Tropical Montane Cloud Forest, TMCF

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Cloud forest region in Panama

Often cloud forests are important for

- the generation of hydropower
- source regions for reservoirs of drinking water

Tree ferns

Upper montane forest
Mosses, lichens and liverworts

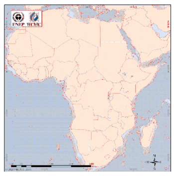
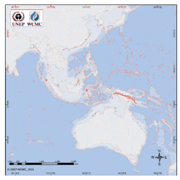
Bromeliads

Dense fine root mats
in the soil organic layer

Tropical Montane Cloud Forest

- are a type of evergreen mountain forests
- they occur where the local conditions cause clouds and mist to be frequently in contact with the forest vegetation
- One of their most obvious features is an abundance of mosses, ferns, orchids and other epiphytic plants on every tree and rock surface.
- aproximately 2.5% of all tropical forest

Potential cloud forest sites

Americas 25% of global cloud forest area

Africa15 %

Asia 60 %

TMCF

– forests that are frequently covered in cloud or mist –

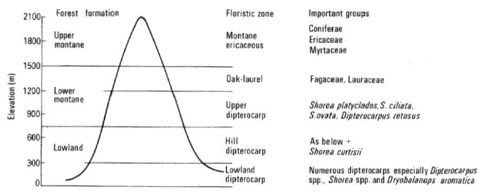
Definitions, names and classifications of these vegetation complexes are overlapping, and, at times, contradictory.

One may distinguish:

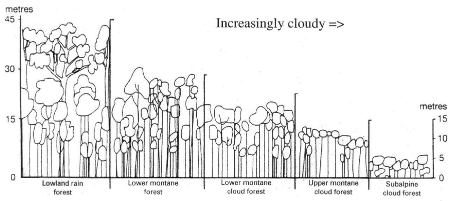
1) Lower montane forest (tall forest, little affected by low cloud but rich in epiphytes)
2) Lower montane cloud forest
3) Upper montane cloud forest
4) Subalpine cloud forest
5) Low elevation dwarf (or elfin) cloud forest (e.g. on small islands)

Bruijnzeel & Hamilton 2000

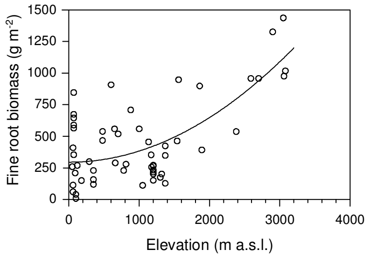
Zonation along an elevational gradient: Forests of the mountains of Malaya



Generalized altitudinal forest formation series in the humid tropics



Tree fine root biomass increases with elevation in tropical forests



Hertel & Leuschner 2006

Altitude of vegetation zones

- There is a large variation in elevation at which one forest formation replaces another
- 18°C mean temperature important from lowland to lower montane
- Cloud condensation belt is decisive for the transition from lower to upper montane
- Cloud formation depends on air humidity and temperature

Local situation - the importance of site exposure -

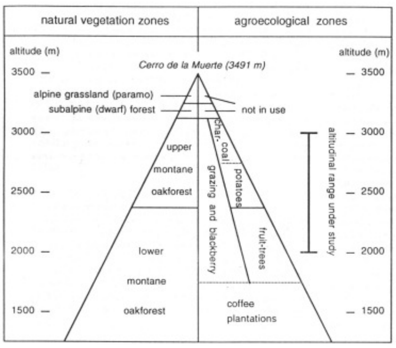
- The lower limits TMCF on leeward slopes lye well above those on windward slopes
- In the Colombian Andes the difference may take 600 m

- At the same altitude trees on leeward side are much taller than the exposed neighbors
- In Monteverde, Costa Rica, difference takes 10 m

Land use

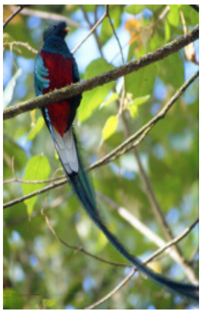
Expansion of agriculture in the cloud forest zone, Venezuela

Agroecological zonation



Tree and forest based land use systems

Ecotourism – bird watching



Hydrology of natural and anthropogenically altered tropical montane rainforests

with special reference to rainfall interception

Tropical montane forests in Costa Rica and Panama

Photo: A. Heger

A montane forest region in Sulawesi, Indonesia

Aims of this presentation

(i) to compare hydrological fluxes among natural and anthropogenically altered forests

(ii) to identify forest structural characteristics controlling hydrological fluxes

Hydrological fluxes considered

- Precipitation
- Transpiration
- Interception
- Runoff (stream flow)

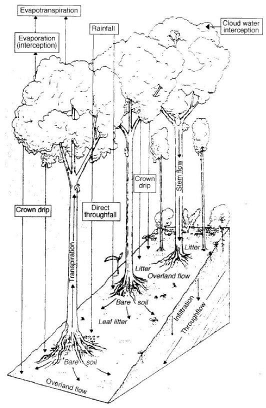
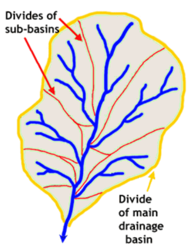


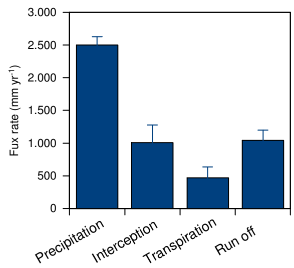
Figure 5. The hydrological cycle for a cloud forest.

1. Water budget

Catchment studies



Water budget of a montane rain forest in Ecuador

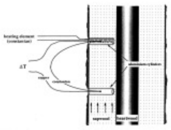


- three 10 ha catchments
-1900 to 2150 m elevation
- 4-yr observation period
- fog input neglectable

Fleischbein et al. 2006

2. Transpiration

sap flow studies



Granier, 1987

Transpiration, sap flux, Ecuador

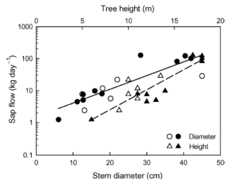


Figure 5. Daily sap flow totals of the investigated trees as a function of tree height (●) and stem diameter (▲). Open symbols = trees of the pilot plot. Sap flow is plotted on a log-scale to linearize the relationship to stem diameter ($r^2 = 0.75$, $P < 0.001$) and height (dashed line, $r^2 = 0.8$, $P < 0.001$).

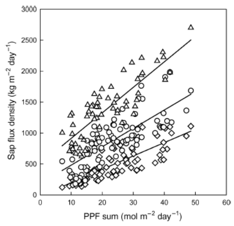
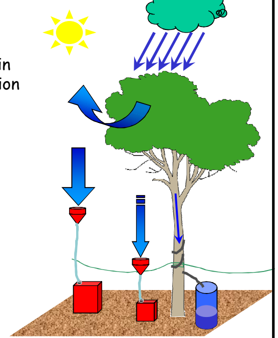


Figure 6. Sap flux density in relation to daily photosynthetic photon flux (PPF) sums. Symbols: △ = *Trichilia guianensis*; ○ = *Ruagea* cf. *pubescens*; and ◇ = *Aniba* cf. *muca*. Linear correlations are significant for all trees at $P < 0.001$; r^2 is 0.71, 0.61, 0.65 for *T. guianensis*, *R. pubescens* and *A. muca*, respectively.

Motzer et al. 2005

3. Interception

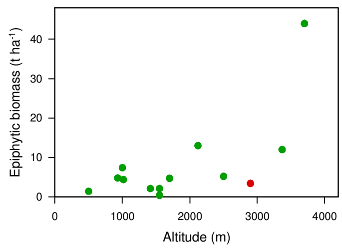
studies on rain fall distribution



Trees and epiphytes in a cloud forest, Costa Rica

Photos: A. Heger

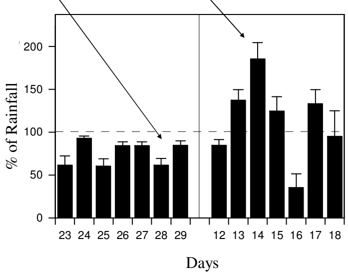
Epiphytic biomass in tropical montane old-growth forests



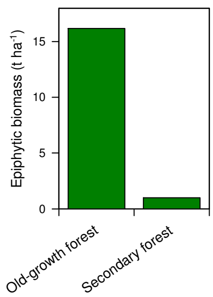
Hofstede et al. 1993, Veneklaas et al. 1990, Edwards & Grubb 1977, Pócs 1980, Nadkarni 1984, Tanner 1980a, 1985, Golley et al. 1971, Weaver 1972, Köhler 2002

How do epiphytes influence the amount of rainfall interception from a forest?

Rainfall interception Cloud stripping



Epiphytic biomass in old-growth and secondary stands of montane cloud forest, Monte Verde, Costa Rica



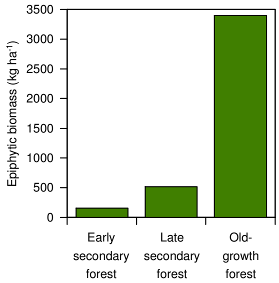
Maximal water storage in epiphyte layer:

4.6 mm old growth forest

1.0 mm secondary forest (40 yrs old)

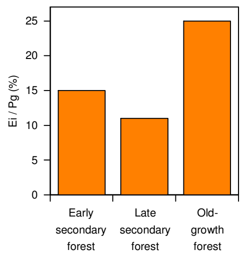
Köhler et al. 2007

Epiphytic biomass along a successional gradient, Costa Rica



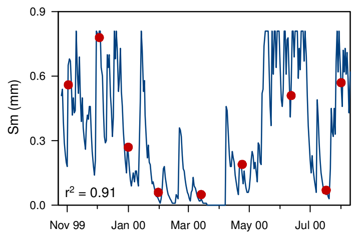
Köhler 2002

Rainfall interception along a successional gradient, Costa Rica



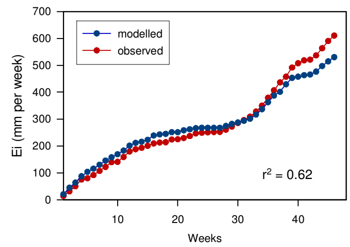
Köhler 2002

Measured and modelled water content of epiphytic bryophytes, old-growth forest (Costa Rica)



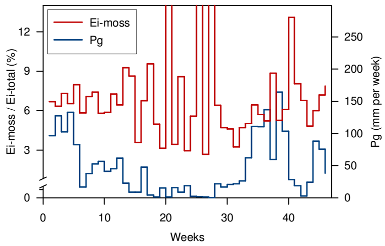
Hölscher et al. 2004

Measured and modelled rainfall interception by the old-growth forest, Costa Rica



Hölscher et al. 2004

The contribution of epiphytic bryophytes to the total rainfall interception, Costa Rica



Hölscher et al. 2004

Summary

epiphytes - interception

- Epiphytes make a significant contribution to the maximal canopy water storage capacity
- Their contribution to rainfall interception at the stand level seems to be low
- This is probably due to the slow rate of desiccation

How does forest use influence the amount of rainfall interception?

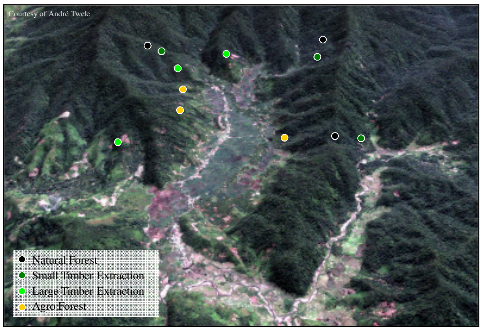
Lore Lindu National Park, Sulawesi, Indonesia



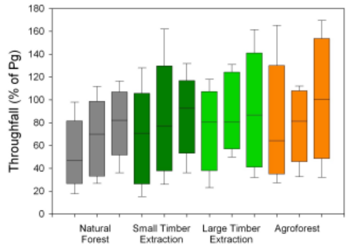
Gradient of land use intensity

from natural forest to agroforestry

Study plots in Sulawesi

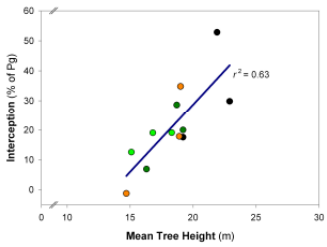


Rainfall partitioning, Sulawesi



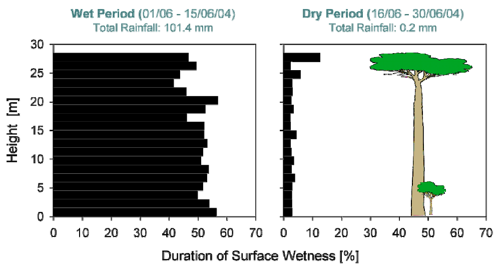
Dietz et al., 2006

Rainfall interception vs. tree height, Sulawesi



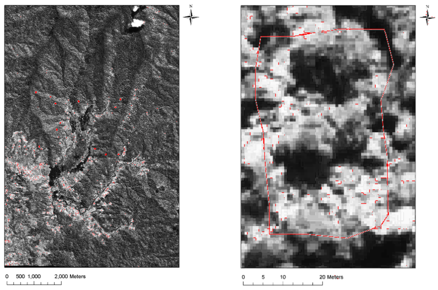
Dietz et al., 2006

Surface wetness in a montane forest of Sulawesi



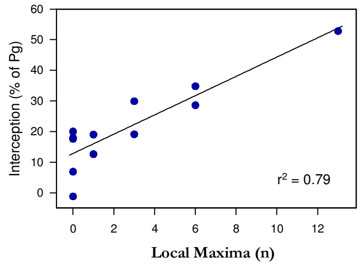
Dietz et al., 2007

Satellite images (Quickbird) and first steps of analysis



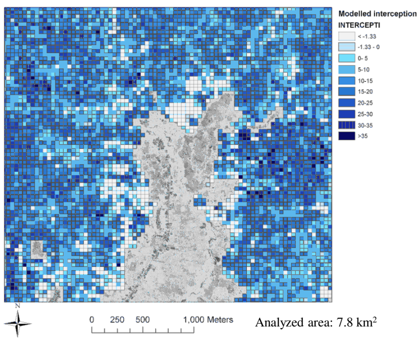
Nieschulze et al., 2009

Local maxima (satellite image) vs. interception, Sulawesi



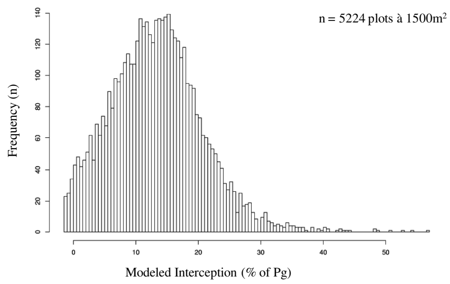
Nieschulze et al., 2009

Regionalization of rainfall interception based on satellite image analysis, Sulawesi



Analyzed area: 7.8 km^2

Interception in the study region, Sulawesi



Summary

forest use – rainfall interception

- In Sulawesi, the rainfall interception decreased with decreasing tree height (land use intensity)
- We assume that this is due to an enhanced energy exchange of rough canopies
- The rainfall interception was regionalized based on satellite image analysis

4. Stream flow

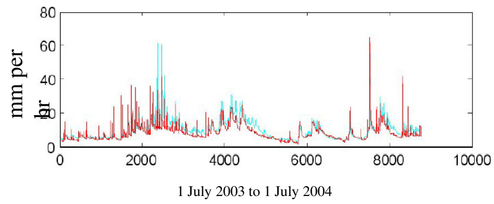
How does conversion of tropical mountain forest influence the stream flow?

Hydrological impacts of converting cloud forest to pasture, Costa Rica

Bruijnzeel et al. 2005

Measured (red) and modeled (blue) river discharges

current land cover



Bruijnzeel et al. 2005

Modeled water balance – land cover

River discharge

Scenario / Component	P	HP		Et		Ei		Q		Leakage		Storage
	mm	mm	%	mm	%	mm	%	mm	%	Mm	%	mm
Current land cover	4680	590	100	465	100	490	100	3500	100	663	100	151
1975 cover (80% forest)	4680	635	107	490	105	540	111	3475	99	658	99	149
Pasture	4680	430	73	375	80	275	56	3625	104	683	103	157
No cloud forest (above 1400 m)	4680	545	92	455	97	440	91	3515	100	664	100	151

Bruijnzeel et al. 2005

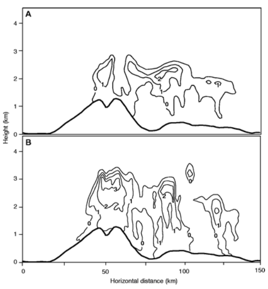
Conclusions from the ‚forest to pasture' project

- Conserving forest has rather small impacts on water budgets in the mountains
- The value of forests must be expressed in terms of their benefits for water quality, conservation of diversity, carbon sequestration potential … rather than water yields

Bruijnzeel et al. 2005

How does land use change in surrounding regions affect the hydrology of tropical mountain forests?

Cloud formation in the mountains depends on land cover in the lowlands, Costa Rica



A: lowlands completely deforested (pasture)

B: lowlands covered by forest

Lawton et al. 2002, Science

Conclusions

- Land use significantly influences the hydrological cycle
- We have only little data on different management types

Much remains to be done!

Thanks for attention!