Deforestation around the World and its impact on soil fertility and quality

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Introduction:

Deforestation means the conversion of forest to other land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold. It includes areas of forest converted to agriculture, pasture, water reservoirs and urban areas. It also includes areas where, for example, the impact of disturbance, over-utilization or changing environmental conditions affects the forest to an extent that it cannot sustain a tree cover above the 10 percent threshold (**FAO, 2001)**.

Deforestation defined broadly can include not only conversion to non-forest, but also degradation that reduces forest quality - the density and structure of the trees, the ecological services supplied, the biomass of plants and animals, the species diversity and the genetic diversity.

Forest is determined both by the presence of trees and the absence of other predominant land uses.The trees should be able to reach a minimum height of 5 m in situ. It includes areas with bamboo and palms provided that height and canopy cover criteria are met, forest roads, firebreaks and other small open areas; forest in national parks, nature reservesand other protected areas, such as those of specific scientific, historical, cultural or spiritual interest, windbreaks, shelterbelts and corridors of trees with an area of more than 0.5 ha and widthof more than 20 m, plantations primarily used for forestry and protection purposes, such as rubberwoodplantations and cork oak stands.

Forest Lost across the World:

Sl. No.	Country	Lost (mh) in 2017	% lost from 2016
1.	World	29.4	-
2.	Colombia	0.42	46
3.	Democratic Republic of Congo	1.5	6.2
4.	Indonesia	decrease	88

(Carrington*et al.,* 2018)

Marginal increase in India's forest:

Total forest cover in 2017	7,08,273 sq km
Total forest cover in 2015	7,01,495 sq km
Net increased	6778 sq km

Forest cover has decreased the most in the north-eastern states:

States	Forest lost
Mizoram	531 sq km
Nagaland	450 sq km
Arunachal Pradesh	190 sq km
Tripura	164 sq km
Meghalaya	116 sq km

(Indian state of forests report, 2017, Forest survey of India)

Important agents leading to deforestation:

The "agents" are those individuals, corporations, government agencies, or development projects that clear the forests as opposed to the forces that motivate them.

Table 1: Important agents leading to deforestation

Agents	**Links to deforestation, degradation and fragmentation**
commercial farmers	clear the forest to plant commercial cash crops, sometimes displace slashand-burn farmers who then move to the forest
slash-and-burn farmers	clear forest to grow subsistence and cash crops
Livestock herders	intensification of herding activities can lead to deforestation
commercial tree planters	clear mostly forest fallow or previously logged forests to establish plantations to supply fibre to

	the pulp and paper industry
firewood collectors	intensification of firewood collection can lead to deforestation
mining and petroleum industrialists	roads and seismic lines provide access to other land users, localized deforestation related to their operations
land settlement planners	relocation of people into forested areas as well as settlement projects displacing local people who then move to the forest
infrastructure developers	new access for other land users from road and highway construction through forested areas, flooding by hydroelectric dams

Table 2: Important agent groups and their regions

Region	**Main agents**
Africa	1. slash-and-burn farmers 2. commercial farmers 3. loggers 4. livestock herders 5. refugee and civil disturbances
Asia-Oceania	1. commercial farmers 2. slash-and-burn farmers 3. loggers 4. commercial tree planters 5. infrastructure developers
Latin America and Caribbean	1. slash-and-burn farmers 2. cattle ranchers 3. commercial farmers 4. loggers 5. infrastructure developers

The causes of deforestation are many and varied.

Direct Causes:
Natural causes: Hurricanes, Natural fires, Pests, Floods
Human activity: Agricultural expansion, Cattle ranching, Logging, Mining and oil extraction, Construction of dams Roads

Underlying Causes:
Market failures
Unpriced forest goods and services, Monopolies and monopolistic forces
Mistaken policy interventions
Wrong incentives, Regulatory mechanisms, Government investment
Governance weakness
Concentration of land ownership, Weak or non-existent ownership, land tenure arrangements, Illegal activities and corruption.
Broader socioeconomic andpolitical causes
Population growth and density, Economic growth, Distribution of economicand political power, Excessiveconsumption, Toxification, Global Warming, War.

Advantages of Deforestation:

It produces lumber and charcoal, offers job opportunities, removes diseased trees, allows for more agricultural land, provides residential land.

Disadvantages of Deforestation:

It harms wildlife and destroys their habitat, leaves a scar on the environment, affects the water cycle, contributes to the problem of climate change, causes soil erosion.

Impacts of deforestation on soil fertility and soil quality:

Soil fertility refers to the ability of a soil to sustain agricultural plant growth, i.e. the ability to supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction and the absence of toxic substances which may inhibit plant growth.

Soil quality means the ability of a soil to function within ecosystem boundaries to support healthy plants and animals, maintain or enhance air and water quality and support human health and habitation.

Soil fertility and quality consists of three components viz. physical, chemical and biological.

Table 3: Selected physical attributes for the cultivated soil and forest soils. Db = bulk density, n = porosity, AW = available water

Property	**VerticHapludolls**			**FluventicCalciudolls**		
	Cultivated Soil	Forest soil	% Change	Cultivated Soil	Forest soil	% Change
Sand (g kg^{-1})	123.3	193.3	36	186.6	243.3	23.3
Silt (g kg^{-1})	386.6	380.0	2.0	436.6	426.6	2.3
Clay (g kg^{-1})	490.	426.6	15	376.6	330.0	14.1
Db (g cm^{-1})	1.63	1.36	19.8	1.36	1.25	8.8
n (%)	37.0	47.0	21.3	52.5	58.3	9.9
AW(%)	10	18	44.4	15	17	11.8

(Rezapour&Alipour, 2017)

The soils under natural forest showed higher sand and lower clay and silt fractions thanthat of soils under cultivation. This may be due to the migration down the clay fraction intosoil profiles (**Rezapour, 2014**). Such finding is evidenced by the higher clay content in the 50–110 cmsoil layer in the forest land (depth distribution data not shown). Surely, the forestcanopy shades the soil surface which can: (a) lead to enhanced infiltration of rainfallwater into the soil and (b) serves as a vapour barrier and suppresses evaporationagainst moisture losses from the soil **(Khresat*et***

***al.,* 2008)**.Such conditions could result in more migration of clay fraction and subsequently its accumulation in the deeper horizons.

A pattern of increased bulk density (a rise of 14–20%) and decreased porosity values (a drop of 10– 22%) was observed for the samples of cultivated sites compared to those of the adjoining forest soils. Although, neither of these values is a limiting factor for plant rootgrowth, higher bulk density of the deforested site could result in a lower soil quality ascompaction could occur and result in non-favourableaeration **(Khresat*et al.,* 2008, Hajabbasi*et al.,* 1997).** The loss oforganic matter and the effects of compaction of machinery and human traffic throughagricultural practices (such as ploughing and harvesting crops) can be the most importantsubject to increasing bulk density in the cultivated soil as compared to the forest land.

Table 4: Runoff content and Soil erosion of adjacent Natural forest, Garden and Cultivated land.

Variables	Forest	Garden	Cultivated land
Runoff (L/M^3)	16.39	12.17	12.95
Soil erosion (g/m^2)	11.47	15.5	18.21

(Kavian*et al*., 2013)

Results of rainfall simulation indicated that change in landuse affected the amount of runoff content. Runoff content at 20 cm depth was lower inthe garden area (12.17±1.25 L/M^2) and cultivated area(12.95±.58 L/M^2) than in the natural forest (16.39±1.23 L/M^2) area. These results are discordant withthose of **Martinez-Mena *et al.,* (2008), Girmay*et al.,* (2009) and Fang *et al.,* (2012)** who found that the change from forestto another land use led to a significant increase in totalrunoff. The highest antecedent soil moisture in samplesfrom the natural forest compared with the other land usesis the main reason for the higher runoff in the natural forest.Higher initial soil water contents may cause reduction in soilpore space and consequently a reduction in permeability,and hence, the soil infiltrability is reduced under higher soilwater contents.

Soil erosion was affected by land use (Table 4). As the results show, soilerosion of the garden and cultivated soil was 1.351 and1.587 times higher than the amount of the natural forest soil, respectively. This result is consistent with thestudies of **Martinez-Mena *et al.,* (2008), Girmay*et al.,* (2009)and Fang *et al.,* (2012).**

Table 5: Selected Chemical attributes for the cultivated soil and forest soils

Property	VerticHapludolls	FluventicCalciudolls

	Cultivated Soil	Forest soil	% Change	Cultivated Soil	Forest soil	% Change
pH	7.16	6.53	9.6	6.96	6.6	5.5
EC (dS m^{-1})	0.65	1.59	59.1	0.61	0.63	3.2
CEC (cmol(+) kg^{-1})	23.0	28.5	19.3	18.5	23.2	20.3
C:N	11.68	10.97	6.5	20.77	11.32	83.5

(Rezapour&Alipour, 2017)

An increasing pattern in pH values was observed in the soils under cultivation (a rise of5–14%) than the forest soils. However, pH values were in an optimal range (6–7.5)for ‘general plant growth and microbial activity’ following deforestation and cultivation.The observed trend in soil pH under cultivation could be attributed to the mixing ofsurface soil with subsurface soil containing carbonates and basic compounds through tillage practices **(Rezapour and Samadi, 2012)**. Another possible explanation may be attributed to the high rate oforganic matter in the forest land that produces organic acids and provides H+-ions inthe soil solution thereby reducing soil pH **(Angassa*et al.,* 2012).**

Regarding the values of EC, both forest and cultivated soils were not saline and hencegeneral plant growth and microbial activity did not seem to be limited due to the presenceof salts. However, the soil EC value was significantly higher in the majority of the cultivatedsoils compared to soils under forest. The observed high level of salinity in the forest landmay be explained by the recycling of basic compounds (e.g. Na and K) through tree-rootuptake, translocation into plant shoots, and re-entry into the soil with litter fall anddecomposition **(Rezapour, 2014**).

The C:N ratio was low, 10–20, in both soils under forest and indicatingthat those soils are in a mineralized state with significant implication on organicmatter cycling and nutrient release **(Angassa,2012).** Decomposition isslowed when the C:N ratio is high (>30:1) and more rapid when the C:N ratio is low(<20:1)**(Tisdale, 1993)**. The cultivated soil manifested a considerable increase in the values of C:N ratio,ranging from 3% to 84%, compared with the adjoining forest soils which is consistentwith the results of Abbasi*et al.,* 2007 who observed high C:N ratios for cropland comparedto soil under forest.

The values of CEC, as a favorable indicator of the fertility and productivity of soils, weremedium to high categories, ranging from 18.5 to 23.0cmolc kg^{-1} for the cultivated soils and from 23.2 to 28.5cmolc kg^{-1} for the adjacent forest soils. The conversion of forest land to thecropland induced a drop of 19.3% (VH) to 20.3% (FC) in the amount of CEC. Typically,this pattern matched the distributive trend of organic carbon, suggesting the significantcontribution of organic matter to CEC.

Table 6: Mass (kg ha^{-1}) of total nutrients in the forest floor

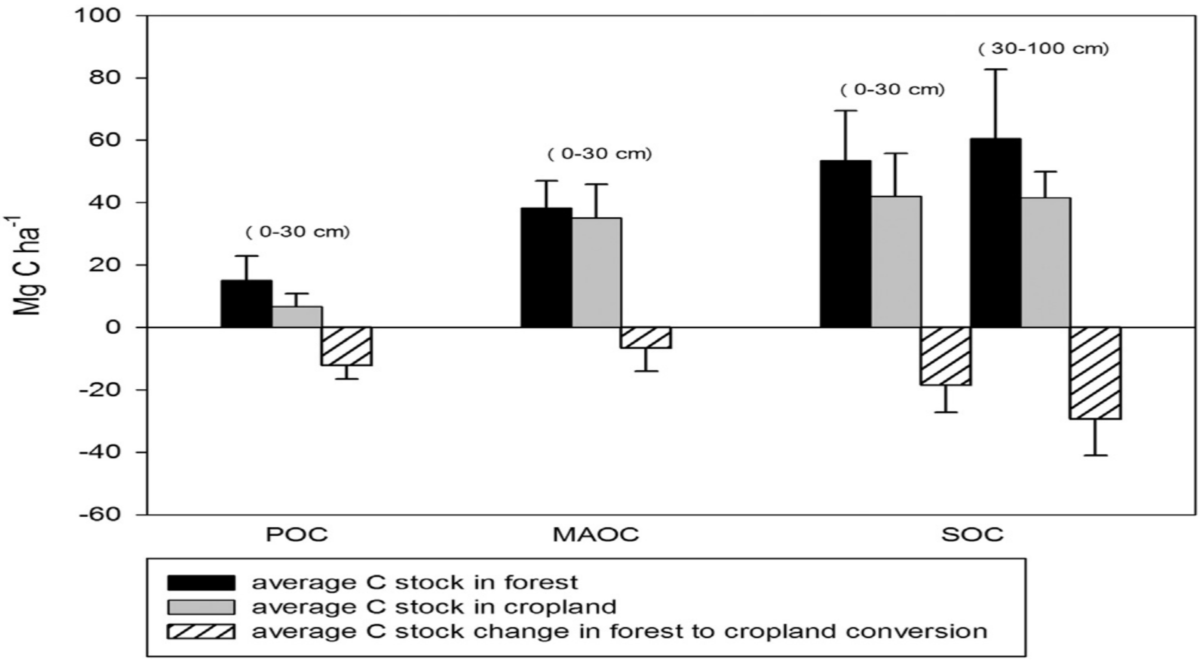
Study area	**St-pere**		
	Burned	**Cut**	**Control**
N	1060b	1870a	2130a
P	81a	120a	120a
K	105b	210a	182a
Ca	330b	670a	400b

Mg	44b	92a	57b

Simard*et al.,* 2001

Nutrient element loss is a common effect of both clear-cuttingand wildfire. Nitrogen is often the most limiting nutrient in borealecosystems and can be lost in large quantities during wildfire. This studyshowed a significant loss in the total mass of N and K in theforest floors of the St-Père burned stands. Nitrogen, whichvolatilizes at 200°C, is easily lostduring wildfires, which can achieve temperatures of300–700°C. Other less volatile nutrients, suchas base cations and phosphorus are subject to loss throughash convection,wind and water erosion,especially more mobile ions, such as K+, which are lostthrough leaching. The youngest study area (St. Père) was the only area inwhich scarification and planting were included as part of thecut treatment. The literature suggests that site preparationcommonly increases the loss of nutrients from disturbed ecosystems. However, mass and concentrationof total nutrients in the forest floor of the cut stands didnot drop significantly below levels in controls in any studyarea, suggesting that clearcutting and scarification did notcause significant nutrient loss.

Fig 1: Average stocks of total soil organic C (SOC), particulate organic C (POC) and mineral associated organic C (MAOC) in forest and in croplands, and average C stock changes in forest to cropland conversion**(Villarino*et al*., 2016)**



Carbon losses account for nearly 19 Mg C ha^{-1} of SOC, composed by 12 Mg C ha−1 of POC and 7 Mg C ha^{-1} of MAOC. SOC stock losses at 30– 100 cm depth account for 30 Mg C ha^{-1}, and this value is around 11 Mg C ha^{-1} higher than the SOC stock loss at 0–30 cm. In the forest, the observed SOC stock in the first meter of soil was 114Mg C ha^{-1}, almost twice of the total C biomass. The average estimatedSOC losses after 10 years of continuous cropping (48 Mg Cha^{-1}) was slightly lower than C stored in biomass (59 Mg Cha^{-1})under forest, **(Gasparri*et al.,***

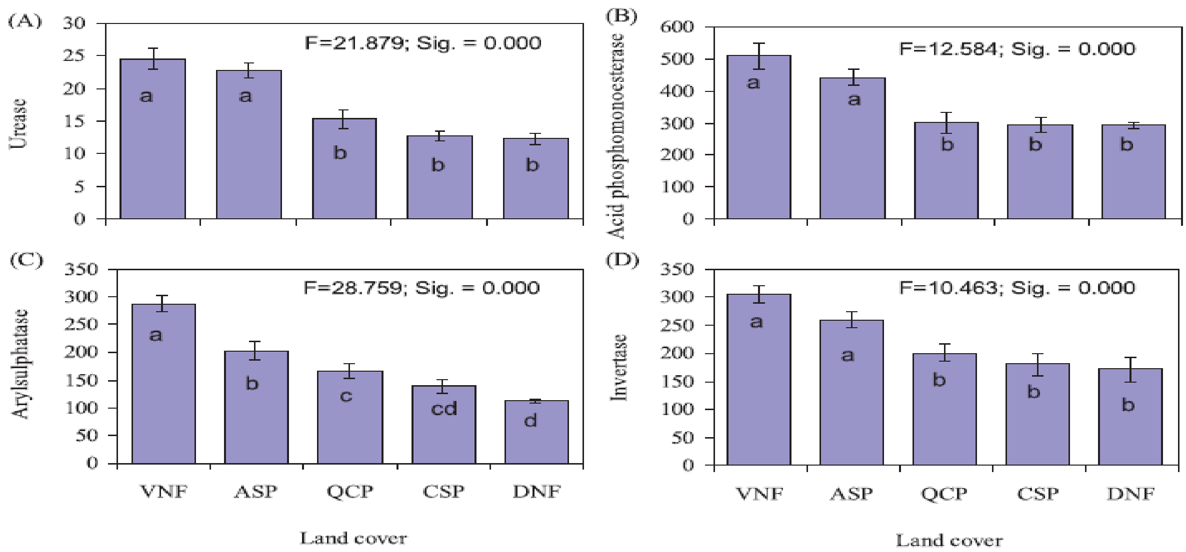
2008). Therefore, deforestation led to a loss of approximately 104Mg C ha−1 (56Mg ha^{-1} in total biomassplus 48 Mg ha^{-1} in SOC stock). Themost widespread deforestation method in the study area consistsin land clearing with heavy bulldozers, burning the remaining vegetationand then plowing down the residues **(Boletta*et al.,* 2006).**This practiceproduces strong changes in soil, such as surface exposure toprecipitation,wind and solar radiation, aeration and temperature increases, root removal,and aboveground biomass and charcoal incorporation. Thesechanges severely affect SOC dynamics in different ways. Surface exposure
to climatic conditions, aeration and temperature increases, and root removalcould deplete SOC stocks, either by mineralization increases or bywater and wind erosion. However, aboveground biomass and charcoal incorporationcould have the opposite effect and this could explain thehigher SOC stocks during the first 2–3 years of cropping. Soil organicC, POC, and MOAC (0–5 and 0–30 depths) losses under longer periodsof cropping are probably due to decreases in the above ground net primary production (ANNP) incroplands **(Volante*et al.,* 2012),**increases in the mineralization rate dueto higher temperature and aeration, and wind erosion **(Rojas *et al.,*2013)**. POC is considered a key soil quality indicator (**Haynes, 2005),** it is very likely that high losses under cropping are indicating strong soil degradation in the region.

Table 7: Soil microbial and biochemical properties analyzed (Kooch*et al.,* 2018)

Soil features	Virgin natural forest (VNF)	Degraded natural forest (DNF)
Microbial biomass C (mg kg^{-1})	685.50 a	453.62 c
Microbial biomass N (mg kg^{-1})	65.74 a	41.52 d
Microbial biomass P (mg kg^{-1})	81.31 a	37.93 e
Particulate organic C (mg kg^{-1})	3.15 b	1.21 c
Particulate organic N (mg kg^{-1})	0.50 a	0.34 b
Dissolved organic C (mg kg^{-1})	68.96 b	39.21 c
Dissolved organic N (mg kg^{-1}	39.21 a	26.60 b

Soil MBN and MBP were differentamong the land covers, and the natural forest (65.74 and81.31 mg kg−1) had the highest values but the least were found in thedegraded forests (41.52 and 37.93 mg kg−1), respectively. The enhanced levels of soil MBC, MBN and MBP under natural forestand also rehabilitated area could be explained by the higher nutrientconcentrations and soil organic matter as compared to degraded sites**(Aponte *et al.,* 2013).** Thus, the higher microbial biomasses(C, N and P) under natural forest as compared to other sites aremainly attributable to the greater availability of organic matter in theseforest sites, which is in agreement with the findings of **Wang and Wang(2007)** in San Menjiang Forest. DOC and DONrelease is often controlled by different factors. DOC is the primary formof C that is transported from forest floor to mineral soils. In general, theleaching of freshly fallen litter and the decomposition of forest floororganic matter are thought to be the major sources of DOC and DON inforest soils **(Kooch and Bayranvand, 2017).**

Fig 2: Enzyme activity**(Kooch*et al*., 2018)**

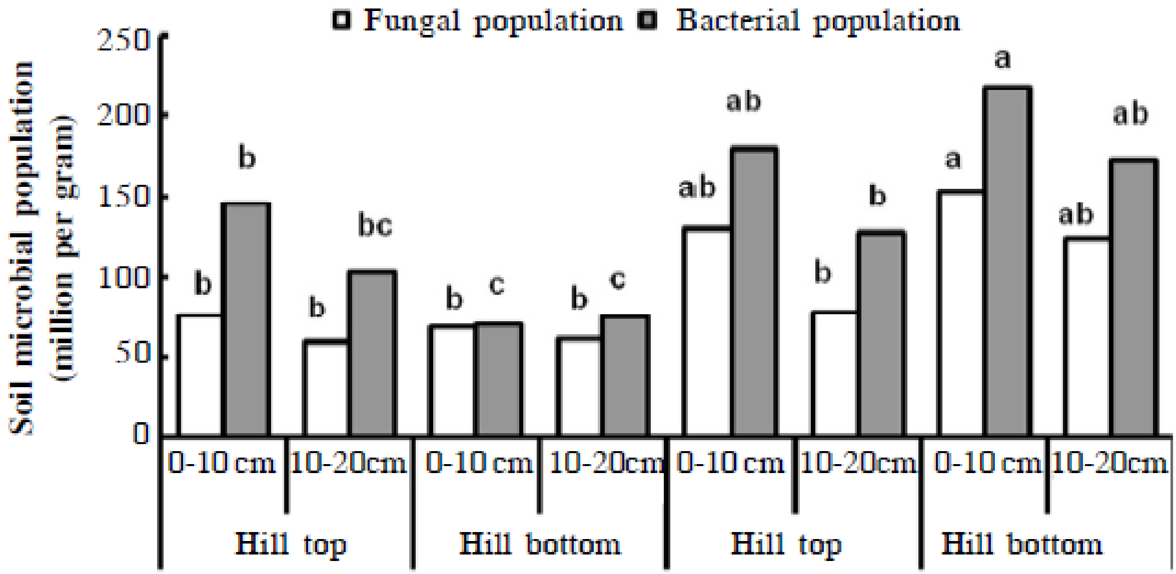


Soil activities were assigned to Urease (μg NH^{4+}–Ng^{-1} 2 h^{-1}); Acid phosphomonoesterase (μg PNP g^{-1} h^{-1}); Arylsulfatase (μg PNP g^{-1} h^{-1}); Invertase (μg Glucose g^{-1} 3 h^{-1}). Virgin natural forest (VNF), Alnussubcordata C.A.M. plantation (ASP), Quercuscastaneifolia C.A. Mey plantation (QCP), Cupressussempervirens var. horizontalis plantation (CSP) and degraded natural forest (DNF).

Enzyme activities may be more quickly influenced by changesin forest management, which might be useful as an early indicator ofbiological changes **(Hu *et al.,* 2006)**. The activities of some of them like urease, invertase, phosphatases, andarylsulfatase, which are respectively involved in N, C, P, and S cycles,are more sensitive to land cover changes **(Raiesi and Beheshti, 2014)**.The results obtained in this study show that the tree species in theecosystem influenced the enzyme activities in the topsoil (Raiesi andBeheshti, 2014). The urease, acid phosphomonoesterase, arylsulfataseand invertase activity of virgin natural forest with native tree species(dominated by Carpinusbetulus and Parrotiapersica) was significantlyhigher than that of the Quercuscastaneifolia and Cupressussempervirensmonoculture plantations with a negative effect on deforestation. This

suggested that a natural broad-leaved forest could have a better effectin promoting soil enzyme activity compared with pure plantations**(Pang *et al.,* 2009)** of Quercuscastaneifolia and Cupressussempervirens aswell as degraded sites. Parallel to virgin natural forest, after 30 years plantation of Alnussubcordata,the biomass on the afforest soil surface increased and returnedmore litter to the soil, thus increasing urease, acid phosphomonoesteraseand invertase enzyme activity. This emphasized the importanceof long-term monitoring in order to adequately evaluate and understandthe impacts of Alnussubcordata afforestation on degraded forestland soil properties.

Fig 3: Soil fungal and bacterial populations in deforested land and natural forest of Baroitoli Forest Beat, Chittagong South Forest Division.**(Miah*et al*., 2014)**



Both fungal and bacterial populationswere significantly ($p\leq0.05$) lower in deforested land compared toadjacent natural forest in both the surfaces (0-10 cm and 10-20 cmdepth) on top and bottom hill position in the study area (Fig. 3). Indeforested land, fungal population ranged from 59 to76 million g^{-1}dry soils while in natural forest it was 78 to 153 million g^{-1}dry soil.In deforested land, the bacterial population ranged from 70 to 146million g^{-1} dry soil but in natural forest it was from 127 to 218million g^{-1}dry soil. In land with thepresence of forest, a definite ecological condition sets in withrespect to light, moisture, drainage, aeration, organic food materialsand both fine and coarse roots, in which a distinct type of faunasurvives. Forest clearing and conversion to other land uses oftenresult in a low level of microbial population **(Jha*et al.,* 1992)** and enzymaticactivity **(Salam *et al.,* 1998)**due to changes in soil microclimate. In the present investigation, both fungi and bacterialpopulations were found higher in upper layer (0-10 cm) than in thelower layer (10-20 cm) at both the hill position of natural forestand deforested land. **Chenge*et al., 1992***showed comparatively lower fungiand bacterial population with increased depth of soil profile fromdeforested hill slope of China, the similar tropical region of thepresent study.

Summary & conclusion:

The soils under natural forest showed higher sand and lower clay and silt fraction's than that of soils under cultivation.A pattern of increased bulk density and decreased porosity values was observed for the samples of cultivated sites compared to those of the adjoining forest soils.The rainfall runoff experiments indicate that runoff content of the natural forest soils was higher than the garden and cultivated land soils. Garden soil erosion and cultivated land was higher than the forest.pH values was high under cultivation than the forest soils. The cultivated soil manifested a considerable increase in the values of C:N ratio with the adjoining forest soils. The conversion of forest land to the cropland induced a drop in the amount of CEC.Soil organic C, POC, and MOAC) losses under longer periods of cropping are probably due to decreases in the above ground net primary production (ANNP) ,increases in the mineralization rate due to higher temperature and aeration, and wind erosion.The microbial community *i.e.,* the fungal and bacterial population was also significantly lower in both surfaces (0-10 cm and 10-20 cm) of hill positions in the deforested land compared to natural forest.Microbial/biochemical indicators showed perceptible deterioration in the topsoil due to deforestation.In general, deforestation provides some advantages to human but it deteriorates soil fertility and quality significantly. So we need to stop deforestation and search for new way for our mankind.

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