

RAINFORESTS AT THE BEGINNING OF THE 21ST CENTURY

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Abstract. Rainforests are situated at low latitude where forests enjoy steady and strong radiation. Biodiversity in rainforests has been very high, for historical and climatic reasons. The number of species is very high and tends to increase with precipitation and decrease with seasonality. Disturbance, soil fertility and forest stature also influence the species richness and high turnover of species contribute to diversity. Field observation and studies revealed that large scale deforestation could alter the regional and global climate significantly. Deforestation alters the surface albedo which leads to climate change. Regional land use contributes to climate change through surface-energy budget, as well as the carbon cycle. Forest fragmentation, logging, overhunting, fire and the expanding agriculture threaten the biodiversity. Rainforest covered area has significantly shrunk in the last decades. It is hard to protect the forests because of the growing demand for agricultural area and forest-derived products. Most measures proved ineffective to slow down the destruction. Hence, more forest will be lost in the future. Conservationists should take into consideration the secondary forests because biodiversity can be high enough and it is worth protecting them.

Keywords: *rainforest, climate change, conservation*

Richness of rainforests

An interesting phenomenon can be observed in the living world: the number of species and the biodiversity is decreasing from the Equator to poles (Willig, 2001; Qian et al., 2003; Weiser et al., 2007; Moya-Larano, 2010). With a few exceptions, this observation is true, regardless of the continent or group of organisms. From the beginning of the 1950's scientist tried to determine the magnitude of species richness in equatorial moist forests and the processes which establish and maintain the extremely high variability (Schemske, 2002). Beside coral reefs, tropical rainforests represent the highest biodiversity and species richness (Myers, 2000). For instance in the Tesso Nilo National Park in Indonesia was found 900 species of vascular plant in the sample area of 1800 m² (Gillison, 2001). In particular, the Western Amazon area is very rich in the soil of terra firme (Gentry, 1988a; Valencia, 1994). African forests are relatively poor in

species, in comparison to other continents, due to the effect of the last glacial period (Permantier, 2007). But even here, there are areas where the number of endemic species and the biodiversity are considerably high: for instance the Ngovayang forest in Cameroon, where 293 tree species was found in one hectare of forest (Gonmadje, 2011). In recent decades, our knowledge has largely increased about the ecology of rainforests, thanks to extensive research.

Table 1. Biomass distribution of the major terrestrial biomes. Data from Chapin, F.S., Matson, A.P., Vitousek, M. (2002): *P. Principles of terrestrial Ecosystem Ecology*.- Springer-Verlag, New York

Biome	Shoot (g m ⁻²)	Root (g m ⁻²)	Root (% of total)	Total (g m ⁻²)
Tropical forests	30 400	8400	0.22	38 800
Temperate forests	21 000	5700	0.21	26 700
Boreal forests	6100	2200	0.27	8300
Mediterranean shrublands	6000	6000	0.5	12 000
Tropical savannas and grasslands	4000	1700	0.3	5700
Temperate grasslands	250	500	0.67	750
Deserts	350	3500	0.5	700
Arctic tundra	250	400	0.62	650
Crops	530	80	0.13	610

Table 2. The biomass of rainforests in some tropical countries. Data from Brown, S. (1997): *Estimating biomass and biomass change of tropical forest. - A Forest Resources Assessment publication, Urbana, Illinois, USA*

Country	Forest type	General climate	Aboveground biomass (T/ha)
Africa			
Cameroon	closed forest	moist	310
Ghana	Closed forest	moist-short dry season	395
Republic of Congo	closed forest	Moist	276
Asia			
Bangladesh	closed	Moist	210
Cambodia	Dense	moist	295
Malaysia-Peninsular	Superior to moderate hill	Moist	245-310
Malaysia-Sarawak	Mixed dipterocarps dense	moist	325-385
Philippines	Old-growth dipterocarp	moist	370-520
Sri Lanka	Evergreen	Moist	435-530
America			
Bolivia	closed forest	moist	230
Brazil	closed forest	moist	315
Ecuador	closed forest	moist	182
French Guyana	closed forest	Moist	309
Guatemala	closed forest	Moist	254
Guyana	mixed forest	Moist	275
Nicaragua	mature forest	Moist	240
Panama	high density mixed	Moist	239-366
Peru	Primary	Moist	210

And now, let us consider the factors establishing and maintaining biodiversity. Firstly, the geographic and abiotic factors are very important. Near the Equator the climate is warm all the year and the annual precipitation is considerably high. At least 1600 mm rainfall is needed to maintain the flora. The vegetation and animals do not suffer from the lack of water. Therefore, it is observed that when the length of dry season decreases, the number of species grows. The temperature is never too low and thus the cold does not cause stress to flora and fauna. The favourable climate must persist for long time, in order to create such a complex system. The steady warm climate promotes evolving of species and rapid evolutionary changes (Gilbert, 1980; Terborgh, 1983). The observed species richness is shaped by edaphic and topographic factors. The conditions, which are necessary for organisms to grow, survive and reproduce, are spatially and temporally very variable (Jhon, 2006). Hence, the composition of communities varies along the ecological gradients. Different type of soils can cause large changes in species richness and composition, and facilitate the co-existence of species (Bohlman, 2009). Different species adapt to different edaphic conditions, allowing the maintenance of species richness. On different type of soil and different water supply different plants can grow and survive. The plants compete for light, water, nutrients and pollinators. They use their resources in different ways to maintain the co-existence. Most of the abiotic resources are located in certain places, the micro-topographical changes in soil structure, moisture and nutrient content can vary in a short distance from hill to valley (Potts, 2003). Most of the plants are for some extent linked to a particular microhabitat, which is characterized by a soil type, water supply and nutrient content. The following detailed example outlines the importance of water supply and how the water can influence the distribution of plants. *Mora excelsa* lives on creek-banks and the water carries the seeds. *Mora gongrijpii* is distributed a few metres further from creek-banks and too much water kills the seeds. But it can absorb water from relatively dry soils. These two *Mora* species represent the two extremities, the two endpoints of the gradient. Along with other *Mora* species, they occupy the whole water supply gradient. This gradient contributes to the maintenance of alpha diversity. The spatial variability contributes to the development of diversity, but does not fully explain the richness. Warm climate is favourable for high plant productivity and rapid development. High productivity increases biodiversity and complexity. Along with the complexity of vegetation the number of habitats increases and also the number of organisms that occupy them. The high biodiversity is characterised by high turnover, individuals rapidly rotate. Dead organisms are rapidly replaced by another species. Rapid rotation allows for long term coexistence (Phillips, 1994). Due to the high productivity a lot of species can coexist even on a relatively small area. Too high density has a negative effect on the survival of individuals. Herbivore insects and pests which are specialised in a certain host species or group of host species can proliferate rapidly if the host species' density is high. Herbivores and pests have an important role in the maintenance of diversity. One species can't occupy too large an area. If the host species' density grows, the density of pests will consequently reduce the survival of the host (Hubba, 2001). There will be an increasing chance that a certain individual has a neighbour of a different species. According to a study, the distribution of 80% of species is affected by pests or herbivores on Barro Colorado Island, Panama. Wet, warm climate is favourable for parasites; therefore they influence the vegetation richness and complexity. Drier climate is favourable for the production of secondary metabolic products and decreases the productivity. The number of parasites and herbivores

decreases and cannot influence the distribution of plants and density-dependent mortality diminishes (Givnish, 1999). Wet weather is favourable for the parasites and natural enemies increase the mortality because of high consumption.

Table 3. Biodiversity of some tropical areas. Data from Myers, N., Mittermeier, A.R., Mittermeier, G.C., da Fonseca, G.A.B., Kent J.(2000): Biodiversity hotspots for conservation priorities.- *Nature* 403: 853-858.

	Original extent of primary vegetation (Km ²)	Remaining original vegetation (km ²) (% of original extent)	Area protected (km ²)	Plant species	Endemic plants(% of global plants, 300 000)	Vertebrate species	Endemic vertebrates (% of global vertebrates, 27 298)
Tropical Andes	1 258 000	314 500 (25)	79 687 (25.3)	45 000	20 000 (6.7%)	3389	1567 (5.7%)
Mesoamerica	1 155 000	231 000 (20)	138 437 (59.9)	24 000	5000 (1.7%)	2859	1159 (4.2)
Brazil's Atlantic Forest	1 227 600	91 930 (7.5)	33 084 (35.9)	20 000	8000	1361	567 (2.1)
Western African Forest	1 265 000	126 500 (10)	20 324 (16.1)	9000	2250 (0.8)	1320	270 (1)
Sundaland	1 600 000	125 000 (7.8)	90 000 (72)	25 000	15 000 (5)	1800	701 (2.6)
Wallacea	347 000	52 020 (15)	20 415 (39.2)	10 000	1500 (0.5)	1142	529 (1.9%)
Philippines	300 800	9023 (3)	3910 (43.3)	7620	5832 (1.9)	1093	518 (1.9)
Indo-Burma	2 060 000	100 000 (4.9)	100 000 (100)	13 000	7000 (2.3)	2185	528 (1.9)
Western Ghats/Sri Lanka	182 500	12 450 (6.8)	12 450 (100)	4780	2180 (0.7)	1073	355 (1.3)

When a big tree falls down, a gap is formed in the canopy and the light can penetrate and reach the forest floor. In other words, a special space is formed where the intensity of light is increased. The high rainfall makes the soil loose and the shallow roots increase the chance of falling. This is very important for new individuals to appear. The species of new individuals depends on the composition of the surrounding vegetation. Some seeds germinate exclusively under open canopy and they require a certain amount of light. The total of 75% of species need light for germination and growth of seedlings according to a survey in La Selva Biological Station, Costa Rica. This result was confirmed in Australia, Malaysia and Africa. In the area of the gap, the intensity of growth and the chance of survival become increased. One of the seedlings will take the place of the fallen tree. The gap itself is a complex habitat and rapidly changes spatially and temporally. Numerous species share the area of the gap and the resources. The individuals who cannot exploit the resources effectively will not survive. Falling down of trees is a random event, that is why chance has a role in the maintenance of diversity (Denslow, 1987). Most plants live under the canopy, in shade. Thanks to the warm, wet weather and fertile soil the compensation point is low and this way they tolerate the shade better. In turn, more species and individuals can live under the canopy. The

fertility of soil depends on structure, chemical composition, air and water supply. Less fertile soil decreases the productivity and provides a favourable environment for the production of tannins and phenols. Comparing the sandy and fertile soils we can see that trees on sandy soil produce twice more tannins than on fertile soil. Furthermore, the P concentration is twice higher than on sandy soil (MacKay et al., 1978). Differences in leaf structure and nutrient content lead to less intensive consumption by herbivores.

High rainfall facilitates nutrient uptake and the decomposition of organic matters. Cations get into the soil easier (Clinebell et al., 1995). In contrast, as the altitude grows the nutrient uptake slows down. In general, on higher altitude the temperature of soil is lower and the process of mineralisation is slower. The decreased nutrient availability has stronger effect than high rainfall (Tanner et al., 1990). An interesting phenomenon was observed in rain forests: lots of plants produce juicy, fleshy fruits that are eaten by animals that distribute the seeds. This phenomenon is more frequent in moist forests than in drier areas. This promotes the diversity on evolutionary scale (Gentry, 1988b). The large biomass, richness and complexity of vegetation involve the increase of the number of animals. Vast amounts of diverse resources are available for the next trophic level. The complex vegetation provides diverse habitats for animals.

Table 4. Vertebrate species and endemism. Data from Myers, N., Mittermeier, A.R., Mittermeier, G.C., da Fonseca, G.A.B., Kent J.(2000): Biodiversity hotspots for conservation priorities.- *Nature* 403: 853-858

	Bird species and endemism		Mammal species and endemism		Reptile species and endemism		Amphibian species and endemism		Total species and endemism	
Tropical Andes	1666	677	414	66	479	218	830	604	3389	1567
Mesoamerica	1193	251	521	210	685	391	460	307	2859	1159
Brazil's	620	181	261	73	200	60	280	253	1361	567
Atlantic Forest										
West African Forests	514	90	551	45	139	46	116	89	1320	270
Sundaland	815	139	328	115	431	266	226	179	1800	701
Wallacea	697	249	201	123	252	159	84	65	1142	529
Philippines	556	183	201	111	252	159	84	65	1093	518
Indo-Burma	1170	140	329	73	484	201	202	114	2185	528
Western Ghats/Sri Lanka	528	40	140	38	259	161	146	116	1073	365

Table 5. Note that ecoregions differ in size, which limits the comparability of mean plant species richness per ecoregion. Data from. Kier, Gerold., Mutke, Jens., Dinerstein, Eric., Ricketts, H. Taylor., Küper, Wolfgang., Kreft, Holger., Barhlott, Wilhelm. (2005): Global patterns of plant diversity and floristic knowledge. *Journal of Biogeography* 32:1–10

Biome	Mean plant species richness per ecoregion
Tropical moist broadleaf forest	3161
Temperate broadleaf and mixed forest	1909
Boreal forest	822
Tropical grassland/Savanna	1731
Temperate grassland	1372
Tundra	438
Desert and xeric shrublands	1078

Human activity and climate change

The effect of climatic change on tropical vegetation has become global and regional concern because of its high biodiversity and the potential feedback to the carbon, water, and nutrient cycles (Ostendorf et al., 2001). Tropical forests are one part of the tropical vegetation that has already been facing threats from deforestation, fragmentation and habitat degradation (Giam et al., 2010). They are likely to encounter further challenges from the ongoing and impending changes in climate. Although the role of tropical forests, as they are both sinks and sources of CO₂, has been well recognized, less is known about the impact of climate change on tropical biotas (Bawa and Markham, 1995).

Tropical forests are among the biologically richest ecosystems on Earth, but they are being rapidly degraded and destroyed by habitat conversion (Myers et al., 2000). These forests are also vulnerable to global warming and other large-scale environmental changes, but much uncertainty exists about the nature and magnitude of these anthropogenic impacts on tropical forest organisms (Laurance et al., 2011).

Climate is one of the primary constraints on species distribution and ecosystem function. Ecologists face with the challenge of forecasting species range shifts, extinction risks, biome shifts, altered disturbance regimes, biogeochemical cycling, and other ecological responses to climate change (Williams et al., 2007). A simulation study in order to investigate the response of vegetation to global warming and rainfall anomalies has been done by White *et al.* (1999). White *et al.* predicts four key changes in vegetation:

1. Some areas of the tropical evergreen forest in Amazonia will change to savanna, grassland or even desert by 2080s, in response to a warming of over 7°C and a decreases in rainfall of up to 500mm y⁻¹.
2. Large areas of tropical C4 grassland (e.g. in the Sahel, India and Australia) will be lost to desert by 2080s in response to warming, increasing CO₂ level and decreasing rainfalls, or will be superseded by C3 grassland where rainfall increased.
3. Annual precipitation will decrease by up to 200mm y⁻¹ resulting in the conversion of large areas of the temperate forest to grassland or savanna in southern Europe and eastern United States.
4. Needle-leaved boreal forests will extend northwards in response to warming with loss of tundra, and will extend southwards in Asia in response to increased precipitation.

Another study in a tropical forest located in Northern Queensland, Australia has been done by Ostendorf *et al.* (2001). Ostendorf *et al.* evaluate how the spatial arrangement of a forest pattern may constrain vegetation change, as predicted by the spatially static artificial neural network (ANN) model. In the model, they evaluate the effect of an increase in the mean annual temperature by 1°C and the decrease of the mean annual precipitation by 10%. Depending on the strength of spatial effects included in the model, the predicted future vegetation patterns differ by 1% to 10% from the study area. However, if in addition to spatial constraints ecological constraints are also considered, the predictions may differ by as much as 27% showing a relatively strong dependence of prediction on assumptions about patch-level processes.

Tropical montane forest ecosystems are also affected by climate change. Foster's study (2001) tried to explain the negative potential impacts of climate change on

tropical montane cloud forests. He argues that cloud forests will also be affected by climate changes, particularly in cloud formation. A number of global climate models suggest a reduction in low level cloudiness with the coming climate changes. One site in particular, Monteverde – Costa Rica, appears to already be experiencing a reduction in cloud immersion. The coming climate changes appear very likely to upset the current equilibrium of cloud forests. Results will include biodiversity loss, altitude shifts in species' ranges and subsequent community reshuffling, and possibly forest death. He also mentions that the difficulties for cloud forest species to survive in climate-induced migrations include no remaining location with suitable climate, no pristine location to colonize, migration rates or establishment rates cannot keep up with climate change rates and new species interactions.

In other perspectives, million hectares of forests have turned into unforested area caused by forest fires, illegal loggings, land use changes (Flannigan et al., 2000). The deforestation of an area is affecting the regional climate especially by increasing green house gasses (van der Werf et al., 2008). McGuffie et al. (1995) describes the impacts of tropical deforestation on regional climates in terms of change detected in five regions, i.e. Northern Amazon, Southern Amazon, Central Amazon, Southeast Asia, and Africa. For each of these regions, seasonal distributions of three climatic variables are discussed which are the ground (or soil) surface temperature, the total precipitation and the atmospheric moisture convergence. McGuffie's results show that precipitation always decreases following tropical deforestation. Although the ground surface temperature increases in southern Amazon and over Basin as a whole, the northern Amazon, Southeast Asia and Africa all exhibit decreases in ground temperatures. Then, atmospheric moisture convergence decreases in the Amazon. In contrast, the moisture convergence increases over Southeast Asia and a similar effect can be seen in Africa. These changes suggest that regional-scale circulation has been affected by tropical deforestation. If this is the case, then it is possible that locations distant from the disturbed tropics may also be affected.

Abundance of vegetation depends on climatic factors. Firstly, radiation, temperature and rainfall determine the complexity of vegetation. Secondly, physical and chemical attributes of soil and water supply influence the plants. Rainforests can exist in areas where rainfall is high enough, the dry season is short or does not exist at all and attributes of soil allow constant water supply for roots of plants. Previously, it was thought that the mechanisms that maintain the biodiversity of rainforests are independent of the vegetation. By now we know that atmospheric processes are not independent of forests. Vegetation or lack of vegetation can influence the weather. Consequently, current climate and rainforests mutually influence each other and are in dynamic balance. This means that disturbing the dynamic balance influences the entire system (Sato et al., 1989). The increasing pace of deforestation continues on each continent. The economic development will accelerate in tropical countries and deforestation will be intensified (Skole et al., 1990). Amazon forest is the largest in extent, but the area of forests rapidly dwindle. The remaining forests will disappear within 100 years. Approximately 22 000 km² of forest disappears every year (Costa and Foley, 1998). As a consequence of deforestation, the weather may change after the area had been cleared. It is difficult to estimate the extent of change caused by lack of precipitation and increased mean temperature. According to calculations, evapotranspiration is responsible for more than 50% of precipitation. Thus, the water easily gets back to the atmosphere through the process of evapotranspiration.

Considering the whole area of rainforest, this means that a vast amount of water is moving between the surface and the atmosphere. The vapour has a considerable effect on the atmosphere. After cutting the forest, on grazing land or plantation the rate of evapotranspiration and the number of cloudy days are decreased (Henderson-Sellers and Gornitz, 1984). On deforested area the albedo varies in a wide range throughout the year. This important biophysical attribute depends on the structure and phenology of vegetation, hydrological properties of the soil, colour and surface roughness (Berbet and Costa, 2002; Roelandt, 2001). The varying albedo can modify the weather. The albedo is less variable in case of pristine forests. In case of pasture the albedo is very variable because of the lack of trees (Wright et al., 1996). Along with albedo, radiation rises and the precipitation falls. This is true for soybean plantations, too. As the forests disappear evapotranspiration becomes reduced, daily mean temperatures vary in a wide range and the annual mean temperature increases. The amount of precipitation decreases and the dry season becomes longer. As a consequence, the water content of the soil decreases (Zeng and Neelie, 1999). Due to lack of water the remaining forest begins to perish and savannah is formed in the place of rainforests. This process reinforces itself that's why the pristine area is affected. Agriculture is a very important sector in developing countries. Farmers will need larger and larger areas for pasture and plantations in the future and the importance of biofuel is rising. Biofuel production increases the demand for new agricultural area and loss of forests. On areas, which are affected by logging the forest is forced back. The remaining forest patches are very susceptible for many elements of anthropogenic activity, particularly fire (Taylor et al., 1999). Effects of wind are stronger there, making the shallow-rooted sensitive trees to fall down. More parasites dwell there and the survival of trees decline. Trees are prone to dehydration. High mortality rate reduces the complexity of forests, changes the biogeochemical cycles, evapotranspiration and increases CO₂ emission (Laurance et al., 2000). Rainforests contain large amount of carbon and absorb vast amounts of carbon from the atmosphere every year. In recent decades, the concentration of CO₂ grew continuously. In the 19th century the CO₂ concentration was 275 ppm in air. By now the concentration has increased to 350 ppm (Houghton, 1991). One reason for high CO₂ is the combustion of fossil fuels. It takes two third of the whole CO₂ emission. Deforestation is responsible for another one third. Logging of temperate forests has slowed down, so new balance is formed between emission and absorption in this area. Rapid deforestation is responsible for the vast scale of stored CO₂ emission. According to estimations the amount of released CO₂ is between 0.4×10^{15} and 2.5×10^{15} g C a year (Detwiler and Hall, 1988). According to the experiment of Carvalho et al. (2001) the amount of carbon released as gas into the atmosphere was about 69 Mg ha⁻¹. During the process of photosynthesis the plants absorb CO₂ from air, and exhale or build it in. Later, carbon gets into soil as organic matter. During the process of decomposition, carbon-dioxide is released into atmosphere. Surveys reveal that near Manaus one hectare vegetation absorbs 30.4 t of carbon and exhale 14.8 t of carbon. 15.6 t of carbon is the net primer productivity that is built in the body of plants. The carbon remains in this form for 16 years on average. And then, the carbon located in soil for 13 years on average. After decomposition, it gets into air again (Malhi and Grace, 2000). Currently, rainforests store about 90-140 billion tons of carbon (SoaresFilho et al., 2006) (Nepstad et al., 2008). After cutting the forest, the observed warming and rising CO₂ concentration enhance each other's effect and the joint impact on exerted on the climate will be bigger than the two effects of two separate factors. In situ measurement and

simulations show that average monthly precipitation drops by 26.4 mm after deforestation and in case of high CO₂ concentration (Zhang et al., 1996). Zhang et al., (2001) assessed the joint impact of climate change and deforestation. Result shows large reduction in evapotranspiration on surface (by about -180 mmyr⁻¹) and precipitation (by about -312 mm yr⁻¹) over the Amazon Basin and the surface temperature rises by +3 °C. Strength and directions of currents change and this alteration has an influence on precipitation. Decreased radiation is accountable for the cooler upper air layer and, in turn, this induces the temperature dependent circulation, which leads to decreased amount of precipitation. Carbon-dioxide would increase slightly the rainfall without the effect of deforestation, but deforestation is the dominating factor. High carbon-dioxide concentration would have positive effect on evapotranspiration, but the combined effect of altered albedo and increased carbon-dioxide finally leads to a decline (Costa and Foley, 1998). Thanks to dry weather lots of plants desiccate and die. Dry dead plants can catch fire easily and fire becomes more frequent. Fires, caused by people, make the situation worse. The fragmentation increases the impact and frequency of fire (Cochrane and Laurance, 2002). Under the process of combustion vast amounts of greenhouse gases are released and enhance the greenhouse effect (Tinker et al., 1996). Shifting cultivation is common practice in tropical countries. Farmers set fire to forest to obtain new lands for agriculture. This practice contributes to climate change because of the released gas (Carvalho et al., 2001). Farmers used to set fire on a small area of forest and after abandonment the forest could regenerate rapidly. But nowadays vast areas of forests are burnt to satisfy demands and forest will not regenerate, they will disappear in the long run. Dry weather causes drastic change in vegetation. New species will appear which can tolerate the lack of water (Malhi et al., 2008). For instance, over the Guinean Coast evergreen forests will decrease by 49% and deciduous forests will increase by 56% in 2084-2093 comparing with the extent one hundred years earlier. Over Sahel Region precipitation will increase by 23% in summer and grass cover will increase by 31% according to the study of Aga and Wang (2010). Results of this simulation show that vegetation can response to climate change to some extent.

Another phenomenon of interest is the growing mean temperature of oceans. When the temperature of water is high in the Western part of the Pacific Ocean, severe drought is observed in Indonesia and Brazil. This climatic phenomenon is called El Nino and can modify the weather all over the Earth (Barlow and Peres, 2004). Above Atlantic Ocean between Africa and the Caribbean region a similar climatic phenomenon exists and called North Tropic Atlantic Anomaly. It can cause drought too. These climatic phenomena will be more frequent because of the accumulation of greenhouse gases, and enhance the human effect on forests. The forest fire threatens large areas and vast amounts of gas and ash get into atmosphere. In developing countries policy-makers consider that the short-term benefit of deforestation is more important than the long-term benefit of maintaining rainforests. Protection of biosphere should be more important, because change in atmosphere, climate and land use affect the climate system, the ecosystems and sustainable development. Since the main element of climate change is the anthropogenic activity, human intervention can influence the rate and magnitude of change (Ni, 2011). There are numerous scenarios to predict the weather in the future. For instance, surface temperature, precipitation and evapotranspiration are simulated by high HASM (High Accuracy and Speed Method) in study of Yue (2011). He used data from 2766 weather observation stations situated all over the planet for surface modelling. Observation stations employed DEM (Digital Elevation Model) on

resolution of 13.5×13.5 km as auxiliary data. Result shows that the size of polar, alpine areas and rainforests will decrease continuously. But other tropical ecosystem types, like savanna, dry forest and desert would increase. In general, climate change would cause a continuous decrease of ecological diversity. Claussen and Esch (1994) used BIOME model to simulate the vegetation under the regime of elevated carbon-dioxide concentration according to IPCC scenario. They found that the largest changes would occur for boreal forests, and little change is seen for rainforests and Sahara. This simulation predicts changes in conditions favourable for certain biomes. Herzs Schuh et al. (2011) show in their simulation that elevated carbon dioxide concentration leads to more humid, warm climate and increases net primary production without logging. These results show that some scenarios predict opposite responses and there is severe uncertainty about the ecological impact (Bachelet et al., 2001).

Consequences of human activity

Human activity causes serious damages to rainforest and the whole biosphere too. Therefore, organisms lose their habitat due to the shrinking rainforests (Wright, 2005; Sodhi et al., 2007). Rapid disappearance of forests is especially spectacular in Southeast-Asia where biodiversity and number of species is very high (Owen, 2009). In this area the area of forests is especially rapidly dwindling compared to other continents (Sodhi et al., 2004). In addition, the number of endemic species is very high. Studies show that rainforests are very fragile and sensibly react to human disturbance. In the last decades the forests suffered large scale disturbance. This biota tolerates human disturbance less compared to boreal forests (Morris, 2010). Every group of organism showed reduced reproductive rate. Hence, unfavourable demographic trends begin as a result of reduction in reproductive success. In fragmented forests, biodiversity is reduced because a lot of species cannot live in small patch of forest or re-colonize the distant fragments (Fahrig, 2003). After logging the forest the circumstances change dramatically. The flora and fauna undergo significant change too, because lot of species cannot tolerate the new circumstances. But different group of organisms react differently to new environment. The effect on alpha diversity is less significant than on beta diversity (Kessler et al., 2009; Pastro et al., 2011). Although there is consensus that human activity has a serious impact on biodiversity, we know very little about the impact on ecological processes and communities (Morris, 2010). The reduced biodiversity influences or ruins the ecological processes. Current knowledge about the connection between biodiversity and ecological processes resulted from small-scale studies (Montoya et al., 2006; Duffy, 2009). Ecological systems depend on different kind of processes and these processes involve the interactions of organisms over trophic levels (Reiss et al., 2009). Decreased number of species has a negative effect on ecological processes. The effect depends on the role the species plays in the system. The extinction of an important species has an impact on the whole system (Hillebrand et al., 2008; Sethi and Howe, 2009). Beside biodiversity, the composition of communities is very important. Human activity alters the amount and distribution of resources. This fact entails alteration of abundance and distribution of organisms (Slade et al., 2011). Those animals which are more mobile can seek new habitats and resources. They are somewhat more protected against extinction and can compensate the species loss to some extent. New species appear on the logged area which can adapt to the open field. The composition of communities may undergo significant change. For instance, the

community of birds changed a lot after a forest-fire in Southeast-Asia. One year after the fire the number of species and abundance were significantly altered compared to pristine forests. Three years after the fire the richness was similar to the unaffected area but the community structure had been altered. Some species disappeared, but new species enriched the community. Less complex vegetation is accountable to altered animal communities because it doesn't provide enough habitats for animals to live. For instance, most insectivorous birds disappeared, but nectar and seed eater birds could persist or their abundance even rose after a fire in Brazil (Slik and Van Balen, 2006). The result is that some generalist species dominate the community because they can adapt to new circumstances. Specialist species became rare or extinct because they prefer closed canopy. Spatial variability of vegetation and extent of canopy were reduced which resulted in less resource for animals. What's more, new pioneer plant species appeared after fire (Slik et al., 2008). This entails appearance of new animal species preferring open areas. Amazonia also suffers great losses every year. Establishment of new settlements, pastures and plantations occupy more and more area and logging destroys vast amounts of forest every year in Brazil. The eastern part of the country especially loses large areas of vegetation. From 2000 to 2008 the three eastern states have lost 40% of their forests. Annual rate of deforestation is approximately 7500 km² in this region. In the whole country 70 000 km² of forest is degraded every year (Briant et al., 2008). Near the edge of the forests, communities are particularly vulnerable to damage. Warmer and drier micro-climate evolves here; therefore plants suffer from lack of water and desiccate (Giambelluca et al., 2003). During drought foliar conductance and water use is reduced. This way plants try to limit the severity of drought (Hanson and Weltzin, 2000). But this ability of plants is limited in rainforests. Patchiness makes the forest vulnerable to be invaded by other vegetation class. Hence, patchiness accelerates degradation (Gao et al., 2004). Increased desiccation leads to higher mortality rate within 100 m distance from the edge. But sometimes the impact can be detectable within a 300 m area. Dead plants increase the concentration of carbon-dioxide further in atmosphere and decrease the amount of biomass. The fragmentation largely threatens the biodiversity and the genetic diversity of populations because of the weaker connections among populations (Keyghobaldi, 2007). After disturbance, small populations and decreased genetic variability leads to genetic shift, and increases the possibility of endogamy: evolutionary potential declines which may lead to extinction (Reed and Frankham 2003). The chance of extinction depends on the mobility of species. If the species can migrate to new habitat easily, it will avoid extinction. Further, survival depends on the extent of specialism. If a species is specialized to a certain food or condition, the individuals will not find food or other resource after disturbance. Bigger animals are in more intense jeopardy because they need more feed and larger area to live. The second largest rainforest is located in Congo-Basin which is about 2.2 million km² (Geh Meh, 2011). The biggest threat to rainforest is logging. Loggers look for the most valuable trees. These are rare, often one or two specimens are found per hectare (Hall et al., 2003). This does not cause so much harm to forest, but if this selective logging occurs repeatedly it can cause harm to the ecological system, because the large trees represent a vast amount of biomass. These species may become extinct in the affected area. Selective logging can represent another type of harm, because it opens the forest to colonization. Loggers construct new roads which facilitates establishment of new settlements on previously uninhabited area. And then, they start agricultural activity. Farmers rapidly destroy the forest, as they need more and more agricultural

area (Laurence, 2001). The rainforest is a source of great variety of products for human population. Hunters can acquire vast amount of meat from forest. The intensity of hunting is growing to satisfy demand. Most of the hunted species are endemic and live exclusively in rainforest. For instance, 80% of meat comes from the forest. Hunting is cheap and easy method of acquiring meat. Therefore, it has an important role in nutrition (Wilkie and Carpenter, 1999). Hunters can reach pristine forests on new roads. The intensive hunting and loss of habitats may lead to extinction of species in the long run.

Table 6. Tropical deforestation rates (RAN 1999)

Country	Area of country km ²	Original Forest Cover km ²	Present Forest Cover km	Annual rate of Deforestation km ²
Bolivia	1 098 581	90 000	45 000	1500
Brazil	8 511 960	2 860 000	1 800 000	50 000
C. America	522 915	500 000	55 000	3300
Columbia	1 138 891	700 000	180 000	6500
Congo	342 000	100 000	80 000	700
Ecuador	270 670	132 000	44 000	3000
Indonesia	1 919 300	1 220 000	530 000	12 000
Ivory Coast	322 463	160 000	4000	2500
Laos	236 800	110 000	25 000	1000
Madagascar	590 992	62 000	10 000	2000
Mexico	1 967 180	400 000	110 000	7000
Nigeria	924 000	72 000	10 000	4000
Philippines	299 400	250 000	8000	2700
Thailand	513 517	435 000	22 000	6000

Conservation

It is important to protect rainforests because the most species live there. Policy-makers and management of companies don't consider protection and sustainable farming to be a priority. However, today we can see measures to preserve wildlife. For example, authorities have taken successful measures to curb deforestation in Brazil. Government made the permits of exploitation more stringent. Unauthorized forest clearing was strictly punished. This measure was successful in Mato Grosso state from 1999 to 2001. It attests that government was able to slow down the deforestation (Fearnside and Barbaros, 2003). Establishment of reserves is also very important where nobody is allowed to cut trees. But the establishment of infrastructure is an unavoidable threat to vegetation. Therefore, it is not enough to designate the area, but it must be taken into consideration when the infrastructure is improved (Fearnside and Graca, 2006). The development of economy is the most important for government, so the number of sawmills and pastures are growing constantly. But most of the measures proved ineffective because of expanding population. Loggers cut trees and build sawmills in contempt of retribution. Conversely, according to some observations, urbanization may slow down the deforestation because the people live in relatively small area and it is unnecessary to clear new forests to establish settlements (Wright and Muller-Landau, 2006). This observation however, is questioned.

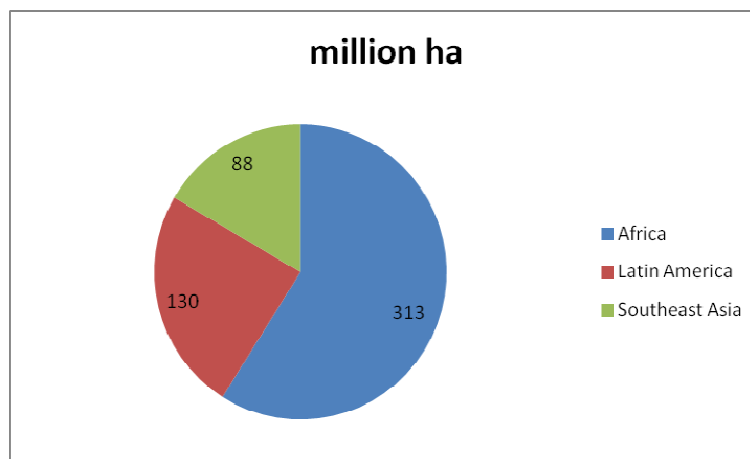


Figure 1. Distribution of secondary forests in the tropics (1990, in million hectares). Data from Society for Socio-ecological Programme Consultancy

There are measures that indirectly cause forest loss. For example, a slaughterhouse received a bank loan to develop equipment in Manaus. The management could take up more staff but more people wanted rising cattle and cleared more forest to establish new pasture (Fearnside, 2008). There is another, novel attempt in Africa. A campaign was launched to render popular the shadow coffee. Shadow coffee is produced under the canopy as undergrowth to save the forest. Quality of shadow coffee was low because the numerous parasites, and did not become so popular like light coffee grown on conventional plantations (Rappole et al., 2003). Socio-ecological status of countries strongly influences the fate of natural vegetation. In most countries the measures are ineffective or government gives priority to short-term economical benefits and they are not interested in saving wildlife. Despite the hitherto insufficient measures it is very important to take steps to save the remaining forests. Firstly, conservationists should identify the most diverse and richest areas. These areas are most valuable for the purpose of conservation and it's worth saving. They should establish national parks there (Faith et al., 2001; Felinks et al., 2011). But this is not an easy task because the economical state of the countries: nearby settlements, population expansion and climate change should also be taken into consideration. It would be important to standardize protocols for measuring biodiversity because global monitoring of biodiversity would benefit from it. Standardizing should be accompanied by provision and training in their implementation. This should increase the capacity of tropical countries where the majority of species live (McMahon et al., 2011). But the climate changes the vegetation and trees may disappear. Some species become extinct or seek new habitat. If corridors are left among forest patches it can help animals to persist and migrate among patches. Corridors may decrease the chance of endogamy and increase the chance of survival. But it is not true in many cases because they are too narrow. As mentioned above, the edge effect prevails in corridors so they should be more than 300 m in width. This effect was studied in Queensland, Australia. Six arboreal mammals were observed migrating among bigger fragmentations. Scientist considered width, length and vegetation of the corridor. The most threatened *Hemibelideus lemuroids* was observed only once in a corridor. Two other species, *Pseudochirulus herbertensis* and *Dactylopsila trivirgata* were common there, and they liked this area and occurred frequently in the less rich secondary forest. *Trichosurus vulpecula*, *Pseudochirops archeri* and *Dendrolagus*

lumholtzi occurred in remote isolated fragment using the corridors. If the corridors are wide enough and vegetation is more diverse animals will use it or live there. A wide corridor promotes migration. But if the corridor is poor in plants species and consists only of *Acacia* species it's hard to colonize remote forest fragments for animals (Laurence and Laurence, 1999). If a plantation is abandoned, succession will begin with colonization of new species and a secondary forest evolves. There are areas where 40% of vegetation is made up by secondary forests. If these forests are properly managed, after some decade loggers can cut trees again and the pressure on pristine forests will ease. Hence, these forests can be used for sustainable economical and conservation purposes. There is an opportunity in Puerto Rico to study different land use practices' impact on succession progress. Intensive logging is accountable for forest loss. This country has lost 90% of its forests and agriculture occupied the area (Marconi-Vega et al., 2002; Birdsey and Weaver, 1982). Today, economy shifted from agriculture to industry. More and more farmers abandoned their lands and new forests occupy the area. 32% of the area of the country was occupied by forest in 1990 (Franco et al., 1997; Helmer, 2004). The most important agricultural product is coffee in Puerto Rico (Cruz-Báez and Boswell, 1997). It is very important to know for conservationists that secondary forests grown on abandoned pastures or coffee plantations are how different or similar to each other or to pristine forests. 40 years after ending the cultivation, two secondary forests were very similar to each other. The diversity was nearly as high as before agricultural activity. Species composition was similar on former pasture and plantation (Marcano-Vega et al., 2002). As a result of an another study 60 years after ending the cultivation the structure of vegetation was similar to each other and converged to original forest but the species composition was different even after such a long time (Pascarella et al., 2000). Lot of rare and endemic species were absent from the secondary forest. Those species could not recolonize that area. Tree plantations are established in tropical countries mainly for timber production. Extent of plantations is about 140 million hectares and this area is growing annually by 2-3%. But plantations are established to reduce erosion and for recreation purposes. So far, it was thought that a plantation has a low diversity and only some species live there, and it doesn't provide habitat for many species to live. Recent studies reveal that rare species can live in tree plantations but fewer specimens are observed than in pristine forests. In comparison with soybean, coffee plantations and pasture the biodiversity is considerably higher in tree plantations (Brockerhoff et al., 2008). Therefore, tree plantations and secondary forests must be taken into consideration when a reserve is established. These would be valuable for conservationists. The cost of maintaining national parks is a very important issue for politicians and the country's economy. And how much revenue may come from national parks and tourism? For instance, the Mabira Forest is 300 km² of lowland tropical forest in Uganda and it is surrounded by agricultural area. It is located 50 km to north of the capital. Indigenous people frequently cut trees and burn the forest. So, the pressure is very high on the forest. A centre was established for tourists in 1996. From that time, a growing number of tourists came to see the wildlife. Today, the revenue from tourism almost covers the entire cost of maintaining the reserve. Tourists are ready to pay for untouched forest (Naidoo and Adamowicz, 2005). If the revenue from tourism covers the costs of maintaining forests we have a chance to save wildlife. This revenue may compensate the indigenous population for the loss of agricultural income. The climate change and environment pollution affects the entire planet and directly and indirectly destroy rainforests. This destruction could be hold up or, at least, slowed

down by international collaboration. However, it is difficult to carry out because policymakers consider the short-term benefits more important than environmental protection. It would be important to standardize protocols for measuring biodiversity because global monitoring of biodiversity would benefit from it. Standardizing should be accompanied by provision and training in their implementation. This increases the capacity of tropical countries where the majority of species live (McMahon et al., 2011).

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