Effect of plantation tree species with varied cropping systems on depth wise rate of soil carbon sequestration and soil chemical properties in Uttar Pradesh, India

ASTRACT

Litterfall and root turnover from trees enrich the organic material and nutrient content of soil beneath the trees. The influence of seven different cropping systems with tree species was evaluated on pH, EC, CEC, OC and carbon sequestration. Soil sampling was done on GPS basis investigation area of the agro-forestry farm to assess the effect of plantations of tree species and cropping systems on soil carbon sequestration. One hundred twenty representative soil samples from the five soil depths viz. 0-15, 15-30, 30-60, 60-90 & 90-120 cm, soil samples were collect from 17 years older*Casuarina + Guava + Turmeric, Casuarina + Paddy + Wheat, Shisham, Shisham + Peragrass, Shisham + Mustard, Shisham + Paddy + Wheat, Eucalyptus*in plots of Forestry farm have been collected during August-September, 2019, from ANDUA&T, Narendra Nagar, Kumarganj, Ayodhya Uttar Pradesh, India. The initial condition of research area considered as control. The soil samples were analyzed with following the standard procedures. Among the investigation plots of the farm, the maximum buildup of carbon sequestration was found in the plantation of Casuarina+Guava+Turmeric followed by Casuarina+Paddy+Wheat, Shisham+Paddy+Wheat. The minimum buildup of carbon sequestration was found plantation with Eucalyptus. Soil organic carbon decreased with increase in deepness irrespective of tree species. The chemical properties the pH from 7.85-10.40, E.C ranged from 0.15 – 4.97 dSm^{-1}, organic carbon ranged from 2.07- 6.81 gkg^{-1} and CEC ranged from 9.50- 30.03 $cmol(p+)kg^{-1}$. Soil carbon sequestration was ranged from 0.20-0.32 tonne ha^{-1} $year^{-1}$. Soil organic carbon

decreased with increase in depth and soil pH, EC and CEC increase with decreased in depth irrespective of tree species. Therefore, the tree plantations can improve the physico-chemical properties of the soil profile.

Keywords: CEC, EC, Carbon sequestration, Organic carbon, pH and Plantations

INTRODUCTION

Soil is a constituent of the lithosphere and biosphere structure. It is an imperative natural source on which supporting life system and socio economic enlargement depends. In India, the land resources obtainable for agriculture are decrease our plan of optimizing the use of land resources with a strengthening of agriculture resulted also in the rapid depletion of nutrients or occasionally in their accumulation. Agro forestry systems are usually perceived to be sustainable and to improve soil properties. Growing trees in conjunction with yearly crops or pastures is believed to provide an extra thorough plant cover to defend the soil from erosion and a deeper or additional prolific root system to improve nutrient cycling. Tree species can be different in their effects on maintaining in soil fertility, including rates of nutrients input, output, and cycling. Different land use systems viz. agriculture, horticulture, forestry, agri-horticultural, pastures and wasteland system lead to the change in physico-chemical properties and also alter in nutrient content **(Ally-said *et al*., 2015).** Soil sustainability and productivity depends on dynamic equilibrium between its physical, chemical and biological properties. These properties are incessantly influence by land uses with put forward influence on soil properties and therefore, help in refurbishment of soil quality. The available land area under cultivation for Agriculture productions are decreasing continuously due to the increasing population and acquisition of fertile land. The increasing population is also a major cause of Land degradation. The per capita globally or Indian land has declined from 0.32ha in 1950's to 0.14ha by the twist of the century.

It is supposed to be less than 0.1ha by 2020 **(Kees Klein Goldewijk *et al.,* 2017).** The tree plantations influence the soil physico-chemical and biological properties through litterfall addition and root turnover. It is therefore essential to examine the fertility status of soil from time to time with a vision to monitor the litter falls and decaying of roots which affect the soil health for long time can improve the physico-chemical properties of soil. A considerable quantity of organic matter and nutrients are returned to the soil through litterfall and root decay. Return of nutrients to soil varies with species, plantation age, decomposition rate, season and spacing (**Munoz and Beer, 2001)**. Trees can capture nutrients underneath the rooting zone of crops because of their deep root system and move them to surface soil. The effects of soil organic matter gathering are higher on surface than subsurface horizons.

Plantations of different tree species alone or joint with agricultural crops could be an effectual land rehabilitation approach. Nutrient release and litter decay of trees decide the potential of tree species to get better soil productivity and fertility of lands. Soil organic matter (SOM) has main role in improving the productivity of soils. Litter fall addition from trees leads to organic matter refill and a considerable amount of nutrient come back to the soil. It helps in maintaining soil fertility. Long and extensive roots of trees permit them to take up large amount of nutrients beneath the rooting zone of crops and transmit them to upper soil surface **(Hartemink *et al.,* 1996).** The effects of litter accumulation from trees are higher on the upper soil surface than the lower surface soils. The soil organic carbon and nutrient content below trees is usually more than the contiguous open sites. Plants are the major source of the soil organic carbon, either from the decay of aerial plant parts or underground plant parts such as roots in the form of root demise, root respiration and root exudates. About 40 percent of the photosynthates synthesized in the plant parts mislaid through the root system into the rhizosphere within an hour and the speed of loss is influenced by numerous factors, i. e. plant age, different biotic and abiotic stresses, etc. Soil organic carbon is usually considered as essential regulating factor of both soils physico-chemical qualities **(Cotrufo *et al.*, 2011).** About 30% loss of soil organic carbon owing to conversion of natural grassland and forests into croplands **(Bot and Bnites, 2005).** Soil macro and micro nutrients availability and distribution are depends on soil pH, soil organic matter contents and numerous physical, chemical and biological situations of the rhizosphere. Different land uses play an important role in affecting soil quality and health by leaf litter, soil binding through root system, checking runoff, soil and nutrient losses etc.

MATERIALS AND METHODS

Study Site:

The experiment was carry out in different plantation of the experimental field site of Forestry farm Acharya Narendra Deva University Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India during year 2019-20. This work is based on Ph.D. degree program. The Farm is located at a distance of 42 kms from Ayodhya city on Ayodhya - Raebareli road. Experimental position falls under subtropical climate in Indo-Gangetic plains having alluvial calcareous soil and lies between 26^{o}33’N latitude and 81^{o}50’E longitude with an evolution of about 113.0 meters from the mean sea level. Tree plantations of 17 years old tree species namely casuarina, shisham and eucalyptus were selected for the present investigation. The initial condition of research area considered as control. These species had been planted in six replications in a block in the monsoon season during August 2002.

Soils, Climate and crops:

The district Ayodhya falls underneath sub-humid climate receiving a mean yearly rainfall of about 1100 mm about 85% of the total rainfall is concentrated from mid June to end of

September. However, occasional showers are also beginning during winter months and occasional frostiness occurs during this period. The soils are confined to the alluvial belt whose geology is dominated by alluvium deposits from the Gomati and Ghaghara rivers where slope gradients are almost negligible. The area falls under sub- tropical zone which is characterized by hot and dry summers and cold winters. The temperature in summer reaches up to 45^0 C with desiccate winds and in winter it goes down to 5^0C. The potential evaporation is very high from March to October. In this tract, rains are received from south west monsoon. The average rainfall is about 1070 mm and about 85% of which is received during the rainy season and rest 15% water is applied by tubewell. Irrigation facility is very good of this farm. Generally in *Kharif* season Rice, Jowar, Maize, Arahar, Pigeon Pea, Kodo, Sawan, Green Gram and Black Gram are grown while Wheat, Barley, Mustard, Pea, Gram, Oat, Berseem and Potato are the common crops of *Rabi* season. Sugarcane is also grown as an annual crop.

Soil sampling, preparation of soil samples and methods employed for soil analysis:

The eight plantations were selected for the study which is considered as treatments agro forestry farm Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. The soil samples were collected from eight treatments of the agro forestry farm. For collection of soil samples the spots were selected by using the Geographical Positioning System (GPS) location of treatments, show the table no. 1. The samples were withdrawn from each replication of the treatments with GPS location with the help of post whole Auger, Phavara and Khurpi with depths; surface (0-15 cm) and sub-surface; (15-30 cm), (30-60 cm), (60-90 cm) and (90-120 cm).Total 120, samples were collected from the 8 treatments with five depths which was replicated as thrice. The soil sampling depths were viz. 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm & 90-120 cm depth. Among collected 120 soil samples from different depths of the spots. The samples were collected from different spots for different physico-chemical study was brought to the laboratory and dried under the shade. The entire soil samples were crushed with the help of mortar and pestle and sieved through 20 mesh sieve and it is separated until it remains about 1000 gms only, then it was kept in cool, dry and dark place in laboratory.

Chemical analysis:

The soil pH was estimated in 1:2.5 soil-water suspensions using an Elico-glass electrode pH meter (Jackson 1973). Electrical conductivity (dSm^{-1}) was estimated with the assist of Conductivity Bridge meter using 1:2.5 soil water suspensions as described by Bower and Wilcox (1965). A known weight (1.0 g) of 0.2 mm sieved soil was treated with a known surplus volume of chromic acid ($K_2Cr_2O_7$ + H_2SO_4). After the oxidation of organic carbon (%), the unreacted $K_2Cr_2O_7$ left in the contents was reverse titrated with standard ferrous ammonium sulphate using diphenylamine indicator (Walkley and Black rapid titration method, 1934). CEC ($cmol(p^+)kg^{-1}$) at each sampling point was measured by Black, C.A., Ed. Methods (H. D. Chapman, 1965).

Carbon sequestration:

Carbon sequestration was calculated as described by Vicente-Vicente *et al.* (2016)

$$\text{Soil C sequestration rate} = \frac{Ct - Ct^1}{t}$$

Where Ct = Present condition during investigation

Ct^1 = 30 years before plantations

t = Duration of plantation in years

RESULTS AND DISCUSSION

Soil pH, Electrical Conductivity (EC), Organic Carbon (OC) and Cation Exchange Capacity (CEC):

The data for soil pH, EC (Electrical conductivity), OC (Organic Carbon) and CEC (Cation Exchange Capacity) of the investigation site presented in table no. 2. It is evident from the data that the maximum pH (10.40) was recorded in treatment No.1 (Control) with depth 60-90 cm and minimum pH (7.85) value was analyzed in treatment No.3 (Casuarina + Paddy + Wheat) at the depth of 0-15 cm. The pH value of the eight treatments of the investigation ranged from 7.85-10.40 and with an average value of 8.99. The Standard deviation of pH was 0.57, 1.14, 1.73 and 5.04 respectively. The data regarding soil pH of the investigation site evident that the maximum pH (10.40) was recorded in control with depth 60-90 cm and minimum pH (7.85) value was analyzed in Casuarina + Paddy + Wheat at the depth of 0-15 cm. It may be due to the cropping system and plantation of trees and leaching of salts from upper layer to lower depth. The pH value of the investigation ranged from 7.85-10.40 with an average of 8.99. The Standard deviation of pH was 0.57 respectively. The maximum Electrical Conductivity (4.97 dSm^{-1}) was recorded in treatment No. 1 (Control) at 60-90 cm depth, and minimum E.C. (0.15 dSm^{-1}) was found in treatment No.2 (Casuarina + Guava + Turmeric) at the depth of 0-15 cm. Electrical conductivity (E.C.) ranged from 0.15 – 4.97 dSm^{-1} and with an average value 0.70 dSm^{-1}. The Standard deviation of Electrical conductivity was 1.14 respectively. The data regarding soil EC (Electrical conductivity) of the investigation site evident that the maximum Electrical

Conductivity (4.97 dSm^{-1}) was recorded in control at 60-90 cm depth, and minimum E.C. (0.15 dSm^{-1}) was found in Casuarina + Guava + Turmeric at the depth of 0-15 cm. It may be due to the cropping system and plantation of trees and leaching of salts from upper layer to lower depth. The Electrical conductivity (E.C.) ranged from 0.15 – 4.97 dSm^{-1} with an average value 0.70 dSm^{-1}. The Standard deviation of electronic conductivity was 1.14 respectively. The maximum Organic Carbon (6.81 gkg^{-1}) was analyzed in treatment No. 2 (Casuarina + Guava + Turmeric) at 0-15 cm, and minimum O.C. (2.07 gkg^{-1}) was found in treatment No. 1 (Control) at the depth of 90-120 cm. Organic carbon ranged from 2.07- 6.81 gkg^{-1} with an average value 3.85 gkg^{-1}. The Standard deviation of Organic Carbon was 1.73 respectively. The data regarding soil Organic Carbon of the investigation site evident that the maximum O.C. (6.81 gkg^{-1}) was analyzed in cropping system Casuarina + Guava + Turmeric at 0-15 cm, and minimum O.C. (2.07 gkg^{-1}) was found in control at the depth of 90-120 cm. It is also clear that the organic carbon is high at surface soil, its decreased with increasing the depth of soil. The Organic carbon ranged from 2.07- 6.81 gkg^{-1} with an average value 3.85 gkg-1. The Standard deviation of organic carbon was 1.73 respectively. The maximum Cation Exchange Capacity (30.03 $cmol(p^{+})kg^{-1}$) was found in treatment No. 2 (Casuarina + Guava + Turmeric) at the depth 0-15 cm, whereas, minimum C.E.C. (9.50 $cmol(p^{+})kg^{-1}$) was found in treatment No. 1 (Control) at the depth of 90-120 cm. Cation Exchange Capacity (C.E.C.) ranged from (9.50- 30.03 $cmol(p^{+})kg^{-1}$) with an average value of Cation Exchange Capacity 21.45 ($cmol(p^{+})kg^{-1}$). The Standard deviation of Cation Exchange Capacity was 5.04 respectively. The data regarding Cation Exchange Capacity of the investigation site evident that the maximum C.E.C. (30.03 $cmol(p^{+})kg^{-1}$) was found in Casuarina + Guava + Turmeric at the depth 0-15 cm, whereas, minimum C.E.C. (9.50 $cmol(p^{+})kg^{-1}$) was found in control at the depth of 90-120 cm. It is also clear that the C.E.C. is high on surface of the soil C.E.C. is decreased with increasing the depth. The Cation Exchange Capacity (C.E.C.) ranged from 9.50- 30.03 cmol(p^+)kg^{-1}) with an average value of Cation Exchange Capacity 21.45 (cmol(p^+)kg^{-1}). The Standard deviation of cation exchange capacity was 5.04 respectively. These results were also corroborated by **Habtamu *et al.*, (2014) and Muche *et al.*, (2015).**

Carbon sequestration:

The data regarding carbon sequestration at variable depth with response to plantation of tree species and cropping system are presented in table no. 3. The data depicted in table evident that the higher carbon sequestration (0.32 tonne $ha^{-1}year^{-1}$) was recorded from treatment No. 2 (Casuarina + Guava + Turmeric) followed by T_3 - (Casuarina + Paddy + Wheat), T_7 - (Shisham + Paddy + Wheat), T_5 - (Shisham + Paragrass) and T_6 - (Shisham + Mustard), T_4 - (Shisham) respectively at the soil depth 0-15 cm. where minimum carbon sequestration (0.20 tonne $ha^{-1}year^{-1}$) was found at treatment No. 8 (Eucalyptus) with the depth of 0-15 cm. it is also clear from the data the level of carbon sequestration was decreased with increasing the depth of soil. The minimum reduction was found in carbon sequestration with in increasing the depth of soil in T_2 (Casuarina + Guava + Turmeric) and T_7 (Shisham + Mustard). The available Carbon sequestration was ranged from 0.20-0.32 tonne $ha^{-1}year^{-1}$ with an average value of 0.23 tonne $ha^{-1}year^{-1}$, the Standard deviation of Carbon sequestration was 0.10 respectively.

The data regarding carbon sequestration at variable depth with response to plantation of tree species and cropping system evident that the higher carbon sequestration (0.32 tonne $ha^{-1}year^{-1}$) was recorded in Casuarina + Guava + Turmeric followed by Casuarina + Paddy + Wheat, Shisham + Paddy + Wheat, Shisham + Paragrass and Shisham + Mustard, Shisham, respectively at the soil depth 0-15 cm. Where minimum carbon sequestration (0.20 tonne $ha^{-1}year^{-1}$) was found Eucalyptus with the depth of 0-15 cm. It is also cleared the level of carbon sequestration was decreased with increasing the depth of soil. The minimum reduction was found in carbon sequestration with in increasing the depth of soil in Casuarina + Guava + Turmeric and Shisham + Mustard. The available carbon sequestration was ranged from 0.20-0.32 tonne ha^{-1} year^{-1} with an average value of 0.23 tonne ha^{-1}year^{-1}, the standard deviation of carbon sequestration was 0.10. It is also cleared that the organic carbon is high in surface of soil and it's decreased with increasing the depth of soil. The Similar results were also found by **Jina*et al.*, (2008) and Janzen (2004).**

Conclusion

On the basis of present study it may be concluded that for the maintenance of soil health, improvement of soil physico-chemical and biological properties, availability of nutrients and sustainability of soil may be possible with the adoption of plantation of tree species along with cropping system for their soil health, profitability and productivity. The results of the study indicate that Casuarina + Guava + Turmerichas higher potential of accumulating organic carbon in the soil than other tree species. There is need to plantation of Casuarina + Guava + Turmeric system in the field.In addition to fulfilling the demand of wood and wood products, the trees can ameliorate the poor quality sites and mitigate the climate change through accumulation of carbon in the biomass and soil. The carbon sequestration was highest in the 0-15 cm depth and decreased with increase in depth irrespective of tree species.

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Table No.-1: GPS location of soil sampling place

Forestry farm		**GPS Locations**	
Treatment	**Replication No.**	**Latitude**	**Longitude**
$T_{1.}$ Control	R_1	26^{o} 55″76″ N	81^{o} 84″89″E
	R_2	26^{o} 55″98″ N	81^{o} 84″89″E
	R_3	26^{o} 56″04″ N	81^{o} 85″03″E
$T_{2.}$ Casuarina + Guava + Turmeric	R_1	26^{o} 55″83″ N	81^{o} 84″82″E
	R_2	26^{o} 55″84″ N	81^{o} 84″84″E
	R_3	26^{o} 55″86″ N	81^{o} 84″85″E
$T_{3.}$ Casuarina + Paddy + Wheat	R_1	26^{o} 55″98″ N	81^{o} 84″89″E
	R_2	26^{o} 56″01″ N	81^{o} 84″90″E
	R_3	26^{o} 56″02″ N	81^{o} 84″91″E
$T_{4.}$ Shisham	R_1	26^{o} 55″76″ N	81^{o} 84″89″E
	R_2	26^{o} 55″77″ N	81^{o} 84″91″E
	R_3	26^{o} 55″78″ N	81^{o} 84″92″E
$T_{5.}$ Shisham + Peragrass	R_1	26^{o} 55″74″ N	81^{o} 84″82″E
	R_2	26^{o} 55″75″ N	81^{o} 84″82″E
	R_3	26^{o} 55″76″ N	81^{o} 84″82″E
$T_{6.}$ Shisham + Mustard	R_1	26^{o} 56″01″ N	81^{o} 85″02″E
	R_2	26^{o} 56″01″ N	81^{o} 85″03″E
	R_3	26^{o} 56″02″ N	81^{o} 85″03″E
$T_{7.}$ Shisham + Paddy + Wheat	R_1	26^{o} 56″04″ N	81^{o} 85″03″E
	R_2	26^{o} 56″04″ N	81^{o} 85″05″E
	R_3	26^{o} 56″04″ N	81^{o} 85″06″E
$T_{8.}$ Eucalyptus	R_1	26^{o} 55″93″ N	81^{o} 84″85″E
	R_2	26^{o} 55″95″ N	81^{o} 84″85″E
	R_3	26^{o} 55″96″ N	81^{o} 84″87″E

Table No.-2: Depth wise distribution of soil chemical properties under different plantation of tree species with cropping system

S. No.	Treatment Name	Depth (cm)	pH	EC (dSm^{-1})	Organic Carbon (gkg^{-1})	CEC ($cmol(p^{+})kg^{-1}$)
1.	Control	0-15	8.50	1.90	3.10	13.00
		15-30	9.35	2.87	2.80	11.50
		30-60	10.00	3.80	2.43	10.53
		60-90	10.40	4.97	2.13	10.10
		90-120	10.20	4.00	2.07	9.50
		Mean	9.69	3.51	2.51	10.93
		Range	8.50-10.40	1.90-4.97	2.07-3.10	9.50-13.00
2.	Casuarina + Guava + Turmeric	0-15	8.00	0.15	6.81	30.03
		15-30	8.46	0.19	6.41	28.03
		30-60	9.00	0.23	4.15	26.50
		60-90	9.20	0.29	2.72	25.00
		90-120	8.90	0.28	2.12	24.00
		Mean	8.71	0.23	4.44	26.71
		Range	8.00-9.20	0.15-0.29	2.12-6.81	24.00-30.03
3.	Casuarina + Paddy + Wheat	0-15	7.85	0.16	6.38	28.97
		15-30	8.20	0.17	6.06	27.53
		30-60	8.80	0.28	4.08	26.00
		60-90	9.10	0.44	2.54	24.00
		90-120	8.73	0.41	2.08	23.10
		Mean	8.54	0.29	4.23	25.92
		Range	7.85-9.10	0.16-0.44	2.08-6.38	23.10-28.97
4.	Shisham	0-15	8.30	0.18	5.95	24.00
		15-30	8.87	0.21	5.71	22.03
		30-60	8.97	0.24	3.64	20.57
		60-90	9.60	0.36	2.23	19.00
		90-120	9.50	0.30	1.92	18.57
		Mean	9.05	0.26	3.89	20.83
		Range	8.30-9.60	0.18-0.36	1.92-5.95	18.57-24.00

5.	Shisham + Peragrass	0-15	8.25	0.18	6.14	25.57
		15-30	8.67	0.20	5.80	24.00
		30-60	9.03	0.28	3.74	22.50
		60-90	9.20	0.46	2.36	21.10
		90-120	9.10	0.43	2.02	19.53
		Mean	8.85	0.31	4.01	22.54
		Range	8.25-9.20	0.18-0.46	2.02-6.14	19.53-25.57
6.	Shisham + Mustard	0-15	8.28	0.18	6.08	25.03
		15-30	9.00	0.20	5.76	23.00
		30-60	9.03	0.35	3.71	21.03
		60-90	9.50	0.44	2.30	19.60
		90-120	9.37	0.43	1.95	18.57
		Mean	9.04	0.32	3.96	21.45
		Range	8.28-9.50	0.18-0.44	1.95-6.08	18.57-25.03
7.	Shisham + Paddy + Wheat	0-15	8.23	0.17	6.26	26.50
		15-30	8.90	0.20	5.95	25.00
		30-60	9.30	0.40	4.03	23.60
		60-90	9.40	0.50	2.47	21.50
		90-120	9.23	0.45	2.04	20.50
		Mean	9.01	0.35	4.15	23.42
		Range	8.23-9.40	0.17-0.50	2.04-6.26	20.50-26.50
8.	Eucalyptus	0-15	8.46	0.29	5.40	22.00
		15-30	8.80	0.35	5.34	21.03
		30-60	9.10	0.40	3.24	19.50
		60-90	9.47	0.43	2.10	18.47
		90-120	9.37	0.41	1.89	18.00
		Mean	9.04	0.38	3.60	19.80
		Range	8.46-9.47	0.29-0.43	1.89-5.40	18.00-22.00
T. Average			8.99	0.70	3.85	21.45
S. Deviation			0.57	1.14	1.73	5.04

Table No.-3: Study the sequestration of carbon under different cropping system with tree plantation

S. No.	Treatment Name	Carbon sequestration (tonne $ha^{-1} year^{-1}$)				
		Depth				
		0-15	15-30	30-60	60-90	90-120
1.	Control	-	-	-	-	-
2.	Casuarina + Guava + Turmeric	0.32	0.31	0.15	0.05	0.00
3.	Casuarina + Paddy + Wheat	0.29	0.28	0.14	0.04	0.00
4.	Shisham	0.25	0.25	0.11	0.01	0.00
5.	Shisham + Peragrass	0.26	0.26	0.11	0.02	0.00
6.	Shisham + Mustard	0.26	0.26	0.11	0.01	0.00
7.	Shisham + Paddy + Wheat	0.27	0.27	0.14	0.03	0.00
8.	Eucalyptus	0.20	0.22	0.07	0.00	0.00
Range		**0.20-0.32**	**0.22-0.31**	**0.07-0.15**	**0.00-0.05**	**0.00-0.00**
T. Average		**0.23**	**0.23**	**0.10**	**0.02**	**0.00**
S. Deviation		**0.10**	**0.10**	**0.05**	**0.02**	**0.00**