

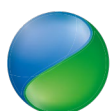


Consultation on BioDT draft Cultural Ecosystem Service Digital Twin

Responses to structured interviews BES
2024

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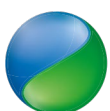
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Executive Summary

Interviews were conducted at British Ecological Society meetings in Liverpool 10-13 Dec 2024. The interviews consisted of an introduction to the digital twin and an invitation to provide personal views via a semi-structured feedback tool accessed by a QR code or on paper.

The interviews focused on (i) the graphical user interface, (ii) the components of both the (ii) recreational and (iii) species distribution models and (iv) the sustainability of the digital twin following the completion of the BioDT research project. For the graphical user interface and the models, the format was bold statements which the interviewee had to mark their level of agreement using a 5-point Likert scale. If the interviewee was unfamiliar with the technical details of anything e.g. species distribution models they were invited to select the neutral option. If they disagreed with the statement or had additional thoughts, they were encouraged to write them in the open question which followed the Likert scale question.

The prototype digital twin trailed with participants was demonstrated and a handout explaining the main features given to 77 people, 58 provided feedback via the tool and one sent an email with their thoughts (75% response rate).

The prototype digital twin (pDT) was well received with the concept of linking recreational potential maps with the probability of viewing biodiversity considered very relevant.

The overall conclusions were:

- Most respondents considered the three base maps provided in the digital twin sufficient (74%) but several commented that the addition of the OS map or a cost-effect alternative would be helpful.
- Most respondents agreed that the filters were a useful addition to the graphical user interface of the pDT for both the recreational potential (78%) and species (93%) occurrence but questioned why it was possible to move the slider in both directions.
- Most respondents (88%) agreed that viewing the probability of encountering a specific species or multiple species (e.g. all birds) was valuable.
- The colour scheme was questioned by many respondents even when they scored the question positively. Many recognised that there was a lot of information to impart but considered the present colour scheme unclear.
- The use of additional tabs such as viewing supplementary information on other web sites or apps was welcomed with suggestions in addition to the biodiversity including route planners, public transport routes and timetables, and weather apps.
- There was general agreement that the recreational potential model incorporated the main elements (72%) but concern that the user may need



to parameterise the model with 87 parameters, the concept of personas to choose from and only alter specific parameters of interest to the user was suggested.

- Over 90% of respondents considered the 20 m resolution of the digital twin output map sufficient but many respondents considered that both the recreational potential and biodiversity data should be seasonally adjusted and not only updated annually.
- Species distribution models were considered a sensible approach for the biodiversity aspect of the digital twin, but it was recommended by many respondents that other biodiversity datasets not just citizen science data should be used.
- Funding to ensure sustainability of the prototype digital twin from some government source was favoured by 81% of respondents. The reason given were typically either because they considered the digital twin a public good or because restricting the knowledge was seen as fostering inequality or they did not think private subscription would be commercially viable.

Many people were complimentary on the work completed so far writing statements such as *Congratulations, amazing tool, and Great job!!!*

1. Introduction

The Biodiversity Digital Twin (BioDT) project is an innovative EU funded project ([About | BioDT](#)), offering advanced simulation and prediction models to tackle critical global biodiversity challenges. This report centres on the Prototype Digital Twin (pDT) for Recreation and Biodiversity Cultural Ecosystem Services. This use case is focused on the management of the cultural ecosystem services provided by landscapes.

Cultural ecosystem services encompass non-material benefits people obtain from ecosystems, such as recreation, tourism, intellectual development, spiritual enrichment, and aesthetic experiences. Biodiversity is central to these services as it enhances human experiences and connects people to nature. This prototype digital twin integrates models to assess both the physical landscape's recreational potential and the biodiversity component, offers dynamic insights into how these services are accessed, used and importantly how they can be managed sustainably.

This report details the result of interviews conducted at the British Ecological Society meetings in Liverpool 10-13 Dec 2024. The interviews consisted of an introduction to the digital twin and an invitation to provide personal views via a structured feedback tool accessed by a QR code. The feedback tool was also available in paper form.



2. Method

All interviews were conducted by a single member of the project BioDT team (Jan Dick) at the ACC Liverpool (King's Dock, Port of Liverpool, Kings Dock St, Liverpool, UK, L3 4FP). Participants at two sequential events were targeted as they brought together policy makers, land managers, scientists and individuals who may recreate in nature.

On the 10th December the National Environment Monitoring Conference ([National Environment Monitoring Conference - British Ecological Society](#)) was held which sought to bring together those who either delivered, used or could benefit from information provided from a wide range of national monitoring activities across the four UK nations e.g. biodiversity monitoring schemes. This one-day conference took place the day before the British Ecological Society Annual Meeting at the same venue 11-13 Dec 2024 ([BES Annual Meeting 2024 - British Ecological Society](#)). Targeting both events was a cost-efficient way of obtaining feedback from individuals who understood the technical aspects of the recreational and species distribution models and a cohort of individuals who enjoyed recreating in nature.

The interviewer usually approached potential interviewees in the lunch and coffee breaks or in the social spaces offered at the venue during sessions. Typically, she approached either groups or single people who were not obviously in a meeting and invited them by handing them individually the invitation leaflet (Annex 1). She also invited all potential respondents to read the Participant Information Sheet (Annex 2) explaining that this study has been reviewed and given favourable opinion (HREC0058) by UK Centre for Ecology & Hydrology Human Research Ethics Committee (UKCEH-HREC).

The interviewer gave each person a sticky button badge (Fig 1) which she typically attached to their name badge enabling the tracking of the number of invitees and number of completed interviews (also avoided inviting people twice). In addition to the information provided in the handout (Annex 1) she frequently demonstrated the prototype digital twin using a portable computer. She typically highlighted the three base maps (and ability to toggle to grey scale), the difference between the hard and soft recreationalists and the users ability to filter outputs and select individual or multiple species. She then invited people to play with the computer themselves, while she explained the survey questions (Annex 3) and then invited the potential participants to scan the QR code to access the questionnaire and record their opinion of the prototype digital twin.





Figure 1. Button badges given to invited participants enabling tracking of the proportion of invitees who accepted the invitation to be interviewed and the number who completed the questionnaire.

After explaining the model and feedback form, participants were left uninterrupted to work through the questions at their own speed. She was happy to answer questions or discuss issues raised by the participants. During the discussions the interviewer encouraged the interviewee to express their opinions in their own words following discussions (Fig 2). She particularly encouraged participants to write in the feedback tool any comment which had not already been mentioned by another respondent.

Periodically, (typically 2-3 times a day) the interviewer recorded her own summary of the points noted to date. This was to ensure all comments were recorded in case an interviewee did not write in the tool something that had been mentioned.

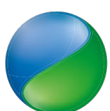




Figure 2 Participants offering their opinions in the survey tool on their mobile phones after trailing the prototype digital twin.

One potential interviewee working at the event did not have time to complete the feedback tool but asked if she could write a paragraph with her thoughts. They sent an email the following Monday which is provided below:

Sent: Monday, December 16, 2024 1:01 PM
To: Jan Dick <jand@ceh.ac.uk>
Subject: Paragraph on recreation biodt.eu

CAUTION: This email originated from outside of the organisation. Do not click links or open attachments unless you recognise the senders email address and know the content is safe.

Hello Jan,

Here is my paragraph:

During the pandemic, selecting a green space for a walk was fairly easy as we stayed local because at the time we lived in Sheffield. I regularly went for walks to my favourite park; the Bole Hills which became my favourite because it was atop a hill, and it had the most amazing views.

After we moved to London, selecting a park to have a walk was based on:

Distance to the park

Underground tube lines that were running that day

The weather

Sunset time (only during darker months)

Necessary shopping

And of course, a lot of those factors were interlinked. For example, if we simply wanted a chance to walk through a park with minimum time because we needed to do shopping afterwards, Hyde Park would be ideal as it's near Oxford Street.

For me at least, part of the fun of walking in a park is not knowing what will be there in terms of water bodies, species etc. Being in flat London I do miss the hills of Sheffield, and every time we go back to Sheffield, I always like to return to the Bole Hills no matter what the weather.

I hope the above paragraph helps. If you are looking for quotes too, I'm happy for you to use the above.

Regards,



3. Results

In total 77 people were invited to offer their opinion on the prototype digital twin and 58 responses were logged in the response tool (response rate of 75%). The most common reason for declining to participate was time constraints as attendees were transiting to another conference session. In addition, several people listened to the demonstration, took the handout, opened the QR code on their phone and said they would complete later, it was not possible to determine if they did, but one response was lodged on 23 Dec 2024 indicating that at least one person did offer feedback after the event.

3.1 Characteristics of interviewees

Most of the respondents (91%) selected to complete the feedback tool from the perspective of a recreational/wildlife enthusiasts/citizen scientist with only five individuals selecting land manager/policy end user (Fig 3).

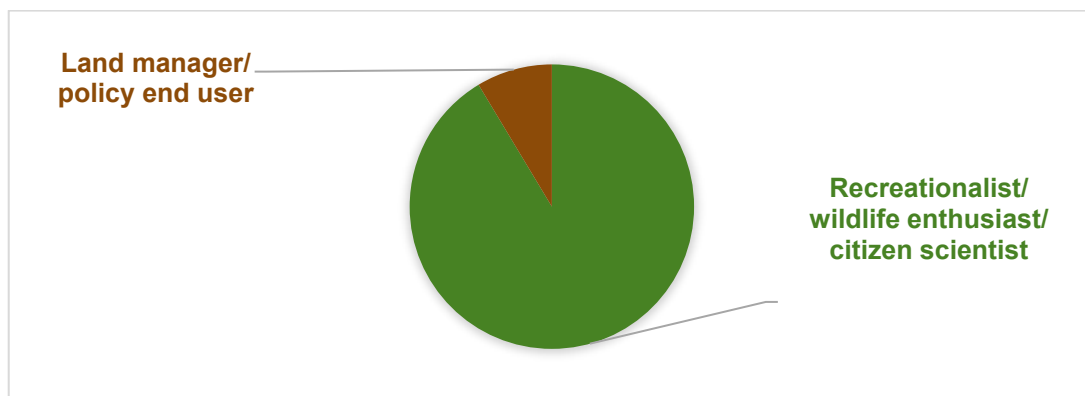


Figure 3. Response to the question “Please select the view point you want to adopt while completing this questionnaire” n=58

None of the five respondents selected land manager in the later questions (Table 1). Four reported an academic affiliation/role suggesting that they were involved in advising on policy formation. One respondent who attended the National Environment Monitoring Conference reported they were a conservation officer involved in monitoring, but it is not possible to say if they actively managed land. It is concluded that most responses therefore were not considering the utility of the pDT from the prospective of a land manager.

Table 1. The role and affiliation of the five respondents who selected to consider the prototype digital twin from a land manager/policy end user perspective.

Q2. Please elaborate on the role you selected to help us understand your perspective	Q12. The type of organisation/institute you are affiliated with	Q14. What is your role?
Conservation officer working on a specific piece of land to conserve wildlife	Wildlife charity	Practitioner monitoring officer
I'm a university researcher and would like access to the data.	University	Research fellow
I'm not from the UK, from Libya.	University	Lecturer
Native reasonably fit - walking and photography. Science research in upland issues- mainly ?? and bracken. Plant surveying in the Highlands for BSBI	retired ex university	retired prof
Ecology Professor	University	Senior researcher

Unsurprisingly most respondents were associated with a university (Fig 4); 59% of respondents' self-reports an affiliation with a university while almost a fifth (19%) were affiliated with a research centre such as the Meteorological Centre. In total 8 respondents (14%) self-reporting they were affiliated to a commercial company/business, these were exhibitors of equipment at the event or self-employed ecologists.

Almost a third of respondents did not identify with any of the roles offered in the feedback tool choosing the 'Other' category. It was clear when conducting the interviews that some respondents were unsure if they were junior or senior researchers. Eight of these respondents were reassigned primarily to either junior or senior researcher if associated with a university or research organization depending on their age. The remaining nine respondents occupied management roles, senior position in a company or were retired.

Following reassignment 24% of respondents self-reported their role as a PhD student, or a junior (21%) or senior researcher (21%). No respondents reported that their role was a land manager or a consultant (Fig 5).



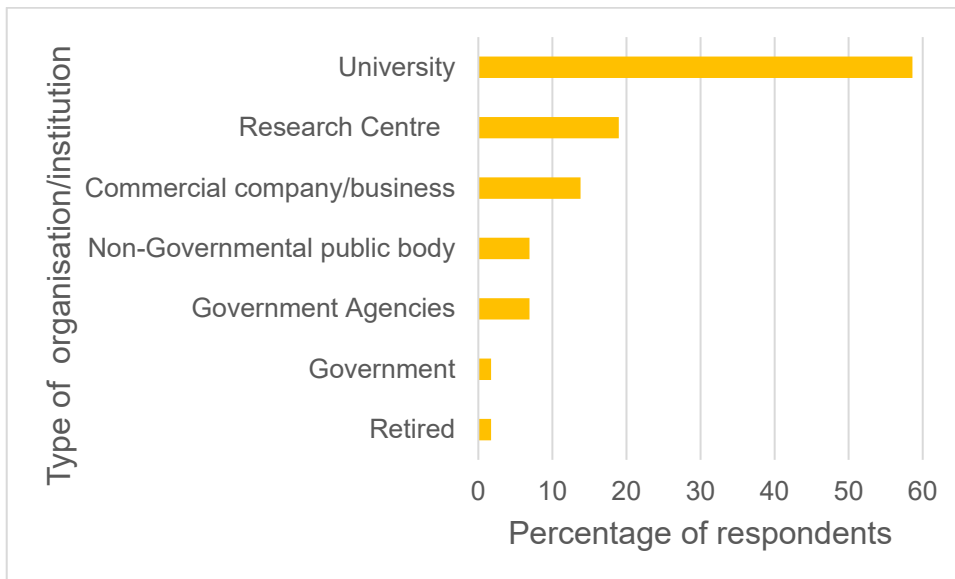


Figure 4. Self-reported type of organisation/institute with which respondents were affiliated (n=58).

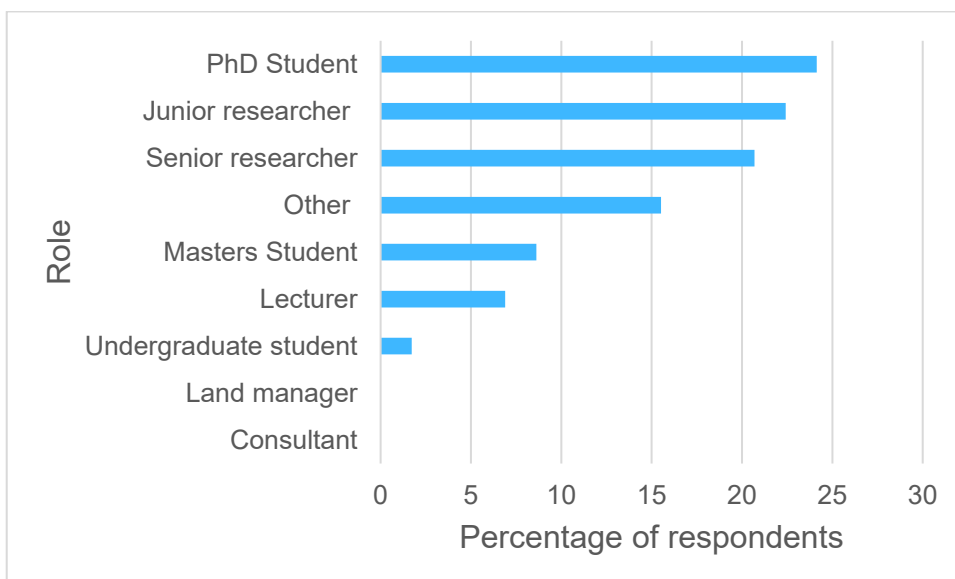


Figure 5 Self-reported role of respondents (n=58)

The age groups sampled reflected the population attending the events. The majority were young researchers although a few old, retired individuals agreed to take part in this study (Fig 6).

All respondents self-reported their gender. Almost equal number of female (30) and males (28) were interviewed.



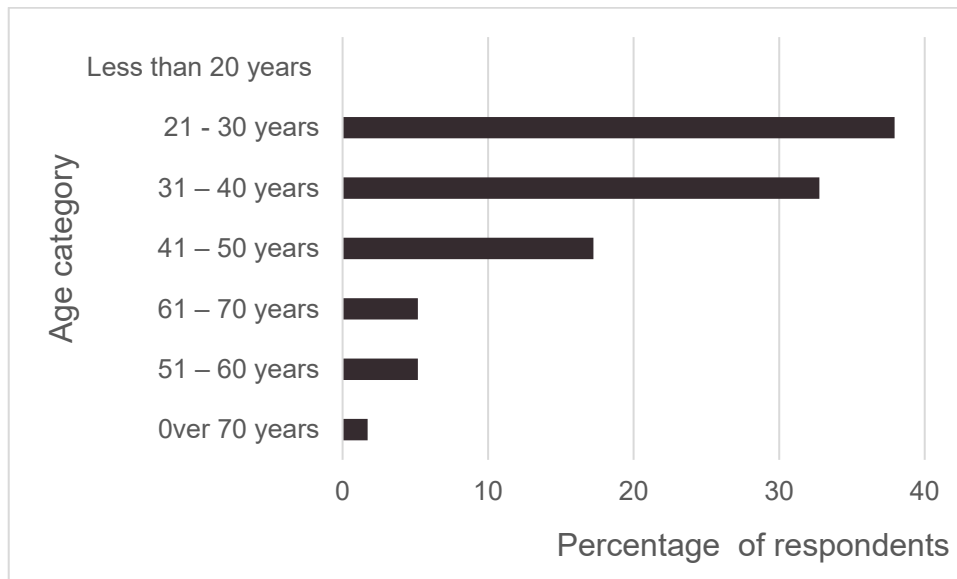


Figure 6. Self-reported age range of respondents (n=58)

3.2 Response time

Interviews generally took between 15-30 min depending on the length of time the respondent trailed the pDT following the demonstration. The total time the interviewer spent offering their opinion in the feedback tool can be judged approximately from the time the respondent was engaged with the feedback tool after scanning the QR code (Fig 7). This time is only indicative of the length of the interview because it was observed that some respondents immediately opened the feedback tool when given the handout and then listened to the demonstration, tested the pDT and discussed the pDT with the interviewer while others only scanned the QR code after a full discussion with the interviewer. Several respondents listened to the demonstration took the handout and said they would complete the feedback later. It is probable that the respondent approached at the start of the lunch break on the 10th December at the National Environment Monitoring Conference opened the feedback tool and then had lunch before completing the feedback questions and closing the tool (start time 11:57:55 close time 13:24:21 duration 01:26:26). The interviewer considered that interviews were seldom longer than 45 min.



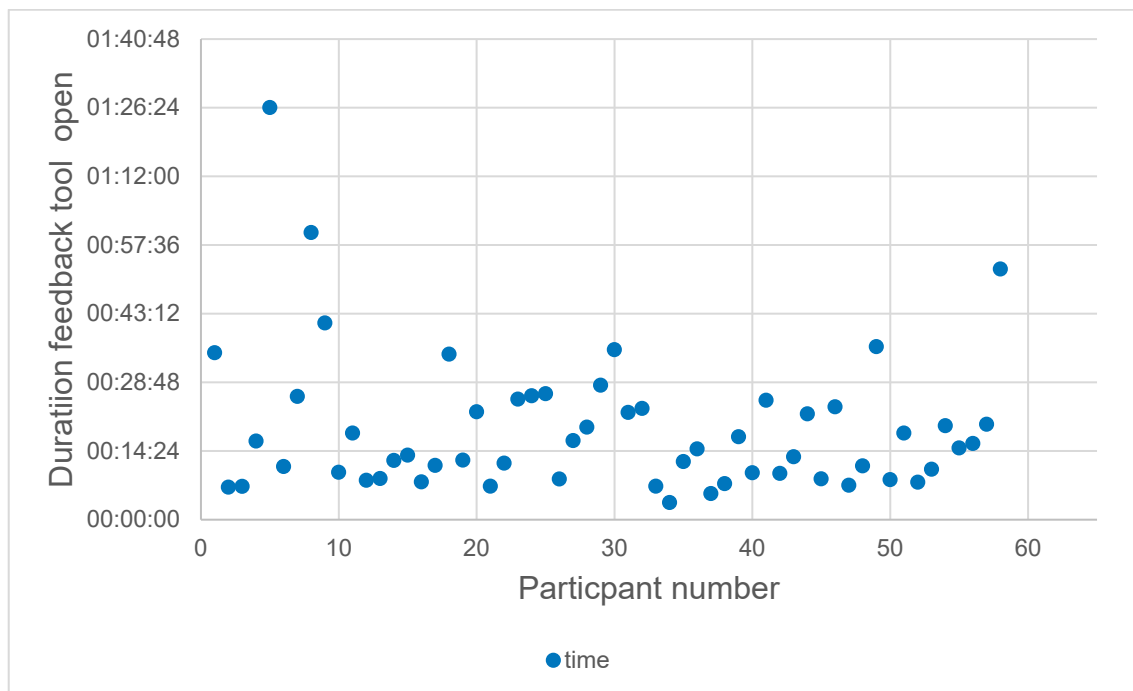


Figure 7 Duration (hh:mm:ss) the respondents had the feedback tool open after scanning the QR code (n=58).

3.3 Graphical User Interface

Base maps

Most respondents considered the three base maps were sufficient (74%). Three respondents either disagreed or strongly disagreed (Fig 8). Only one respondent offered a reason for their negative score to this question suggesting that the official OS map could be useful. They wrote:

- *I think integrating a map such as the OS map (or cheaper equivalent) showing the positions of footpaths would help people plan routes. This could replace the infrastructure section [of the model] honestly.*

In discussion they considered the three elements of the infrastructure component (Paths, Road tracks, and Cycle network) could be found from the OS map and they considered they would prefer these features simply to be seen rather than scored and incorporated into the pDT.

Others also considered OS maps as useful (Table 2), one respondent who scored that they agreed that the three base maps were sufficient wrote:

- *Ordinance survey map would be useful.*



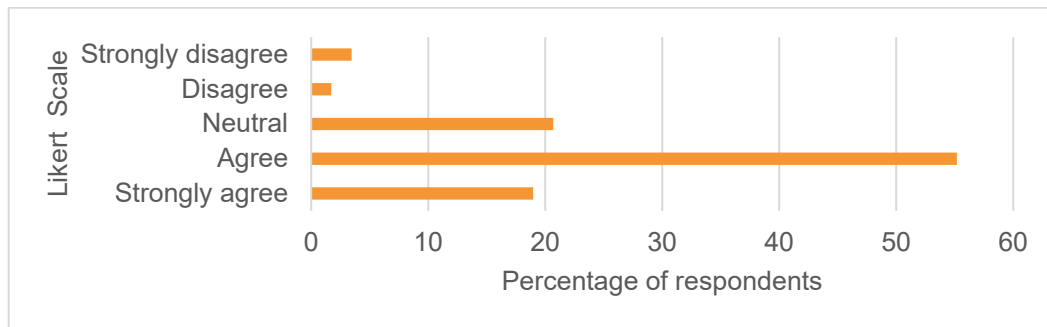


Figure 8 Responses to the question 3.1 'The choice of three base maps is sufficient'

Table 2 Respondents opinion of the Graphical User Interface. Q3.1-3.7 are the individual Likert scale scores respondents provided on the base maps (Q3.1), ability to use sliders to the maps recreational (Q3.2) and species (Q3.3), the ability to select a single (Q3.4) or multiple (Q3.5) species, the colour scheme (Q3.6) and additional species information (Q3.7) provided, Q4 is text written to elaborate their opinions of the graphical user interface (Q4).

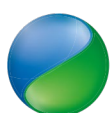
Question 3.							Q4. Please elaborate on your views of the output shown – particularly if you have disagreed with any of the statements above, how can we improve the output e.g. are there other features you would like added to the output for example access to data detailing places other have visited, ability to view routes others have taken, ability to print your map etc.?
1	2	3	4	5	6	7	
1	1	1	1	1	1	1	It's well design and intuitive, it's easy to use and the idea of combining the biodiversity with recreational information is really exciting. The ability to view and plan routes would be a good feature.
1	1	1	1	1	1	1	I believe that is a novel interactive map
1	1	1	1	1	1	1	Graphical interface is clear and concise. Would be nice if the map would draw slightly quicker, but the features are great
1	1	1	1	1	1	1	It looks good
1	1	1	1	1	1	1	I think the colour gradient is helpful for visualising the patterns, and the ability to use the grayscale toggle is very useful
1	2	1	1	1	1	1	x
2	1	1	1	1	1	1	Appreciate the accessible colour palette. Map renders fast. Access to raw data would be helpful.
1	1	1	1	1	2	2	No comments
1	1	1	1	1	1	3	Maybe consider not putting detailed information for protected species.
2	1	1	1	1	3	1	yellow and green tend to blue a bit
2	1	1	1	1	3	1	The colours could be more vivid on the UI. It's also slightly slow.
2	1	1	2	1	2	1	Ordinance survey map would be useful



1	1	1	1	3	3	1	Different colour schemes could be chosen to avoid any conflict with the the base maps. Some text by the scale sliders to give some context to what 0-1 means would be nice e.g. 1 for biodiversity being a 100% chance of encountering that species etc.
1	2	2	1	1	3	1	It should cover broader range of accessibility
1	3	2	1	1	2	1	I would like to be able to filter the recreation map based on some of the underlying data. For example if, one day I was just interested in walking near water, could I just look at those elements of the map and exclude irrelevant variables?
2	1	1	1	2	3	1	Ability to export data would be important. I would experiment with different colour schemes for recreation potential. Yellow as low and blue as high is not so intuitive for me.
2	2	2	1	1	1	2	The app is already great
2	2	1	1	1	2	2	ability to print your map
3	1	1	1	1	2	2	.
2	1	1	3	2	2	1	Interested in overall ecosystem richness rather than just one specific species
2	2	1	1	1	2	3	I think it important to show diversity for different social groups and different abilities.
2	2	1	2	2	1	2	I think it would be good to have a way of indicating accessibility from a starting point e.g. a home post code. Maybe travel times or public transport.
2	2	1	2	1	2	2	Agree with the above statements!
2	2	1	1	4	2	1	Link to specific recreational facilities
2	3	2	1	1	2	2	Clarity of imaging is a little pixelated but workable
2	2	1	2	1	3	2	It's good
2	2	1	1	1	3	3	Potentially add in seasonal affects I.e would an activity disturb during only spring
2	2	1	1	1	4	2	- colour scheme is not intuitive, heat map like cold to warm would be better - the scale on the recreation categories is skewed so most probabilities fall in the >0.45 group - change sp occurrence filter label to probability of spp occurrence - a base map with more info on walks, bothies etc would be good incorporated into the app e.g. OS map - more
3	2	2	1	1	3	1	Colour scheme is a bit unclear but have no proposals, especially considering colour blind people. Need to bring in new datasets.



3	1	1	1	2	3	5	Based on a quick trial of the system I would likely cross reference with OS map data to understand access and footpath locations for recreational activity. The lack of a map key for the layers (at least I couldn't find one) left me uncertain as to where footpaths or byways that would provide access were. A map key or alternate map layer (it may just be my familiarity/comfort with OS maps) might solve this and provide a one stop shop for planning a recreational visit for me. I initially thought the GBIF pages that opened were a distraction and not required for me. If I already know the species I want to search/filter for I wouldn't anticipate needing any further information. If I wasn't sure what something was e.g. a rare plant or insect, the GBIF page on first view seemed too technical for a layman, and that a general overview would be more useful. On closer inspection I found some information that may be useful (description and photos), so familiarity with the pages might allow me to find the snippets that could be useful.
2	3	1	1	2	2	3	Ensure that all colours are colourblind friendly. Personally being able to view biodiversity in areas that I'm in would be really cool, looking at one species at a time.
2	3	2	1	1	3	2	Ability to print map with os features so can be used to navigate. Key hotspots for certain species being clear on the maps. Regularly used routes shown on maps
2	2	2	2	2	3	1	X
2	3	2	1	2	2	2	I think adding recommended walking routes, filtered for the soft and hard recreationalist would be good
2	2	1	2	2	3	2	na
2	2	3	3	2	2	3	Vero well done and useful
2	2	3	1	1	4	1	I need more contrast
3	2	1	1	1	4	2	While completely agreeing palette should be color blind friendly, I think better ones could be found. It's not necessarily clear
5	1	1	1	2	1	3	I think integrating a map such as the OS map (or cheaper equivalent) showing the positions of footpaths would help people plan routes. This could replace the infrastructure section honestly
2	2	2	2	2	3	2	I think the two colour scales can be mixed up a bit
2	2	1	1	2	4	3	I think that multiple species view could be improved, and make easier for users to visually grasps the different species
3	4	1	1	1	4	1	What would help for more passive wildlife enjoyers, would be, to be able to pick a route and THEN see what you can find there. It doesn't have to be that you start with species or families and then pick your route.
2	2	2	3	2	3	2	Could simplify or better training



2	3	1	1	3	4	2	Sliders don't need two handle bars. Lower one is enough, the other hard-coded to 1 What is actually needed is an intersection of the two available maps, derived by multiplying them. If two maps are shown, they should be distinguishable by distinct color schemes
3	3	2	1	2	2	3	Common/popular walks could be a useful addition (including info on walk distance, likely duration, and an easy-moderate-difficult guide
3	2	2	1	1	4	3	I think you should be clear we're the I fo came from, but I don't need the direct link myself.
3	2	2	2	2	2	3	It looks fine
3	3	2	2	2	3	1	I would recommend to improve the loading speed.
2	5	2	2	2	2	2	X
2	2	2	2	3	3	3	Overlapping colours can be a bit unclear
3	2	2	2	2	4	2	It would be good to include land use data and land ownership data
3	3	2	2	2	3	2	N/a
5	3	2	1	3	2	1	Accessibility of the area would be nice to review.
2	2	3	3	2	3	3	It looks quite complex for a recreational user. Would suggest simplicity is a priority if this is targeted at a public audience.
2	2	2	4	2	4	2	Colours are too similar.
3	2	2	3	3	2	3	It looks good and has all the obviously necessary map features
4	2	2	2	2	4	2	1. When the species is present there, I don't understand why there's need to add the slider to reduction the chances of finding it. 2. Same for the recreation potential.
2	3	3	3	3	3	3	haven't see the map

Footnote: Emboldened numbers were missing– replaced with 3=neutral

Q3.1 The choice of three base maps is sufficient;

Q3.2 Ability to use the slider to filter level of Recreational potential shown on the map is vital;

Q3.3 Ability to use the slider to filter the probability of viewing biodiversity shown on the map is vital;

Q3.4 Ability to select a specific species shown on the map is vital;

Q3.5 Ability to select multiple species to be viewed on the map is vital;

Q3.6 Colour scheme is clear;

Q3.7 Ability to view additional knowledge on the species via the GBIF website is vital.



Ability to use sliders to filter level of outputs shown

The majority of respondents agreed that the filters were a useful addition to the graphical user interface of the pDT for both the recreational potential (78%) and species (93%) occurrence (Fig.9 & Fig 10).

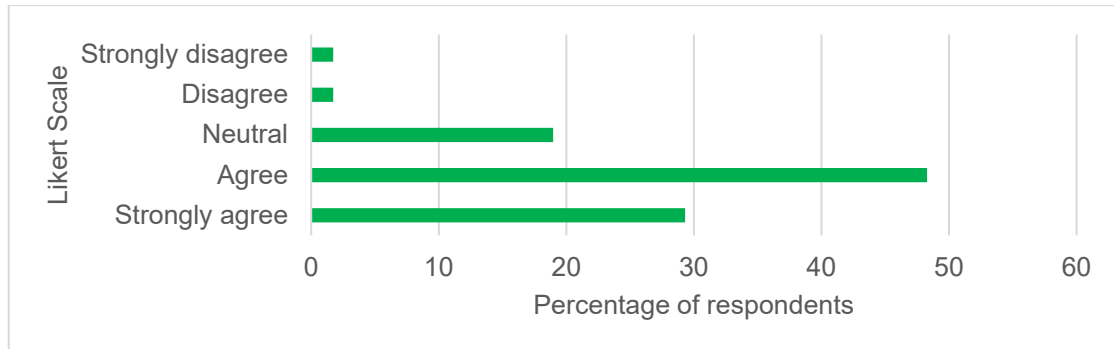


Figure 9 Responses to the question 3.2 Ability to use the slider to filter level of Recreational potential shown on the map is vital.

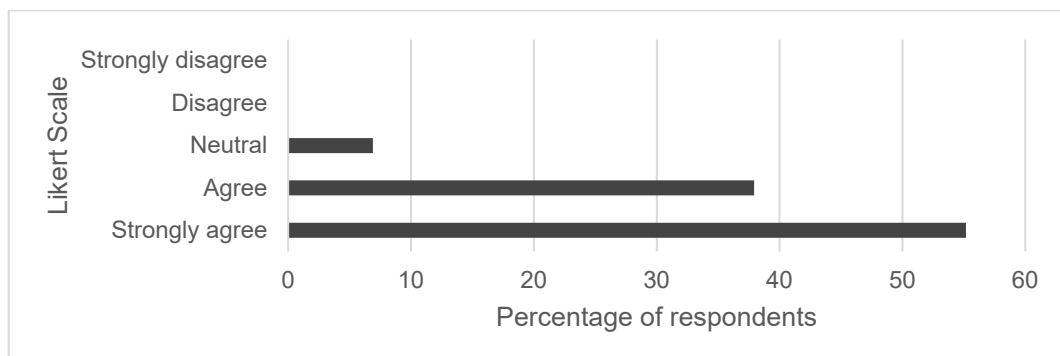


Figure 10 Responses to the question 3.3 Ability to use the slider to filter the probability of viewing biodiversity shown on the map is vital.

A few respondents questioned why it was possible to move the slider from the maximum to a lower value, they considered it important to highlight recreational areas and probability of viewing a species with high probability i.e. without showing the lower values but could not imagine why anyone would want to see areas which were not good for recreation or viewing a species. They wrote for example: *Sliders don't need two handle bars. Lower one is enough, the other [should be] hard-coded to 1*

Several respondent particularly requested the ability to filter the recreational potential map by a specific variable in the recreational model. Although only one respondent wrote in the question asking for elaboration of their views others also commented on the desirability to filter on different aspects of the recreational model. The individual wrote:

I would like to be able to filter the recreation map based on some of the underlying data. For example if, one day I was just interested in walking near water, could I



just look at those elements of the map and exclude irrelevant variables? Another respondent who recommended adding walking routes to the map output suggested an additional filter when walks of a specific type could be filtered. They wrote: *I think adding recommended walking routes, filtered for the soft and hard recreationalist would be good.* This is not currently possible but may be possible in future version of the pDT.

A few respondents questioned exactly what the filter score was delivering and called for more clarity e.g. *Some text by the scale sliders to give some context to what 0-1 means would be nice e.g. 1 for biodiversity being a 100% chance of encountering that species etc.*

Ability to select single or multiple species.

The proportion of respondents (88%) agreed that being able to show the probability of encountering a specific species or multiple species e.g. all birds were valuable (Fig 11 & Fig 12).

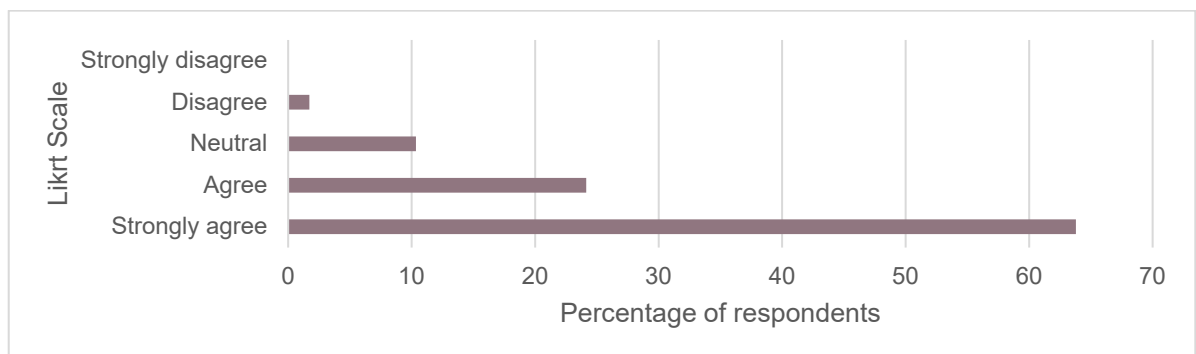


Figure 11 Responses to the question 3.4 Ability to select a specific species shown on the map is vital.

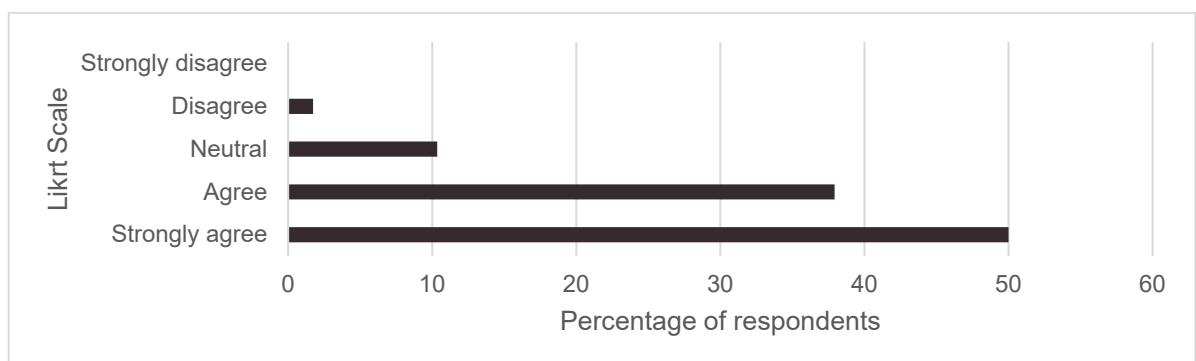


Figure 12 Responses to the question 3.5 Ability to select multiple species to be viewed on the map is vital.

One of the respondents wrote: *What would help for more passive wildlife enjoyers, would be, to be able to pick a route and THEN see what you can find there. It*



doesn't have to be that you start with species or families and then pick your route. This statement highlights the various ways people could use the digital twin (the interviewer had demonstrated the digital twin suggesting people may want to see a particular species and use the digital twin to find places where they would have a high probability of sighting that species).

Colour Scheme

The colour palette for the recreational and species scales was the most frequently discussed aspect of the graphical user's interface. Almost a fifth of all respondents (Fig 13) disagreed with the statement *Colour scheme is clear* (17.5%). Many respondents considered the colour of the scales was not clear but could offer no alternative so marked it as neutral (33%).

Even individuals who scored agreement with this question considered improvement was needed who wrote: *Colour scheme is a bit unclear but have no proposals, especially considering colour blind people.* Others called for *more contrast* or *colours could be more vivid* or commented *two colour scales can be mixed up a bit.* One respondent suggested *a heat map like cold to warm would be better.*

One respondent specifically complimented the use of the grey scale toggle on the base maps writing *and the ability to use the grayscale toggle is very useful.*

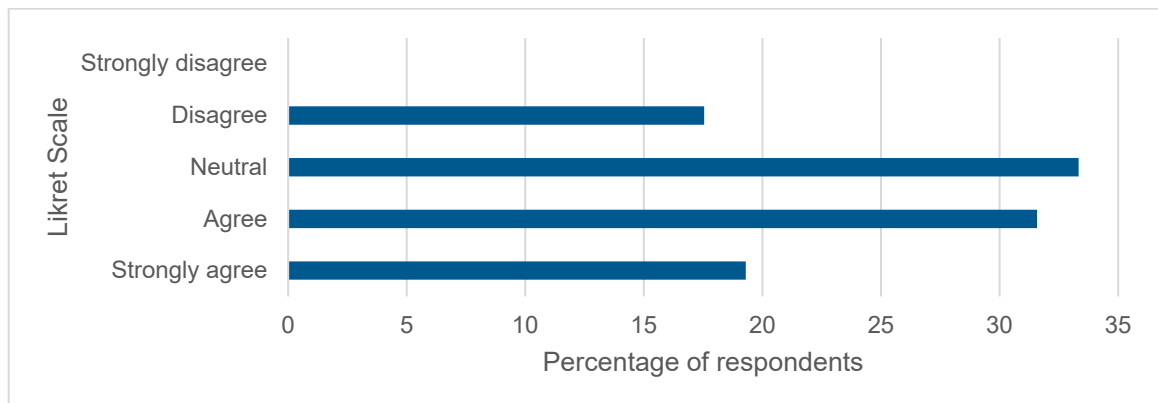


Figure 13 Responses to the question 3.5 Colour scheme is clear.

Ability to view additional species knowledge

Three quarters of the respondents agreed that the ability in the biodiversity tab to view additional species by linking to the GBIF site was useful (Fig 14).

This relatively rapid assessment while welcomed was limited in when the respondent did not spend sufficient time trailing the pDT. One respond thought initially the additional species information was not required but when spending more time trailing the pDT themselves wrote: *I initially thought the GBIF pages that opened were a distraction and not required for me. If I already know the species I want to search/filter for I wouldn't anticipate needing any further information. If I*



wasn't sure what something was e.g. a rare plant or insect, the GBIF page on first view seemed too technical for a layman, and that a general overview would be more useful. On closer inspection I found some information that may be useful (description and photos), so familiarity with the pages might allow me to find the snippets that could be useful.

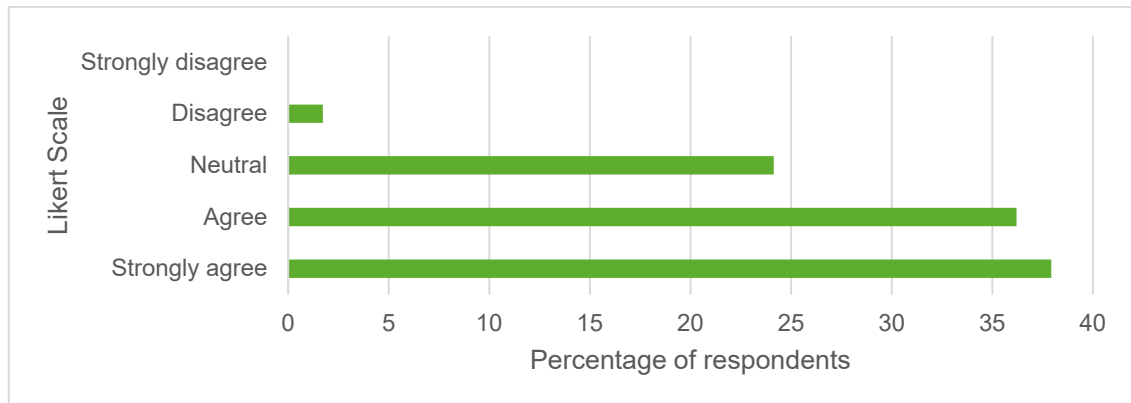


Figure 14 Responses to the question 3.7 Ability to view additional knowledge on the species via the GBIF website is vital.

Additional thoughts on the Graphical user interface (GUI)

Several individuals specifically questioned the speed of the graphical user interface. One wrote: *Would be nice if the map would draw slightly quicker, but the features are great;* and another wrote *I would recommend to improve the loading speed.*

Several respondents suggested additional features e.g. *Link to specific recreational facilities* and *Regularly used routes shown on maps* or include *land ownership data*. One disabled respondent considered the pDT would be more useful if it could *cover broader range of accessibility* and another wrote *I think it important to show diversity for different social groups and different abilities*. In discussions several people mentioned that wheelchair or push chair accessibility would not be easy to judge from the present configuration of the pDT. No one questioned knew of a national dataset which could be incorporated but stated in discussion that perhaps a series of tabs or map overlays could be added, and the information built up by the user community over time using a participatory model like Strava (<https://www.strava.com/onboarding>) fitness app and social network that tracks physical activity, such as running, cycling, and hiking.

Linking to other established apps such as route planners e.g. Google maps (<https://www.google.co.uk/maps>) and Romo2 public transport (<https://www.rome2rio.com>) was mentioned to enable people to fully plan their recreational activity e.g. *I think it would be good to have a way of indicating accessibility from a starting point e.g. a home post code. Maybe travel times or public transport.*



Several respondents enquired how the maps would be stored and if they could be exported i.e. printed to take to the field or added to a photograph album; one wrote *Ability to export data would be important*, while another expressed this wish as *Ability to print map with os features so can be used to navigate*.

The issue of rare species was frequently mentioned but no clear conclusions on the best course of action was suggested e.g. *Maybe consider not putting detailed information for protected species*. The dynamic nature of the pDT was highlighted by several people particularly in the context of showing seasonal information e.g. *Potentially add in seasonal affects I.e would an activity disturb during only spring*. In discussion the breeding seasons of birds like the golden eagle and lekking behaviour of Capercaillie were mentioned. A strong advantage of the digital twin approach to enable dynamic showing of recreational potential depending on season was frequently mentioned but no clear guidelines as to the area of exclusion around rare species was suggested.

3.4 Recreational potential model

Model components.

There was general agreement that elements of the landscape infrastructure, natural features, water features and landcover suitability were important aspects to incorporate in the recreational potential model (72%), with no one recording disagreement.

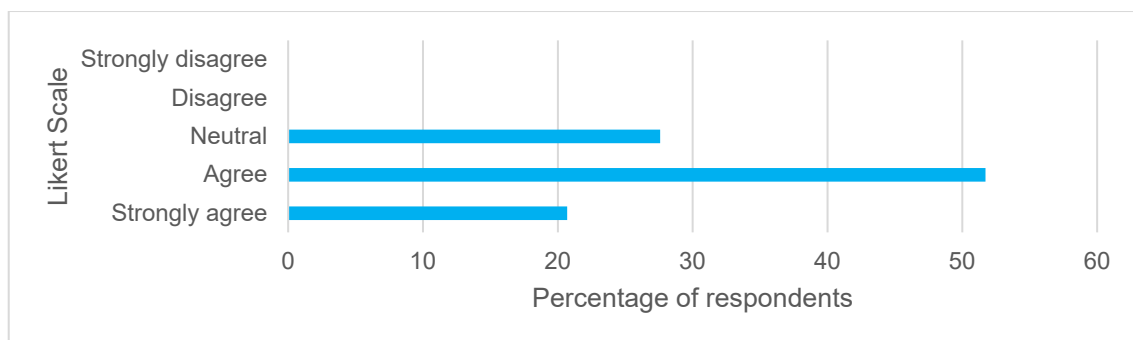


Figure 15 Responses to the question 5.1 Current four model components (infrastructure, natural feature, water feature, landcover suitability) are sufficient

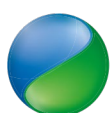
But many commented (Table 3) that while these aspects were important the inclusion of walking routes, car parks, and public transport links would significantly enhance the utility of the output. The few that were specifically questioned did not see the value of scoring these features as parameters in the model rather they wished it added as another layer which could be investigated (similar to the current link out to the GBIF site for additional species information).



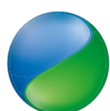
One respondent questioned the datasets used in the Infrastructure component; *Infrastructure is not perhaps represented best*. The same individual had commented in question 4 that *I think integrating a map such as the OS map (or cheaper equivalent) showing the positions of footpaths would help people plan routes. This could replace the infrastructure section honestly*.

Table 3 Respondents opinion of the recreational model. Q5.1-5.6 are the individual Likert scale scores respondents provided on the model components (Q5.1), number of parameters to be scored by the user (Q5.2) influence of surrounding landscape (Q5.3), ability of store data (Q5.4) spatial resolution of the map (Q5.5) and update time of the model (Q5.6).

Question 5.						Q6 -Please elaborate on your views concerning our data sources and recreational model structure e.g. can you provide other data sources you think should be included and scored in the model, what data do you think should be shared with others or should a login ensure privacy etc.
1	2	3	4	5	6	
1	1	1	1	1	1	I believe the data sources consider sufficient components to make well informed models.
1	1	2	2	1	4	X
1	1	3	1	2	1	I don't have suggestions for this topic
1	1	3	2	1	1	Very comprehensive, I think it would be vital to have access to download raw files to edit size etc.
1	1	4	2	2	2	It would be nice to introduce seasonality for biodiversity
1	2	2	1	1	2	biomass estimate and abundance would be good to add
1	2	2	1	1	3	It would be good to have a login to save parameters.
1	2	4	3	2	2	Its great so many variables have been included. It would be great to look at subsets of these, for example, just the infrastructure ones, so that different needs could be explored. E.g can I look up just landscape designations if I want to prioritise reserves.
1	3	2	2	2	2	I don't know
1	3	3	1	2	4	I'm unsure if a sub-annual time step matches up with the biodiversity databases but I would think there would be changes in distribution/ species' ranges within the year that would be useful to know.
1	3	3	3	2	3	I'm not sure about most of those above, that's why I scored neutral. The five min usage of the tool over a conference coffee break is not enough to understand all about the tool. I still need to read the leaflet.
1	3	4	1	1	2	Possibility the table of components is maybe has too many categories.
2	1	3	2	1	1	.
2	1	3	3	1	1	Annual update sounds very reasonable.
2	1	4	2	1	2	Topography, climate and land use type should also influence surrounding pixels
2	1	4	2	2	2	Landcover and land type can also influence nearby land
2	2	2	1	1	1	Not sure
2	2	2	1	2	4	Perhaps a more frequent time step would be beneficial



2	2	2	2	1	1	National River Authority could also make available biological and biodiversity data on a very detailed spatola scale
2	2	2	2	2	4	Species are seasonal so we need to account for seasonal changes in distributions
2	2	2	2	4	2	N/A
2	2	3	1	1	1	20 m resolution is definitely ok for this sort of purpose. Annual updates sufficient and may even be too often for some parameters e.g. slope.
2	2	3	1	1	4	In a seasonal environment you need updates per few months
2	2	3	1	2	2	Path important to show
2	2	3	2	1	1	Species conservation listing. Likelihood of sighting. Using as many datasets as possible to input into the map. Where you have been should be anonymous.
2	2	3	2	1	2	-
2	2	3	2	1	2	Maybe cultural heritage could also be considered. Also more on climatic/weather conditions. Degradation, pollution.
2	2	3	2	1	3	Do recreational scores change depending on the season and seasonal climate? E.g. is one area ok for soft recreationalist in summer but becomes more challenging in winter due to temperature, snow cover etc
2	2	3	3	1	2	It all seems a bit complex.
2	2	3	3	1	3	c
2	2	3	3	2	2	The ability to look at travel times from named locations or assess accessibility would be useful.
2	2	4	1	1	3	I guess the additional information's, mostly on species seasonality could be added, so that a more frequent update of the map may result not necessary
2	2	4	2	4	4	I think more if not all parameters should influence the surrounding pixels. Also looking at hills can be very nice :) Also, I think it should be more than 20m. Having a view into the distance is also important for outdoor enthusiasts.
2	3	2	1	2	3	X
2	3	2	2	1	2	The app is already great
2	3	2	2	1	2	Nothing
2	3	2	3	2	2	No idea really
2	3	3	2	1	3	You could also have seasonal data, as sometimes there are species that could be seen only in certain seasons. Also if possible it would be interesting to add other suggestions as wikiloc.
2	3	3	2	2	2	x
2	3	3	3	2	2	The windy App is great for real time climate updates if that is within the parameters of the intended model
2	3	3	3	2	2	na
2	3	4	1	1	4	Needs a seasonal component



3	1	2	1	2	5	Infrastructure is not perhaps represented best (see my earlier comments). I agree that components should be editable
3	2	2	1	1	1	I think these are good data sources for selection criteria but perhaps they could be used to filter other data sources in external apps e.g. Strava routes matching various values.
3	2	2	1	2	2	A login would be good- would be good to be able to save
3	2	2	2	2	3	Data shared on where people want to go and if they went. Annual data collection could be done at different times of year but still annually.
3	2	3	2	2	2	Logging in to an account which stored preferences could be useful for frequent users
3	2	4	4	2	2	Na
3	3	3	2	3	1	Supporting people understanding how they can visit those places
3	3	3	2	3	2	I don't recreate in nature
3	3	3	3	2	2	Not very knowledgeable about that topic
3	3	3	3	3	1	I don't feel I understand how the data or how the GUI is generated well enough to comment. From a quick test it seems sufficient for soft recreational needs, at least to direct attention to sites that may be more suitable in a area I'm not familiar with.
3	3	3	3	3	3	not my area of expertise - I haven't seen the model
3	3	4	1	2	2	Yearly update is fine, but seasonal variations should be taken into account scores for water and POIs: additional to distance, line of sight may be a weighting criteria. A river is still nice to see from a mountain top 5km away 20m resolution is fine, but sum blurring may be needed visually
3	3	4	1	2	4	UI element settings should be stored using cookies, local storage etc
3	3	4	1	2	4	Data needs seasonal info.
3	3	4	2	4	2	Don't know
3	3	5	2	2	4	The change in seasons (especially in the mountains in Scotland) means that for the recreational & wildlife viewing potential will need to be updated seasonally.
3	4	4	3	2	4	It would be great if you can include seasonal time update.

Footnote: Emboldened numbers were missing– replaced with 3=neutral

Q5.1 Current four model components (infrastructure, natural feature, water feature, landcover suitability) are sufficient.

Q5.2 Number of parameters requiring to be scored (87) is sufficient.

Q5.3 Scores for water and infrastructures components are the only two that should influence surrounding pixels

Q5.4 Storing recreational potential preferences for later reference is vital.

Q5.5 Spatial resolution of 20 m is sufficient for your needs.



Q5.6 An annual time step to update the model components is sufficient.

Number of parameters

Many respondents (60%) considered that the parameters mentioned was necessary (Fig, 16) often commenting that they should be editable by the individual e.g. *I agree that components should be editable*. However, many respondents were concerned that they may be asked to score all 87 parameters *Possibility the table of components is maybe has too many categories*. While others considered it would be useful to have all these scored for a persona (like hard or soft recreationalist) and then have the ability alter only the few they may wish to change.

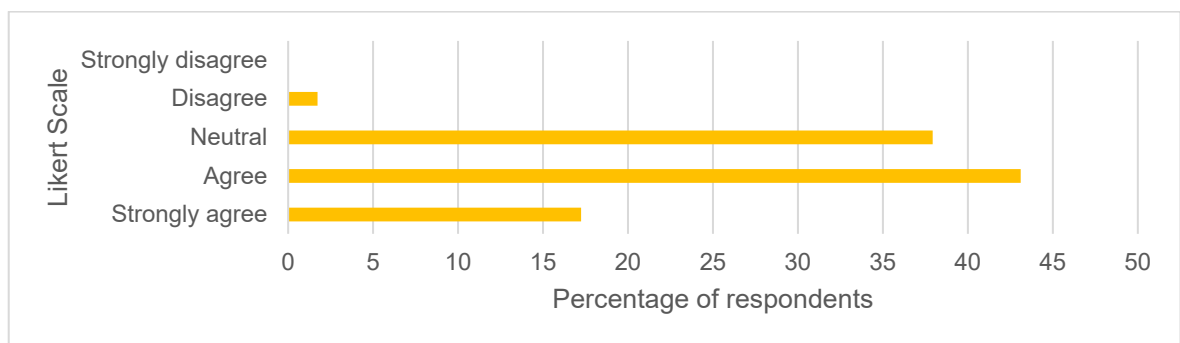


Figure 16 Responses to the question 5.2 Number of parameters requiring to be scored (87) is sufficient.

One respondent suggested the windy app (<https://windy.app/>) as a useful addition to the output by commenting; *The windy App is great for real time climate updates if that is within the parameters of the intended model*

Influence of surrounding features

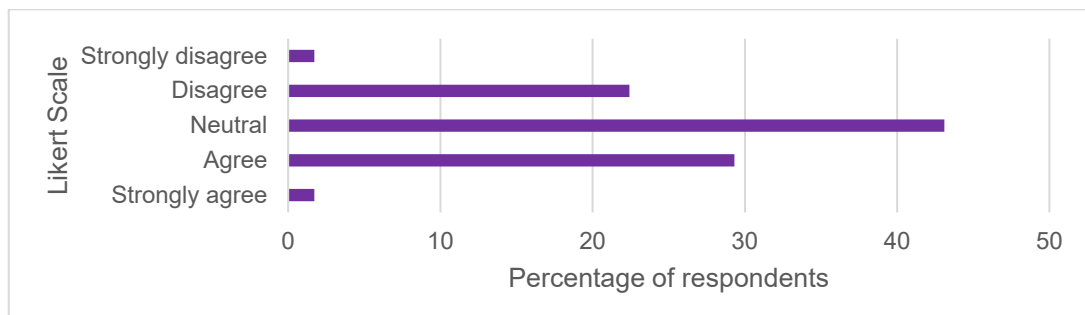


Figure 17 Responses to the question 5.3 Scores for water and infrastructures components are the only two that should influence surrounding pixels



One of the most frequent points which respondents sought clarification on was the use of the Euclidean distance applied to the pixels within a 1500 radius of the water and infrastructure features. Many respondents simply scored this question as neutral (%) but for those that questioned it most commented that it was not only these features which influence the surrounding areas potential to offer recreational potential commenting

- *Landcover and land type can also influence nearby land*
- *I think more if not all parameters should influence the surrounding pixels. Also looking at hills can be very nice :)... Having a view into the distance is also important for outdoor enthusiasts.*
- *Topography, climate and land use type should also influence surrounding pixels*

Storing recreational potential preferences

Three quarters of the respondents considered that storing recreational potential preferences for later reference is vital with only person disagreeing.

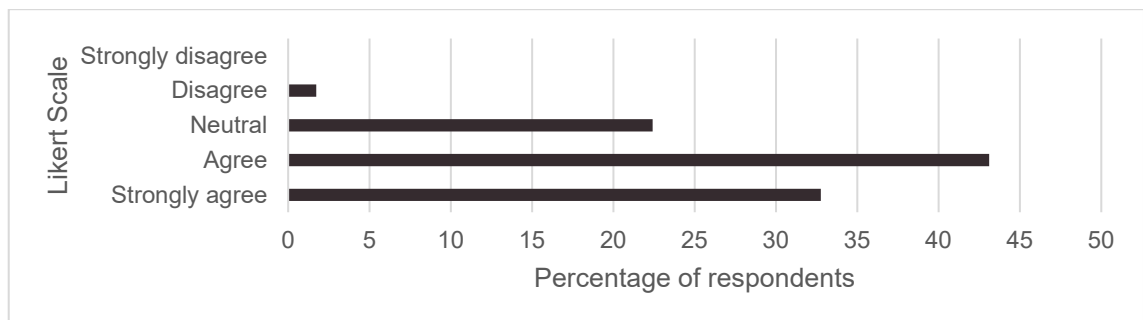


Figure 18 Responses to the question 5.4 Storing recreational potential preferences for later reference is vital

The majority of responds agreed that storing preferences was useful for example

- *A login would be good- would be good to be able to save*
- *Logging in to an account which stored preferences could be useful for frequent users*
- *It would be good to have a login to save parameters.*

Spatial resolution



Over 90% of respondents (Fig 19) considered the 20 m resolution of the recreational map sufficient e.g. *20 m resolution is definitely ok for this sort of purpose.*

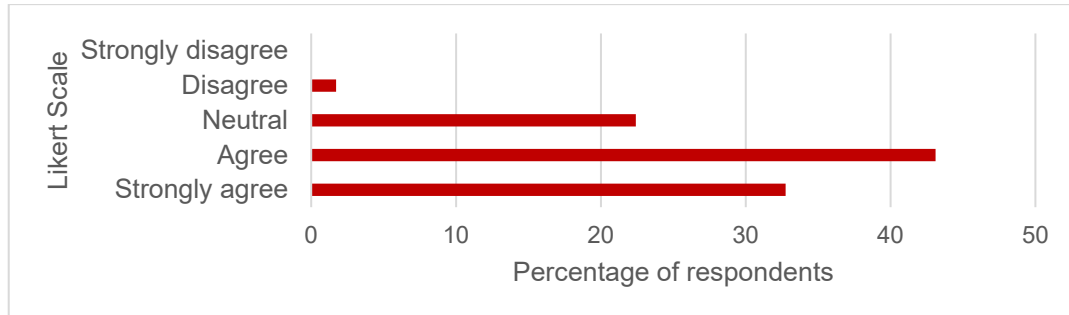


Figure 19 Responses to the question 5.5 Spatial resolution of 20 m is sufficient for your needs

Dataset update timestep

The majority of respondents agreed with the statement that an annual update on model components was sufficient with several suggesting it may be too often e.g. *Annual updates sufficient and may even be too often for some parameters e.g. slope.*

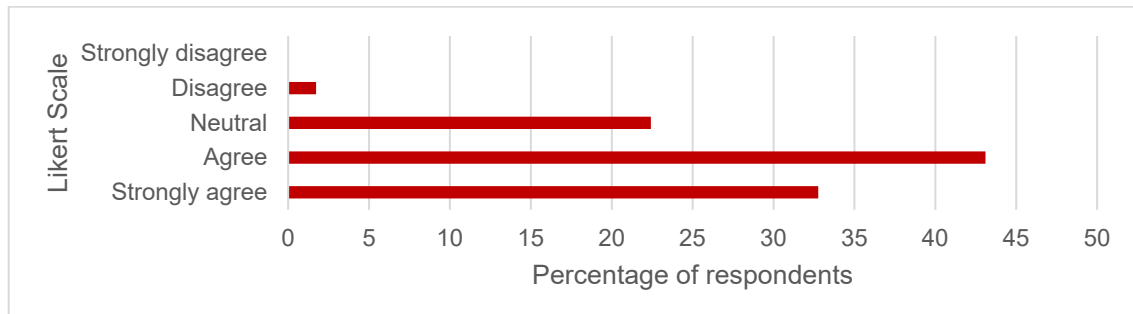


Figure 20 Responses to the question 5.6 An annual time step to update the model components is sufficient

However, many commented (Table 3) on the need to ensure the seasonal aspect of both recreation and species data was visible for example

- *The change in seasons (especially in the mountains in Scotland) means that for the recreational & wildlife viewing potential will need to be updated seasonally;*
- *Do recreational scores change depending on the season and seasonal climate? E.g. is one area ok for soft recreationalist in summer but becomes more challenging in winter due to temperature, snow cover etc*
- *Data needs seasonal info.*



3.5 Species distribution models (SDM)

Data sources

While many people agreed that GBIF was a reasonable first step when considering data sources (50%) many did not (21%) and the remaining scored neutral for this question as they were unsure (29%).

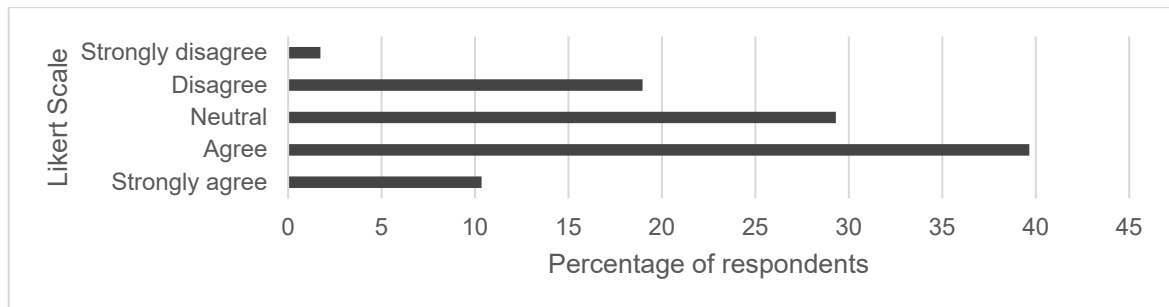


Figure 22 Responses to the question 7.1 Citizen science data held by GBIF is sufficient for this digital twin

Most discussion and commented (Table 4) focused on the need to include a wider range of data sources e.g.

- *Gbif data relies on citizen science and doesn't have many checks. Instead it could be beneficial to use biodiversity data direct from the source of organisations in the UK. I know that data from these are eventually put into gbif.*
- *Better data sources needed to populate the map in regards to species.*
- *Don't limit your data sources.*
- *E bird platform for birds data.*
- *Gbif can be less up to date when compared to other citizen science archives due to bottlenecks in data flow*
- *could use Inaturalist*

In conversation with respondents many of whom were not from the UK, the source of biodiversity data was mentioned as a limitation to expanding the digital twin to other areas

- *Depends on location and species, in the UK GBIF data is likely to be good, but not for certain species/groups and not abroad*

The biased nature of citizen science data (often primarily reflecting where people go and observe species rather true biodiversity distribution) was commented on by several respondents e.g.

- *If available, bringing in new datasets would make the map less biased towards settlement areas.*



- *GBIF is biased but would be hard to get better data*

Some respondents suggested other data sources e.g. *BSBI data could be useful as it is very complete and has a high resolution (and mostly isn't on GBIF)*

Table 4 Respondents opinion of the data sources and SDM mode structure for the biodiversity component of the prototype digital twin. Q7.1-7.3 are the individual Likert scale scores respondents provided for the data source used (Q7.1), model type (Q7.2) and frequency of data updates (Q7.3).

Question 7.			Q8 Please elaborate on your views concerning our data sources and SDM model structure for the biodiversity component of the prototype digital twin e.g. do you know of other biodiversity data sources you would recommend, are there other modelling techniques you feel would be more appropriate etc .
1	2	3	
1	1	2	I think this is great and especially like possibly to look at cultural ES
1	1	2	I think citizen science data is sufficient but could be supplemented with survey data from population monitoring projects for more academic purposes.
1	1	3	No comments to add
1	1	4	I think biannual updates would be better so that people making multiple trips to the same area can see what's new/what's changed.
1	2	3	No
1	2	3	Powa
2	1	1	Don't limit your data sources.
2	1	2	I don't have suggestions for this topic
2	1	2	Abundance mentioned in previous question not distribution. Otherwise sounds good, could use Inaturalist
2	2	1	x
2	2	2	x
2	2	2	NA
2	2	2	N/a
2	2	2	X
2	2	2	No comments.
2	2	2	Gbif can be less up to date when compared to other citizen science archives due to bottlenecks in data flow
2	2	2	no
2	2	2	I love this element. It would be brilliant to prioritise visiting a space where I'm more likely to see species of interest. I think the data and approaches are sufficient, ensuring relevant variables are included.
2	2	3	Is it possible to consider seasonal dynamics of species availability?
2	2	3	For popular taxa I think activity periods would be really useful so that people can go at appropriate times.



2	2	4	Species are seasonal so need to show this seasonality in the models. Particularly for species which are sensitive but only during e.g. breeding seasons.
2	3	1	.
2	3	1	Lola fine
2	3	1	Don't feel I know enough to comment. From a recreational viewpoint it seems sufficient and would point me in the direction of biodiversity hotspots or the specific areas I could visit to give a greater chance of observing certain species. The system doesn't appear to take seasonality into account i.e. if I was planning a visit in the winter hoping to see a specific species and didn't realise it was a summer migrant. For example I noticed there is data for common swift. A layman or pure recreationalist without knowledge of the species may find this misleading. Indeed I might for a species I wasn't familiar with, and knowing this would have to go and research further elsewhere.
2	3	2	Depends on location and species, in the UK GBIF data is likely to be good, but not for certain species/groups and not abroad
2	3	2	again, yearly updates are fine, but seasons should be taken into account
2	3	2	N/a
2	3	4	E bird platform for birds data.
2	4	4	More data is always better, right? And there are quite some inaccuracy coming with SDMs, so you might get disappointed users.. I understand the complications of more refined data models though, especially computational power.
3	1	1	GBIF is biased but would be hard to get better data
3	2	1	I wonder if you couldn't use national records instead of GBIF data. gBIF data can be a bit biased.
3	2	2	Gbif data relies on citizen science and doesn't have many checks. Instead it could be beneficial to use biodiversity data direct from the source of organisations in the UK. I know that data from these are eventually put into gbif.
3	2	2	i think the models could improve if vouchered data from museums are used to validate the sdms
3	2	2	None
3	2	2	Would be good to have more data sources and cross-reference them
3	2	2	Maybe if you could find other data providers, but I don't have any ideas.
3	3	2	This sounds reasonable
3	3	2	N/A - I don't know enough about data models
3	3	2	Not my topic
3	3	2	N/A
3	3	2	I don't have enough information to further elaborate
3	3	3	Don't know
3	3	3	x
3	3	3	These questions are too ambiguous to answer



3	3	3	Not too much expertise in species distribution unfortunately, so no strong views.
3	3	3	na
4	1	1	If available, bringing in new datasets would make the map less biased towards settlement areas.
4	2	3	Maybe hierarchical occupancy modelling?
4	2	3	X
4	2	4	I'm sure the UK will have other species data sets should be used.
4	3	2	GBIF very biased
4	3	2	for plants I would worry that dispersal limitation would limit the accuracy of SDMs. BSBI data could be useful as it is very complete and has a high resolution (and mostly isn't on GBIF)
4	3	2	C
4	3	2	I don't know of other appropriate sources for models that give the same information as species distribution models but more exploration into info sources would be interesting.
4	3	3	Na
4	3	4	It would be interesting to include seasonal updates for species abundance
4	4	2	I would give occupancy models a shot!
5	4	4	Better data sources needed to populate the map in regard to species.

Species distribution models

Many responds were unsure of species distribution models (SDMs) scoring neutral to this question (40%) however, just over half (55%) agreed that SDMs were the best or at least a reasonable type of model to apply in this pDT.

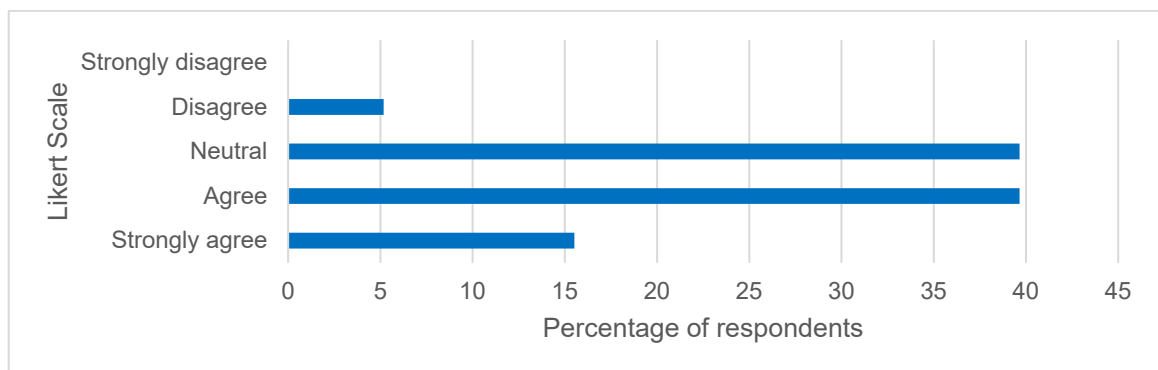


Figure 23 Responses to the question 6.2 Species distribution models are the best type of models for this digital twin

A few you were active with this area of research commented on the accuracy of SDMs and suggested other models (Table 3) they wrote for example:



- *More data is always better, right? And there are quite some inaccuracy coming with SDMs, so you might get disappointed users. I understand the complications of more refined data models though, especially computational power.*
- *I would give occupancy models a shot!*
- *Maybe hierarchical occupancy modelling?*

Species occurrence updates

Most people either agreed that annual updates were sufficient (65%) or were unsure and recorded a neutral score (22%) with only 7 individuals disagreeing (Fig 24).

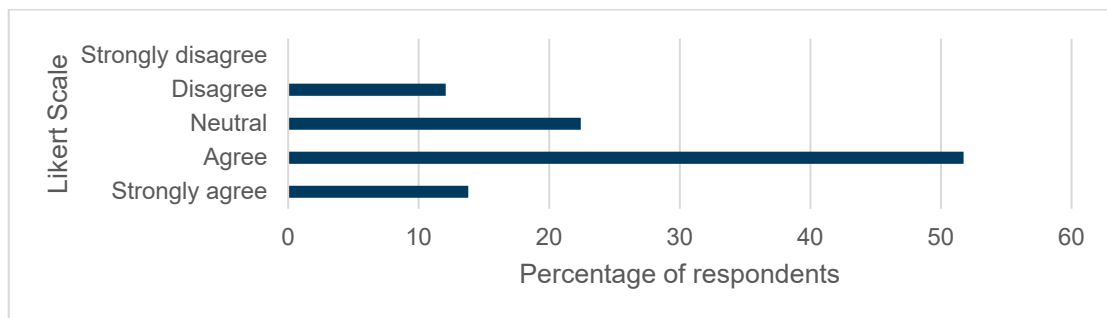


Figure 24 Responses to the question 6.3 Annual updates of species abundance is sufficient.

As for the recreation many respondents considered annual updates sufficient but wanted to show season availability of sightings e.g.

- *Is it possible to consider seasonal dynamics of species availability?*
- *Species are seasonal so need to show this seasonality in the models. Particularly for species which are sensitive but only during e.g. breeding seasons.*
- *again, yearly updates are fine, but seasons should be taken into account*
- *For popular taxa I think activity periods would be really useful so that people can go at appropriate times.*

One respond wrote that to keep the digital twin dynamic at least biannual updates should be considered;

- *I think biannual updates would be better so that people making multiple trips to the same area can see what's new/what's changed.*

3.6 Sustainability of the digital twin

Funding from some government source was favoured by 81% of respondents (Fig 25) with the other two options each polling 10% or less.



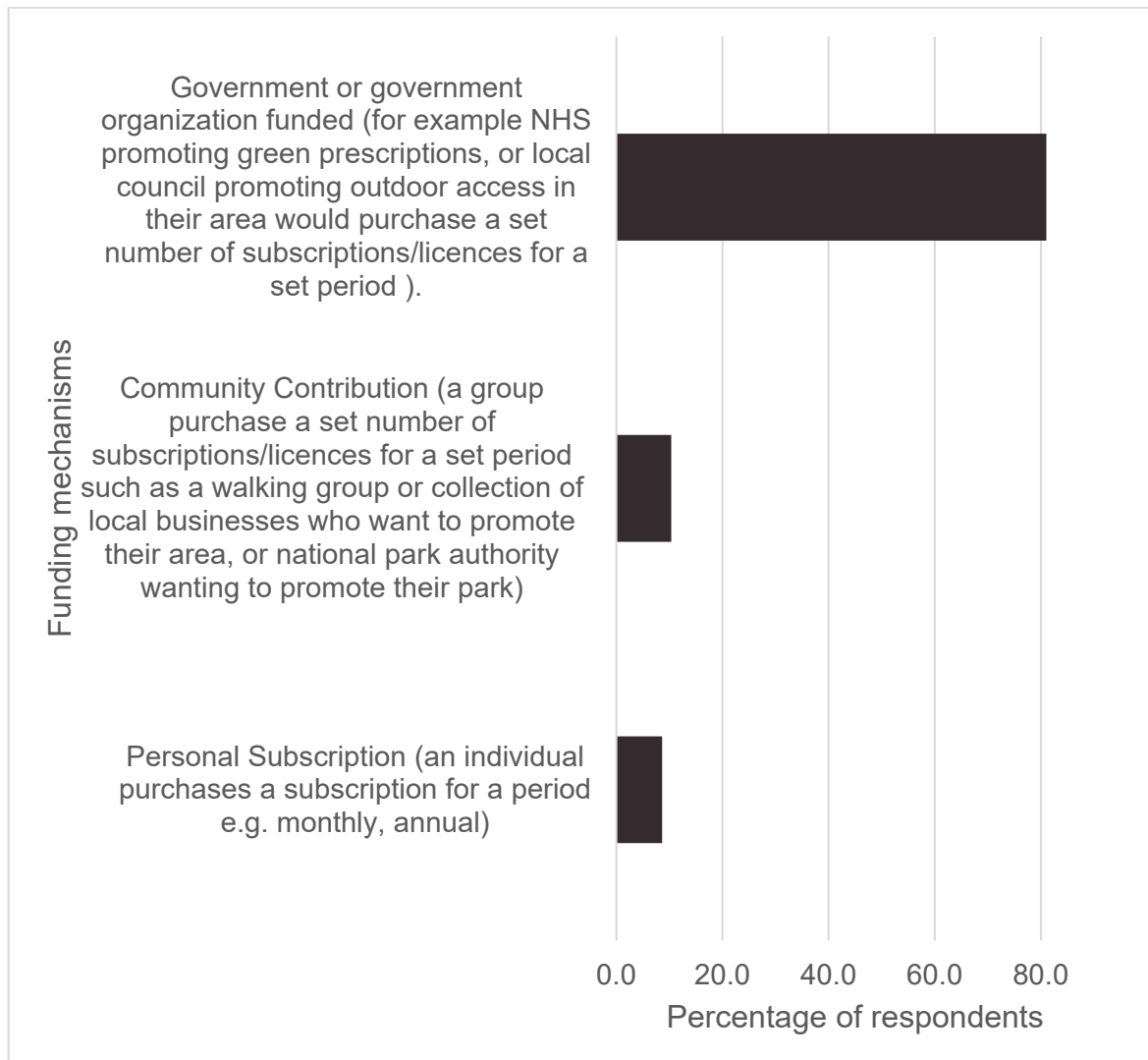


Figure 25 Responses to the question 9 To offer access to the digital twin after the EU funding stops (March 2025) please rank which the following funding mechanisms you feel we should explore most actively.

There were several reasons given for favouring some sort of government funding mechanism (Table 5). However, three main reasons were discussed with the interviewer and recorded in the feedback tool (i) because respondents considered the digital twin a public good e.g.

- *I think this is public asset and need to be funded by public money*
- *I would like the app to be public*
- *Nature is a common good that should be accessible by everybody.*

(ii) because respondents considered that restricting the knowledge was seen as fostering inequality e.g.

- *There is inequality regarding data use and ability to get outdoors. This resource should be free if possible to reduce inequality.*



- *Just out of ethical principles, making it easier to enjoy and connect with natural environments should be encouraged and publicly funded.*
- (iii) respondents did not think private subscription would be commercially viable
- *I think you would really struggle to fund this kind of capability under a subscription model. I would target government sponsorship.*
 - *I don't think personal subscriptions work here. Especially because you want to make sceptical our neutral people enthusiastic about outdoors and nature. The hurdle of making them pay for that is too high. Also, this should be in the interest of governments, so they should fund it.*

Many respondents considered a hybrid form of funding e.g.

- *Asking individuals to pay for this service might be a bit much. Instead government backed initially with an option to donate on site could be better. Could you incorporate the service into national trust memberships?*
- *I'd attempt to look for a mixed model of funding through grants/foundations mixed with governmental support. Community share capital, or create a CIC. Or look at green finance.*
- *The other structures could be implemented on top of individual subscription (group bundles, NHS-purchased subscriptions). This way it is the most accessible*
- *I think this maybe could be integrated into other apps for outdoor activity society subscriptions e.g. mountain biking organisations or paddle board organisations*

Table 5 Respondents score on which funding model should be pursued (Q9) and their reasons (Q10).

Q9	Q10 Each of the above options require different commercialisation characteristics (e.g. data storage, data governance, business governance, cost model, risk strategy, product validation etc). Please explain your reasons for your selected funding mechanisms and tell us any thoughts you have on commercialisation characteristics.
1	N/A
1	The other structures could be implemented on top of individual subscription (group bundles, NHS-purchased subscriptions). This way it is the most accessible
1	The difference between this app and what is currently available is the ability to see where cool nature stuff is vs just places to go. Anyone prescribed to access nature, does not require the cool stuff so NHS funding can be spent better in other places.
1	I think this maybe could be integrated into other apps for outdoor activity society subscriptions e.g. mountain biking organisations or paddle board organisations
1	It seems like the type of work that would be very popular commercially and for accessibility you could potentially adapt to discounts for certain a groups (low income, students etc.)
2	Would be a good way for government to promote access to nature.
2	I don't see why there can't be multiple funding possibilities
2	Say £5 with cosy distributed between client and group



2	x
2	I think it will be more popular with people who are already in the outdoor recreational space, so targeting it at walking groups etc is a good place to start
2	Data storage
3	I think you would really struggle to fund this kind of capability under a subscription model. I would target government sponsorship.
3	x
3	There is inequality regarding data use and ability to get outdoors. This resource should be free if possible to reduce inequality.
3	Asking individuals to pay for this service might be a bit much. Instead government backed initially with an option to donate on site could be better. Could you incorporate the service into national trust memberships?
3	Nature is a common good that should be accessible by everybody.
3	X
3	I don't think personal subscription would be successful. I would use the digital twin if it was a free, but I don't think it offers so much value that I would pay for it.
3	NA
3	It needs to be free or affordable
3	I would not be happy for my privet data to available. But, I expect the authority to fund this model to encourage tourism.
3	I don't think people should be made to individually pay for this, but it is a great tool to have.
3	I think it could be useful for local authorities to promote areas of recreational value but I don't know that I would pay for it for personal use
3	.
3	I don't think personal subscriptions work here. Especially because you want to make sceptical our neutral people enthusiastic about outdoors and nature. The hurdle of making them pay for that is too high. Also, this should be in the interest of governments, so they should fund it.
3	Just out of ethical principles, making it easier to enjoy and connect with natural environments should be encouraged and publicly funded.
3	x
3	I think good recreational activities should be available to everyone and not linked to personal wealth/possibilities. Popular map choices may be stored and made available.
3	Government should be invested in nature as a form of health benefits to its citizens. To improving biodiversity and the value of nature to individuals.
3	Na
3	I'd attempt to look for a mixed model of funding through grants/foundations mixed with governmental support. Community share capital, or create a CIC. Or look at green finance.
3	No thoughts
3	Selling such a service is hard, but good luck :) potentially crowd funding could be worth a thought? Else credit card-based subscriptions with automatic renewals



3	I would hope that government funding would allow for open access.
3	It is very important that government supports model like this.
3	I would like the app to be public
3	If people have to pay, the tool won't be available broadly, including minority groups.
3	Government should offered this so everyone could use
3	if its free I'd be willing to give my data to track
3	Easier for people to enjoy it
3	ERICs, as LifeWatch, can have a role
3	I have no idea, honestly
3	All are relevant, we need to be more ambitious. I wanted to tick all of them.
3	that is because this is crucial for both scientific community and policy decisions.
3	I think this is public asset and need to be funded by public money
3	Pros and cons to all of them. Perhaps starting with community or subscription approach with view of later moving to government funding
3	Personal commercialisation tends to attract outside interest that might exploit through price rises, advertisement etc
3	Not familiar with the schemes...
3	It should be funded by Europe mainly to ensure a constant financial support. Individual based might not be enough.
3	If there's money from any government that wants to support this, open source is great. However, this might need lots of advertising money to make sure there's good uptake and doesn't fade away.
3	The commercialisation bit is a bit difficult. As a tourist who would be in the area only for 1-2 weeks I am not sure that I would pay for a monthly subscription. But I would want to use this tool to plan my holiday in advance, so the local business solution wouldn't work super well either.
3	X
3	Trustee. Fundings
3	I'm not sure individuals would pay unless visiting regularly. Something for one off uses would be good for tourists.
3	I don't think an individual should pay for this
3	NA
3	If it was a previously government - all be it EU funded activity - the UK / devolved government should take over
3	It seems to me this would be the most likely route to make it available to me for recreational purposes. Otherwise a tourism agency or similar might fund to provide free access/information for visitors or potential visitors to plan recreation.

Footnote Q9. To offer access to the digital twin after the EU funding stops (March 2025) please rank which the following funding mechanisms you feel we should explore most actively.



4. Conclusions

Generally, people were impressed with the concept of combining recreational potential and probability of viewing biodiversity in the form of a digital twin. One respondent wrote:

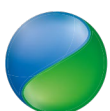
It's well design and intuitive, it's easy to use and the idea of combining the biodiversity with recreational information is really exciting. While another wrote: I love this element. It would be brilliant to prioritise visiting a space where I'm more likely to see species of interest. I think the data and approaches are sufficient, ensuring relevant variables are included.

There were, however, aspects which could be improved. Most notably careful consideration should be paid to the information provided in the graphical user interface with the use of additional tabs and links to other apps suggested.

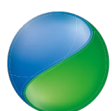
A limitation of this rapid assessment approach was that some people felt that they needed more time to explore e.g. *I'm not sure about most of those above, that's why I scored neutral. The five min usage of the tool over a conference coffee break is not enough to understand all about the tool. I still need to read the leaflet and another commented I don't feel I understand how the data or how the GUI is generated well enough to comment. From a quick test it seems sufficient for soft recreational needs, at least to direct attention to sites that may be more suitable in a area I'm not familiar with.* It is worth noting however even although the interview was short all except two respondents wrote additional comment to elaborate on their opinion as well as scoring the Likert scale question. The two who did not elaborate on their opinions did not score all the questions as 3 neutral and they had the feedback tool open for 7-8 min suggesting that these considered responses.

5. Acknowledgements

We are very grateful to all the respondents who spent time evaluating the prototype digital twin and providing the feedback reported in this document. Their willingness to share their time and insights is very much appreciated. We also acknowledge the other members of the BioDT team active with this case study including Simon Rolph, Chris Andrews



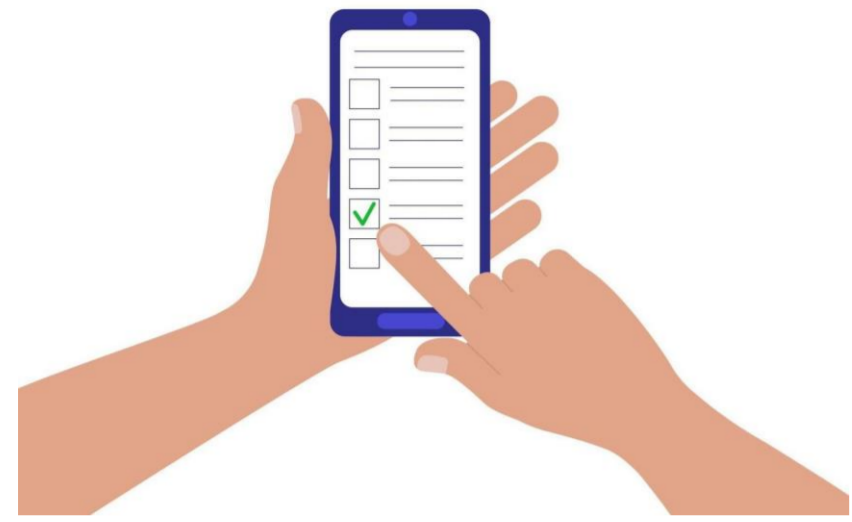
Annex 1 Invitation Handout





An invitation to participate in research

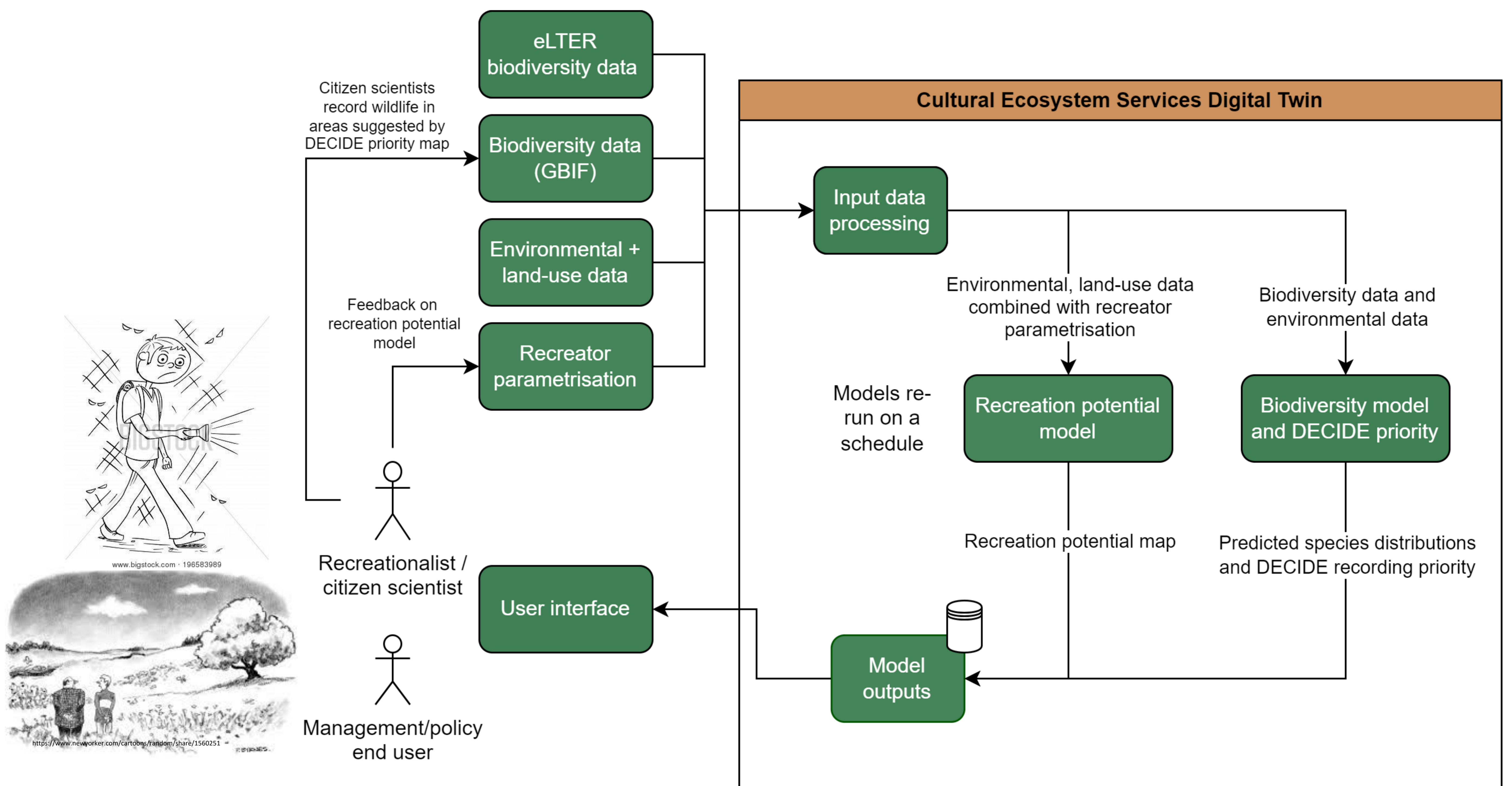
The aim of the research is to develop a digital twin integrating a customised recreation potential model to quantify the cultural ecosystem services of the physical landscape and species distribution models to quantify the biodiversity component for an area.



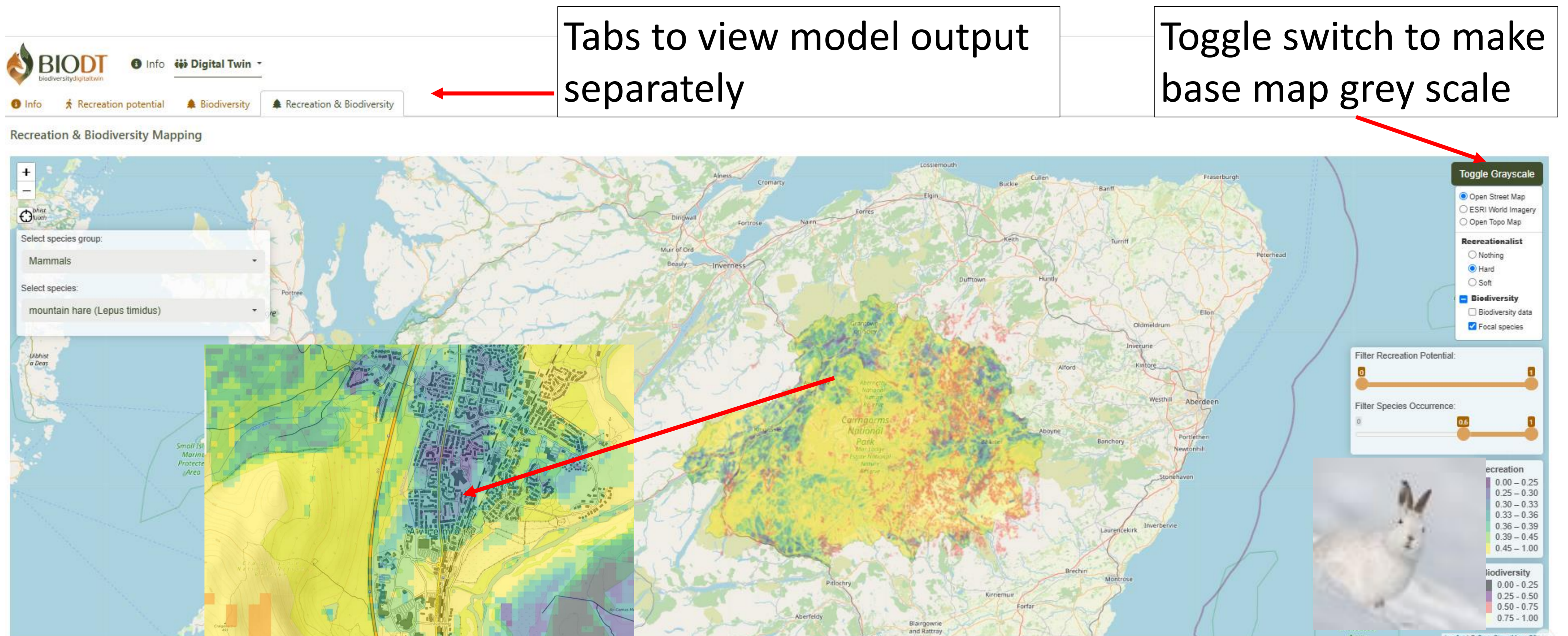
Please provide your views on the utility of this digital twin by scanning this QR code .



Conceptual schema of the Recreation and Biodiversity Cultural Ecosystem Services Prototype Digital Twin.



Example output from the prototype digital twin: Cairngorms National Park highlighting recreational potential for hard recreationalists and probability of viewing mountain hare



Map around Aviemore enlarged by using +/- zooming in/out function



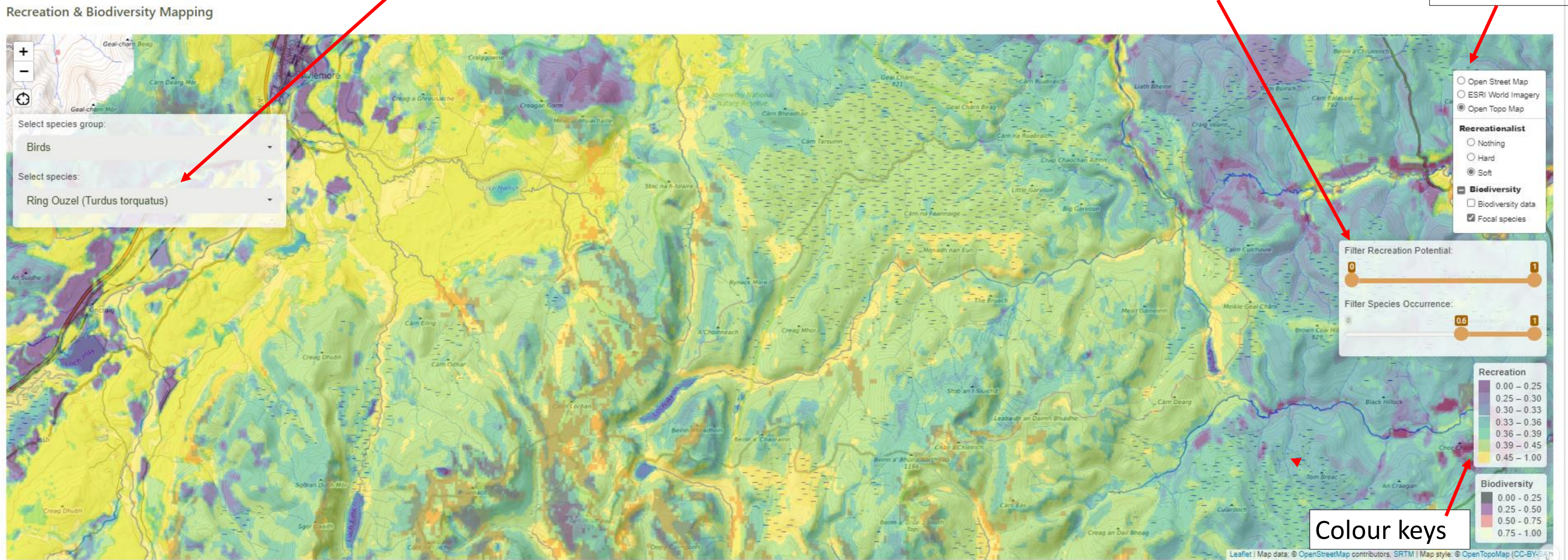
Cairngorms National Park The maps below show differences in the recreation potential of areas in Aviemore in response to user parameterization of the model. Areas with a higher recreation potential (appear yellow) were predicted to be more desirable to the user. The maps also show areas filtered to show 70% or more occurrence of Ring Ouzel (*Turdus torquatus*).



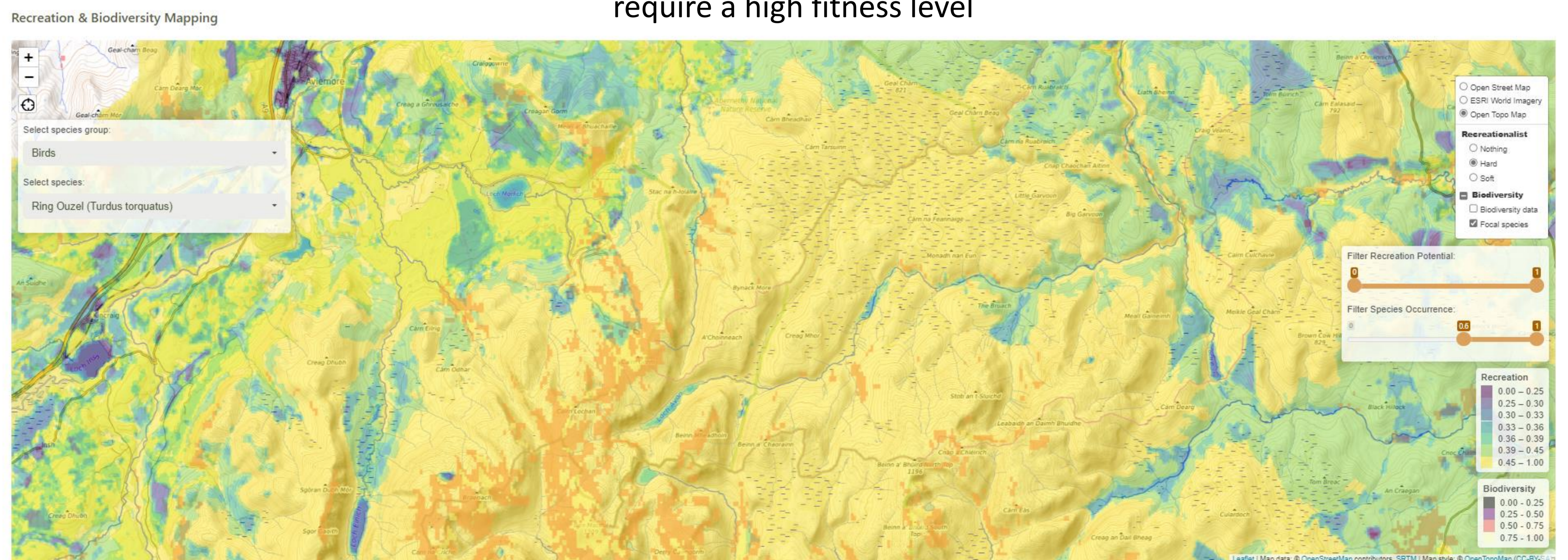
Selection sliders to filter recreation potential model and species distribution model outputs.

Base Map selector

Species selector

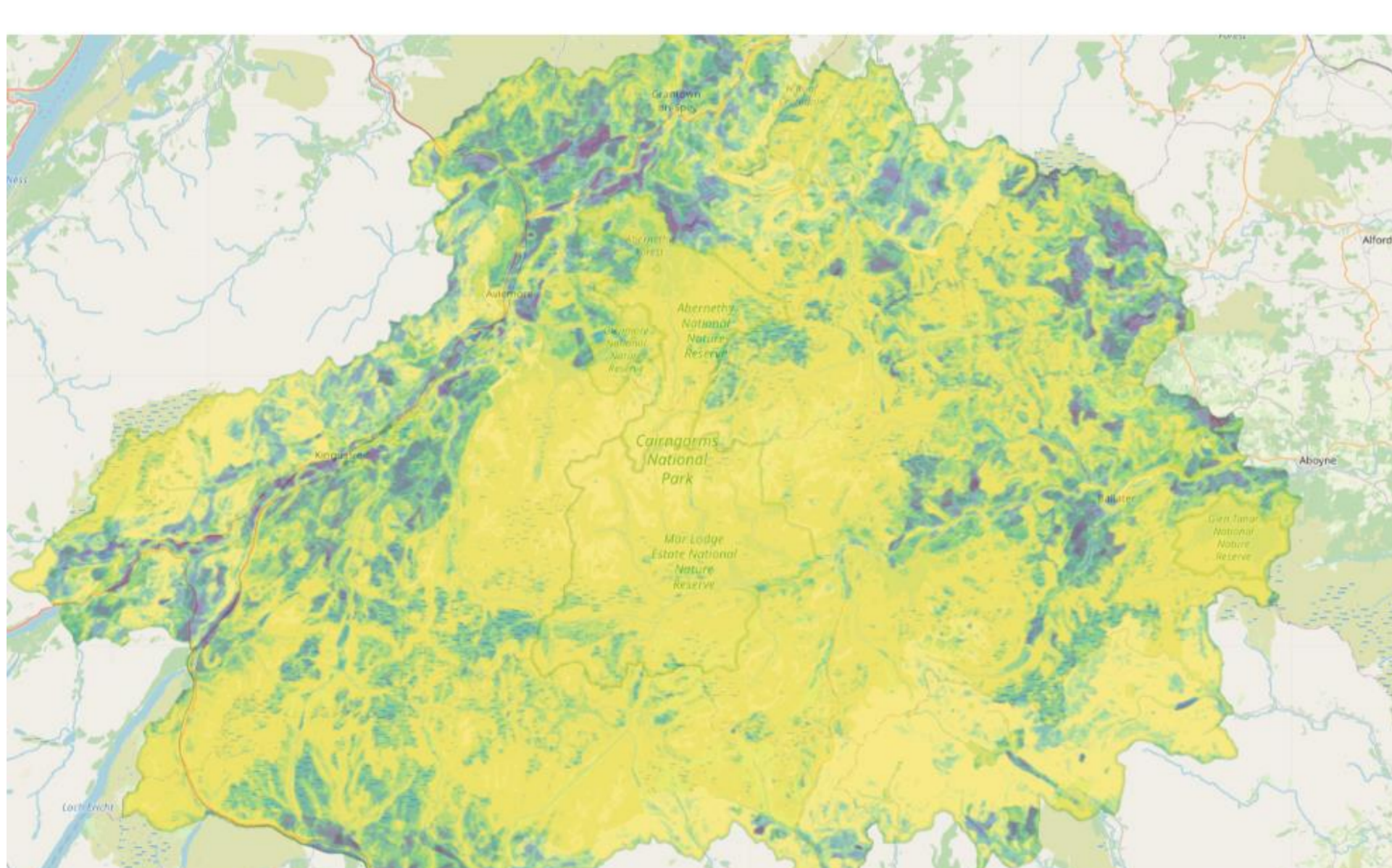


Model parameterised for a **'soft'** recreationalist i.e. some who prefers gentle slopes and activities that do not require a high fitness level

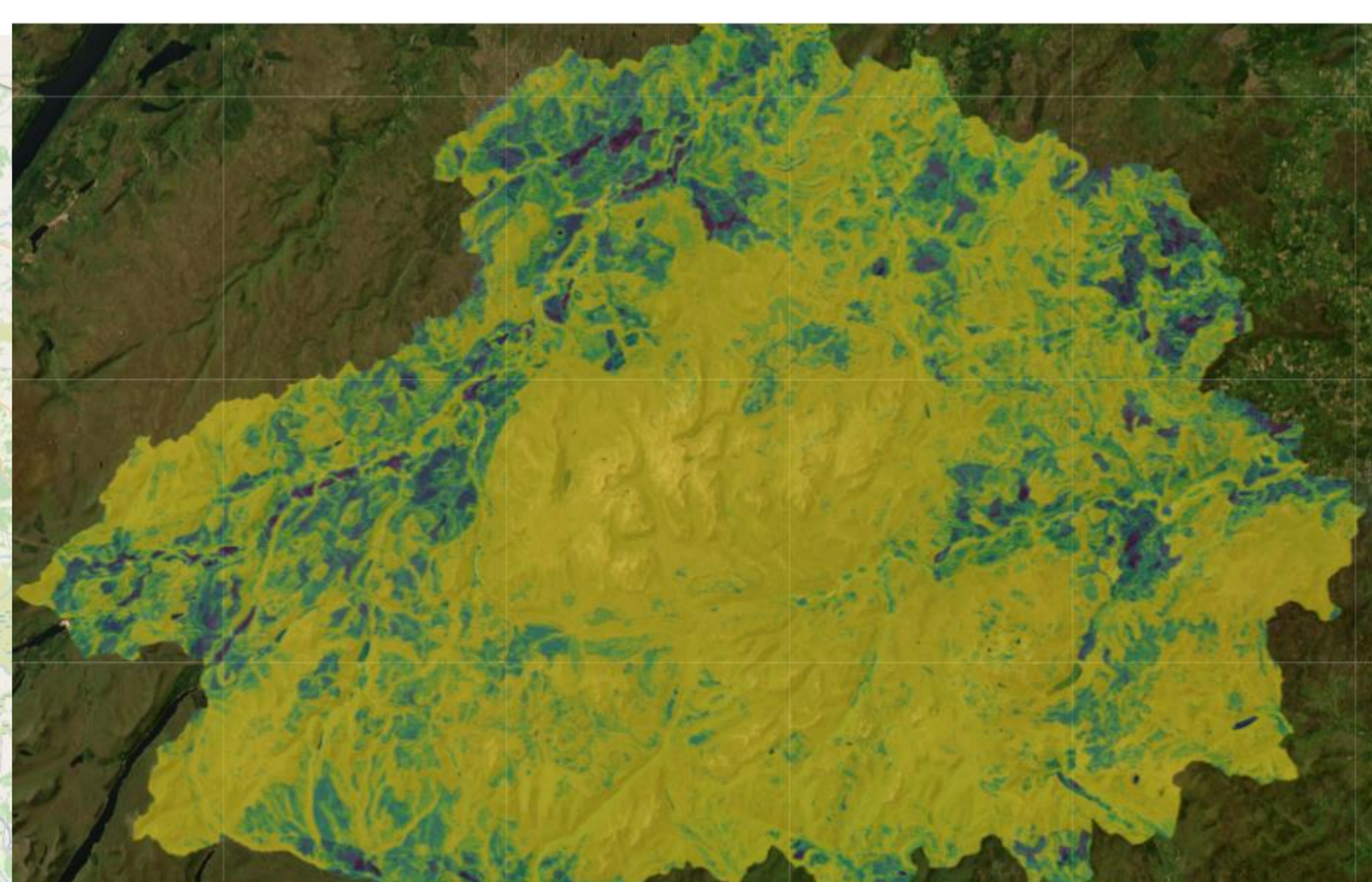


Model parameterised for a **'hard'** recreationalist i.e. someone who prefers high-adrenaline activities that require a high level of fitness

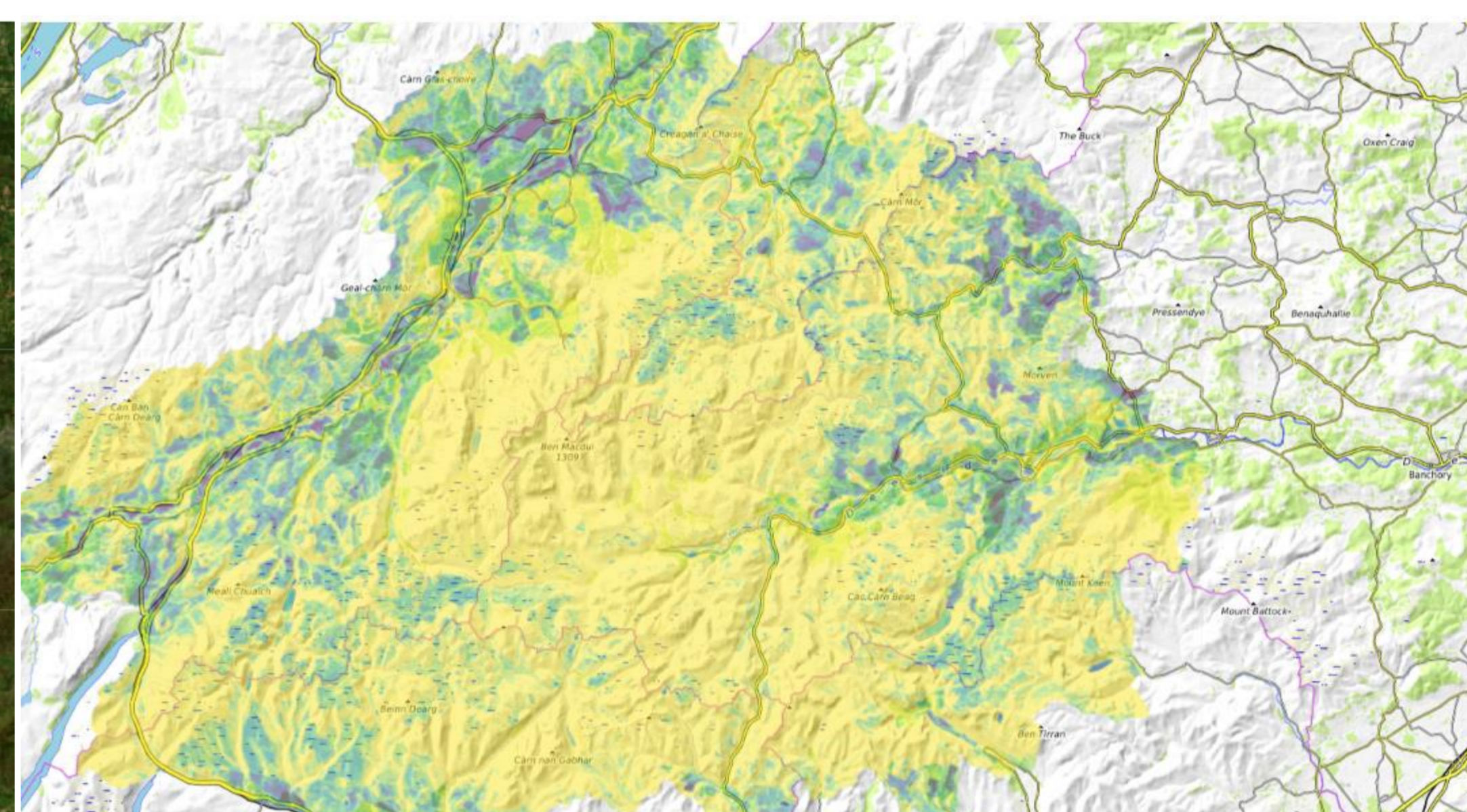
Choice of three base maps – all can be toggled to grey scale



Open Street Map



ESI World Imagery



Open Topo Map



Table of four components and scores selected for 87 parameters

order	Component	Sub- component	Description	Recreationalist		
				Soft	Hard	
1	Infrastructure features that influence recreational potential	Paths	Path	7	5	
2			Motorway	0	0	
3		Road Tracks	A Road	0	0	
4			B Road	3	0	
5			Minor / local road	5	0	
6			Access roads / Track	8	8	
7		Cycle Network	On Road: Paved Surface	5	2	
8			Traffic Free: Unpaved Surface	6	8	
9			Traffic Free: Paved Surface	10	6	
10			On Road: Unpaved Surface	5	7	
11	Natural features which influence recreational potential	Landform	Foothills	8	7	
12			Mountains	4	10	
13			Terraces	3	5	
14			Flood plain	2	1	
15			Beaches / Dunes	9	7	
16			Rocks / Scree	1	6	
17			Depressions	1	1	
18			Hills	4	8	
19			Lowlands	8	3	
20			Rock Walls	1	10	
21			Uplands	7	7	
22			Valley sides	2	7	
23			Valley bottom	7	3	
24			Built-up areas	1	1	
25			Saltings	0	0	
26			Hummocks / mounds / moraines	3	3	
27			Influence of water features on recreational potential	Slope	easy	10
28	gentle slope	8			1	
29	medium slope	6			2	
30	steep slope	4			4	
31	very steep slope	3			10	
32	extremely steep slope	1			8	
33	Soil	Peat / Organic			3	6
34		Mineral			5	2
35	Lakes	Pond			5	1
36		Lochan			3	3
37		Small Lochs	3	5		
38		Medium Lochs	5	4		
39		Large Lochs	7	7		
40		Major Lochs	10	7		
41		Rivers	Minor river or tributary	4	3	
42	Unnamed minor stream or tributary		1	3		
43	Major river or tributary		8	7		
44	Named minor stream or tributary		2	3		
45	Water body		8	5		
46	Tidal river or estuary		7	4		
47	Canal	7	3			
48	The suitability of land to support recreational potential	Land cover	Alpine and subalpine grassland	2	8	
49			Arable land and market gardens	4	2	
50			Arctic, alpine and subalpine scrub	2	8	
51			Bare field / exposed soil	1	1	
52			Base-rich fens and calcareous spring mires	5	2	
53			Broadleaved deciduous woodland	9	7	
54			Built-up area	3	1	
55			Coastal dunes and sandy shore	10	7	
56			Coastal shingle	6	3	
57			Dry grassland	3	5	
58			Freshwater	9	7	
59			Inland cliffs, rock pavements and outcrops	3	10	
60			Lines of trees, small planted woodlands, early-stage woodland and coppice	6	2	
61			Littoral sediment / saltmarsh	4	2	
62			Mesic grassland	5	4	
63			Mixed deciduous and coniferous woodland	9	5	
64			Non-native coniferous plantation	7	2	
65			Raised and blanket bog	5	1	
66			Riverine and fen scrubs	4	2	
67			Rock cliffs, ledges and shores	6	10	
68			Scots pine woodland	9	7	
69			Scree	1	5	
70	Seasonally wet and wet grassland	5	5			
71	Temperate montane scrub	3	7			
72	Temperate shrub heathland	7	7			
73	Landscape designation	Landscape designation	Valley mires, poor fens and transition mires	3	1	
74			Windthrown woodland	1	1	
75			Woodland fringes and clearings and tall forb stands	3	1	
76			NNR Reserve	7	6	
77	National Park	10	10			
78	Nature Reserve	6	3			
79	Regional Park	4	2			
80	RSPB Reserve	6	1			
81	SAC	6	3			
82	SPA	5	3			
83	SSSI	3	2			
84	SWT Reserve	3	2			
85	Wild Land Areas	3	7			
86	Country Park	8	1			
87	HNV	5	4			

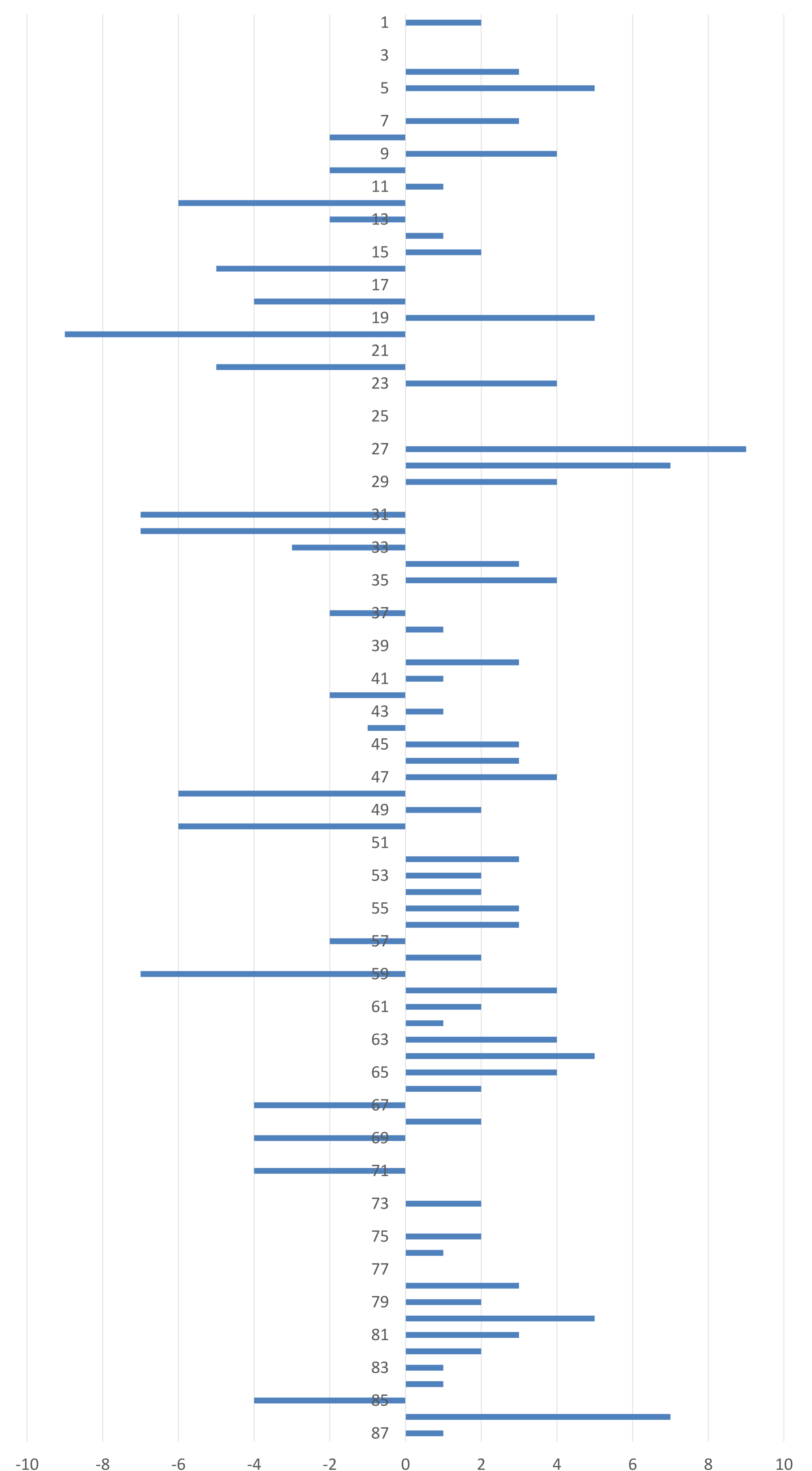
The model (based on Zulian et al. 2028, Dick et al. 2022) enables the individual parameterisation of 87 features on a scale from 0-10 for each pixel of a raster map. Water and infrastructure features are recognised as particularly important for recreation so Euclidean distance is applied in the surrounding 1500 m.

These scores are then combined within the four components and normalised before totalling to give a recreational potential score between 0-1 which is then outputted as a raster map.

Maps plotted in quantile colour range

Dick, J., Andrews, C., Orenstein, D. E., Teff-Seker, Y., & Zulian, G. (2022). A mixed-methods approach to analyse recreational values and implications for management of protected areas: A case study of Cairngorms National Park, UK. *Ecosystem Services*, 56, 101460. <https://doi.org/10.1016/j.ecoser.2022.101460>

Zulian, G., Stange, E., Woods, H., Carvalho, L., Dick, J., et al., 2018. Practical application of spatial ecosystem service models to aid decision support. *Ecosyst. Serv.* 29 (Pt C), 465–480. <https://doi.org/10.1016/j.ecoser.2017.11.005>.



Difference in the scores between soft and hard recreationalist



We fitted Species Distribution Models (SDMs) using citizen science records of species occurrence obtained from GBIF (and in future, eLTER) as response variables, and bioclimatic variables available on Google's Earth Engine Data Catalog as explanatory variables. Models were fitted using R packages, flexsdm (Velazco et al., 2022) and terra (Hijmans et al., 2024). The app can additionally visualise the mean estimated probability of occurrence by grouping predictions across selections of multiple species.

Hijmans, R. J., Bivand, R., Pebesma, E., & Sumner, M. D. (2024). terra: Spatial Data Analysis (Version 1.7-71) [Computer software]. <https://cran.r-project.org/web/packages/terra/index.html>

Velazco, S. J. E., Rose, M. B., de Andrade, A. F. A., Minoli, I., & Franklin, J. (2022). flexsdm: An r package for supporting a comprehensive and flexible species distribution modelling workflow. *Methods in Ecology and Evolution*, 13(8), 1661–1669 <https://doi.org/10.1111/2041-210X.13874>

Bioclimatic variables dataset: https://developers.google.com/earth-engine/datasets/catalog/WORLDCLIM_V1_BIO

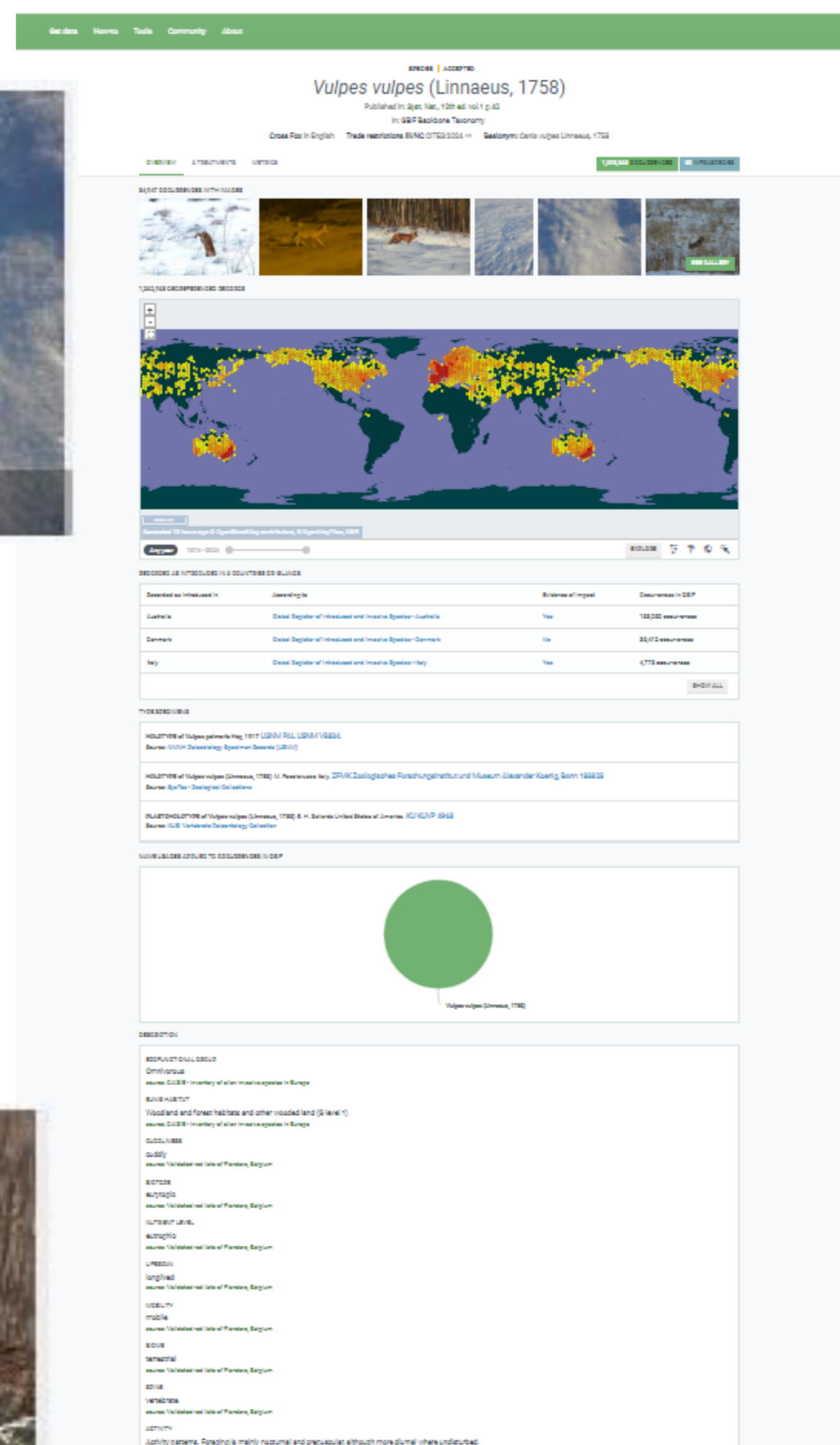
Biodiversity tab selected

List of mammals selected

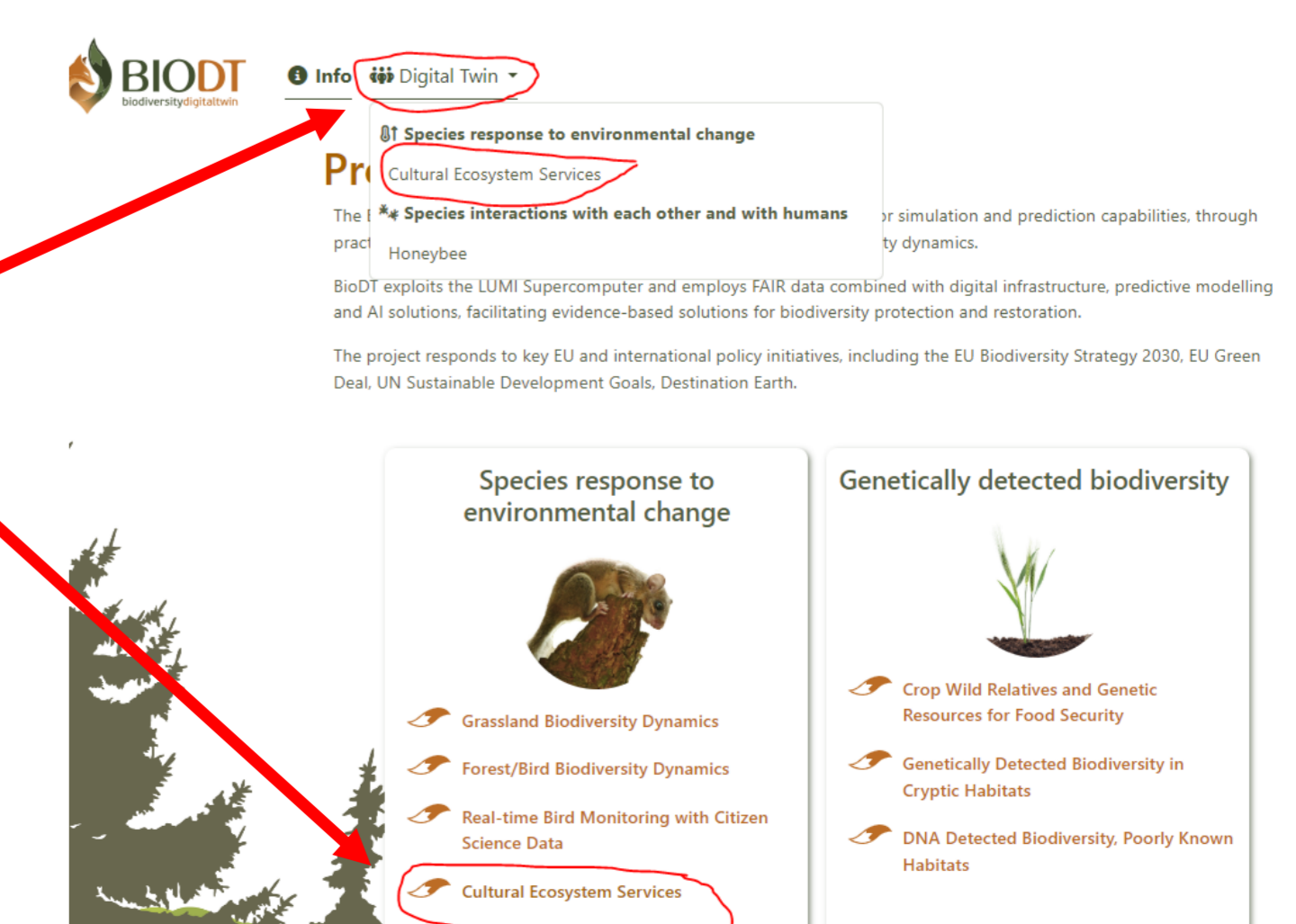
Red Fox (*Vulpes vulpes*) selected to view

Additional information available to view with link to Global Biodiversity Information Facility (GBIF) website

You can access the prototype digital twin via this QR code



Click on: Cultural Ecosystem Services



If you would like more information please contact Jan Dick jand@ceh.ac.uk

app.biodt.eu/app/biodtshiny

Annex 2 Participant Information Sheet

BioDT project consultation on a Digital Twin that links recreation to biodiversity.

You are invited to participate in a rapid survey that will help us to further develop our Biodiversity Digital Twin (BioDT) framework for use in the BioDT project. This cutting-edge project is designed to address complex biodiversity dynamics by using practical case studies, which will provide invaluable insights and tools for ecosystem conservation and restoration efforts.

This *Participant Information Sheet* will help you to understand why and how the research is being carried out and what your participation will involve. Please contact Dr Jan Dick (jand@ceh.ac.uk), if anything is unclear or you have any questions.

Who is conducting the research?

Representatives of UK Centre for Ecology and Hydrology (UKCEH). The key contact from the project team is Dr. Jan Dick (jand@ceh.ac.uk).

Who is funding the research?

The BioDT programme started in 2022 and is funded by the European Research Executive Agency (REA) (grant number 101057437).

What is the purpose of the research?

The aim of this current survey is to understand the perspectives of potential users of the prototype Digital Twin such as ; (1) those who want to enjoy a particular land area and see particular species of plants, insects, birds or mammals , and may want to contribute to data acquisition citizen science programmes (e.g. recreationalists, tourists, citizen scientists); (2) those who want to be informed by and/or make evidence-based decisions using knowledge generated by the DT(i.e. land owners, land managers, policy makers, researchers).

Do I have to take part?

No. Taking part in this knowledge sharing activity is completely voluntary and deciding not to take part will not disadvantage you in anyway.

What will happen if I take part?

Participating will entail completing an anonymous rapid survey. Your data will then be combined with all other responses and analysed to help the BioDT team improve the Digital Twin. We do not ask for contact details.



Are there any risks in taking part?

5.1.1 There are no risks to taking part in the survey, which the research team can foresee. The research team are not part of the any UK regulatory agencies.

What are the possible benefits of taking part?

There are no immediate direct benefits to taking part in this project; however, we hope that following analysis of results the BioDT project will better inform the people-nature sector of the UK and further afield.

Will my taking part in this project be kept confidential?

Yes - UKCEH will present only anonymised data. Contact details are not requested.

What will happen to the information I provide?

The information you provide will be captured either digitally or on paper. The data will be stored on secure UKCEH servers to support analysis and any potential future publication documenting the co-production of this survey process. We intend to archive the anonymised data for future research use; however, there will be no way to link these data to anyone that has participated.

Data Protection

No contact information will be collected, and only generic data on occupation, gender, age range etc will be asked for so that we can describe in general terms the survey participants.

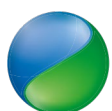
If you wish to raise any issues about the use of your information please contact the UKCEH's Data Protection Officer in the first instance (email: Quentin Tucker, quetuc@ceh.ac.uk). You may also wish to contact the Information Commissioner's Office (<https://ico.org.uk/>).



Please scan the QR code to complete the survey or navigate to this website
<https://app.onlinesurveys.jisc.ac.uk/s/ceh-online-surveys/biodt-bes-2024-draft-final>



Annex 3 Questionnaire tool



BioDT BES 2024 Final

BioDT Cultural Ecosystem Service Prototype Digital Twin Survey

The aim of this research is to understand the perspectives of potential users of our digital twin (DT) including; (1) Recreationalist/wildlife enthusiast/citizen scientist who want to enjoy an area and contribute to citizen science programmes; (2) Land manager/policy end users who want to be informed by and/or make evidence-based decisions using knowledge generated by the DT. The DT will enable users to find places to visit that meet their physical and mental needs, highlights the biodiversity they may find there and gives them the opportunity through citizen science to enhance the knowledge of land and park managers to manage the interdependencies between people and nature. No personal data will be collected. The information you provide will be captured electronically via this survey tool or a paper copy. The data will be stored to support analyses and any potential future publication documenting this co-production process. We intend to archive the anonymized data for future research use; however, there will be no way for these data to be linked to individual survey participants. Please see full Participants information Sheet for further details. If you consent to take part in this survey please click on the Next button below

Survey

1. Please select the view point you want to adopt while completing this questionnaire

Responses: 58



2. Please elaborate on the role you selected to help us understand your perspective e.g. do you recreate in nature frequently or infrequently, are you a conservation officer, are you a university lecturer in tourism and would like access to data as perhaps a land manager might.

Responses: 58

Frequently walk on moors and mountain bike.

Like to combine walking with wildlife and biodiversity observation

I'm a university researcher and would like access to the data.

I am a PhD student who's main field is biodiversity modelling who also enjoys nature recreationally. Visiting nature frequently through local parks and national trust sites.

I use nature for recreation frequently, but might also be interested in using forestry data for work.

Ecologist

Conservation officer working on a specific piece of land to conserve wildlife

Interested in citizen science, general interest in wildlife and nature

Frequent recreationist

Mountain leader/recreational hiker

I'm not from the UK, from Libya.

I recreate in nature frequently

MPhil student, frequently in nature

I'm a conservation master's student who enjoys birdwatching

I record wild species regularly with iNaturalist, I spend a lot of time in nature

I recreate in nature frequently (out of the UK)

Working in ecology, mostly analyzing data. Not the classic field ecologist

Theoretical ecologist and occasional nature enthusiast. I don't spend much time in nature, but when I do, I like to go far.

I'm a researcher in forest ecology and an avid recreationalist, often enjoying natural environments.

American

UK based

I work as an ecological field researcher but also regularly access nature during dog walks and for birdwatching.

Postdoc in forestry. Based in Sweden.

Not living in the UK atm but have visited Scotland many times. PhD in Sweden

UK national, used to live in Scotland, likes to visit, but now lives in Sweden. I am a postdoc in biodiversity stuff.

Native reasonably fit - walking and photography. Science research in upland issues - mainly heather and bracken. Plant surveying in the Highlands for BSBI

I live in London, so do not recreate in nature often, but I would like to more!

I occasionally go into nature for recreation, and enjoy bird watching and plant identification

I am a Wildlife researcher.

tourist in UK, just curious

Recreationalist and university lecturer in geography

I am lecturer at the university

Ecology Professor

Walk in nature with my children

I recreate in nature frequently and I'm ecologist

i'm a biodiversity research and birdwatcher

I spend summertime in the countryside

I'm a eu project scientific community networking Officer in RI partner

I like walking on the seaside and observe small animals in the Mediterranean Coastal vegetation

Neither.

University PhD student studying ecology

no uk

University lecturer, recreationalist

I would like access to the data to potentially supplement my own research, and out of interest

I recreate in nature frequently. I am a research scientist who works in nature also.

I would be a frequent hard recreationalist but I have young children so the ability to look at the data and pick areas that can be suitable for both levels of activity would be good.

I like recreation

I like to go hiking and I don't have experience as a land manager

I am a keen paddleboarder and occasional hiker. I'm also a peatland researcher and Remote Sensing scientist for land management so I'm aware of some recreation and land degradation issues as well as policy.

I love to walk in nature, and I am a conservationist

i recreate in nature very frequently

University lecturer in Marine Biology focus on recreational fisheries

Yes ,I would like to access the data

I am a research Fellow in ecology but like to spend time in nature. Mostly for walking and to see insects and birds.

I relate more to recreationalist as I have hiked and camped in the cairngorms before but do not work as an enduser

I frequently spend time in nature and would love to have detailed information about observing animals

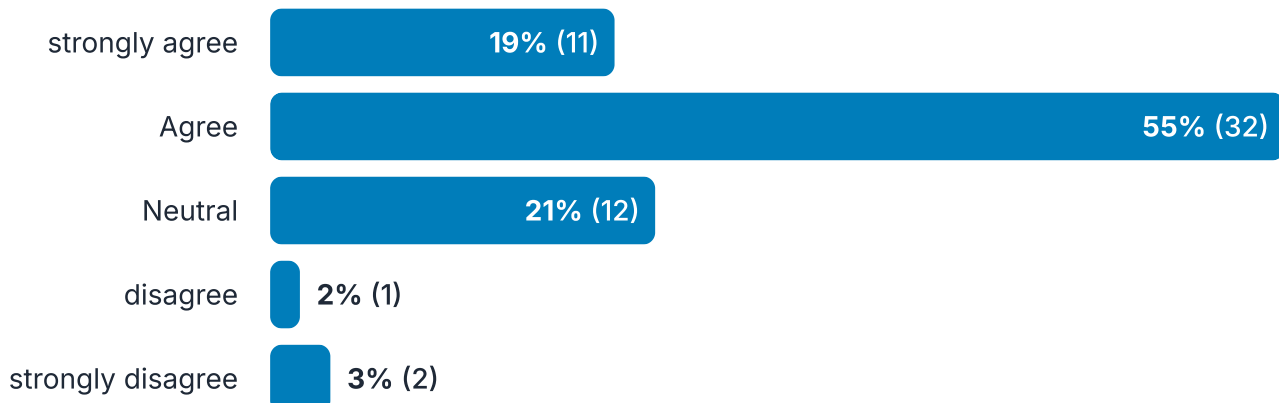
I am an equipment specialist for a UKRI funded facility. My work day is spent in a calibration laboratory, so I have no work (direct) related activities outdoors. However, the equipment I maintain is used for ecological research - habitat management, land classification etc. Personally, I don't spend much free time in nature, but do appreciate the conservation work conducted.

Moderate recreationalist with family including younger children. Conservation volunteer at local nature reserves and participant in citizen science projects.

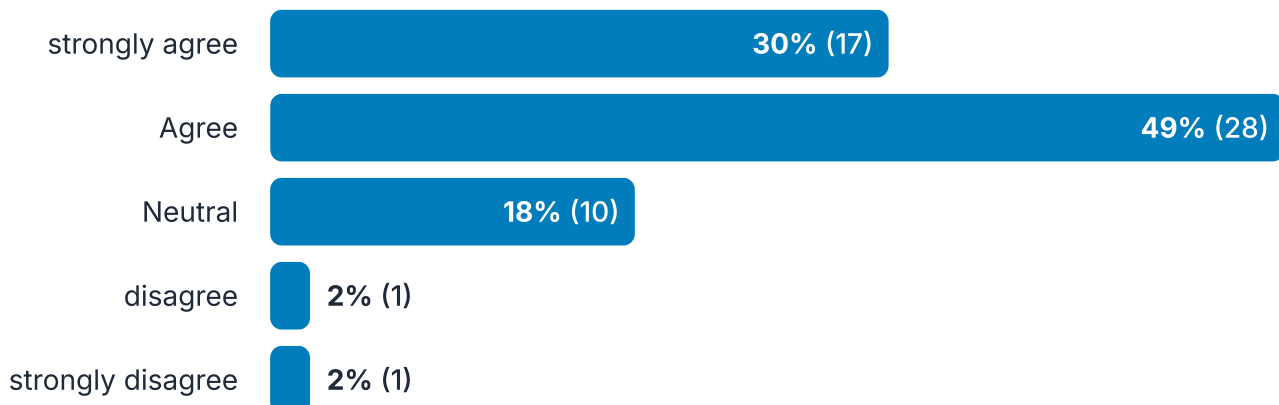
3. What do you think of the model outputs shown via a Graphical User Interface (see the accompanying booklet or QR code at end of explanatory booklet)? Please rank the following attributes of the Graphical User Interface

Responses: 58

The choice of three base maps is sufficient



Ability to use the slider to filter level of Recreational potential shown on the map is vital



Ability to use the slider to filter the probability of viewing biodiversity shown on the map is vital



Neutral 7% (4)

disagree 0% (0)

strongly disagree 0% (0)

Ability to select a specific species shown on the map is vital

strongly agree 65% (37)

Agree 25% (14)

Neutral 9% (5)

disagree 2% (1)

strongly disagree 0% (0)

Ability to select multiple species to be viewed on the map is vital

strongly agree 50% (29)

Agree 38% (22)

Neutral 10% (6)

disagree 2% (1)

strongly disagree 0% (0)

Colour scheme is clear

strongly agree 20% (11)

Agree 32% (18)

Neutral 30% (17)

disagree 18% (10)

strongly disagree 0% (0)

Ability to view additional knowledge on the species via the GBIF website is vital

strongly agree 39% (22)

Agree 37% (21)

Neutral 23% (13)

disagree 0% (0)

strongly disagree 2% (1)

4. Please elaborate on your views of the output shown – particularly if you have disagreed with any of the statements above, how can we improve the output e.g. are there other features you would like added to the output for example access to data detailing places other have visited, ability to view routes others have taken, ability to print your map etc.?

It looks quite complex for a recreational user. Would suggest simplicity is a priority if this is targeted at a public audience.

Interested in overall ecosystem richness rather than just one specific species

It would be good to include land use data and land ownership data

Ensure that all colours are colourblind friendly. Personally being able to view biodiversity in areas that I'm in would be really cool, looking at one species at a time.

Accessibility of the area would be nice to review.

N/a

Ability to print map with OS features so can be used to navigate. Key hotspots for certain species being clear on the maps. Regularly used routes shown on maps

Common/popular walks could be a useful addition (including info on walk distance, likely duration, and an easy-moderate-difficult guide

Link to specific recreational facilities

Clarity of nimagery is a little pixelated but workable

X

X

Overlapping colours can be a bit unclear

I think integrating a map such as the OS map (or cheaper equivalent) showing the positions of footpaths would help people plan routes. This could replace the infrastructure section honestly

I think the two colour scales can be mixed up a bit

.

It looks good and has all the obviously necessary map features

What would help for more passive wildlife enjoyers, would be, to be able to pick a route and THEN see what you can find there. It doesn't have to be that you start with species or families and then pick your route.

Colour scheme is a bit unclear but have no proposals, especially considering colour blind people. Need to bring in new datasets.

Could simplify or better training

x

Colours are too similar.

While completely agreeing palette should be color blind friendly, I think better ones could be found. It's not necessarily clear

It's good

I think you should be clear we're the I fo came from, but I don't need the direct link myself.

yellow and green tend to blue a bit

I think adding recommended walking routes, filtered for the soft and hard recreationalist would be good

The colours could be more vivid on the UI. It's also slightly slow.

1. When the species is present there, I dont understand why there's need to add the slider to reduction the chances of finding it. 2. Same for the recreation potential.

Sliders don't need two handle bars. Lower one is enough, the other hard-coded to 1 What is actually needed is an intersection of the two available maps, derived by multiplying them. If two maps are shown, they should be distinguishable by distinct color schemes

Ability to export data would be important. I would experiment with different colour schemes for recreation potential. Yellow as low and blue as high is not so intuitive for me.

I think it important to show diversity for different social groups and different abilities.

The app is already great

No comments

It's well design and intuitive, it's easy to use and the idea of combining the biodiversity with recreational information is really exciting. The ability to view and plan routes would be a good feature.

na

I think that multiple species view could be improved, and make easier for users to visually grasps the different species

ability to print your map

Vero well done and useful

It looks fine

Appreciate the accessible colour palette. Map renders fast. Access to raw data would be helpful.

I believe that is a novel interactive map m

I need more contrast

Graphical interface is clear and concise. Would be nice if the map would draw slightly quicker, but the features are great

Potentially add in seasonal affects I.e would an activity disturb during only spring

I think it would be good to have a way of indicating accessibility from a starting point e.g. a home post code. Maybe travel times or public transport.

It looks good

I would recommend to improve the loading speed.

Different colour schemes could be chosen to avoid any conflict with the the base maps. Some text by the scale sliders to give some context to what 0-1 means would be nice e.g. 1 for biodiversity being a 100% chance of encountering that species etc.

Agree with the above statements!

Maybe consider not putting detailed information for protected species.

Ordinance survey map would be useful

It should cover broader range of accessibility

I would like to be able to filter the recreation map based on some of the underlying data. For example if, one day I was just interested in walking near water, could I just look at those elements of the map and exclude irrelevant variables?

- colour scheme is not intuitive, heat map like cold to warm would be better - the scale on the recreation categories is skewed so most probabilities fall in the >0.45 group - change sp occurrence filter label to probability of spp occurrence - a base map with more info on walks, bothies etc would be good incorporated into the app e.g. OS map - more

I think the colour gradient is helpful for visualising the patterns, and the ability to use the grayscale toggle is very useful

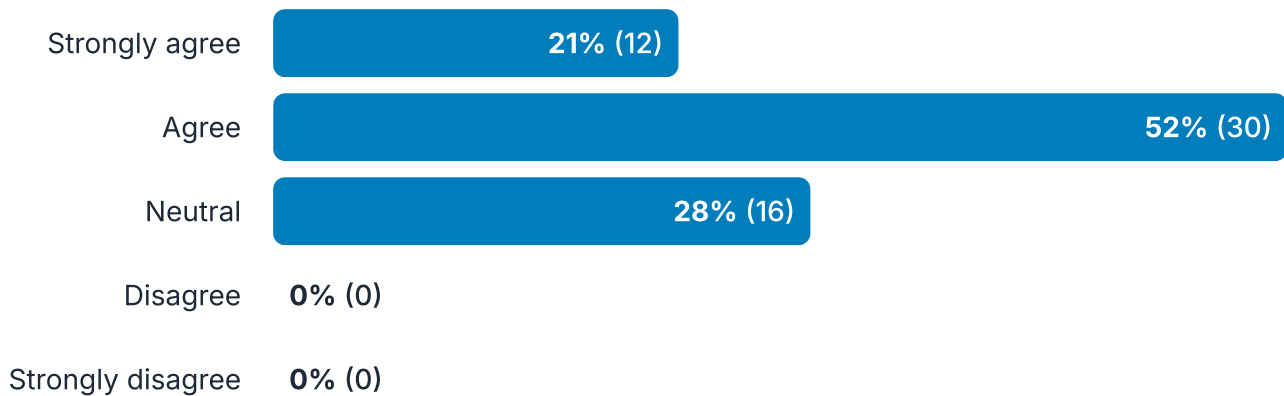
haven't see the map

Based on a quick trial of the system I would likely cross reference with OS map data to understand access and footpath locations for recreational activity. The lack of a map key for the layers (at least I couldn't find one) left me uncertain as to where footpaths or byways that would provide access were. A map key or alternate map layer (it may just be my familiarity/comfort with OS maps) might solve this and provide a one stop shop for planning a recreational visit for me. I initially thought the GBIF pages that opened were a distraction and not required for me. If I already know the species I want to search/filter for I wouldn't anticipate needing any further information. If I wasn't sure what something was e.g. a rare plant or insect, the GBIF page on first view seemed too technical for a layman, and that a general overview would be more useful. On closer inspection I found some information that may be useful (description and photos), so familiarity with the pages might allow me to find the snippets that could be useful.

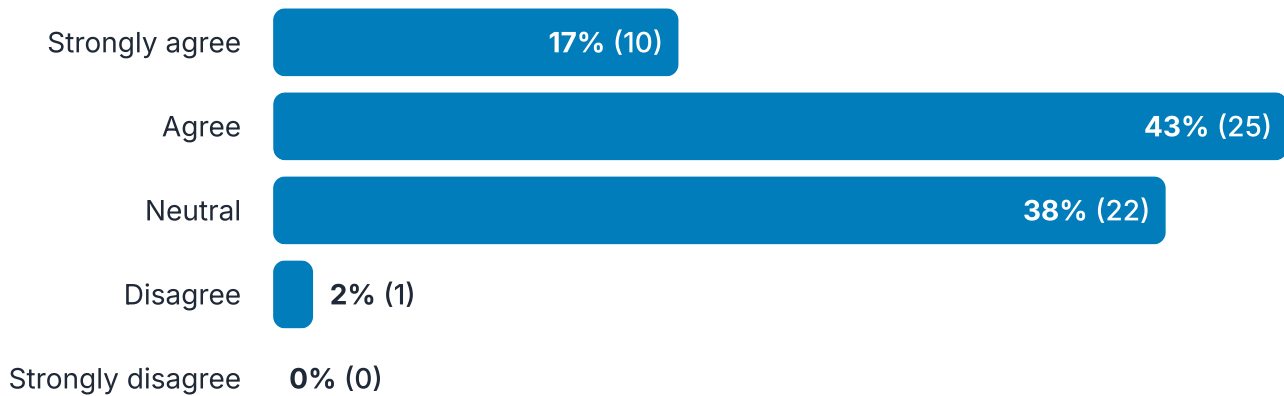
5. In the recreational potential model we have used data sources modified to enable mapping of the whole of Scotland. Please indicate your agreement with the following statements related to the recreational potential model

Responses: 58

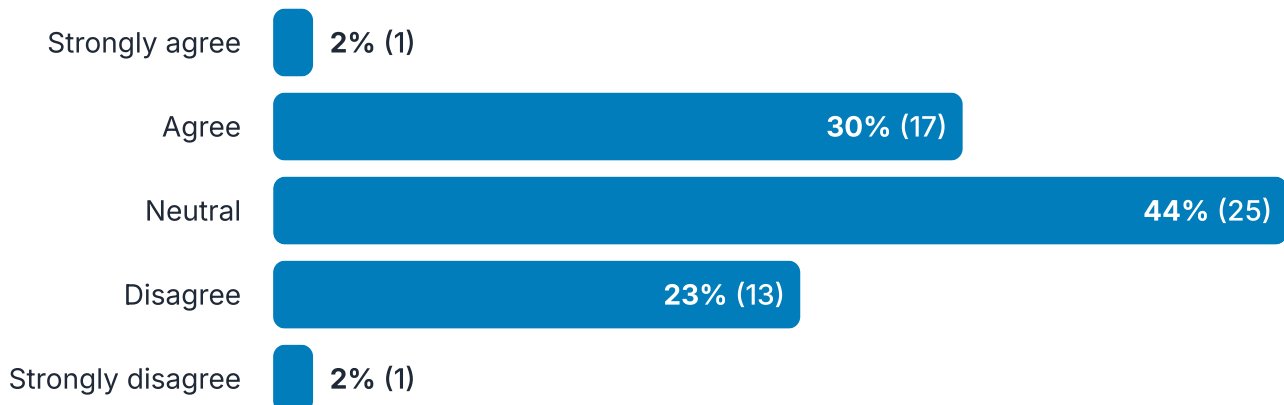
Current four model components (infrastructure, natural feature, water feature, landcover suitability) are sufficient



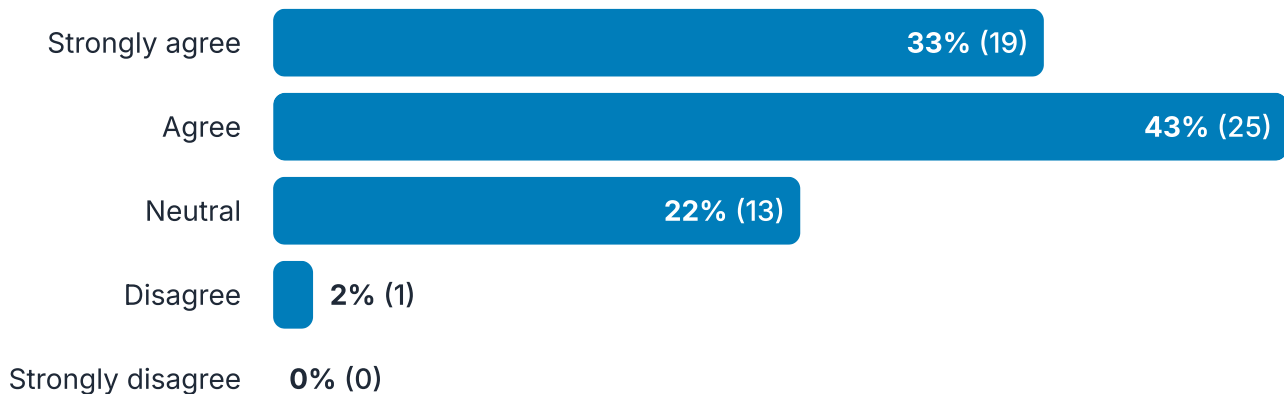
Number of parameters requiring to be scored (87) is sufficient



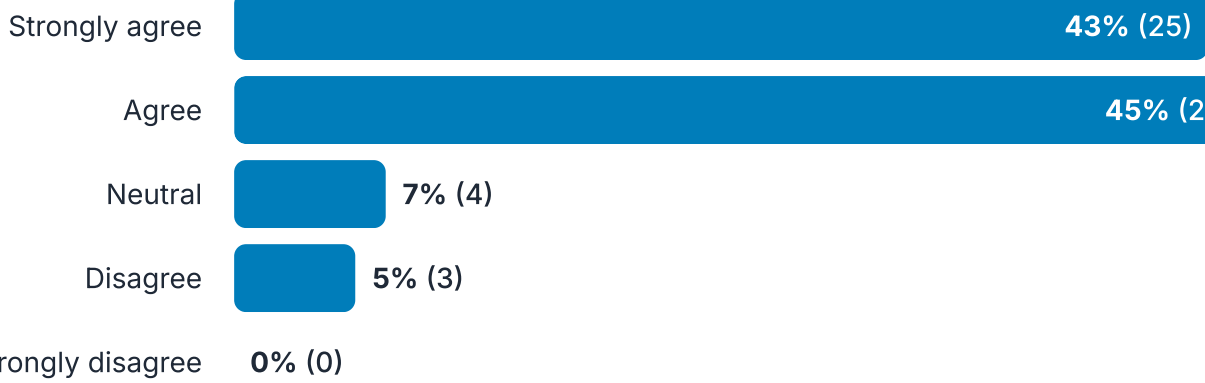
Scores for water and infrastructures components are the only two that should influence surrounding pixels



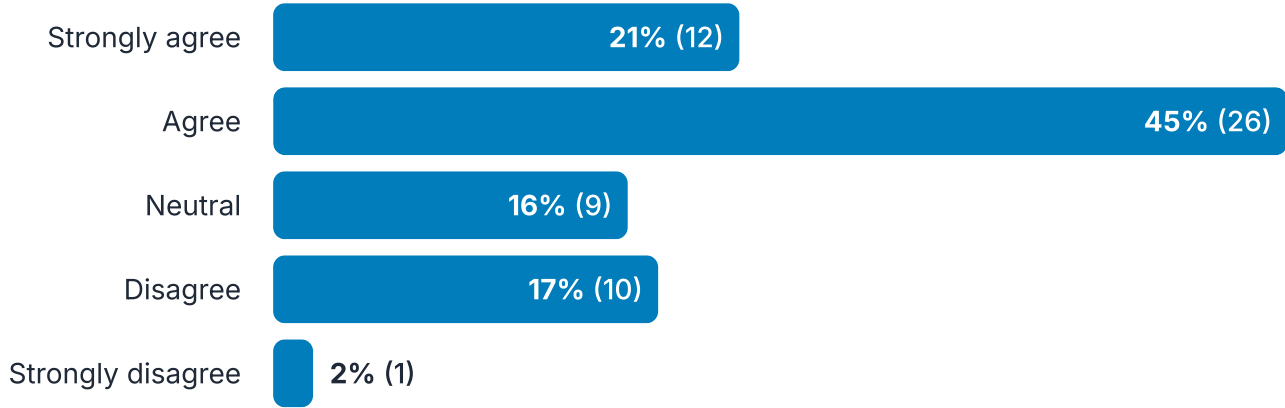
Storing recreational potential preferences for later reference is vital



Spatial resolution of 20 m is sufficient for your needs



An annual time step to update the model components is sufficient



6. Please elaborate on your views concerning our data sources and recreational model structure e.g. can you provide other data sources you think should be included and scored in the model, what data do you think should be shared with others or should a login ensure privacy etc.

Responses: 58

It all seems a bit complex.

x

The change in seasons (especially in the mountains in Scotland) means that for the recreational & wildlife viewing potential will need to be updated seasonally.

Do recreational scores change depending on the season and seasonal climate? E.g. is one area ok for soft recreationalist in summer but becomes more challenging in winter due to temperature, snow cover etc

Don't know

N/A

Species conservation listing. Likelihood of sighting. Using as many datasets as possible to input into the map. Where you have been should be anonymous.

Logging in to an account which stored preferences could be useful for frequent users

Na

The windy App is great for real time climate updates if that is within the parameters of the intended model

X

X

Landcover and land type can also influence nearby land

Infrastructure is not perhaps represented best (see my earlier comments). I agree that components should be editable

-

.

Not very knowledgeable about that topic

I think more if not all parameters should influence the surrounding pixels. Also looking at hills can be very nice :) Also, I think it should be more than 20m. Having a view into the distance is also important for outdoor enthusiasts.

Topography, climate and land use type should also influence surrounding pixels

Path important to show

c

Species are seasonal so we need to account for seasonal changes in distributions

I guess the additional informations, mostly on species seasonality could be added, so that a more frequent update of the map may result not necessary

Data shared on where people want to go and if they went. Annual data collection could be done at different times of year but still annually.

Data needs seasonal info.

20 m resolution is definitely ok for this sort of purpose. Annual updates sufficient and may even be too often for some parameters e.g. slope.

A login would be good- would be good to be able to save

It would be good to have a login to save parameters.

It would be great if you can include seasonal time update.

Yearly update is fine, but seasonal variations should be taken into account scores for water and POIs: additional to distance, line of sight may be a weighting criteria. A river is still nice to see from a mountain top 5km away 20m resolution is fine, but sum blurring may be needed visually UI element settings should be stored using cookies, local storage etc

Maybe cultural heritage could also be considered. Also more on climatic/weather conditions. Degradation, pollution.

Possibility the table of components is maybe has too many categories.

The app is already great

I'm not sure about most of those above, that's why I scored neutral. The five min usage of the tool over a conference coffee break is not enough to understand all about the tool. I still need to read the leaflet.

I don't have suggestions for this topic

na

Supporting people understanding how they can visit those places

I don't know

National River Authority could also make available biological and biodiversity data on a very detailed spatola scale

I don't recreate in nature

Very comprehensive, I think it would be vital to have access to download raw files to edit size etc.

biomass estimate and abundance would be good to add

Nothing

It would be nice to introduce seasonality for biodiversity

The ability to look at travel times from named locations or assess accessibility would be useful.

I think these are good data sources for selection criteria but perhaps they could be used to filter other data sources in external apps e.g. Strava routes matching various values.

In a seasonal environment you need updates per few months

You could also have seasonal data, as sometimes there are species that could be seen only in certain seasons. Also if possible it would be interesting to add other suggestions as wikiloc.

I'm unsure if a sub-annual time step matches up with the biodiversity databases but I would think there would be changes in distribution/ species' ranges within the year that would be useful to know.

Perhaps a more frequent time step would be beneficial

Annual update sounds very reasonable.

Needs a seasonal component

No idea really

Its great so many variables have been included. It would be great to look at subsets of these, for example, just the infrastructure ones, so that different needs could be explored. E.g can I look up just landscape designations if I want to prioritise reserves.

Not sure

I believe the data sources consider sufficient components to make well informed models.

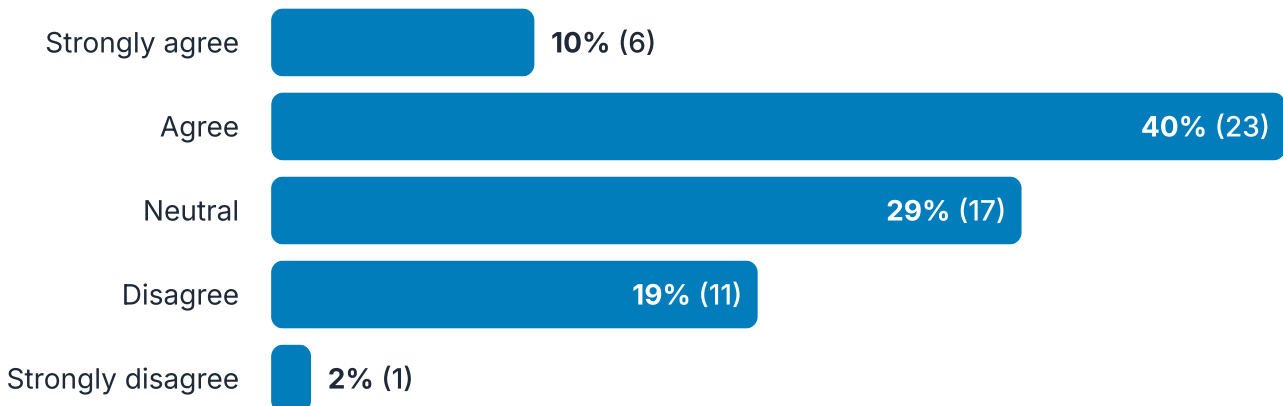
not my area of expertise - I haven't seen the model

I don't feel I understand how the data or how the GUI is generated well enough to comment. From a quick test it seems sufficient for soft recreational needs, at least to direct attention to sites that may be more suitable in a area I'm not familiar with.

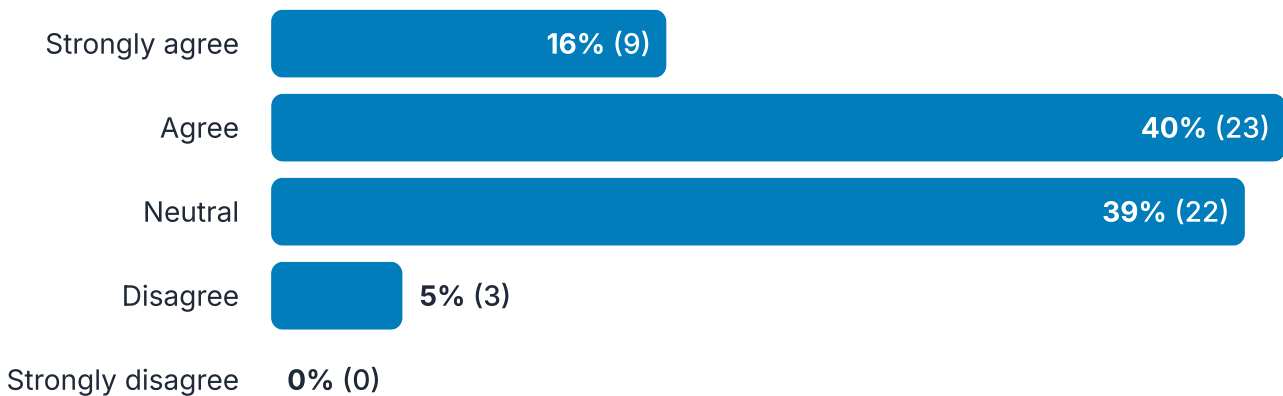
7. We have used Species distribution models (SDM) and citizen scientist data stored in GBIF and species information held in eLTER repository. Please rank your agreement with the following aspects of the biodiversity component of the prototype digital twin

Responses: 58

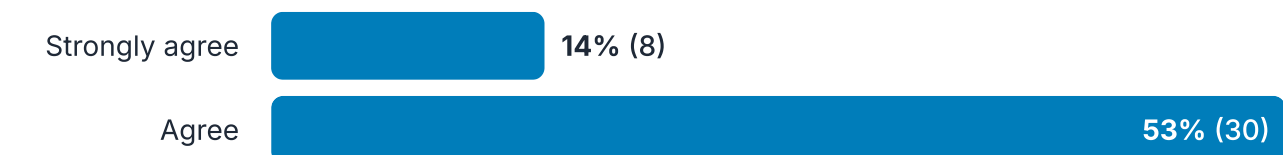
Citizen science data held by GBIF is sufficient for this digital twin

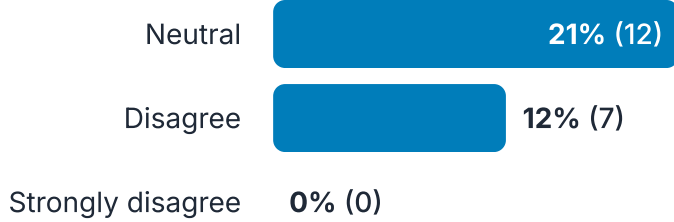


Species distribution models are the best type of models for this digital twin



Annual updates of species abundance is sufficient





Responses: 58

8. Please elaborate on your views concerning our data sources and SDM model structure for the biodiversity component of the prototype digital twin e.g. do you know of other biodiversity data sources you would recommend, are there other modelling techniques you feel would be more appropriate etc .

- This sounds reasonable
- x
- NA
- Gbif data relies on citizen science and doesn't have many checks. Instead it could be beneficial to use biodiversity data direct from the source of organisations in the UK. I know that data from these are eventually put into gbif.
- Don't know
- Better data sources needed to populate the map in regards to species.
- Don't limit your data sources.
- N/A - I don't know enough about data models
- GBIF very biased
- N/a
- I'm sure the UK will have other species data sets should be used.
- X
- Depends on location and species, in the UK GBIF data is likely to be good, but not for certain species/groups and not abroad
- GBIF is biased but would be hard to get better data
- for plants I would worry that dispersal limitation would limit the accuracy of SDMs. BSBI data could be useful as it is very complete and has a high resolution (and mostly isn't on GBIF)
- .

Not my topic

More data is always better, right? And there are quite some inaccuracy coming with SDMs, so you might get disappointed users.. I understand the complications of more refined data models though, especially computational power.

If available, bringing in new datasets would make the map less biased towards settlement areas.

C

x

Species are seasonal so need to show this seasonality in the models. Particularly for species which are sensitive but only during e.g. breeding seasons.

I would give occupancy models a shot!

Na

Maybe hierarchical occupancy modeling?

x

N/A

I think biannual updates would be better so that people making multiple trips to the same area can see what's new/what's changed.

E bird platform for birds data.

again, yearly updates are fine, but seasons should be taken into account

Is it possible to consider seasonal dynamics of species availability?

I think this is great and especially like possibly to look at cultural ES

No comments.

No comments to add

I don't have suggestions for this topic

i think the models could improve if vouchered data from museums are used to validate the sdms

I don't have enough information tonfurther elaborate

No

Lola fine

These questions are too ambiguous to answer

Gbif can be less up to date when compared to other citizen science archives due to bottlenecks in data flow

no

None

It would be interesting to include seasonal updates for species abundance

N/a

For popular taxa I think activity periods would be really useful so that people can go at appropriate times.

Would be good to have more data sources and cross-reference them

Maybe if you could find other data providers, but I dont have any ideas.

I don't know of other appropriate sources for models that give the same information as species distribution models but more exploration into info sources would be interesting.

Not too much expertise in species distribution unfortunately, so no strong views.

I wonder if you couldn't use national records instead of GBIF data. gBIF data can be a bit biased.

X

Powa

I love this element. It would be brilliant to prioritise visiting a space where I'm more likely to see species of interest. I think the data and approaches are sufficient, ensuring relevant variables are included.

Abundance mentioned in previous question not distribution. Otherwise sounds good, could use Inaturalist

I think citizen science data is sufficient but could be supplemented with survey data from population monitoring projects for more academic purposes.

na

Don't feel I know enough to comment. From a recreational viewpoint it seems sufficient and would point me in the direction of biodiversity hotspots or the specific areas I could visit to give a greater chance of observing certain species. The system doesn't appear to take seasonality into account i.e. if I was planning a visit in the winter hoping to see a specific species and didn't realise it was a summer migrant. For example I noticed there is data for common swift. A layman or pure recreationalist without knowledge of the species may find this misleading. Indeed I might for a species I wasn't familiar with, and knowing this would have to go and research further elsewhere.

9. To offer access to the digital twin after the EU funding stops (March 2025) please rank which the following funding mechanisms you feel we should explore most actively.

Responses: 58

Personal Subscription (an individual purchases a subscription fo...



Community Contribution (a group purchase a set number of subscri...



Government or government organization funded (for example NHS or...



10. Each of the above options require different commercialisation characteristics (e.g. data storage, data governance, business governance, cost model, risk strategy, product validation etc). Please explain your reasons for your selected funding mechanisms and tell us any thoughts you have on commercialisation characteristics.

Responses: 58

I think you would really struggle to fund this kind of capability under a subscription model. I would target government sponsorship.

x

There is inequality regarding data use and ability to get outdoors. This resource should be free if possible to reduce inequality.

Asking individuals to pay for this service might be a bit much. Instead government backed initially with an option to donate on site could be better. Could you incorporate the service into national trust memberships?

Nature is a common good that should be accessible by everybody.

N/A

X

I don't think personal subscription would be successful. I would use the digital twin if it was a free, but I don't think it offers so much value that I would pay for it.

NA

It needs to be free or affordable

I would not be happy for my privet data to available. But, I expect the authority to fund this model to encourage tourism.

I don't think people should be made to individually pay for this, but it is a great tool to have.

Would be a good way for government to promote access to nature.

The other structures could be implemented on top of individual subscription (group bundles, NHS-purchased subscriptions). This way it is the most accessible

I think it could be useful for local authorities to promote areas of recreational value but I don't know that I would pay for it for personal use

.

I don't see why there can't be multiple funding possibilities

I don't think personal subscriptions work here. Especially because you want to make skeptical or neutral people enthusiastic about outdoors and nature. The hurdle of making them pay for that is too high. Also, this should be in the interest of governments, so they should fund it.

Just out of ethical principles, making it easier to enjoy and connect with natural environments should be encouraged and publicly funded.

Say £5 with cosy distributed between client and group

x

The difference between this app and what is currently available is the ability to see where cool nature stuff is vs just places to go. Anyone prescribed to access nature, does not require the cool stuff so NHS funding can be spent better in other places.

I think good recreational activities should be available to everyone and not linked to personal wealth/possibilities. Popular map choices may be stored and made available.

Government should be invested in nature as a form of health benefits to its citizens. To improving biodiversity and the value of nature to individuals.

Na

x

I think it will be more popular with people who are already in the outdoor recreational space, so targeting it at walking groups etc is a good place to start

I'd attempt to look for a mixed model of funding through grants/foundations mixed with governmental support. Community share capital, or create a CIC. Or look at green finance.

No thoughts

Selling such a service is hard, but good luck :) potentially crowd funding could be worth a thought? Else credit card-based subscriptions with automatic renewals

I would hope that government funding would allow for open access.

It is very important that government supports model like this.

I would like the app to be public

If people have to pay, the tool won't be available broadly, including minority groups.

Government should offered this so everyone could use

if its free I'd be willing to give my data to track

Easier for people to enjoy it

Data storage

ERICs, as LifeWacth, can have a role

I have no idea, honestly

All are relevant, we need to be more ambitious. I wanted to tick all of them.

that is because this is crucial for both scientific community and policy decesions

I think this is public asset and need to be funded by public money

Pros and cons to all of them. Perhaps starting with community or subscription approach with view of later moving to government funding

Personal commercialisation tends to attract outside interest that might exploit through price rises, advertisement etc

I think this maybe could be integrated into other apps for outdoor activity society subscriptions e.g. mountain biking organisations or paddle board organisations

Not familiar with the schemes...

It should be funded by europe mainly to ensure a constant financial support. Individual based might not be enough.

If there's money from any government that wants to support this, open source is great. However, this might need lots of advertising money to make sure there's good uptake and doesn't fade away.

It seems like the type of work that would be very popular commercially and for accessibility you could potentially adapt to discounts for certain a groups (low income, students etc.)

The commercialisation bit is a bit difficult. As a tourist who would be in the area only for 1-2 weeks I am not sure that I would pay for a monthly subscription. But I would want to use this tool to plan my holiday in advance, so the local business solution wouldn't work super well either.

X

Trustee. Fundings

I'm not sure individuals would pay unless visiting regularly. Something for one off uses would be good for tourists.

I don't think an individual should pay for this

NA

If it was a previously government - all be it EU funded activity - the UK / devolved government should take over

It seems to me this would be the most likely route to make it available to me for recreational purposes. Otherwise a tourism agency or similar might fund to provide free access/information for visitors or potential visitors to plan recreation.

11. We are keen to develop the digital twin so is there anything else you would like to add to help us improve this digital twin?

Responses: 27

x

Sounds cool, would be interested to find out more about the sites planned for the future!

N/A

X

Not at this time

I think this survey is very important, it is scientific, applicable and most important is hugely effective.

Maybe include hiking or cycling tracks. Then it also shows how accessible the different species are.

This could be used as a tourism tool for those of us who are not from the UK

What

Great job!!!

No sorry

Should integrate with walkhighlands.co.uk hikes!

do you have a nice website with a neat landingpage? google search etc.

Add more recreationalist profiles, beyond soft/hard

Not sure if it is possible to provide different views and information for people with disabilities.

Congratulations, amazing tool

na

Yes

It looks like it might be useful for people who'll actually use nature for recreation

Bad weather announcement and warnings

I can't think of anything for now

X

Accessibility and broader audience

I'd like to be able to look up safe walking or hiking routes (eg like the All Trails app). Flag car parks, cafes if available, toilets. Perhaps you could encourage wildlife recording e.g. through iRecord to boost records and improve the biodiversity maps over time.

I would personally love to use it for exploring areas where rare species (e.g golden eagles/ospreys or other birds or prey) have been sighted by citizen scientists.

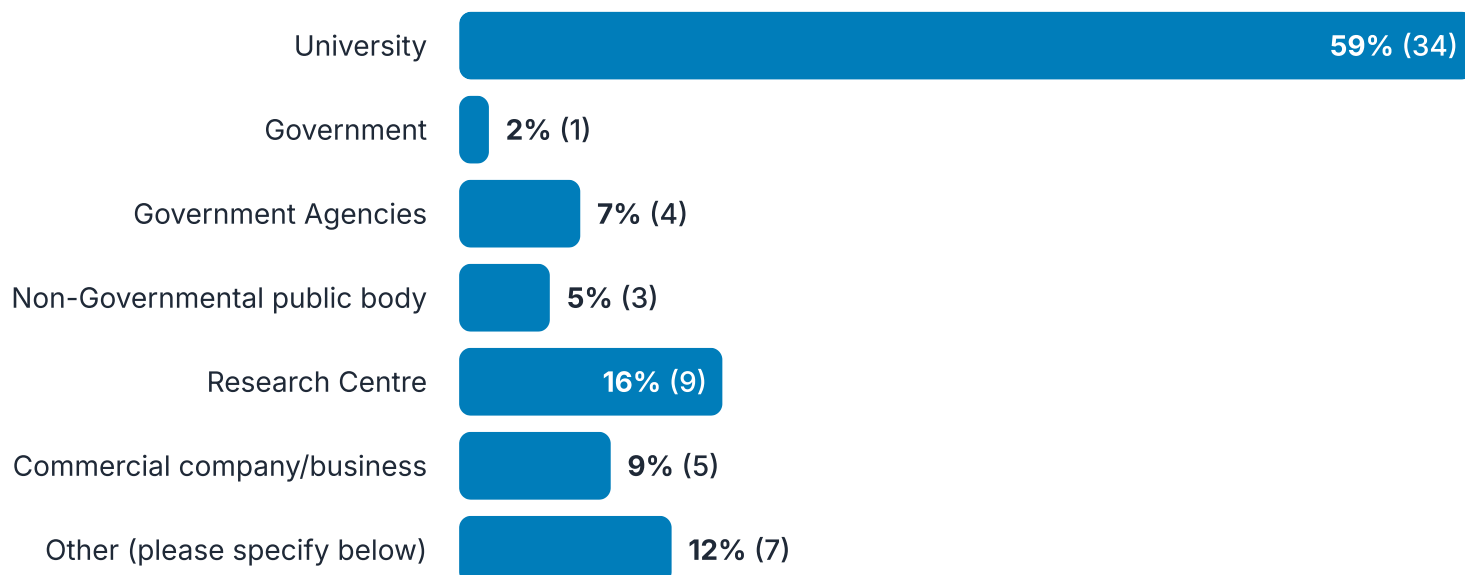
NCEO/NERC work extensively with remote sensing digital twins. Might have information on incorporating twins

Map key Highlight parking/access Seasonality indication or time of year entry/filter for species data The lower and upper limit points (circles, buttons?) on the filters for recreation potential & species occurrence can overlap and sit on top of one another. I couldn't understand why I had no species data showing on the map initially. Once I noticed this filter/slider issue I couldn't immediately separate the lower/upper limits but did manage eventually.

To enable us to describe the cohort sampled in this survey can you please tell us

12. The type of organisation/institute you are affiliated with?

Responses: 58



13. Please elaborate if you selected other above or which to clarify further

Responses: 16

Met Office

University of Essex

Charity

Wildlife charity

self employed ecologist

Phd student in forests and ungulates

retired ex university

British Ecological Society

A company limited by guarantee and a registered charity.

Copernicus Technologies manufacturing wildlife tracking devices

Liverpool John Moores University

Lancaster Environment Centre

European Reasearch Infrastructure

ERIC

Outside UK, situated in Slovenia

X

14. What is your role?

Responses: 58

Undergraduate student



2% (1)

Masters Student



9% (5)

PhD Student

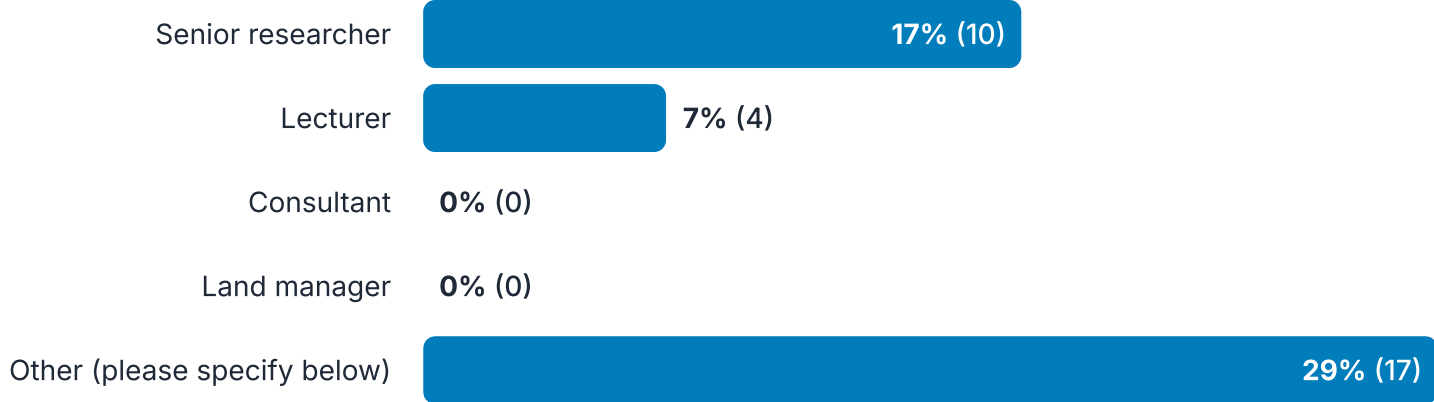


24% (14)

Junior researcher



16% (9)



15. Please elaborate if you selected other above or which to clarify your role further

Responses: 23

Senior Manager

Research fellow

Ecologist and Practitioner Scientist

Practitioner monitoring officer

Publisher

Professor

field ecologist (botanist)

Postdoctoral Researcher

retired prof

Assistant Editor

Senior manager at a charity

founder

Research on climate change and sustainability

Communication director

Scientific networking officer

Dept head

postdoc

Science lead in bioinformatics

I'm a operations manager in a NERC funded technical facility for spectroscopy.

Postdoc

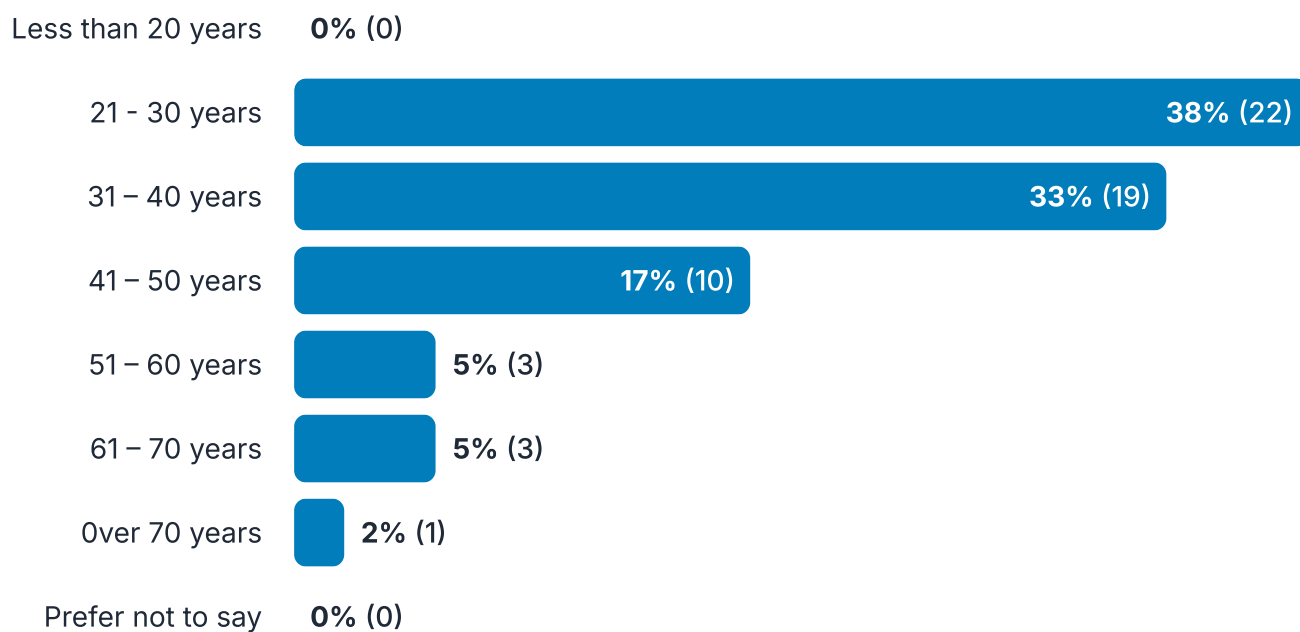
X

Research fellow

Employee

16. What is your age group?

Responses: 58



17. How would you describe your gender

Responses: 58



Prefer to self-describe (e.g. non-binary, gender-fluid, agender,...

0% (0)

18. Is there anything else you would like to add to help us conduct our research?

Responses: 15

N/A

Not at this time.

Thank you indeed

I'm Latin American

From and situated in Germany.

Season info important ... Can not see animal or plant flowering all year

Add walkhighlands.co.uk

na

No

i think that could be helpful to expand this to other regions as well

No

X

Please be inclusive

Contacting NERC/NCEO for further help on DT integration

See notes in previous section

Contact

enquiries@ceh.ac.uk

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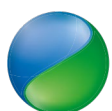
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