Supplementary Information

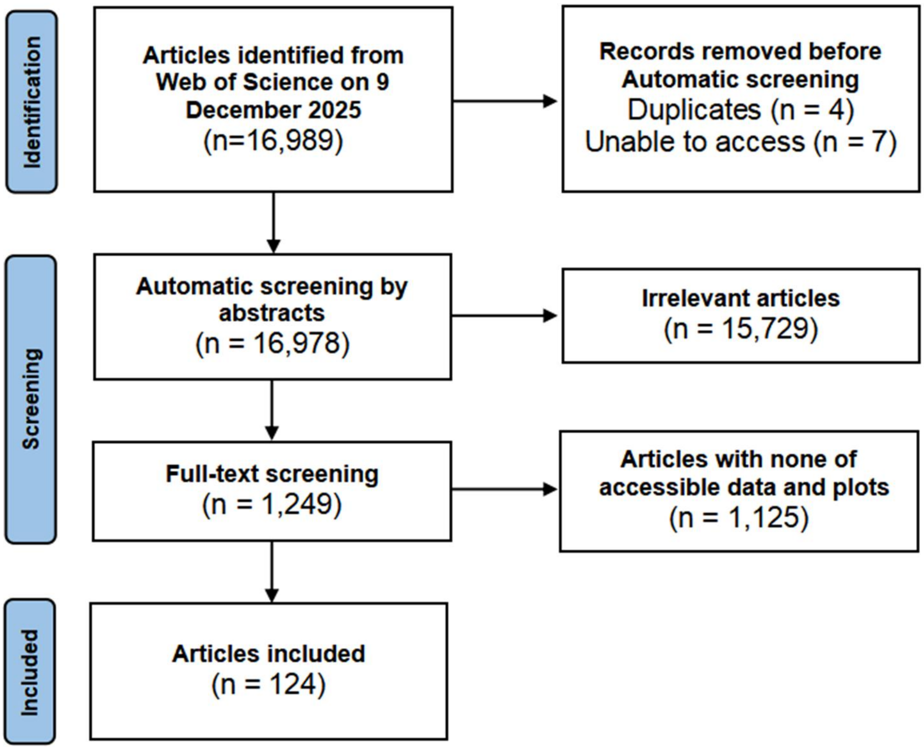


Fig. S1 Number of publications included or excluded at each stage of the literature search.

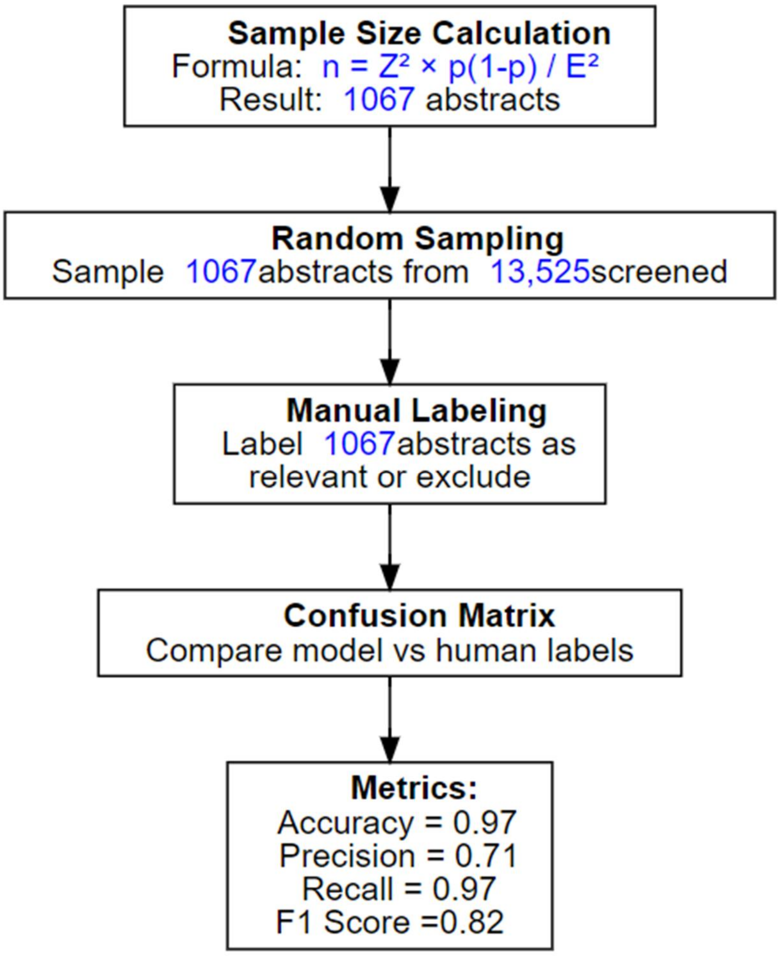


Fig. S2 Flowchart of Confirming the reliability of the model.

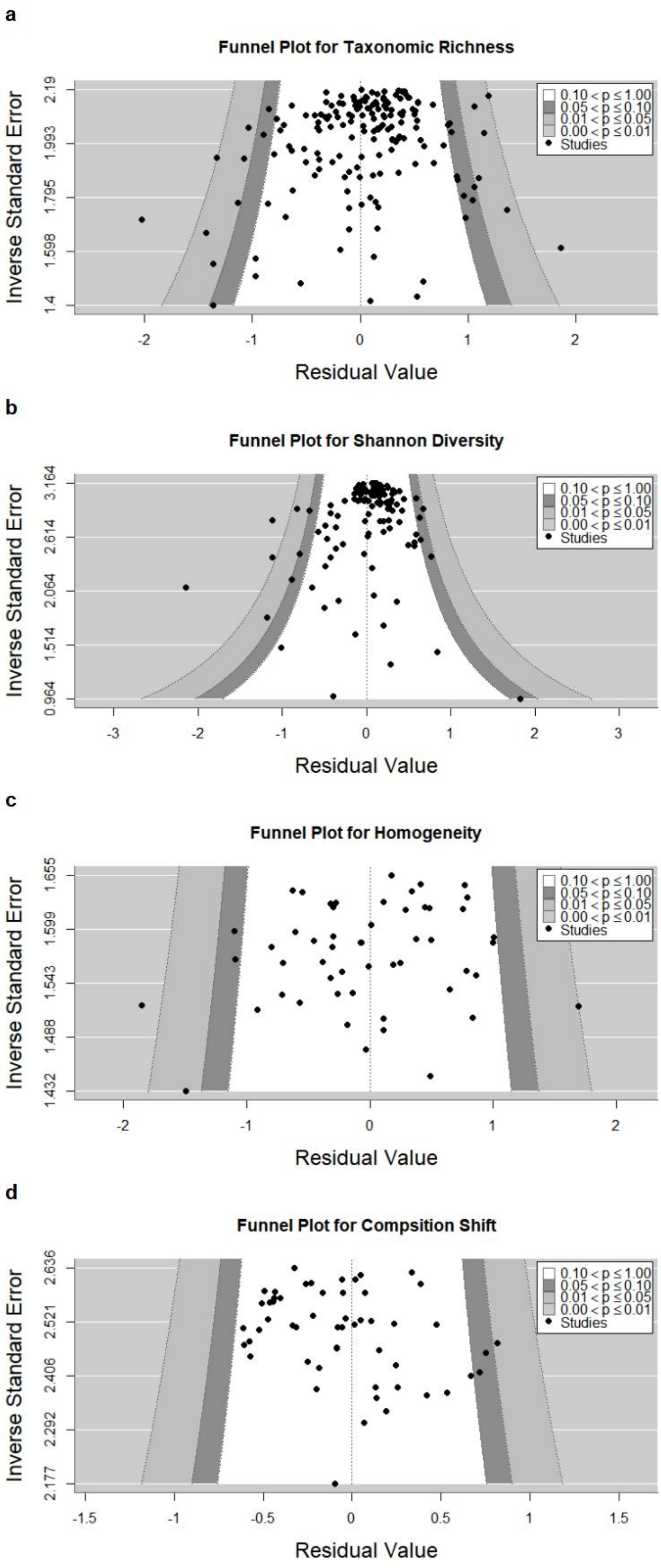


Fig. S3 Funnel plots of LRR taxonomic richness (a), LRR Shannon (b), LRR homogeneity (c) and LRR shift (d).

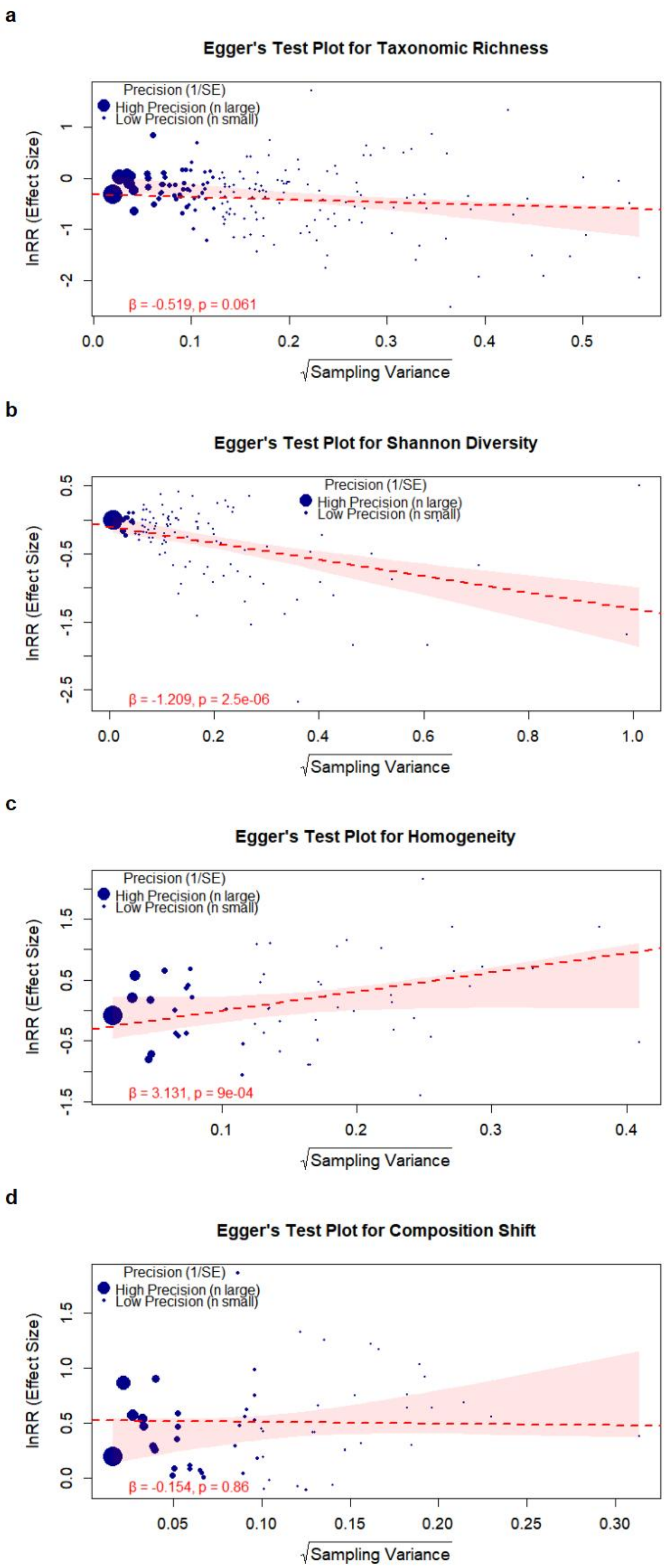
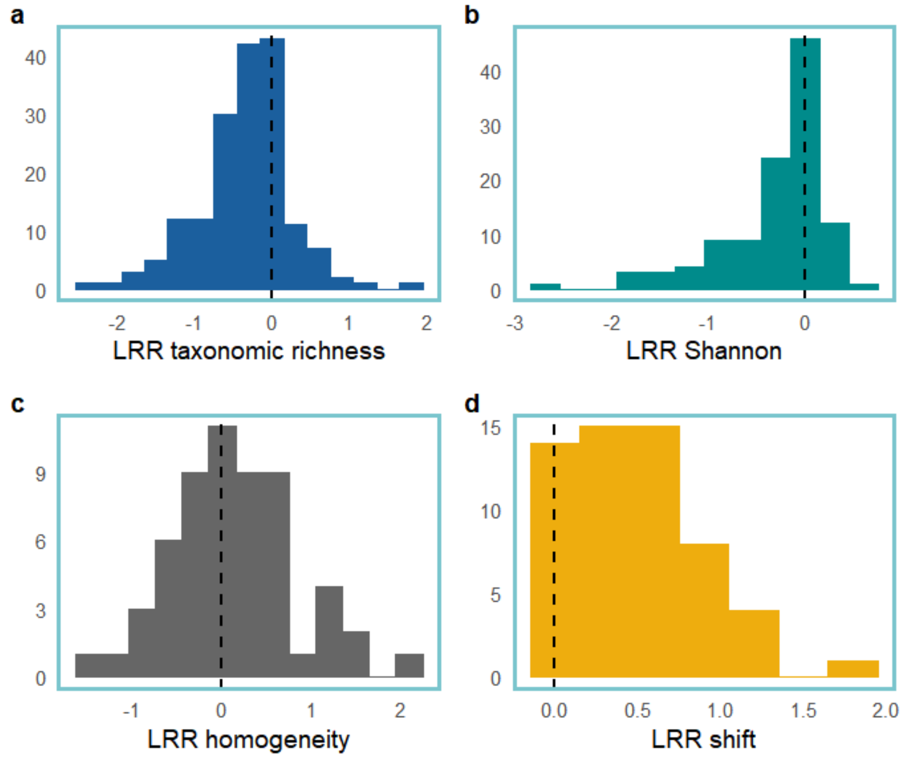


Fig. S4 Egger's test plots for LRR taxonomic richness (a), LRR Shannon (b), LRR homogeneity (c) and LRR shift (d).



Fig, S5 The distribution of the effect sizes of taxonomic richness (a), Shannon diversity (b), homogeneity (c), and species composition shift (d). The grey dashed line indicating the zero x-axis intercept, the range of the effect size values on the *x*-axis and frequency on the *y*-axis.

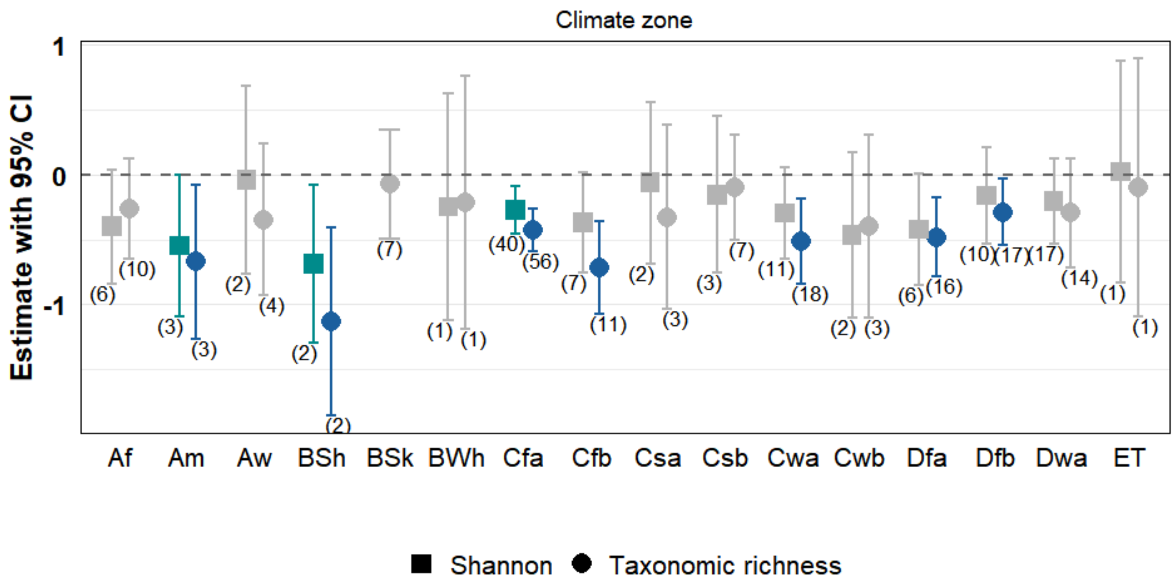


Fig. S6 Impacts of urbanization on taxonomic richness and Shannon diversity across Köppen climate zones. The numbers in parentheses inside the box indicate the number of comparisons. For each category the column represents the marginal mean computed from the model. The error bar shows the 95% confidence interval. Abbreviations for categories on the x-axis are detailed in Table S3.

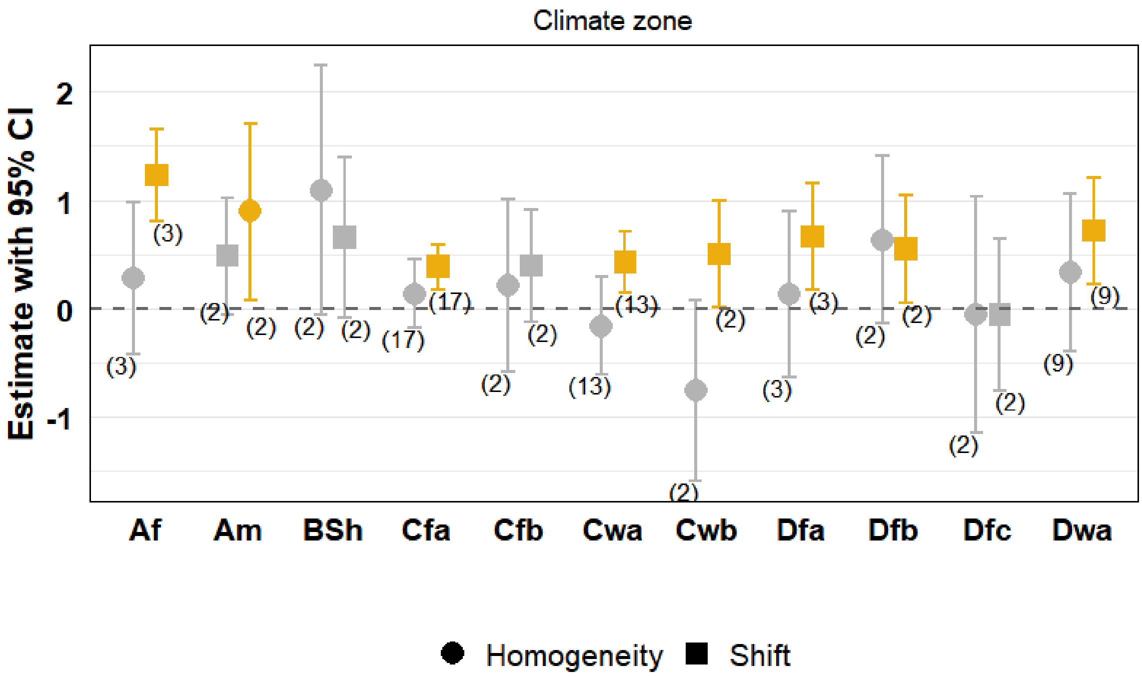


Fig. S7 Impacts of urbanization on homogeneity and composition shift across climate zones. The numbers in parentheses inside the box indicate the number of comparisons. For each category the column represents the marginal mean computed from the model. The error bar shows the 95% confidence interval. Abbreviations for categories on the x-axis are detailed in Table S3.

Table S1 Keywords and Boolean strings used on Web of Science

	Keywords
Urbanization	“urban sprawl” OR “urban growth” OR “urban development” OR “city expansion” OR “urban expansion” OR “metropolitan area expansion” OR “city growth" OR "urbanization” OR “urbanisation” (Topic)
Wetlands	wetland* OR swamp* OR marsh* OR bog* OR fen* OR peatland* OR mire* OR “tidal flat” OR everglade* OR mangrove* OR pond* OR estuar* OR lake* OR river* (Topic)
Document types	Article (Document Types) and Proceeding Paper or Data Paper or Retracted Publication or Book Chapters or Publication With Expression Of Concern (Exclude – Document Types)
Language	English (Languages)

Table S2 Result of type II Wald χ2 tests on moderators

Diversity of wetland	Moderators	Chi^2	p
Taxonomic diversity	Biological group	25.909	0.001
	Wetland type	19.218	0.004
	Scale	1.423	0.927
	Climate zone	16.296	0.418
	Income region	5.755	0.169
	Reference type	0.239	0.971
Shannon diversity	Biological group	22.116	0.003
	Wetland type	20.919	0.0008
	Scale	6.814	0.179
	Climate zone	19.160	0.270
	Income region	8.053	0.073
	Reference type	0.763	0.858
Homogeneity	Biological group	54.280	<0.0001
	Wetland type	5.175	0.378
	Scale	1.275	0.702
	Climate zone	5.960	0.866
	Income region	0.218	0.845
	Reference type	3.345	0.341
Shift	Biological group	39.970	<0.0001
	Wetland type	9.979	0.091
	Scale	10.215	0.086
	Climate zone	24.301	0.003
	Income region	0.0706	0.831
	Reference type	3.258	0.354

Table S3 Climate zones' abbreviations

Code	Description
Af	Tropical, rainforest
Am	Tropical, monsoon
Aw	Tropical, savannah
BWh	Arid, desert, hot
BWk	Arid, desert, cold
BSh	Arid, steppe, hot
BSk	Arid, steppe, cold
Csa	Temperate, dry summer, hot summer
Csb	Temperate, dry summer, warm summer
Csc	Temperate, dry summer, cold summer
Cwa	Temperate, dry winter, hot summer
Cwb	Temperate, dry winter, warm summer
Cwc	Temperate, dry winter, cold summer
Cfa	Temperate, no dry season, hot summer
Cfb	Temperate, no dry season, warm summer
Cfc	Temperate, no dry season, cold summer
Dsa	Cold, dry summer, hot summer
Dsb	Cold, dry summer, warm summer
Dsc	Cold, dry summer, cold summer
Dsd	Cold, dry summer, very cold winter
Dwa	Cold, dry winter, hot summer
Dwb	Cold, dry winter, warm summer
Dwc	Cold, dry winter, cold summer
Dwd	Cold, dry winter, very cold winter
Dfa	Cold, no dry season, hot summer
Dfb	Cold, no dry season, warm summer
Dfc	Cold, no dry season, cold summer
Dfd	Cold, no dry season, very cold winter
ET	Polar, tundra
EF	Polar, frost

Section 1 Process of abstract screening supported by gpt-4o model

Abstract screening was assisted using an automated workflow implemented in R that interacts with the OpenAI API through HTTP requests using the *httr* package. For each record, the script sends a POST request to the API endpoint (https://api.openai.com/v1/chat/completions) containing the abstract text and predefined relevance criteria formatted in JSON. The API processes the request using a specified language model and returns a response containing the classification result.

The request message structure follows the chat completion format and includes two roles ("system" and "user"). The "system" defines the screening instructions provided to the model, including the inclusion criteria and exclusion rules used to determine article relevance. The "user" contains the abstract text together with a prompt instructing the model to return only one of two labels ("relevant" or "exclude").

The API response contains a list of candidate outputs (choices), from which the classification result is extracted and stored for further processing. To ensure reproducibility, the temperature parameter was set to 0, which minimizes stochastic variation in model responses and ensures that identical inputs produce consistent outputs across repeated runs.

Following code is the central to our AI-assisted screening workflow:

```
filter_abstracts <- function(Abstract) {

  prompt_text <- paste0("only output 'relevant' or 'exclude'.\n",
                        "Abstract: ", Abstract, "\n")

   response <- POST(
    url = "https://api.openai.com/v1/chat/completions",
    add_headers(Authorization = paste("Bearer", api_key)),
    content_type_json(),
    body = toJSON(list(
      model = model,
      messages = list(
        list(role = "system", content = "Relevance Criteria: An article is relevant if it meets the following conditions:

Urbanization as a Direct Factor: The study explicitly investigates how urbanization (e.g., land use change, population growth, infrastructure development) affects biodiversity rather than just mentioning urbanization as background context.
```

```
Biodiversity Focus: The article should assess biodiversity at the species, community, or ecosystem level, including:
- Species richness, abundance, or diversity
- Community composition shifts
- Changes in functional groups or trophic interactions
- Habitat loss affecting species directly

Measurable Impact: The study must include quantitative or qualitative assessments of biodiversity changes due to urbanization. Acceptable methodologies include:
- Field surveys (e.g., species monitoring, transect data, eDNA)
- Remote sensing/GIS-based habitat or species distribution analysis
- Statistical modeling of biodiversity trends in urbanized vs. non-urbanized areas

Ecosystem Scope: The study should focus on wetland, freshwater, or marine ecosystems impacted by urbanization (e.g., estuaries, mangroves, lakes, rivers).

Exclusion Criteria: An article is not relevant if it:
- Focuses on general environmental pollution (e.g., water quality, heavy metals, or nutrients) without linking it to biodiversity outcomes.
- Examines ecosystem services or hydrological functions without addressing biodiversity shifts.
- Studies species behavior or habitat preferences without linking findings to urbanization-driven biodiversity change.
- Mentions urbanization as a background factor but does not assess its specific effect on biodiversity."),
          list(role = "user", content = prompt_text)),
        temperature = 0
      ), auto_unbox = TRUE)
  )

  response_content <- content(response, "parsed", simplifyVector = TRUE)

  choices_content <- response_content$choices

  print(choices_content)

  return(choices_content)
}
```

Section 2 Confirm the reliability of the model

To assess the performance of the GPT-4o-based screening model, a sample of 1,067 abstracts was randomly selected from the 13,536 articles obtained on 14 February 2025 using *slice_sample()* in R 4.4.1[1]. Each abstract in this sample was manually reviewed to determine whether it met the inclusion criteria. The manual labels were then compared with the model predictions to construct a confusion matrix. Sample size for validation was calculated using the formula $n=Z^2*p(1-p)/E^2$ with Z=1.96 (95% confidence level), p=0.5 (to maximize sample size), and E=0.03[2]. The result shows overall accuracy of 97.1%, with a precision of 70.7%, recall of 97.2%, and an F1-score of 0.82 (Fig. S2). The high recall indicates that the model rarely missed relevant studies (FN = 2), while a moderate precision suggests that some irrelevant articles were incorrectly classified as relevant (FP = 29).

Section 3 Publication bias

We assessed publication bias using a multilevel version of Egger's regression, with the square root of the sampling variance included as a moderator to test funnel plot asymmetry in the meta-analytic models. We also visually inspected traditional funnel plots to assess asymmetry (Fig. S3).

The intercepts from Egger's regression were statistically significant for LRR of Shannon diversity (p<0.0001) and LRR of homogeneity (p = 0.0009) (Fig. S4b, c), indicating detectable funnel plot asymmetry. In contrast, intercepts for LRR of taxonomic richness (p = 0.0615) and LRR of community shift (p = 0.8604) were not significant, suggesting no strong evidence of asymmetry for these response variables (Fig. S4a, d).

While the Egger's regression indicated statistically significant funnel plot asymmetry for both Shannon diversity and homogeneity, visual inspection of the funnel plots did not reveal obvious asymmetry (Fig. S3b, c). In heterogeneous ecological meta-analyses, the Egger's test can be highly sensitive to subtle, systematic relationships between effect sizes and their precision that may not be visually obvious, and which can arise from factors other than publication bias[3]. The significant regression likely reflects a small-study effect driven by ecological context rather than definitive publication bias[4].

Reference

1. R Core Team. *R: A Language and Environment for Statistical Computing*. (R Foundation for Statistical Computing, 2025).
2. Cochran, W. G. *Sampling Techniques*. (Wiley, New York, NY, 1977).
3. Ioannidis, J. P. A. & Trikalinos, T. A. The appropriateness of asymmetry tests for publication bias in meta-analyses: a large survey. *Canadian Medical Association Journal* **176**, 1091–1096 (2007).
4. Nakagawa, S. & Santos, E. S. A. Methodological issues and advances in biological meta-analysis. *Evol Ecol* **26**, 1253–1274 (2012).