Treelines and island biogeography – a global perspective using an innovative research approach

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Background

- **Climatic treelines** are one of the best studied borders in biogeographical and ecological research
- **Island** and their **unique environmental features** (e.g. isolation, rel. small area, island endemism, young geologic age,…) have been **largely ignored** in global treeline research.
- **Exception**: Leuschner (1996) suggested a lower treeline elevation on tropical and warm-temperate oceanic islands compared to treelines on the continent explained by:
  1. Isolation-induced **absence of species** adapted to high-elevation conditions
  2. Immature **volcanic soils** unable to support tree growth
  3. Trade wind-induced **aridity** above the thermal inversion layer
  4. Small or non-existent ***Massenerhebungseffekt*** due to small island area

Research questions

1. What is the global **latitudinal distribution** of island treeline patterns?
2. How do **island biogeographic parameters** affect global treeline elevations?
3. Do treelines differ between **continental** and **oceanic islands**?
4. What about the tropics/subtropics (roughly from 30°N to 30°S)?

Methods

- **Study area**: Oceanic and continental islands worldwide
- **Sampling method**: Combination of freely available **satellite imagery** and **digital elevation model** (GoogleEarth™, Google Inc.) as well as **expert knowledge** and **literature** were used to identify the highest treeline per island. Island name, maximum elevation, age and surface area were extracted from the **Global Island Database** (GID) and other sources of specific literature and online databases
- **Statistics**: Linear and multiple regression models

Results

Island biogeographical parameters	All islands n = 65		Continental islands n = 36		Oceanic islands n = 29		Tropical/ subtropical islands n = 27		Tropical/sub-tropical oceanic islands n = 16	
	Adj. R^2	Trans./ Dir.	Adj. R^2	Trans./ Dir.	Adj. R^2	Trans./ Dir.	Adj. R^2	Trans./ Dir.	Adj. R^2	Trans./ Dir.
Island surface area	**0.225*** **	√ / +	**0.345*** **	+	0.079 .	log / +	**0.423*** **	√ / +	n.s.	
Maximum island elevation	**0.787*** **	+	**0.801*** **	+	**0.734*** **	√ / +	**0.885*** **	√ / +	**0.854*** **	log / +
Isolation from continent	n.s.		**0.175***	∩ / -	0.126 .	∪ / +	0.124 .	∩ / -	**0.304***	power / +
Isolation from nearest neighbor	n.s.		n.s.		n.s.		n.s.		n.s.	
Island age	n.s.		n.s.		n.s.		**0.213***	log / -	n.s.	
Geology (oceanic vs. continental)	n.s.		-		-		**0.353*** **		-	
Latitude	**0.564*** **	∩ / -	**0.791*** **	∩ / -	**0.487*** **	∩ / -	n.s.		n.s	

Tab .1. **Treeline vs. island biogeographical parameters** for all islands and various subsets. The adjusted R^2 of significant correlations are written in bold. Significance levels are displayed as * for $p < 0.05$, ** for $p < 0.01$ and *** for $p < 0.001$. Near significance is shown as '.' for $p < 0.1$. *Trans.* gives the transformation used for best fit: log = logarithmic, √ = square root, ∪ for a positive and ∩ for a negative hump-shape. *Dir.* indicates the direction of correlation (i.e. positive or negative).

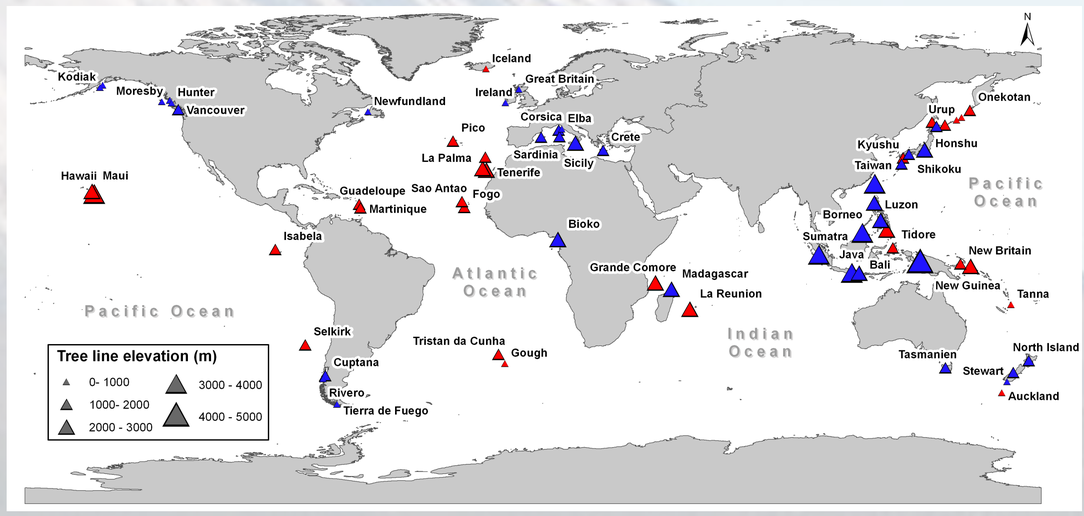

Fig. 1. Distribution and names of **all sampled islands**. 36 continental and 29 oceanic islands were used for the analysis ranging from 64°N to 54°S.

	Adj. R^2
All islands	**0,33*** **
Continental islands	**0,362*** **
Oceanic islands	**0,355** **
Tropical/subtropical islands	n.s.
Tropical/subtropical oceanic islands	n.s.

Tab. 2. **Treeline vs. hump-shaped latitudinal distribution corrected for maximum island elevation** (i.e. by using the residuals).

	Adj. R^2
All islands	**0,890*** **
Continental islands	**0,933*** **
Oceanic islands	**0,858*** **
Tropical and subtropical islands	**0,920*** **
Tropical/subtropical oceanic islands	**0,881*** **

Tab. 3. **Multiple regression model** explaining the distribution of treelines using the best fitting variables and transformations from Tab. 1.

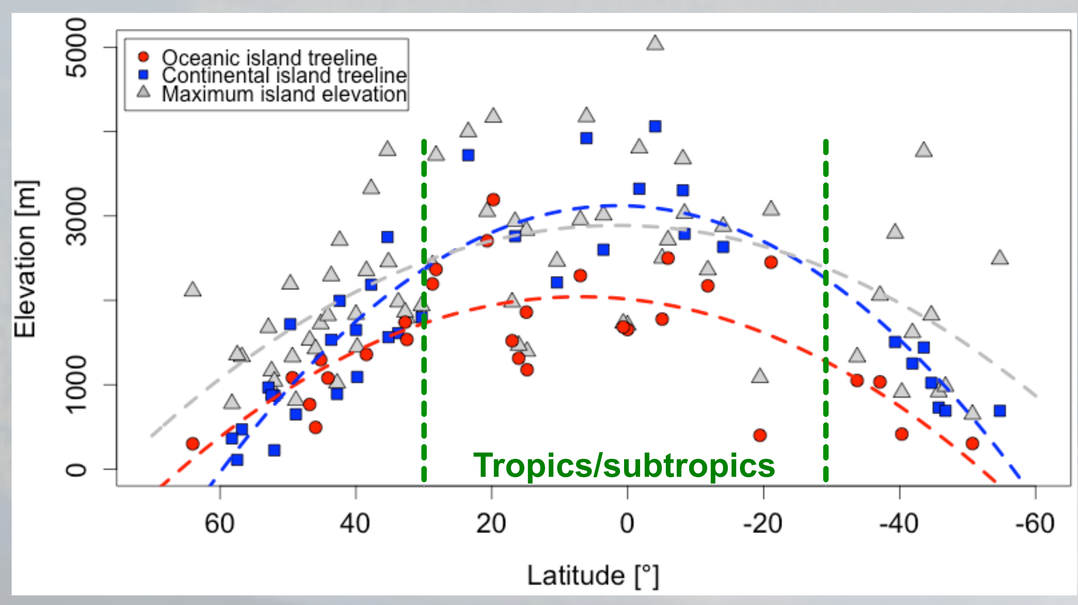

Fig. 2. **Latitudinal distribution** of oceanic and continental island treelines as well as maximum island elevation. Surprisingly, maximum island elevation (for all islands) shows a hump-shaped latitudinal distribution.

Discussion & Conclusion

- Global island treeline distribution: **highest values in the tropics** (and subtropics); **decline towards the poles** → Pattern comparable to treelines on the continent.
- **Treeline variation**: low at locations higher than ± 30°, high in tropics/subtropics (ranging from 400 to 4061 m) (Fig. 2).
- **Max. island elevation:** best explanatory island biogeogr. parameter (Tab. 1). **Possible sampling bias?** → Treelines ± independent of max. island elevation at higher latitudes; tropical/subtropical islands must reach min. elevation to possess a treeline. BUT: **humped latitudinal distribution** significant, if **corrected for max. island elevation** (Tab. 2).
- Treelines **on continental islands higher** only **in the tropics/subtropics** than on oceanic islands. Explanation: many large and high continental islands exist e.g. in Southeast Asia/Northern Oceania → **Humid conditions at high elevations**. Most oceanic islands are influenced by **trade winds** → **drought-prone** at high elevations (see Leuschner 1996).

⇨ **Leveling off of treelines** in the tropics/subtropics, **no subtropical double-hump** as on the continent.

⇨ Island biogeographical approach a good tool to **predict global treeline distribution patterns** on islands (Tab. 3).

⇨ **Next step**: Comparison with treelines on the continent!

Leuschner C (1996) Timberline and alpine vegetation on the tropical and warm-temperate oceanic islands of the world: elevation, structure and floristics. Vegetatio 123: 193-206

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