Tropical ecology
WBNZ-849
starting 14:45 (as in USOS)

Ryszard Laskowski

Institute of Environmental Sciences, Jagiellonian University

http://www.cyfronet.krakow.pl/~uxlaskow/

1. About the course
2. Lecture #1: Introduction to tropical ecology

1

Course organization

- **Place:** Institute of Environmental Sci., Room 1.1.1
- **Time:** Friday, 14:45 – 17:15
  - 8 x 3 h (lectures & discussion classes)
  - 2 seminars (3 h each)
- **Teachers:** Marcin Czarnołęski, Wojciech Fiałkowski, Paweł Koteja, Ryszard Laskowski, Krzysztof Wiąckowski
- **Evaluation**:
  - final exam (5-6 open questions): 80%
  - active participation in classes: 20%

2/62

2

Teachers' emails

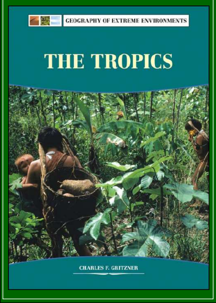
- marcin.czarnoleski@uj.edu.pl
- wojciech.fialkowski@uj.edu.pl
- pawel.koteja@uj.edu.pl
- ryszard.laskowski@uj.edu.pl
- krzysztof.wiackowski@uj.edu.pl

3/62

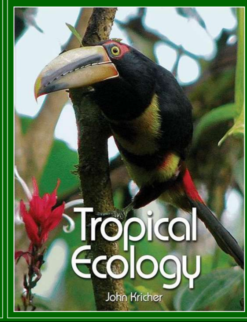
3

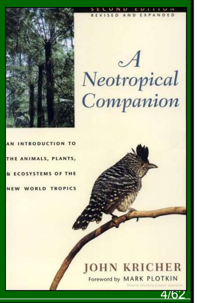
Reading

- **Articles and textbooks available at the course website**



- Books from the Library of Natural Sciences

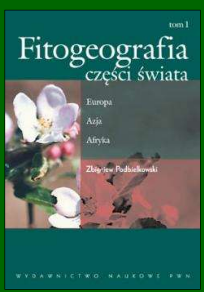


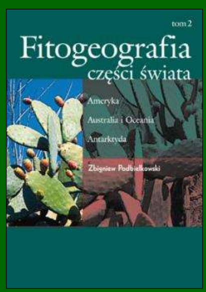


4/62

4

Supplementary reading in Polish





5/62

5

ATTENTION:

The 'Tropical Ecology' course (WBNZ 849) is the prerequisite for 'Tropical Ecology Field Course' (WBNZ 850)

Topics:

Introduction to tropical ecology: tropical biomes – geographical distribution and characteristics

Destruction and protection of tropical ecosystems

Equatorial rainforests – the most diverse biome on Earth

- gradients in biodiversity and theories explaining them
- diversity in life strategies

Adaptations in animals to hot deserts

Biology of coral reefs and mangroves: environmental conditions and biodiversity.

6/62

6

Introduction to tropical ecology

7

Where are the tropics?

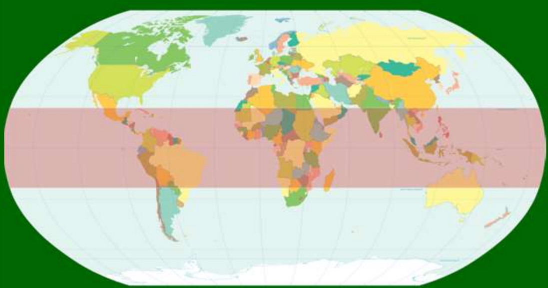
- Origin of the term: from Greek *τρόπος* (*tropos)* = *turn* (the sun appears to "turn back" at the solstices)
- ➔ Area between the *Tropic of Cancer* ($23^{o}30'N$) and the *Tropic of Capricorn* ($23^{o}30'S$)
- ➔ Area of the Earth where the Sun is 90^{o} above the horizon at least once every year
- ➔ = *tropical zone* = *torrid zone*

8/62

8

Where are the tropics located? The simplest possible answer:

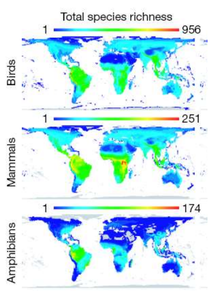
The area between the Tropic of Cancer and the Tropic of Capricorn



9/62

9

Why should we study tropical ecology?



Species richness on Earth (per 1°×1° ≈ 9274 km^2)

Grenyer, R. et al. 2006. Global distribution and conservation of rare and threatened vertebrates. Nature 444: 93-96. (pdf available for course participants at the course web page)

10/62

10

Species richness in tropics

Taxonomic group	Poland (312 000 km^2)	Uganda (241 000 km^2)
vascular plants	2700	4900
mammals	109	330
birds	446	1061
reptiles	9	165
amphibians	18	52

Sources: Wikipedia; http://www.africapedia.com; EarthTrends (http://www.vub.ac.be/klimostoolkit/sites/default/files/documents/uganda_bd.pdf)

11/62

11

Biodiversity hotspots on Earth

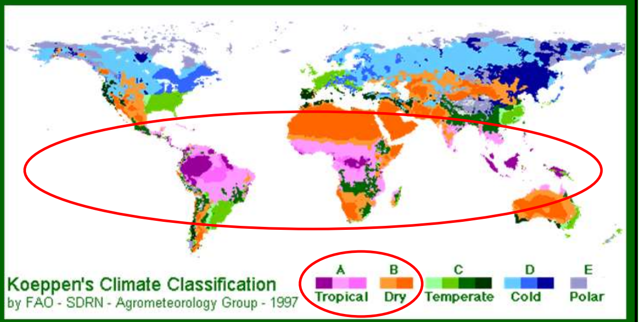
„As many as 44% of all species of vascular plants and 35% of all species in four vertebrate groups are confined to 25 hotspots comprising only 1.4% of the land surface of the Earth."

Myers, N. et al. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858. (pdf available for course participants at the course web page)

12/62

12

Tropical climates according to Wladimir Köppen



13/62

13

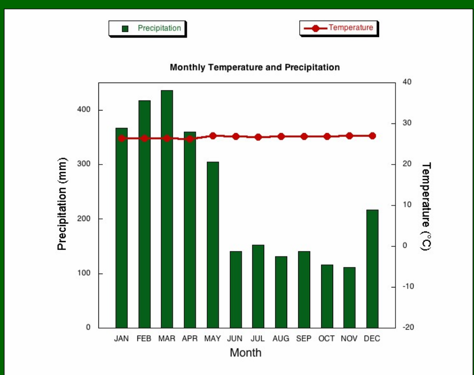
Tropical climates according to Köppen

- **Group A: Tropical (megathermal) climates**
  - *Af*: Tropical rainforest climate (~ 5 - 10° of the equator; in coastal areas can extend to 25°; no seasonality) = hygromegathermal
  - *Am*: Tropical monsoon climate (further from the equator; two seasons – rain and dry)
  - *Aw*: Tropical savanna climate (two seasons, wet and dry – very clear and pronounced)
- **Group B: Dry climates (arid and semiarid)**
  - Only partly belong to tropics

14/62

14

1. Tropical rainforests



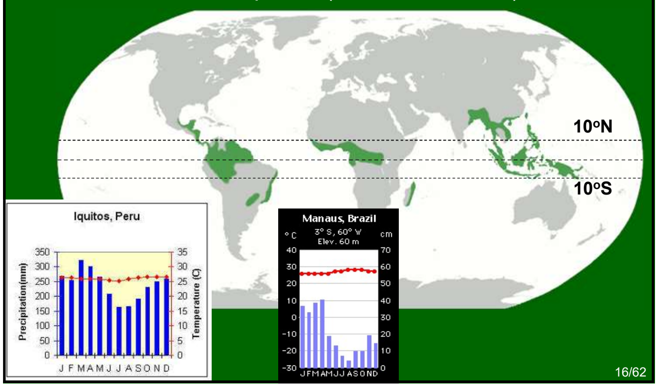
Climatic diagram for Belem (Brazil)

15/62

15

Tropical rainforests: geographical distribution

around equator (ca. 10^{o}S – 10^{o}N)



16/62

16

Tropical rainforests: characteristics

- **Very high annual rainfall: at least 1700 – 2000 mm**
- **Average annual temperature: 27 – 30^{o}C**
- **High rate of biogeochemical cycles**
- **Soils: low in organic matter and nutrients due to intensive weathering (laterization → oxisols)**
- **Four-layer forests: (1) emergent layer – single trees above the canopy (60-70 m); (2) canopy layer (30-45 m); (3) understory layer (only ca. 5% of light!); (4) forest floor (only ca. 2% of light)**
- **Richness of epiphytes and lianas**
- **Extreme species richness: >30% of all plant and animal species living on Earth at only 6% of Earth surface!**

17/62

17

Tropical rainforests: types

- **Lowland equatorial evergreen rainforests**
  - annual precipitation above 2000 mm
  - Amazon, Orinoco and Congo basins, Indonesia, New Guinea
- **Wet broadleaf forests partly evergreen**
  - high annual rainfall, warm and wet summer and cooler and dryer winter
  - Central America, Caribbean, West Africa, India, Indochina
- **Montane cloud forests**
  - cooler mountain climate, high rainfall, low cloud cover
  - tropical and subtropical mountains
- **Floodplain forests**
  - environmental conditions similar to lowland evergreen forests but in poorly drained areas → flooding
  - Borneo, Sumatra, Malay Peninsula, Indochina

18/62

18

Nutrient turnover rate

Average retention time of dead organic matter and nutrients in forest litter: boreal forest (taiga), temperate broadleaf forest, and equatorial rainforest (*time in years*)

Biome	Organic matter	N	P	K	Ca	Mg
Taiga	353	230	324	94	149	455
Temperate forest	4	5.5	5.8	1.3	3.0	3.4
Rainforest	*0.4*	*2*	*1.6*	*0.7*	*1.5*	*1.1*

Schlesinger 1991

19/62

19

Productivity and carbon accumulation

Average NPP of selected biomes (**kg x m^{-2} x year^{-1}**), carbon accumulation rate (**g x m^{-2} x year^{-1}**) and C(biomass)/C(soil)

Biome	Productivity	C accumulation rate	C(b)/C(s)
Taiga	0.8	11.7 – 15.3	0.55
Temperate forest	1.2	0.7 – 5.1	1.13
Rainforest	*2.2*	*2.3 – 2.5*	*1.68*

Lieth & Whittaker 1975, Schlesinger 1991

20/62

20

Main carbon pools in primeval tropical rainforests

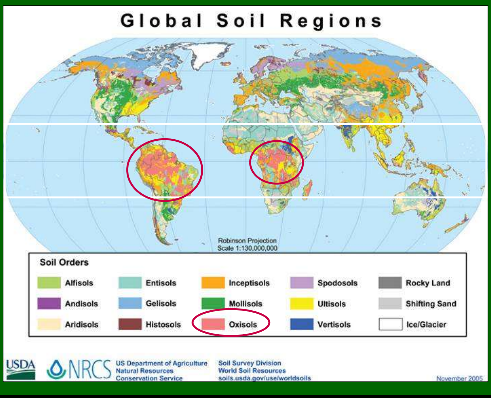
Part of the ecosystem	Accumulated carbon (t C/ha)
Alive plants (above and underground)	210
Dead trees and litter	10
Soil	100
TOTAL:	*320*

After Jonathan Adams, Oak Ridge National Laboratory, TN 37831, USA

21/62

21

Tropical rainforest soils



22/62

22

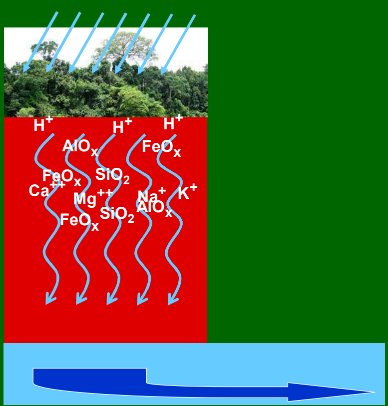
Ferrasols (FAO) = Oxisols (USDA): location and pedogenesis

- Earlier called *laterites*; acc. to FAO - *ferrasols*
- Definition: soils containing in the whole profile ≤10% leachable materials and <10% base saturation; high content of Fe and Al oxides
- Location: ca. 1/3 of the Earth's continental land area, mostly 15-25°S – 15-25° N
- Pedogenesis – tropical weathering (*laterization*):
  - high precipitation + CO_2 → chemical weathering and leaching of humic materials and minerals from the soil profile
  - only stable Fe i Al oxides remain → rusty-red color

23/62

23

Laterization



24/62

24

Ferrasols (Oxisols) – Kenya

25/62

25

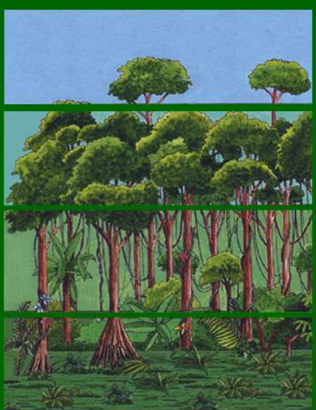
Laterization – consequences:

- Leaching of virtually all organic matter and nutrients
  - → soils very poor in nutrients
  - → very small reservoirs of soil organic matter
  - → plants have to use (re-cycle) all minerals released from decomposing litter very efficiently
  - → no nutrient supply after forest destruction and removal of plants → soils become infertile very quickly → difficult forest regeneration
  - → primeval forests replaced with secondary ecosystems (secondary forests of bushes)

26/62

26

Four-layer forest structure



Emergent layer:
60-70 m high broadleaf trees
birds, monkeys, bats, butterflies

Canopy layer
30-45 m high, very dense layer
toucans, snakes, treefrogs, beetles

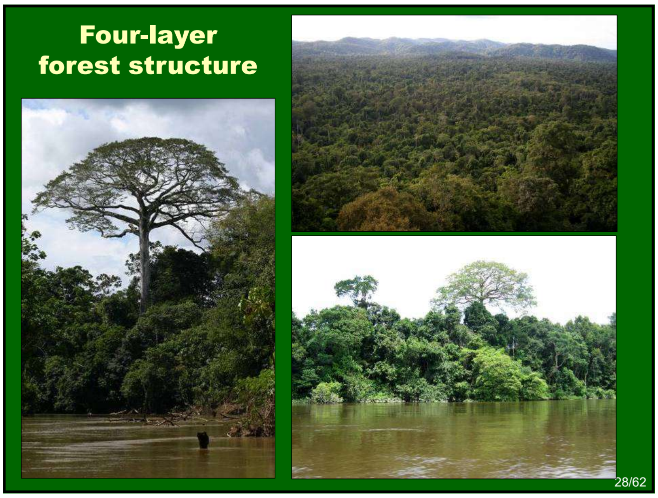
Understory layer
3-4 m high, little sunshine
treefrogs, beetles, leopards/jaguars

Forest floor
very dark → few plants
anteaters, snakes, frogs, beetles

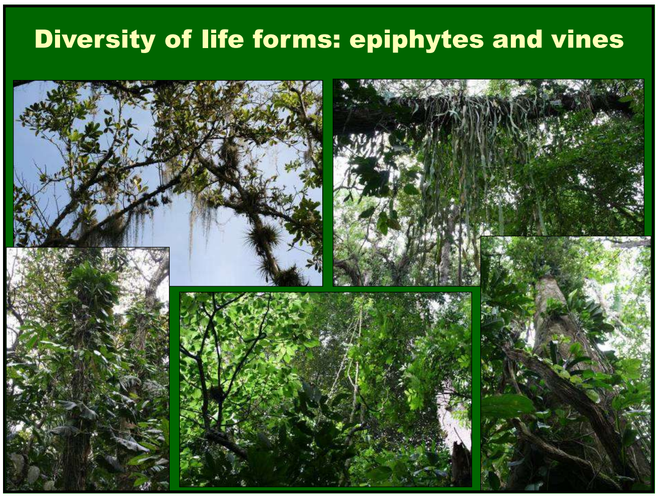
http://www.srl.caltech.edu/personnel/krubal/rainforest/Edit560s6/www/whlayers.html

27/62

27


Four-layer
forest structure
28/62

28


Diversity of life forms: epiphytes and vines

29


Extreme species richness
30/62

30

Species richness of tropical rainforests

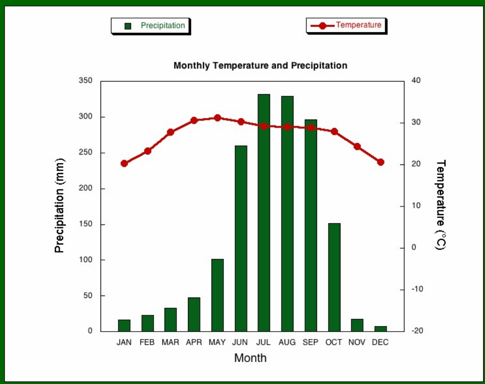
- At 10 ha of forest in Borneo – up to 700 tree species → as many as in whole N. America!
- At 1 Peruvian tree – 43 ant species → as many as in whole UK!
- Ca. 3000 fish species in the Amazon river – more than in whole North Atlantic ocean!
- Species numbers at 15 km^2 in Costa Rica:
  - mammals – 117 (*in whole Poland 105*); birds – 410 (*435*); reptiles – 86 (*9*); amphibians – 43 (*18*); moths – 4000 (*1200*); vascular plants – 1668 (*2700*)

Tropical rainforests: montane cloud forests (fog forest)

- Specific type of tropical rainforests:
  - area: tropical mountains
  - environmental conditions: persistent or frequent low-level cloud cover and fog → reduction of direct radiation and evapotranspiration, very high humidity
  - ecosystem characteristics: particularly rich in epiphytes (mosses, ferns, orchids, etc.)

Montane cloud forests

2. Tropical and subtropical seasonal dry broadleaf forests (monsoon forests)



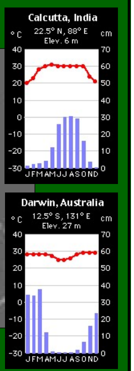
Climatic diagram for Calcutta (India)

34/62

34

Monsoon forests: geographical distribution

Two belts N and S from equatorial rainforests: ca. 10° – 20°N & 10° – 20°S



35/62

35

Monsoon forests: characteristics

- High average annual temperature
- High annual rainfall (~1000 – 2000 mm/year)
- Clearly pronounced, long (few months) dry season
  - ➔ most trees shed leaves in dry season;
  - ➔ plants accumulating water;
  - ➔ rich understory layer (plenty of sunlight in dry season)
  - ➔ three layers: (1) tree canopy; (2) understory; (3) forest floor

36/62

36

Main carbon pools in monsoon forests

Ecosystem part	Accumulated carbon (t C/ha)
Alive plants (above- and underground)	150
Dead trees and litter	10
Soil	100
TOTAL:	*260*

After Jonathan Adams, Oak Ridge National Laboratory, TN 37831, USA

37/62

37

Monsoon forest in dry season

Monsoon forest in Trinidad

38/62

38

Monsoon forests: characteristic tree species

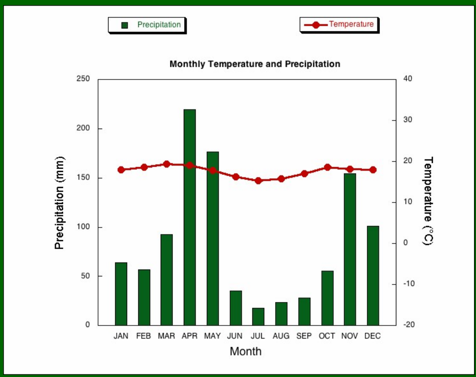
Teak tree (*Tectona sp.*)

Ebony tree (*Diospyros sp.*)

39/62

39

Tropical grasslands



Climatic diagram for Nairobi (Kenya)

40/62

40

Tropical grasslands in the world

- Africa:
  - Savannah, e.g. Serengeti, Masai Mara – high grasses with scattered acacia trees; large herbivores (40 ungulate species) and carnivores
- South America:
  - Llanos in Venezuela (Orinoco basin) – flooded every year, with gallery forests
  - Cerrado in Brazil – grassland covered with forest of different density and gallery forests; high plant diversity
- Australia:
  - Savannah (Northern Australia) – grassland with scattered eucalyptus trees; herbivores – kangaroos and man-introduced ungulates

41/62

41

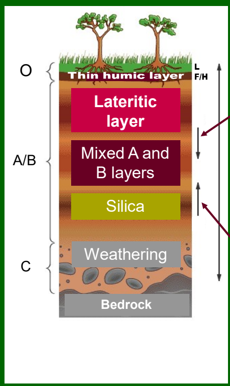
Savannah

- Average annual precipitation 1000-1500 mm (Köppen's *Aw* climate)
- Distinct, long dry season;
- Temperature: 20-30^{o}C
- NPP: ca. 0.7 kg d.w. m^{-2} year^{-1}
- Plants – adaptations
  - to dry season: deep tap roots, thick bark, shedding leaves, storage organs (mostly underground)
  - to herbivores: solid sharp leaves, bitter taste, growing from beneath)

42/62

42

Savannah soils



leaching silica (SiO_2) during rain season

thickness 1-2 m

capillary uptake from ground water during dry season

43/62

43

Tropical grasslands

44

Main carbon pools in tropical savannah

Ecosystem part	Accumulated carbon (t C/ha)
Alive plants (above- and underground)	35
Dead trees and litter	0
Soil	55
TOTAL:	*90*

After Jonathan Adams, Oak Ridge National Laboratory, TN 37831, USA

45/62

45

Main carbon pools in tropical grasslands besides savannah

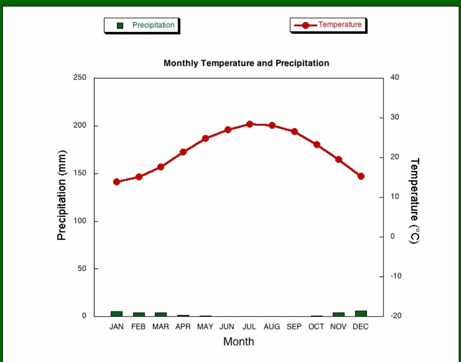
Ecosystem part	Accumulated carbon (t C/ha)
Alive plants (above- and underground)	12
Dead trees and litter	0
Soil	42
TOTAL:	*54*

After Jonathan Adams, Oak Ridge National Laboratory, TN 37831, USA

46/62

46

Tropical deserts



Climatic diagram for Cairo (Egypt)

47/62

47

Desert soils – aridisols (USDA)
(FAO: gypsisols, calcisols, solonchaks, solonetzes)

Desert soil profile: clearly seen calcareous layer

- Main process: $CaCO_3$ and $MgCO_3$ accumulation → development of calcareous layer
  - rain + atmospheric CO_2 → weak carbonic acid
  - → dissolving Ca and Mg salts from surface minerals
  - → transport to deeper soil layers
  - → evaporation → increasing concentration of dissolved minerals
  - → solidification of salts from the solution
  - → **concentrations of salts toxic to plants and animals**
  - → **water-impermeable carbonate layer**

48/62

48

Main carbon pools in tropical deserts

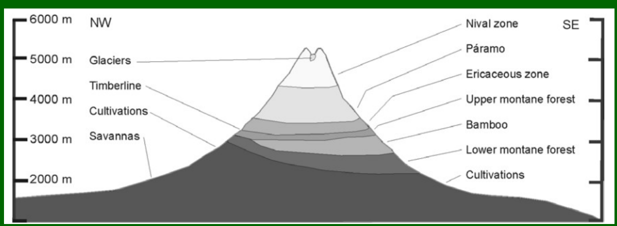
Ecosystem part	Accumulated carbon (t C/ha)
Alive plants (above- and underground)	1
Dead plants and litter	0
Soil	0
TOTAL:	*1*

After Jonathan Adams, Oak Ridge National Laboratory, TN 37831, USA

49/62

49

Mountains change everything: zonation and characteristics of the vegetation of Mt. Kenya

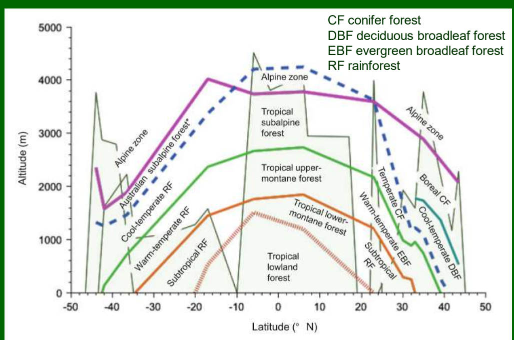


Niemelä, T & Pellikka, P. 2004. Zonation and characteristics of the vegetation of Mt. Kenya (ISBN 952-10-2077-6)

50/62

50

Mountains change everything: Altitudinal *vs* latitudinal zonation

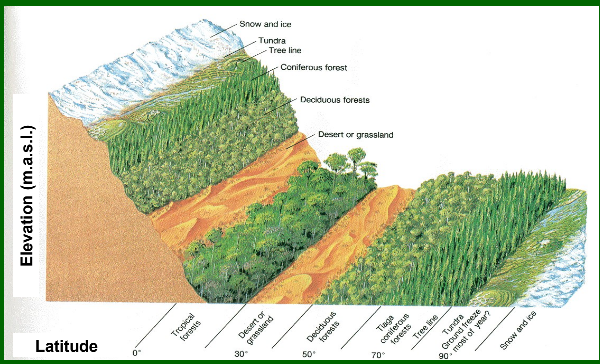


Aiba, S. 2016. Vegetation zonation and conifer dominance along latitudinal and altitudinal gradients in humid regions of the Western Pacific (In: Structure and Function of Mountain Ecosystems in Japan, ed. Gaku Kudo).

51/62

51

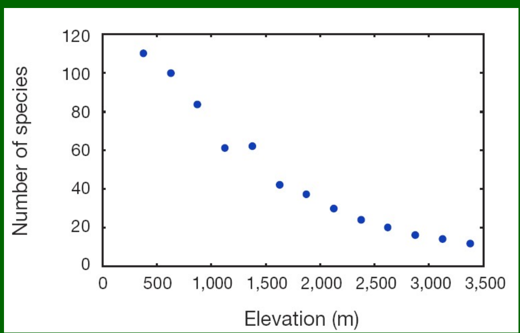
Mountains change everything: Altitudinal *vs* latitudinal zonation



52/62

52

Species richness decreases with altitude



Relationship between the number of species and altitude: bats in Manu Biosphere Reserves (Peru)

Gaston, K. J. 2000. Global patterns in biodiversity. Nature 405: 220-227.

53/62

53

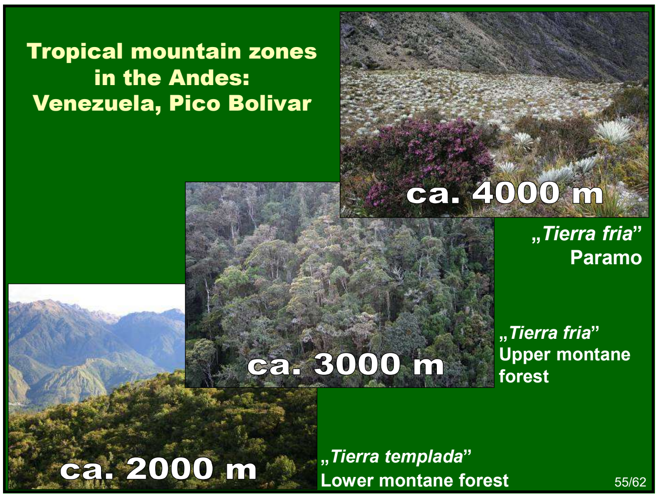
Ecofloristic zones in tropical mountains

- ***Alpine***: ~3800 – ~4500 m
  - high mountain steppe: Afro-alpine, paramo, puna
- ***Subalpine***: ~3400 – 3800 m
  - few lianas and vascular epiphytes, rich moss and lichen flora; characteristic groups: Ericaceae, Brunelliaceae, Asteraceae...
  - ‘elf forests’ at ridges
- ***Montane***: ~2400 – 3400 m
  - short trees, even fewer species; few lianas, still many epiphytes; can be seasonal
- ***Submontane***: ~1000 – 2400 m
  - forest similar to that at lower elevation but with fewer species; trees ca. 25-30 m

54/62

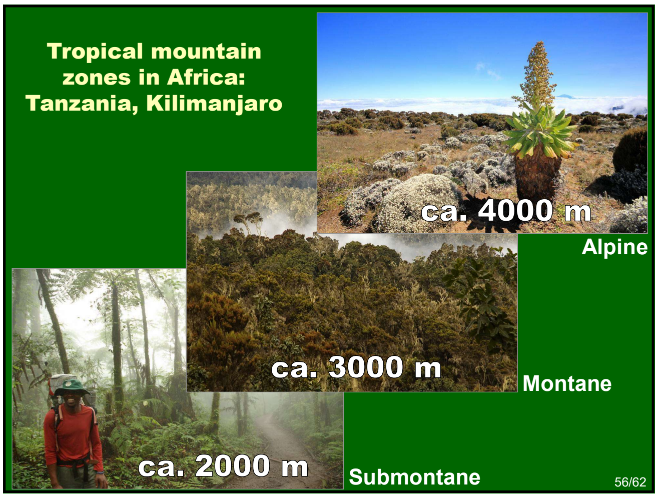
54

Tropical mountain zones in the Andes: Venezuela, Pico Bolivar



55

Tropical mountain zones in Africa: Tanzania, Kilimanjaro



56

Other tropical plant communities

- **Mangroves**
  - areas: shallow, muddy sea coasts;
  - structure: trees or shrubs, very few or even just one species; no understory and forest floor; few epiphytes and lianas
- **Gallery forests**
  - areas: along valleys with surface or underground streams
  - structure: trees or bushes of different density; possible lianas, few epiphytes

57/62

57

Mangroves

Caribbean coast, Venezuela

58

Gallery forests

Gran Sabana, Venezuela

59/62

59

Gallery forests

Gran Sabana, Venezuela

60/62

60

Topics for the seminar:

1) The newest data on the role of tropical rainforests in global carbon balance.
2) The highest tree species diversity in the world – where and why?
3) Species diversity (of selected groups) on altitudinal gradient in the tropics.
4) Is it possible to restore destroyed tropical rainforests? Área de Conservación Guanacaste – a case study in Costa Rica.
5) Tropical diseases: most important diseases, prevention & problems.

...?

61/62

61

Important dates (on my website):

1. 13.10.2023 R. Laskowski – lecture/discussion class: Course plan and rules; Introduction to tropical ecology: tropical biomes – area, climate, soils and characteristics; latitudinal zonation
2. 20.10.2023 R. Laskowski – lecture/discussion class: Anthropogenic destruction and protection of tropical ecosystems; REDD initiative
3. 27.10.2023 K. Wiąckowski – lecture/discussion class: Tropical biodiversity: Latitudinal diversity gradient
4. 03.11.2023 K. Wiąckowski – How can so many species coexist in a tropical rainforest?
5. 17.11.2023 W. Fiałkowski – lecture/discussion class: Biology of coral reefs and mangroves: environmental conditions, biodiversity
6. 24.12.2023 P. Koteja – lecture/discussion class: Adaptations to hot deserts: water balance, behavioural and physiological mechanisms for water conservation; behavioural and physiological thermoregulation, life histories
7. 08.12.2023 M. Czarnołęski – lecture/discussion class: Biodiversity in tropics: diversity in life strategies
8. 15.12.2023 M. Czarnołęski – lecture/discussion class: Tropical societies
9. 12.01.2024 R. Laskowski et al. – seminar (groups 1, 2, 3); Due to the large number of students, there will be parallel seminar sessions.
10. 19.01.2024 R. Laskowski et al. – seminar (groups 4, 5, 6)

Seminar topics to RL: deadline 17th December

62/62

62