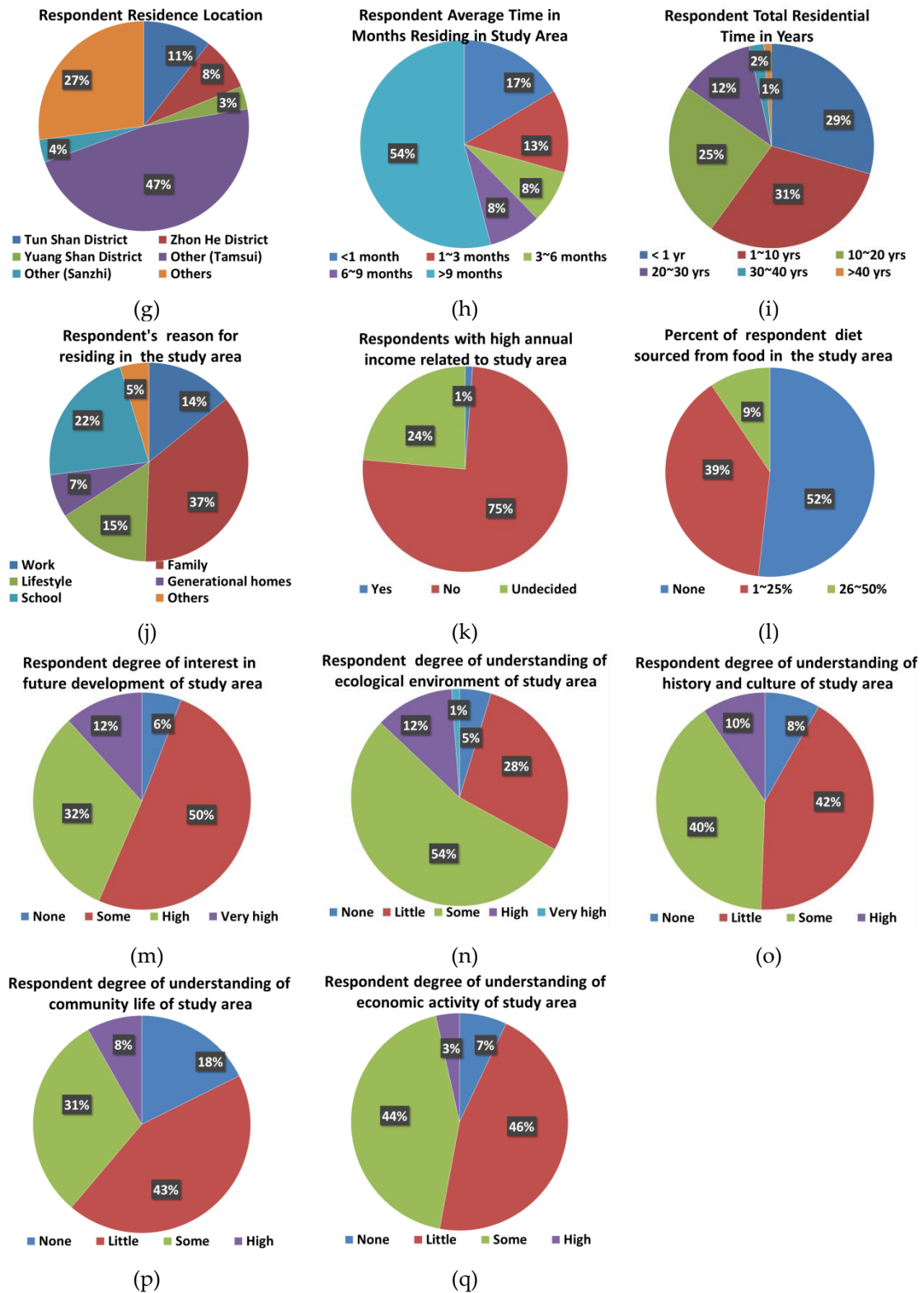
		function [12]
2	Riparian fishing	Fishing in the Datuan Stream
3	Coastal fishing	Fishing along the coastline
4	Cultivation of crops	Agricultural area for specific crop production
5	Cultivation of ornamental plants	Agricultural area for ornamental plant production
6	Industrial land/ commercial land	Built up area for industrial or commercial purposes
7	Fallow ground	Inactive agricultural area
8	Bird sighting	Popular bird sighting locations
9	National parks and conservation areas	Forest area
10	Cemetery	Built up area for public cemetery
11	Historical site	Historic site located in a forest area
12	Construction	Built up area for development
13	Other	Other



(d)

(e)

(f)



**Figure S2.** Respondent demographics and familiarity with research area results. Note: the status reported in figures (n), (p), (o) and (q) were self reported.

Figure S2(a) shows that the proportion of men and women in this study was almost equal with only nine more male respondents than female respondents. Regarding age distribution, Figure S2(b) shows that 15 to 25 year old participants accounted for more than half of the total respondents. This may be due to the web-based questionnaire method used

in this study. Interestingly, respondents who were knowledgeable about ecological issues and public sector staff were mostly between the ages of 25 to 35. While figure S2(c) shows the majority of respondents reside in a household with four family members, household sizes of five people and greater are not uncommon since the local residential families are typically inter-generational households. Figure S2(d) shows that the majority of respondents are educated with many holding master's and bachelor's degrees, or a high school diploma. In figure S2(e) we see that the majority of respondents are unwilling to disclose monthly income, while figure S2(f) shows that about half of the respondents are students. Figure S2(g) shows that respondents were mostly local residents, and Figure S2(h) and Figure S2(i) shows that people living in the study area have lived there for at least one year for reasons shown in Figure S2(j). Most of the respondents who disclosed high annual incomes derive it from sources unrelated to the study area (Figure S2(k)). Despite this, due to the local abundance of bamboo shoots and seafood from the coastal fishing port, half of the respondents reported that the majority of their diet is sourced from the study area (Figure S2(l)). Regarding respondent interest in future development of the study area, Figure S2(m) shows that most of the respondents reported a high degree of interest. Reported levels of understanding of the study area are shown in Figures S2(n-q) with more than eighty percent of the respondents indicating that they had a general to above level understanding of the ecological environment, history and culture, community life, and economic activity of the study area.

### S1.2. Collection method: Crowdsourcing

Cooper et al. [3] pointed out that one could obtain broader information and data collection with longer timeframes through crowdsourcing approaches by promoting surveys on online platforms and recruiting volunteers to participate in research initiatives. Online crowdsourcing in Taiwan is relatively easy since the Taiwan government recognized the public need for internet access and has provided Taiwanese citizens with free indoor and outdoor wireless internet and basic services since October 2011 [4]. In this study, we only targeted residents of the research area. Thus, we invited community members living in Tamsui and Sanzhi districts to respond to the questionnaire mainly through Facebook and NTU PTT, a National Taiwan University online Bulletin Board System. To be more specific, we posted information about this research on Tamsui district and Sanzhi district Facebook community pages and solicited volunteers to participate in the survey by publishing informational posts using NTU PTT portals to other universities within the research area (e.g., Tamsui University, Sanzhi University, St. John's University, Tamkang University, and Aletheia University). Willing participants then completed the questionnaire hosted on the Google Cloud system cooperative platform.

We chose Facebook and the NTU PTT as promotional platforms since Facebook and the NTU PTT can target specific communities, thus, we could focus on the Tamsui and Sanzhi community pages to meet the pre-set definitions of community. Also, Facebook and the NTU PTT are free applications and have a broad user base which can increase participation. We chose Google as a survey platform for four reasons, including: 1) it is an open source free application that is user friendly and widely accessible; 2) Google has a validation mechanism built into its survey application that identifies and excludes erroneous entries; 3) the Google survey application (Google forms) is a Cloud service which allows researchers to quickly and remotely access answers; 4) Google provides diverse form options for time efficient questionnaire design.

### S1.3. Participant characterization methods and survey evaluation

This research did not consider random answers by non-resident participants in the crowdsourced survey. To determine which answers were from reliable sources, our research classified the respondent participants by the following criteria:

1. Whether or not the participant is a resident of Tamsui or Sanzhi Districts and therefore within the study area;
2. Whether or not the age of participant is greater or equal to the residence time;
3. Whether or not the participant chooses contradictory options, such as indicating residence in Datuan Watershed while also residing outside of the Datuan Watershed;
4. Whether or not the participant selects too many locations or social value values in section three;
5. Whether or not the participant is familiar with the ecosystem and environment, the local history and culture, community activities and the local economic activities of the Datuan Watershed as indicated by their questionnaire responses. Please see Fagerholm et al. [2] for more details about how familiarity was determined.

## S2. Study sites and area

The Datuan Watershed area provides a number of ecosystem services. The area is home to riverine and forest ecosystems (Figure 1), which provide refuge for aquatic and coastal species as well as other ecosystem services such as phosphorous sequestration. Figure S3 shows a number of pictures that highlight the natural beauty and diversity of environments located along the Datuan stream. The Datuan Watershed also has a rich cultural heritage (Figure S4). One example is an ancient bridge, Sanbanqiao, found upstream of Dianzi Village in the Sanzhi District, which was constructed during the Qing Dynasty while Emperor Tongzhi (1856 – 1875) was in power (Figure S4). This and many other high natural and social value areas found in the Datuan Watershed (Figure S4) justify the development of conservation strategies and areas. Figure S4 shows a number of reference location sites that were perceived as having high value, and therefore represented reference location types. The ID number corresponds to the reference location types shown in the map of Figure S5 and the captions in Table S4.



(a) upstream area



(b) upstream area



(c) midstream area



(d) midstream area





(e) downstream area



(f) downstream area

**Figure S3.** A number of locations that highlight the natural beauty and diversity of the Datuan watershed (a) a site from the upstream area; (b) a site from the upstream area; (c) a site from the midstream area; (d) a site from the midstream area; (e) a site from the downstream area; (f) a site from the downstream area. Note: these are overall background pictures of the study area.



(b) ID=2



(c) ID=3



(d) ID=4



(e) ID=5



(f) ID=6





(g) ID=7



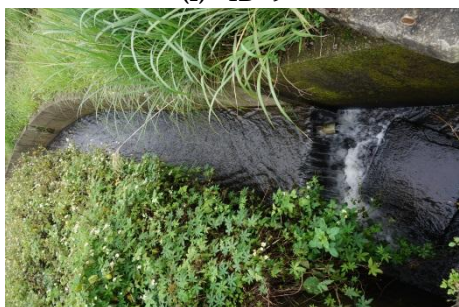
(h) ID=8



(i) ID=9



(j) ID=10



(k) ID=11



(l) ID=12



(m) ID=13



(n) ID=14



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(p) ID=16



(q) ID=17



(r) ID=18



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(w) ID=23



(x) ID=24



(z) ID=26





(aa) ID=27

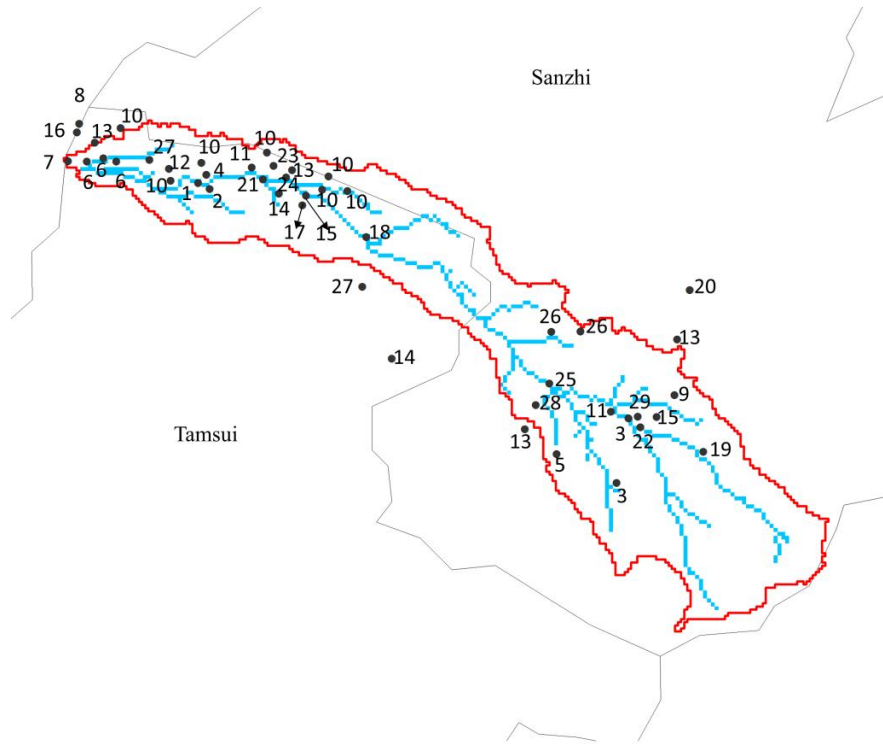


(ab) ID =28



(ac) ID=29

**Figure S4.** Locations that are perceived as having high social value within the Datuan Watershed (a) along the Datuan Stream; (b) Paddy fields; (c) Terraces; (d) Lotus field; (e) ancestry memorial park;(f) Weir downstream of Datuan stream; (g) Estuary of Datuan stream; (h) Coastal intertidal zone; (i) a café shop for art exhibitions; (j) 100-year old historical house; (k) irrigation channel; (l) Wisteria Café shop; (m) Taoist temple; (n) Buddhist temple; (o) Temple of Land God; (p) Liukuaicuo fishing port; (q) Shanfu bridge; (r) ecological pool; (s) Stone House; (t) trail; (u) A sign explaining local ecological ; (v) Datuan Stream historical road; (w) Li's Yanlou(old historical house); (x) Recreational tourist farm; (y) Eco-engineering park; (z) Memorial park; (aa) School; (ab) pottery factory; (ac) Sanbanqiao bridge.



**Figure S5.** locations of high natural and social value survey sites (Li [5]). note: the ID numbers in the map correspond to reference location types as shown in table S4 and some of the pictures in figure S4. In addition, the locations that are located outside of the study area boarder, were also used in the SolVES model..

**Table S4.** The ID of each survey site type

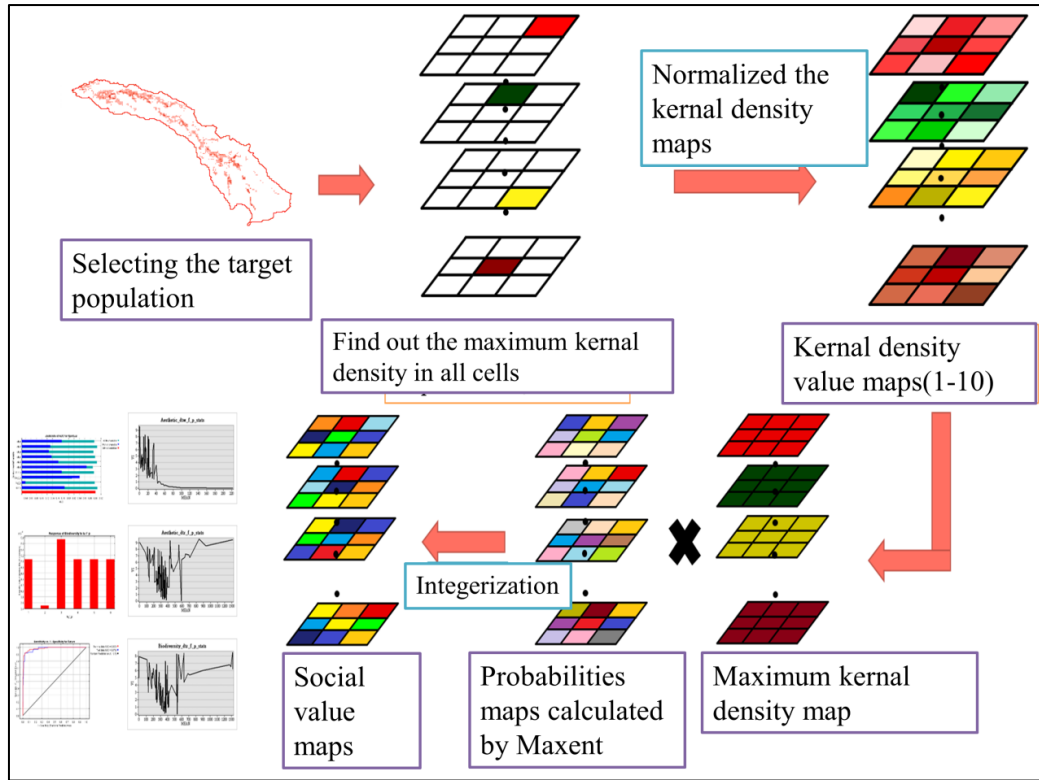
ID	High social value location	ID	High social value location
1	along the Datuan Stream	16	Liukuaicuo fishing port
2	paddy fields	17	Shanfu bridge
3	terraces	18	ecological pool
4	lotus field	19	Stone House
5	ancestry memorial park	20	trail
6	weir downstream of Datuan stream	21	a sign explaining local ecological engineering
7	estuary of Datuan stream	22	Datuan Stream historical road
8	coastal intertidal zone	23	Li's Yanlou(old historical house)
9	a café shop for art exhibitions	24	recreational tourist farm
10	100-year old historical house	25	eco-engineering park
11	irrigation channel	26	memorial park
12	Wisteria Café shop	27	school

13	Taoist temple	28	pottery factory
14	Buddhist temple	29	Sanbanqiao bridge
15	Temple of Land God		

### S3. Social Values for Ecosystem Services (SolVES)

The U.S. Geological Survey (USGS) and Environmental Change Science Center developed the Social Values for Ecosystem Services (SolVES) tool to quantify and project the social values of ecosystem services in a spatially explicit way [6,7]. The software estimates social values by combining both spatial and non-spatial data collected from public preference surveys [6]. The software uses a quantitative 10-point “Value Index” from a value-allocation exercise in the survey to calculate the non-spatial component. The tool then calculates the spatial component with respondent-identified locations, each of which is associated with a specific value type, to project the social values all throughout the focal area based on landscape attributes (environmental data layers such as elevation, distance to water, land-cover type, etc.) [6]. Moreover, SolVES also integrates a maximum entropy model (Maxent) to calculate social-value maps and to yield robust statistical models, e.g., estimations of the relationship between social-value intensities and explanatory environmental variables.

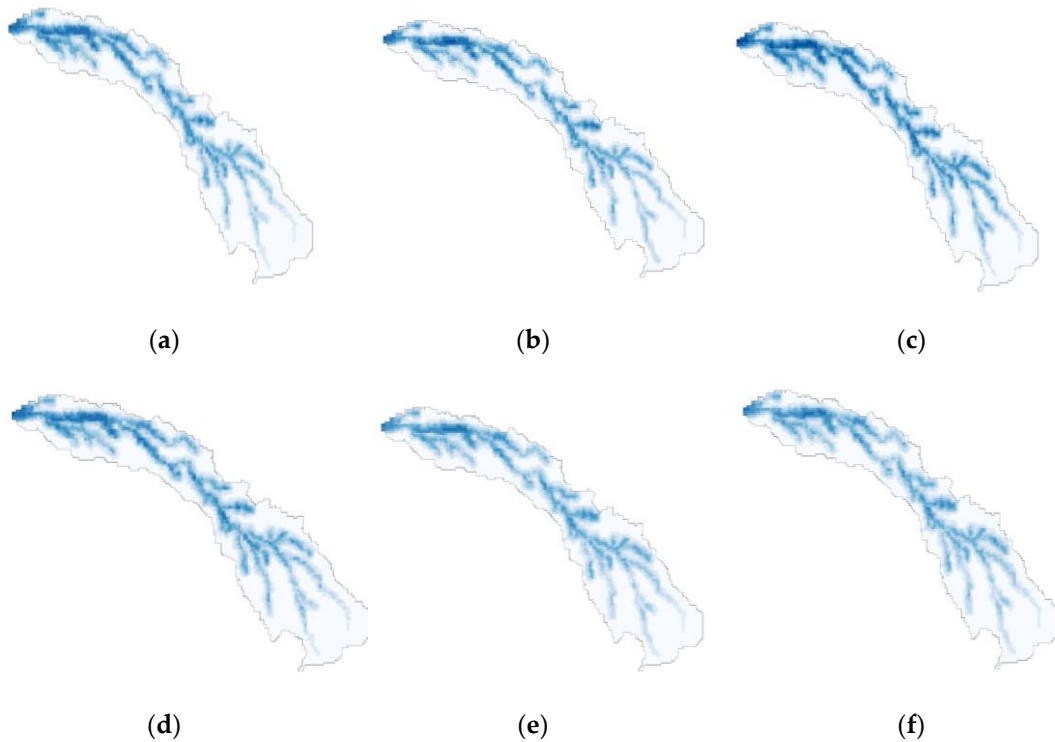
Weighted kernel-density surfaces are estimated for each social-value type considered in the survey (e.g., if the survey includes 10 value types, 10 surfaces are estimated), where the total indicated score for each point serves as weight for respective value types in spatial projections (Fig. S6) [7,8]. Once SolVES generates weighted kernel density surfaces for each social value, it then determines the highest-value cell with respects to all of the surfaces [7]. SolVES then normalizes the surfaces associated with each user-identified value type in relation to the maximum surface value (Fig. S6) [7,8]. Finally, the Value Mapping Model generates a social value map via the Maxent model in combination with kernel density surfaces and social value surfaces [8]. Further details about the SolVES software can be found at <http://solves.cr.usgs.gov> as well as the user’s manual [8,9].



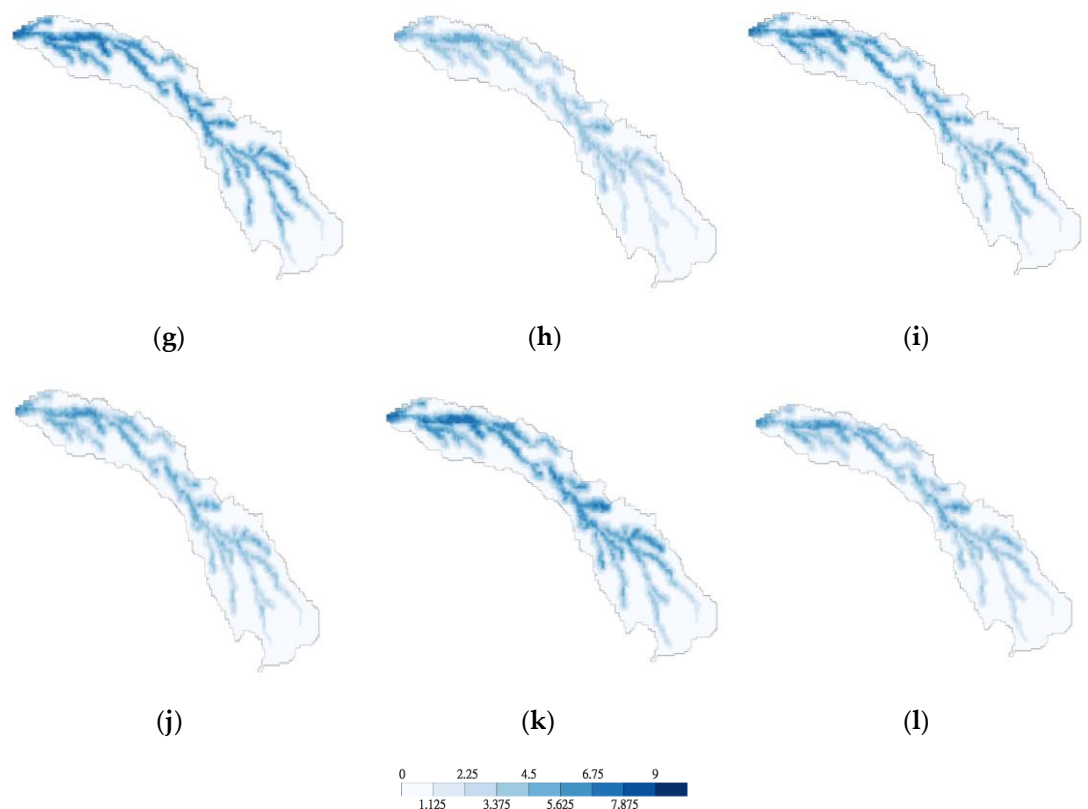
**Figure. S6.** Generalized process flow of social values map generation. (Sherrouse and Semmens [8] and Hsin-Yi Li [5])

### 3.5 Spatial distributions of SV

Here we present the outputs of individual SolVES models for each SV dataset.







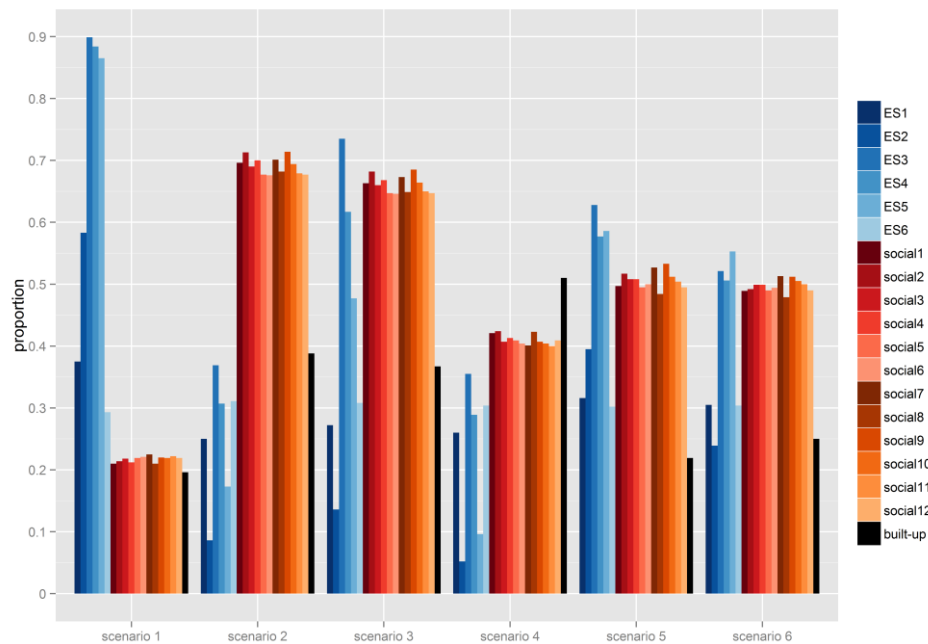
**Figure S7.** Spatial distributions of SV in (a) aesthetic; (b) biological diversity; (c) cultural; (d) economic; (e) future; (f) historic; (g) intrinsic; (h) learning; (i) life sustaining; (j) recreation; (k) spiritual; (l) subsistence values. (based on the data collected by Li et al. [5]).

**Table S5** Area Under the Curve (AUC) values for Maxent training and test data sets

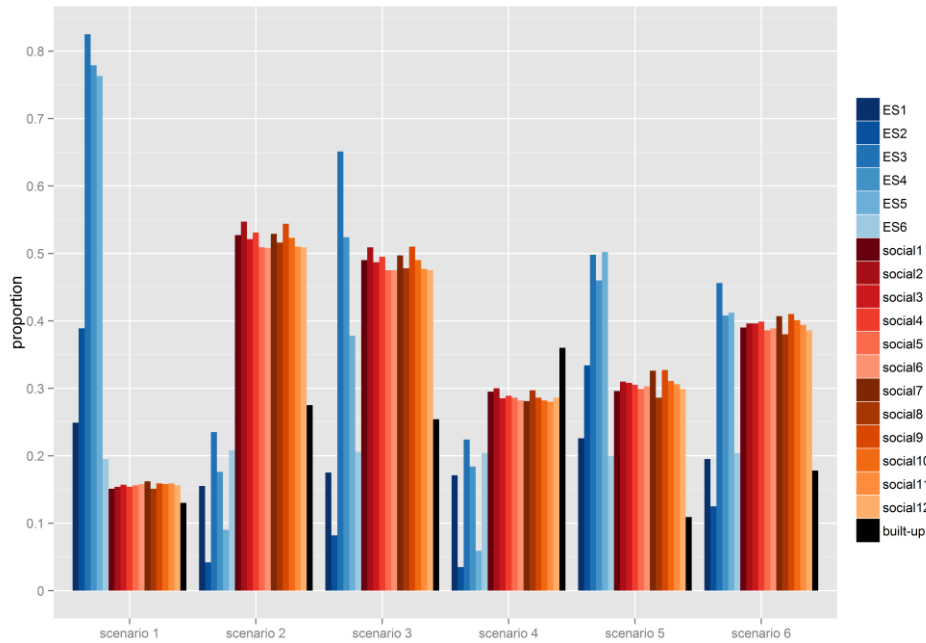
Social value	AUC values	
	training	test
Aesthetic value	0.984	0.986
Biological diversity value	0.989	0.982
Cultural value	0.983	0.977
Economic value	0.979	0.954
Future value	0.983	0.968
Historic value	0.978	0.974
Intrinsic value	0.986	0.984
Learning value	0.980	0.974
Life sustaining value	0.985	0.990
Recreation value	0.979	0.980
Spiritual value	0.984	0.966
Subsistence value	0.976	0.970

### 3.6 Proportions of ecosystem services, social values, and development preferences

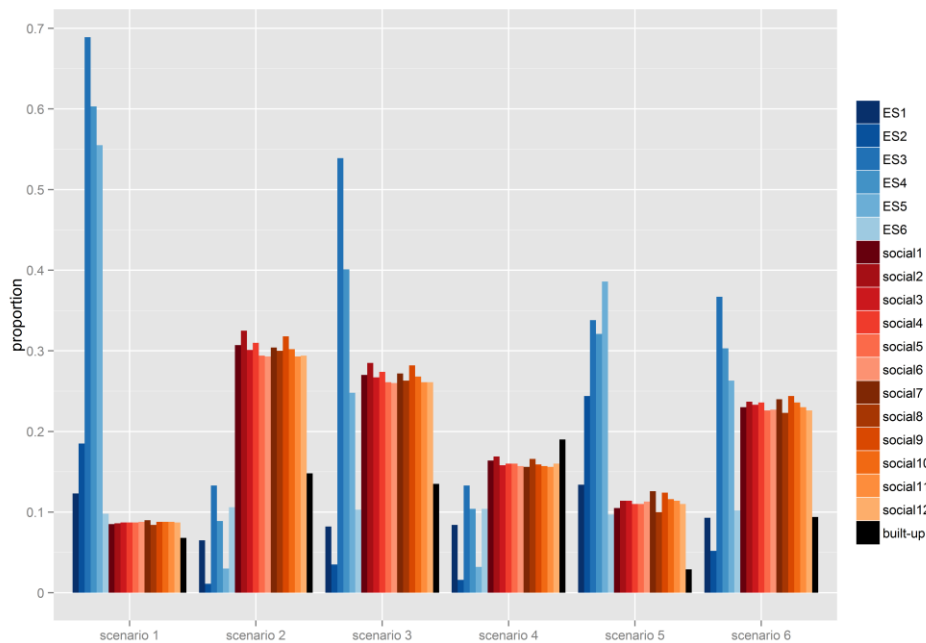
Figure S8 illustrates each of the proportions derived from the six spatially prioritized conservation area scenarios discussed. In scenarios 1 and 2, the top 30% high priority conservation areas have proportionally higher ecosystem service (“ES 1-6”) and social value (“social 1-12”), respectively. These scenarios correspond to spatial prioritization regimes that only consider ecosystem services and social values. In scenario 3, target conservation areas have high proportions of both ecosystem services and social values. The proportion of development preference (“built-up”) is high in scenario 4, relative to ecosystem services and social values. In both scenarios 5 and 6, development preference is proportionally lower than in scenario 3. Similar tendencies are shown in figures S9 and S10 for the top 10% and 20% high priority conservation area.



**Figure S8** Proportions of ecosystem services, social values, and development preferences in the top 30% target conservation areas for six different scenarios.



**Figure S9.** Proportions of ecosystem services and social values, and development preference in the top 20% target conservation areas for six different scenarios.



**Figure S10.** Proportions of ecosystem services and social values, and development preference in the top 10% target conservation areas for six different scenarios.

## References

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