

Assessing cultural ecosystem services supply and demand using Agent-based modeling:

A trail-based approach incorporating hiking activities

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Intro

» This study: provides the novel approach for assessing cultural ES (at indiv-scale)

» Since MEA (2005), global efforts: integrate ES into policies

- Supply: typically aligns with MEA
- Demand: has diversified (varied data sources)

Provisioning
Regulating
Supporting
Cultural

» Mismatch between supply and demand

- For effective & balanced resource allocation
- Provisioning, regulating, supporting ES:

Measured through large-scale human activities (tree planting, restoration of lands, etc.)

Intro

» **This study: provides the novel approach for assessing cultural ES (at indiv-scale)**

» However, how about small-scale direct activity-based assessment?

- i.e., Hiking, Trekking, Tour, Walking, Jogging... -> limited research
- People deliberately consume cultural ES (Recreation / landscape service) through indiv activities, forming the basis for assessing the supply and demand of ES
- Cultural ES uniquely suitable for indiv-scale assessment due to individual engagement

» Why matters?

- Indiv scale -> more flexible, observant, applicable -> ES-related policies and allocation of ES resources.

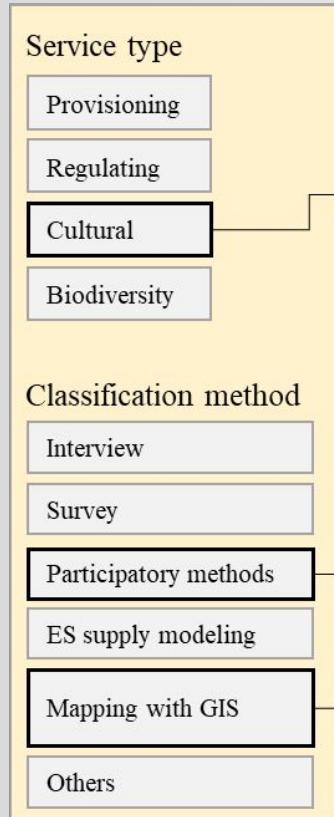
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Previous study**This study****Estimating ecosystem services****Service type**

- Cultural Service
 - Landscape
 - Recreation

Classification method

Discovering supply Indicators,
Assign weight for scoring
by Delphi approach

**Quantifying and Mapping
scores of cultural service****1) ES supply estimation**

Map-based supply score
estimation approach

Trail-based supply score
Estimation approach

2) ES demand estimation

Agent Based Modelling of
individual hiking

Trail-based demand score
Estimation approach

3) ES supply-demand mismatch assessment

Map-based Approach

vs

Trail-based supply

vs

Trail-based demand

: Adopted approaches
: Proposed approaches

Data

- 1) Land use and cover data
- 2) Forest map
- 3) National land and env.
assessment map

Delphi analysis

Map-based approach

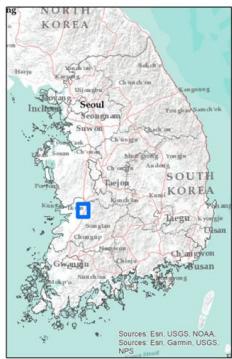
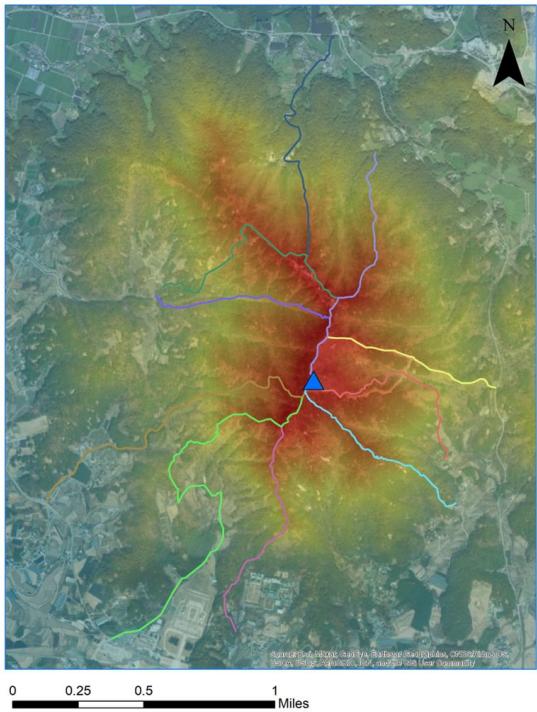
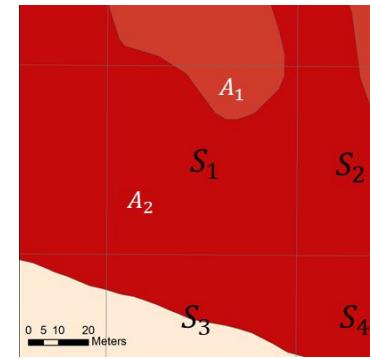
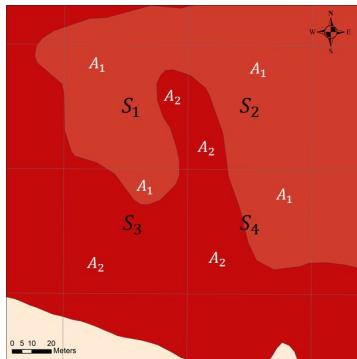
Trail-based supply

Trail-based demand

- » To discover indicator of assessing cultural ES and assign score criterion to each indicator

data	ES	Class	Score
Land use and land cover map	Recreation service	Arid and semi-arid regions	0
		Cultural and sports leisure facilities	2
		Inland wetlands	5
		Natural environments	8
		Agricultural areas	7
		Forested areas	10
	Landscape service	Arid and semi-arid regions	1
		Cultural and sports leisure facilities	2
		Inland wetlands	9
		Natural environments	7
		Agricultural areas	5
Forest map	Recreation	Forested areas	10
		Grassland without tree species	5
		Cultivated areas	0
		Excellent natural environments	7 to 10
	Landscape	Artificial and natural forest	7 to 10
		Non-forest / non-vegetated area	5
		Artificial and natural forest	10
		Grassland without tree species	5
		Other factors	7

...

Delphi analysis**Map-based approach****Trail-based supply****Trail-based demand****DEM**

$$T = \sum_{j=1}^n \sum_{i=1}^m \left(\frac{C_i \times A_i}{S_j} \right) \dots \quad \text{Equation 1. Grid-based scoring}$$

where

T = Total scores

n = The number of grid

m = The number of irregular shaped polygon i in grid j

C = score of one grid

A = Area of irregular shaped polygon

S = Area of one grid

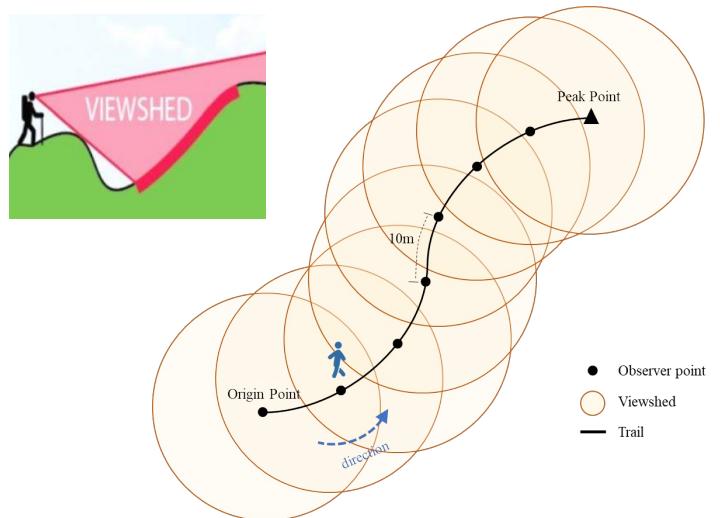
Delphi analysis



Map-based approach

Trail-based supply

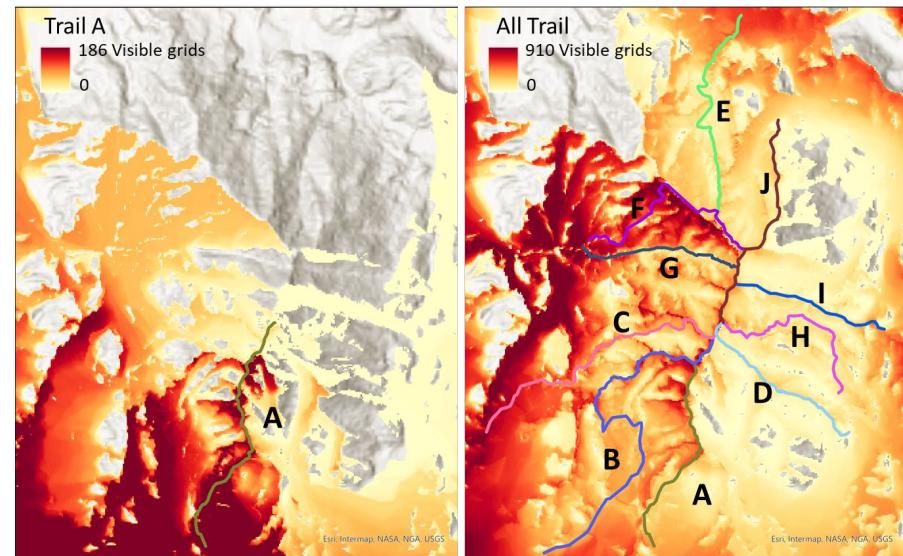
Trail-based demand



where

C_j = The number of raster grids from the observer point j

$score_j$ = grid - based score in each point j



Delphi analysis

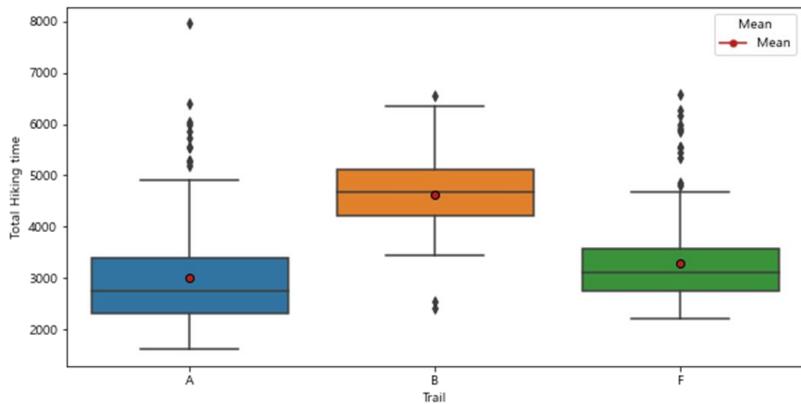


Map-based approach

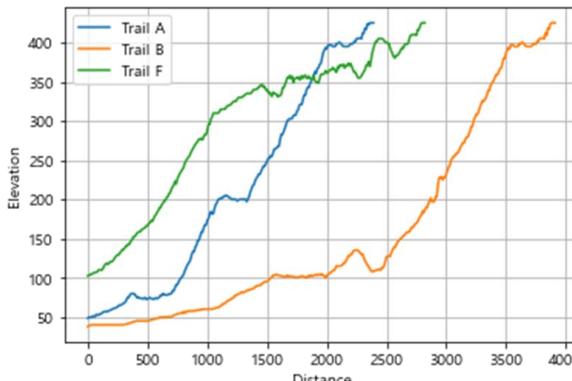
Trail-based supply

Trail-based demand

» Build Agent-based modeling simulation (ABMs) – select A, B, F trails



* Observed data:
Ramblr application (1,010 hikers)



$$T_d = \sum_{j=1}^n (C_j \times score_j \times t_j) \quad \dots \text{Equation 3. Total demand score from each person}$$

where

C_j = The number of raster grids from the observer point j

$score_j$ = grid-based score in each point j

t_j = the time taken at each point j

Delphi analysis



Map-based approach

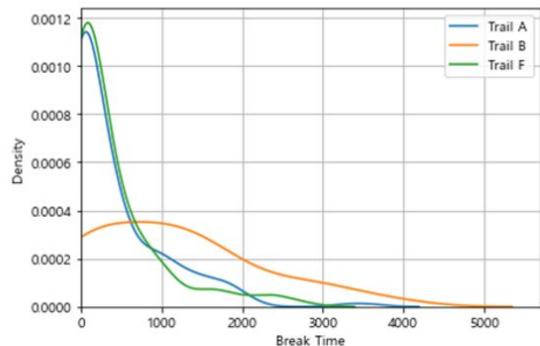
Trail-based supply

Trail-based demand

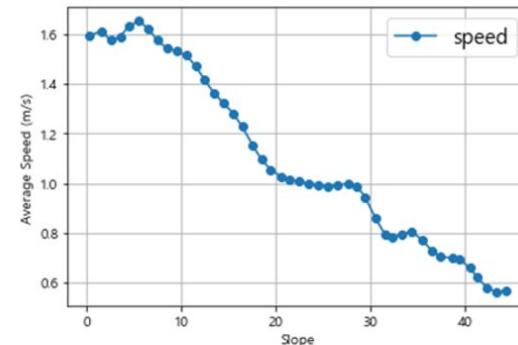
» Build Agent-based modeling simulation (ABMs) – select A, B, F trails

< parameters >

- 1) Stamina: 1000~2000, calibration
- 2) sta_decrement: 2~10, calibration
- 3) break_thres: 0~100, calibration
- 4) break_time: from observed data
- 5) vel_slope : from observed data
- 6) peak_break : from observed data



(a)



(b)

(a) break time by trails, (b) speed by slope

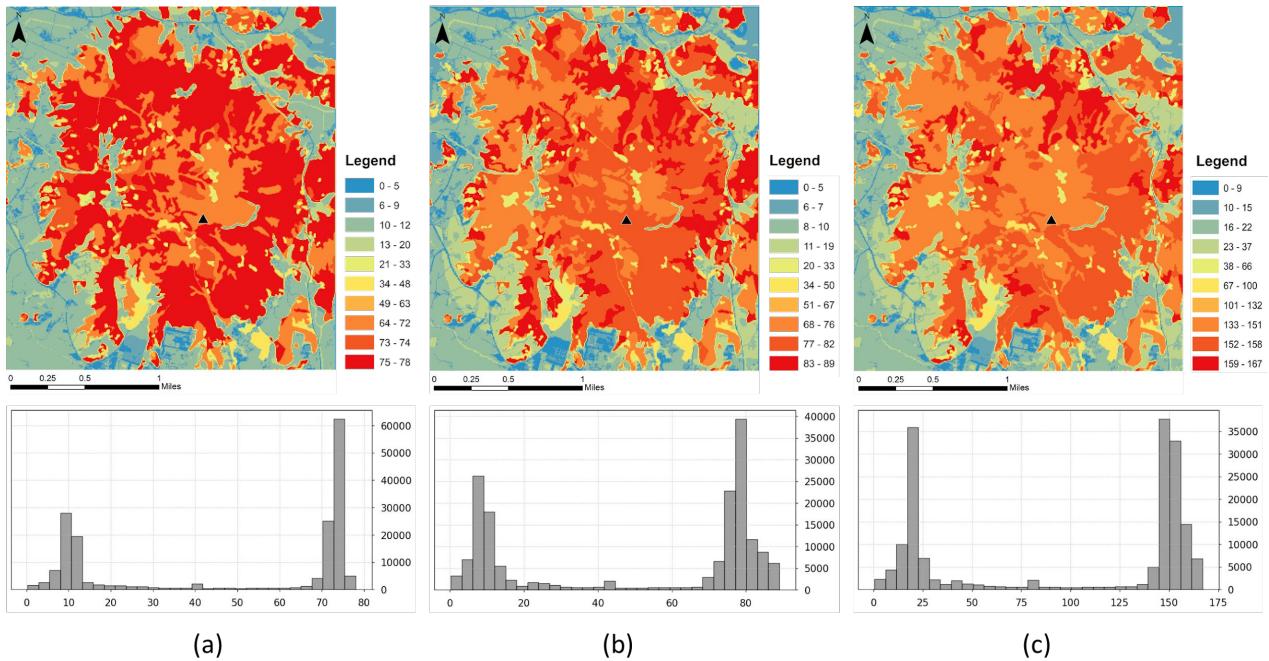
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Delphi analysis**Map-based approach****Trail-based supply****Trail-based demand**

Map-based cultural ES supply score:

(a) Recreation, (b) Landscape (c) Total Culture

Recreation: radial shape

Landscape: less concentrated

Cultural:

- Northern: high
- Southern: low

1. Trail-based supply

3. Result

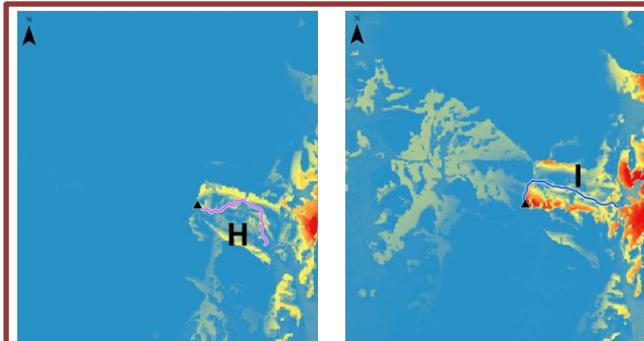
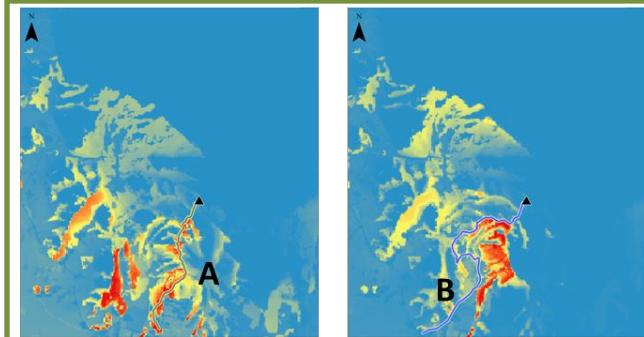
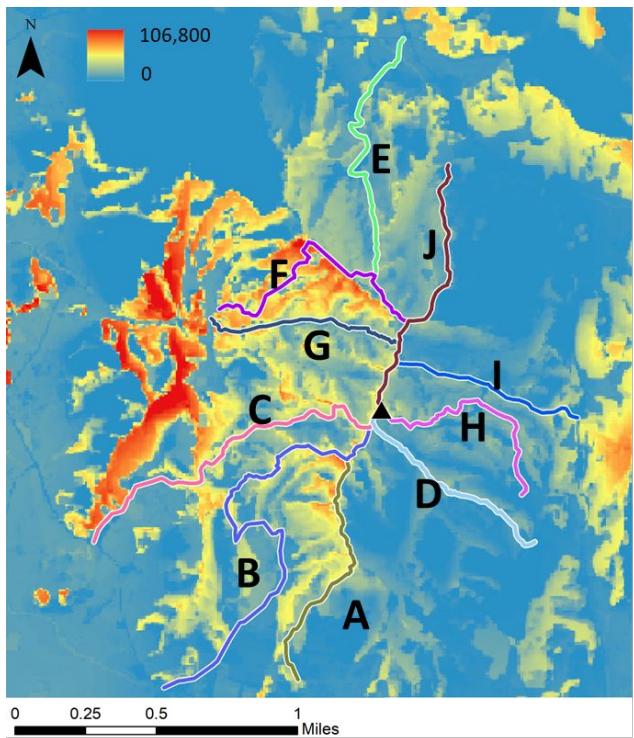
Delphi analysis



Map-based approach

Trail-based supply

Trail-based demand



Trail	Rank
A	2
B	1
C	5
D	10
E	3
F	4
G	7
H	9
I	8
J	6

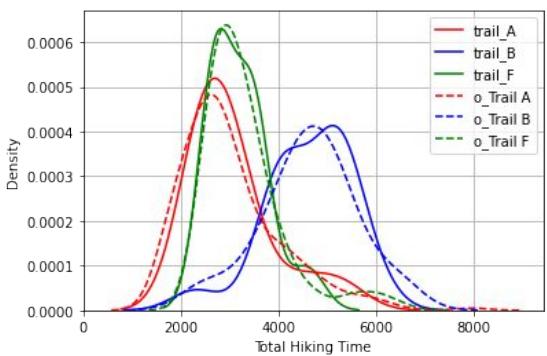
Delphi analysis



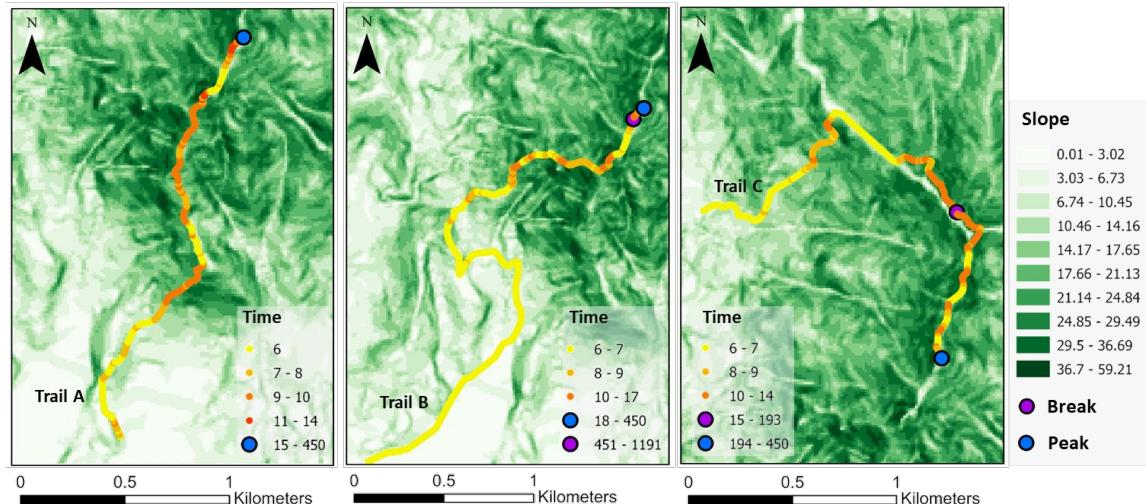
Map-based approach

Trail-based supply

Trail-based demand



Result of model validation with calibrated parameters



(a)

(b)

(c)

Individual hiking simulation result of each trail:

(a,b,c: 10m intervals of spending time)

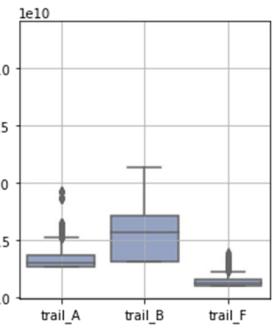
Delphi analysis



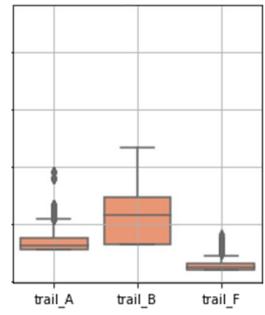
Map-based approach

Trail-based supply

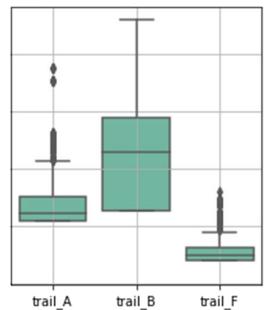
Trail-based demand



(a)

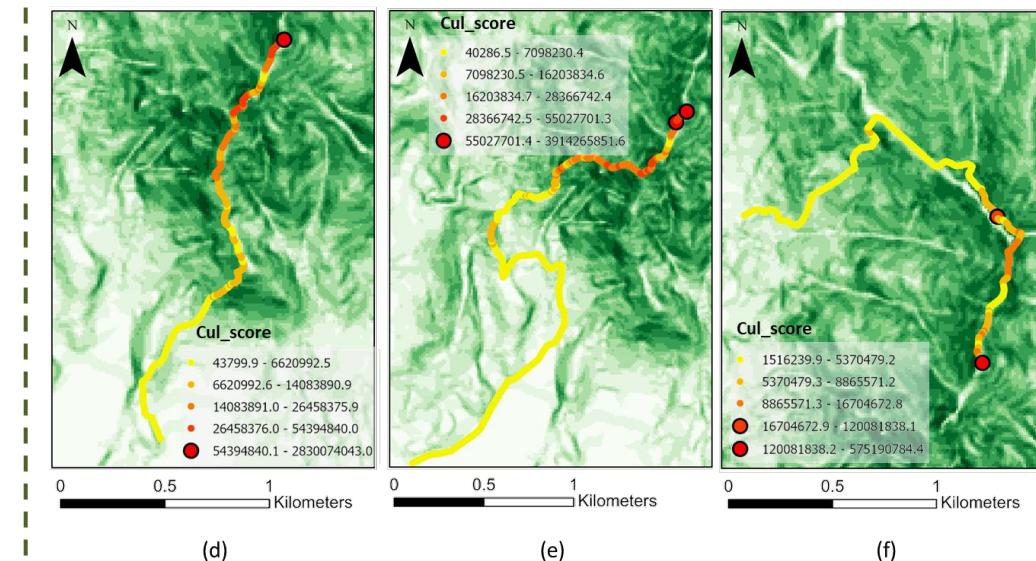


(b)



(c)

*Trail-based cultural ES demand score
(a: recreation, b: landscape, c: culture)*

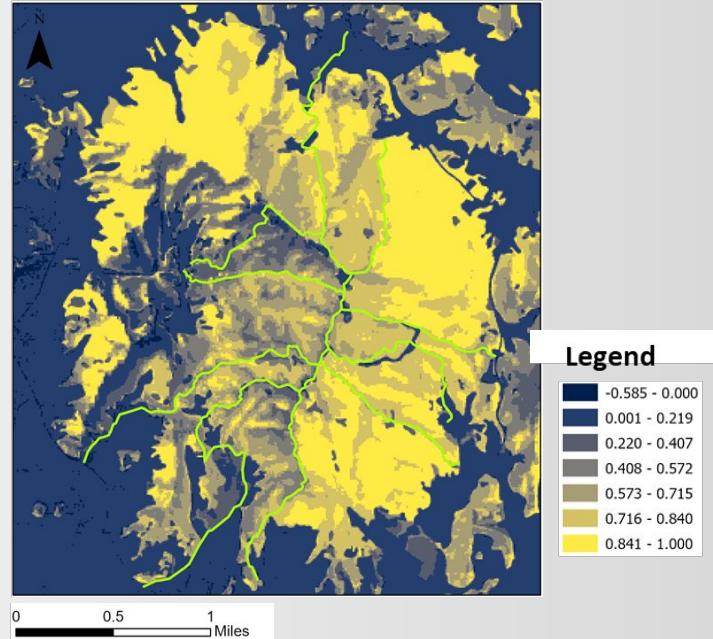
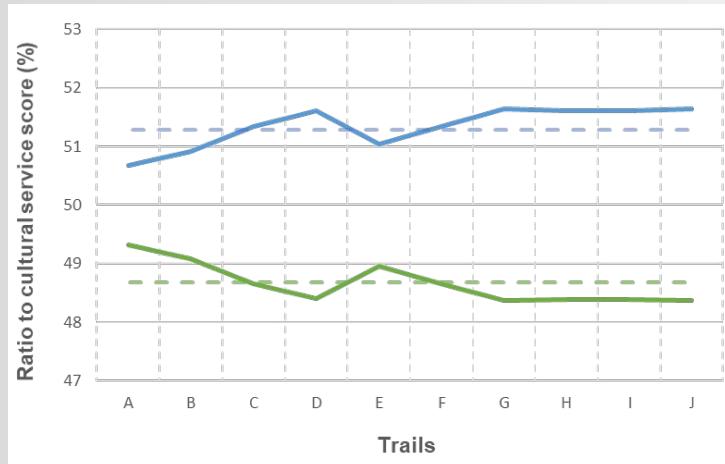


Individual hiking simulation result of each trail:

(d,e,f: cultural ES demand scores on trails A, B, and F)

1. Comparison of cultural ES supply scores between Map-Based and Trail-Based Approaches

» normalized supply score



*Spatial comparison of cultural ES supply score
Between Map-based and Trail-based approach*

2. Mismatch exploration between trail-based cultural ES supply score and demand score

The number of hikers over seasons

Season	Trail	# Hikers
Spring (March)	A	2,778
	B	889
	F	1,333
Summer (July)	A	2,889
	B	333
	F	1,222
Fall (October)	A	3,445
	B	555
	F	1,222
Winter (January)	A	2,556
	B	111
	F	1,111

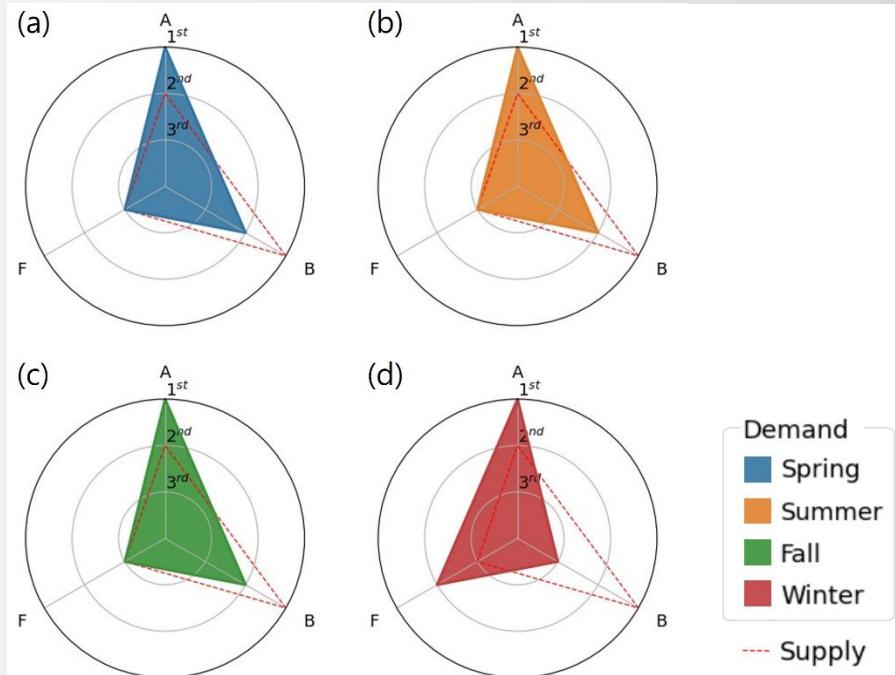


Figure 14. cultural ES supply and demand score rank by season

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» Introducing a New Method: Incorporating Hiking Activity based on trails

- Our approach allows **localized and detailed** analysis of ES scores on each trail, contrasting map-based measurements in traditional methods.
- Relative amount / rank of these service scores varies along different trails.

» Mismatch in Supply and Demand Scores

- We checked discrepancy between rankings of supply scores and actual demand scores.
- Different ranking orders in different seasons highlight **the necessity of considering factors** such as seasonal hiker numbers, socio-economic characteristics, and demographics.

» Future study

- Incorporating **additional layers**: high-resolution imagery, biodiversity indicators, and cultural heritage
- Considering **seasonal variations of supply score criterion** to establish an improved scoring system

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Thank you

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