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Comparison of soil and forest floor properties of floodplain and surrounding forests in Igneada, Turkey

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Abstract: *In this study some soil and forest floor characteristics of floodplain forest, thermophile forest and sand dune were investigated at Igneada, Turkey. In this context, surface soil samples were analyzed and compared to each other in the extension of soil physical, chemical properties and as plant nutrition environment. To investigate the soil characteristics soil samples were collected from 48 sampling point. The distribution of the soils revealed that remarkably physical soil properties figure the ordination of soils in principal component analysis (PCA). We concluded that floodplain forests have quite different soil properties from the thermophile forest and sand dunes under the continuous effect of surrounding thermophile forest land with less sandy proportion to soil texture 52.4 at floodplain forest, 64.0% at thermophile forest and 91.0% at sand dunes and highly organic carbon 5.619, 4.191 and 0.478% respectively at 0-5 cm depth and total nitrogen content 0.213, 0.078 and 0.056% for floodplain forest> thermophile forest> sand dune soils, respectively. Weight and organic matter contents of forest floor were significantly higher in the thermophile forests.*

Key words: *Floodplain forest, Soil nitrogen, Forest floor, Igneada*
PDF of full length paper is available online
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Introduction

Igneada floodplain forests consist approximately quarter of Turkey's total floodplain forest areas (Pamay, 1967) and on Igneada floodplain forests number of studies has been conducted both from Turkey and from Bulgaria (Tecimen, 2005). Floodplain forests provide remarkably high bio-diversity and ecosystem diversity where sustainable protective management is crucial for the future functions. High biodiversity, water purification characteristics, possession of major carbon sink makes forested wetlands very valuable landscapes. In the worldwide, contemporarily applied land use type of wetlands is conversion of wetlands to farmlands which receive economical and political support especially in North America as stated in Wetland Reserve Program (2002) (Aldous *et al.*, 2005). Wetlands supply the beneficial ecosystem functions of subsiding floods and carbon sequestration. It is widely accepted that waterlogging is the dominant factor regulating wetland biogeochemistry. The water recycling at floodplain forest lands make those fields function as CO_2 sink in winter, while a CO_2 emission source in summer with respect to high decomposition rate. Denitrification and methane emission are the basic C and N mechanisms of wetlands. The denitrification process one of the main component of wetlands has received increasing attention since its potential of alleviating environmental impacts of NO_3 in ground and surface waters via the enzymatic reduction of NO_3 (Ambus and Zechmeister-Boltenstern, 2007). Methane emission from wetlands, one of the main dynamic of wetlands which also causes global warming, is induced particularly by the variables such as soil type, temperature, soil redox potential, water management, fertilization with organic carbon or nitrogen (Conrad, 2002).

When waterlogging is reduced by lowering the water table, wetland soils begin to exhibit characteristics which resemble those of other ecosystems (Freeman *et al.*, 1997). Those type of ecosystems supply oligotrophic site conditions especially -N and -P limited nutrition conditions where highly nutrient resorption of plants occur (Rejmánková and Houdková, 2006). As with all ecosystems, the decomposition of dead biomass and the subsequent export of gaseous and dissolved materials from wetlands, is affected by microbial activity. The paucity of enzymatic activity may cause to carbon storage and water quality amelioration (Freeman *et al.*, 1997). The reduced moisture of soils in wetlands is leading to an accelerated process of peat decay, and hence to increased fertility and acidity of the soils (Czerepko, 2008). So wetland soils carry a significant importance in terms of nutrient supply and biogeochemical cycles. Wetland dynamics such as water flooding has a great affect on top soil chemistry and texture chiefly determined by the surrounding environment type. Total nitrogen supply and forest floor characteristics provide the major nutrition regime in wetlands. Water logging mostly affect the reaction of the soils in relation with microbial activities which in turn determine the forest floor decomposition and nutrition status.

In this study some soil characteristics of wetland and the fields surrounding wetlands are investigated to provide some knowledge related to wetland ecosystems. In this context surface soil samples were analyzed and compared to each other in the extension of soil physical, chemical properties and as plant nutrition environment.

Materials and Methods

Site description: Igneada is located in the northwest part of Turkey on the Black Sea coast, and it is also near the national border between Turkey and Bulgaria (Fig. 1). Igneada floodplain forest, located at the down slopes of Istranca mountains, includes 4 lakes in itself. Approximately 1000 ha floodplain forests under high pressure of grazing are managed as protection forests (Pamay, 1967). This type of forest land contains high plant diversity and wetland ecosystems besides biomes of which oak species rely on precipitation sourced soil moisture. Besides, there also exist alder, ash, maple and redwood tree species as the main tree species. The plant communities and some descriptive properties of the study site are given in table 1. A total of 10 phytosociological plant communities were detected on the study site which are *Trachistemo carpinet, Fraxino carpinetum, Carici-fraxinetum quercetosum, Carici-Fraxinetum tipikum, Leucojo fraxinetum, Carici-Fraxinetosum Juglancetosum* in floodplain forest; *Quercetum frainetto-cerris tipikum, Quercetum frainetto-cerris carpinetosum, Quercetum petrea* in thermophile forest and *Otantho – Leymetum sabulosi, Medicago rigidula – Cionura erecta* and meadow plant community behind the sand dune (Kavgaci, 2007a,b).

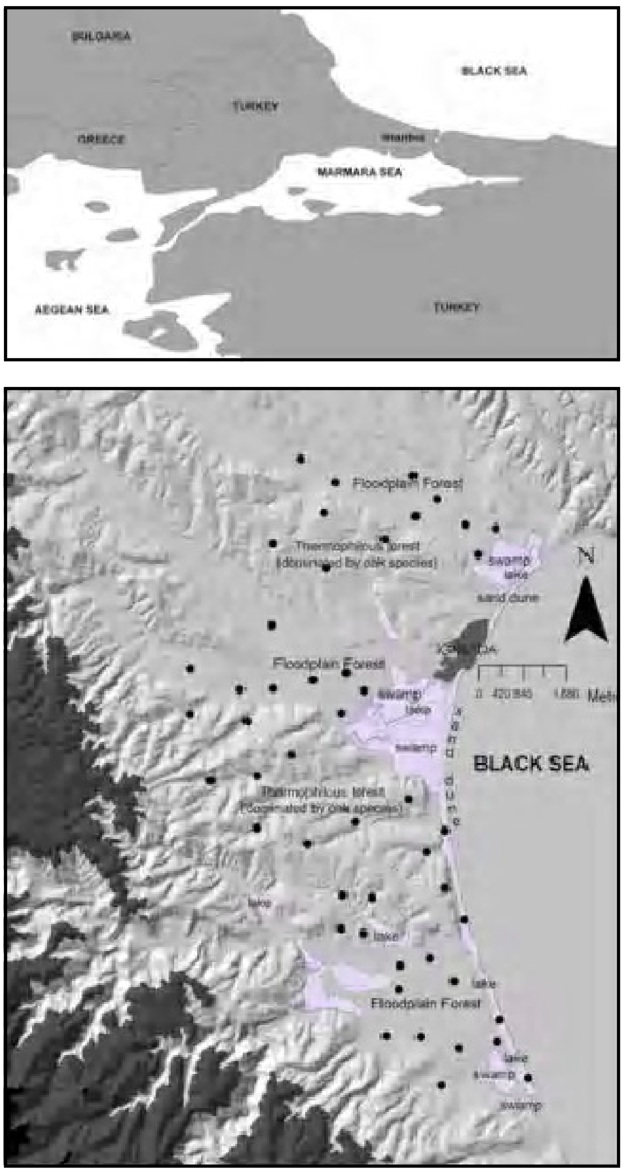

Fig. 1: Map of Igneada floodplain forest illustrating soil sampling areas

Deep and highly drainable longose forest soils developed on alluvial parent material surrounded by peneplane topographic structure micaschist parent rock originated forest soils. The freshwater forms estuary at the end of the floodplain forests and sand dunes just has been constituted beyond the estuary towards seaside. The thermophile forest which mainly has a tree composition of oak species provides the basin for the floodplain forest.

Since there is no meteorological station in Igneada the climate of the research area was examined using the data of Kumkoy Meteorology Station in Istanbul (Anon., 2006). Annual mean temperature is 13.8°C; the coldest month is February; the warmest month is August. Annual temperature difference is 17.7°C. The temperature during the vegetation period (from April to August) is 20.5°C; annual precipitation is 800mm; mostly falling between October – March. According to the Thornthwaite (1948) climate system, the research area has humid; low temperature (microthermal); a moderate water deficit exist in the mid-summer; an ocean like continental climate reigns, formulated as B4 C'2 s b'1.

Sampling and estimation: Soil core samples were collected in April and October 2005 avoiding the high level of water table from the adjacent floodplain forest parts. The sampling points were distributed to the study area due to distances to sea and the sharp vegetation differentiation. Vegetation communities and associations also had been analyzed to provide a comprehensive knowledge about floodplain forest through the TURBOVEG program. Soil sampling points were distributed in accordance with plant community assemblages (Fig. 1). The digging and sampling were made at the same time to avoid chemical variations in soil properties. Soil samples were taken representatively for horizons and afterward these were issued to depth evaluation which permits us to make comparison. Totally 48 points were sampled from soil and forest floor. Forest floor litter sampling were done randomly from 3 points by forest floor circle of which the inner radius is 37cm.

Air dried samples were ground and sieved from 2 mm diameter pores. Bulk soil samples were dried at 105°C for 24 hr to findout oven dry weight which are given as g l^{-1}. The rest of the soil sample left on the sieve was calculated as the skeleton portion of the soil. Soil particle size distribution was determined using the hydrometer method (Jackson ,1962; Karaoz, 1992a). Soil pH in a 1:2.5 soil/

water suspension was determined using the Hanna Instruments pH-meter. Soil moisture was determined gravimetrically. The content of total organic carbon was estimated by potassium dichromate oxidation and the content of total N by Kjeldahl digestion by the Kjeltec (Tecator) Auto 1030 Analyzer (Jackson, 1962; Karaöz, 1989). Organic matter content of forest floor material is subjected to Loss on ignition method at 650°C (Karaöz, 1992b).

Statistical analysis: The statistical analysis for soil samples was applied in SPSS 12.0v. After being checked the homogeneity of variances, the suitable method was chosen for the data set. The data of 0-5 cm depth samples subjected to Dunnett T3, and the sand, clay and soil bulk density rate data of 5-15 cm depth samples permitted us to apply Tukey and the rest of the parameters for the same depth again subjected to Dunnett T3. Comparisons of 2 groups of forest floor values were made by T-test. The PCA analysis was conducted in the CANOCO for windows polynomial statistical program to describe the spatially classification of sampling points.

Results and Discussion

Sand, clay and silt percentages of all sites show significant differences between each other, while soil volume weight values show similarity between floodplain and thermophile forest deviating from sand dune site at 0-5 cm depth (Table 2). At 5-15 cm depth no difference was detected between floodplain and thermophile forest but sand dune shows difference for sand, clay and silt percentages (Table 3). The soil bulk density shows similarity between all site units but floodplain and thermophile forest shows a difference between each other.

While pH of the floodplain forest and thermophile forests shows a great similarity at 0-5 cm depth it illustrates a differentiation at 5-15 cm depth. The average values of both depths for floodplain and thermophile forests are very close to each other but the amplitude for the thermophile forest shows a greater range that might be referred to less water movement than floodplain forest where the amplitude range of pH is not so large. The reduced moisture of soils is leading to an accelerated process of peat decay, and hence increased the fertility and acidity of the soils (Czerepko, 2008). The $CaCO_3$ percentages of both upper and lower soil depths in thermophile forest do not show a wide range where as the values of floodplain forest do in conjunction with the distance to sea. Besides, the sand dune samples have a greater difference in comparison with both the thermophile and the floodplain forest.

The second most striking soil parameter other than the sand and clay percentage is the organic carbon values of soils. All the investigated sites show difference between each other in terms of organic carbon. There has been observed a sequence of floodplain forest > thermophile forest > sand dune with the average values of organic carbon at 5.619, 4.191 and 0.478%, respectively at 0-5 cm depth. The similar sequence can also be seen at the 5-15 cm depth with the values 3.793, 1.872 and 0.393%, respectively with lower organic carbon values in the surficial soil. These results are in accordance with Walters *et al.*

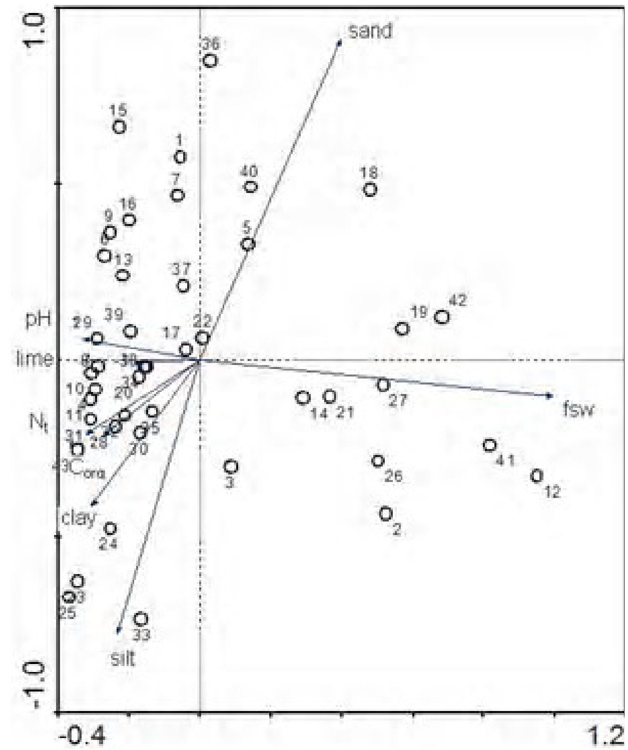

Fig. 2: Distribution and ordination of soils sampled from 0-5cm depth within PCA in their similarity features. In the figure 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 20, 23, 24, 25, 28, 29, 30, 31, 32, 34, 35, 36, 37, 39, 40, 44, 45, 47, 48 refer to floodplain forest, 2, 14, 18, 19, 21, 22, 26, 27, 38, 46 refer to thermophile forest and 1, 41, 42, 43 refer to sampling plots from sand dune sites. fsw: fine soil weight, N_t: Total Nitrogen, C_{org}: Organic carbon

(2006) who recorded that permanently saturated marshes stored more soil carbon because of lower rates of decomposition. The lowest value observed at the sand dune sites could be referred to as less litter fall addition in comparison with the other ecosystem types. The difference between floodplain forest and the thermophile forest might be caused from the highly nutritious tree species' litterfall, where at the thermophile forest there is a monocultural stand type. From another aspect it could be expected that water movement process at floodplain forest which in turn suppresses the decomposition of organic matter giving a high organic carbon outcome. Organic matter decreased from 82% in the upstream locations to 30% in the marine sites near mangrove forests demonstrating that landscape gradient effects on soil characteristics (Chen and Twilley, 1999).

Soil total nitrogen values at 0-5 cm depth show a similar sequence with the soil organic carbon percentages but only the floodplain forest differs from the other ecosystem types, so in the thermophile forest and sand dune total nitrogen values exist in the same group. In the 0-5 cm soil depth total nitrogen average values are as 0.297, 0.154 and 0.062% for floodplain forest, thermophile forest and sand dune soils, respectively. The similar difference between the floodplain forest and the other ecosystem types for the 5-15 cm depth was also observed with the values 0.213, 0.078

Table - 1: Forest floor (FF) litter weight, stable water depth, soil physiological depth and soil structure features on different plant associations of floodplain forest, thermophile forest and sand dune sites

Parameter	Floodplain forest sites						Sand dune	Thermophile forest sites		
	Trach. carp. (n=8)	Frax. carp. querc.(n=11)	C – F (n=2)	C – F tipic. (n=8)	Leuc. fra. (n=1)	C – F jug. (n=3)	Sand dune (n=4)	Querc. Fc tipic. (n=2)	Querc. Fc carp.(n=5)	Qu. pet. (n=4)
FF										
Weight (g m^{-2})	1330	825	1262	735	—	1535	—	2561	1360	1610
Min.	0.0	548	1261	442	—	1318	—	1800	921	1397
Max.	2230	1032	1263	1024	—	1771	—	3322	1825	1845
FF OM (%)	60.9	63.7	64.9	54.7	—	47.1	—	77.8	66.1	74.5
Min.	42.3	51.9	—	41.4	—	38.4	—	75.0	58.5	62.2
Max.	84.5	79.1	—	65.9	—	58.1	—	80.7	72.1	85.7
SSWTD• (cm)										
Min.	24.0	2.0	19.0	1.0	-	-	-	34.0	32.0	11.0
Max.	70.0	65.0	61.0	42.0	15.0	48.0	-	38.0	40.0	40.0
SPD•• (cm)										
Min.	40.0	50.0	-	45.0	-	70.0	-	40.0	35.0	35.0
Max.	74.0	>100.0	70.0	70.0	78.0	>90.0	>75.0	51.0	>100.0	52.0
Soil structure										
Granular•••	<13-56	<1-19	<61	<1-78	<78	<56-100	<100	<15-38	<53-100	<11-40

n = number, • Soil stable water table depth, •• Soil physiological depth, •••The rest is amorphous, †Trach. carp. = *Trachistemo carpinet*, Frax. carp = *Fraxino carpinetum*, C-F querc. = *Carici-fraxinetum quercetosum*, C-F tipic = *Carici-Fraxinetum tipikum*, Leuc. fra = L*eucojo fraxinetum*, C-F jug. = *Carici-Fraxinetosum Juglancetosum*, Qurec. Fc. tipic = *Quercetum frainetto-cerris tipikum*, Querc.fc.carp = *Quercetum frainetto-cerris carpinetosum*, Qu.pet. = *Quercetum petrea*

Table - 2: Soil properties for the 0-5 cm depth under different sites

Soil properties	Floodplain forest (n=33)	Thermophile forest (n=11)	Sand dune (n=4)
Sand (%)	52.4[a*] (18.6-89.5)**	64.0[b] (52.4-84.2)	91.0[c] (89.8-92.7)
Silt (%)	27.5[a] (0.7-68.2)	23.4[a] (12.7-33.9)	3.9[b] (0.7-6.0)
Clay (%)	20.1[a] (3.2-49.9)	12.6[b] (3.1-20.4)	5.1[c] (1.3-7.5)
SBD# (g l^{-1})	907.8[a] (425.0-1245.0)	970.7[a] (822.0-1193.0)	1257.5[b] (1220.0-1330.0)
pH	5.2[a] (4.3-6.0)	5.1[a] (4.1-6.8)	7.9[b] (7.5-8.4)
$CaCO_3$ (%)	0.31[a] (0.08-2.76)	0.17[a] (0.08-0.48)	10.54[b] (8.42-16.04)
C_{org} (%)	5.619[a] (0.890-12.921)	4.191[b] (2.750-5.936)	0.478[c] (0.134-0.882)
N_t (%)	0.297[a] (0.089-0.956)	0.154[b] (0.048-0.242)	0.062[b] (0.004-0.125)

Soil bulk density, *Values in the same row followed by the different letter indicate significant ($p<0.05$) differences, ** Values in parantheses are range

and 0.056% for floodplain forest, thermophile forest and sand dune soils, respectively. The topographic structure around the floodplain forest has a considerable effect on the nitrogen (esp. nitrate (NO_3^-) nitrogen) (Evans *et al.*, 2004). Floods occuring during the growing season could negatively affect the N economy of alder-dominated ecosystems since Alders are actinorhizal trees with the capacity to fix atmospheric dinitrogen (N_2) through symbiosis with actinomycetes (Kaelke and Dawson, 2003), whereas we observed the total nitrogen amount of 0.956% at *Leucojo fraxinetum* sites (in floodplain forestland) whose dominant tree species is *Alnus glutinosa* L. The result we derived may be caused from topographic structure of the study site where the flooding might efflux from the gentle rills that allow roots to achieve temporarily nitrogen fixation.

According to results, both the forest floor litter weight and the organic matter content of the forest floor is higher at the thermophile forest (Table 4). That may be caused from the high water movement in the floodplain forest which provides the sweeping of the forest floor. Besides the tree species composition of the stands in the floodplain forest supply a very easy decomposable forest floor material in accordance with thermophile forest. However Dick and Osunkoya

Table - 3: The results of soil properties for the 5-15 cm depth under different sites

Soil properties	Floodplain forest (n=33)	Thermophile forest (n=11)	Sand dune (n=4)
Sand (%)	51.7[a]	62.5[a]	91.2[b]
	(16.2-79.6)**	(48.9-92.3)	(89.8-93.2)
Silt (%)	25.7[a]	21.2[a]	3.7[b]
	(2.1-48.3)	(4.9-34.1)	(0.70-6.0)
Clay (%)	22.6[a]	16.3[ab]	5.1[b]
	(3.2-52.1)	(2.9-25.6)	(1.3-7.5)
SBD# ($g\ l^{-1}$)	1081.1[ab]	1255.0[ac]	1277.4[a]
	(425.0-1377.0)	(1006.0-1455.0)	(1220.0-1334.5)
pH H_2O (1/2,5)	5.0[a]	5.0[a]	8.0[b]
	(4.2-5.8)	(3.9-7.2)	(7.5-8.4)
$CaCO_3$ (%)	0.26[a]	0.18[a]	11.50[b]
	(0.08-1.20)	(0.08-0.57)	(8.42-16.04)
C_{org} (%)	3.793[a]	1.872[b]	0.393[c]
	(0.890-12.921)	(0.955-2.998)	(0.134-0.761)
N_t (%)	0.213[a]	0.078[b]	0.056[b]
	(0.069-0.956)	(0.046-0.154)	(0.004-0.125)

#Soil bulk density, Values in the same row followed by the different letter indicate significant ($p<0.05$) differences, ** Values in parentheses are range

Table - 4: Forest floor properties under different sites

Forest floor properties	Floodplain forest (n=33)	Thermophile Fores (n=11)	Sand Dune (n=4)*
FF Weight ($g\ m^{-2}$)	1110.1[a]	1566.8[b]	—-
FF OM (%)	59.0[a]	70.9[b]	—-

*No forest floor could be detected at the sand dune site, Values in the same row followed by the different letter indicate significant ($p<0.05$) differences

(2000) supposed that the decomposition rate is higher in the landward sites, who especially compared the tidal floodgates to the inland sites. Eventually the litter quality has a very important effect on decomposition as stated by many authors (Sariyildiz *et al.*, 2005; Haitao *et al.*, 2007).

Measured soil parameters put into the PCA ordination analysis to make the similarities of the soils sampled from 0-5 cm depth available. As the results of analysis variances also remarked the differences between all sampling points in the terms of sand content, clay content and fine soil weight. The ordination of soil sampling points especially 2, 14, 21, 26 and 27 significantly illustrate the effect of fine soil weight (FSW) (Fig. 2). Consistent with the PCA analysis $CaCO_3$ (lime), pH, Nt, Corg and clay properties of the soils demonstrate very low effect on the ordination of soils. It might also be revealed that remarkably physical soil properties shape the ordination of soils in PCA.

It can be revealed that floodplain forests have quite different soil properties from the thermophile forest and sand dunes under the continuous effect of surrounding thermophile forest land. Being in relation with the geographically neighborhood the water flows from the thermophile forest create remarkable effects especially on the soil physical characteristics. Besides floodplain forest itself builds its own site conditions such as being inundated seasonally, exposition to the water flow and provide authentically suitable site conditions for specific tree species. Thereafter in floodplain sites denitrification process activity prevails particularly in the winter season which alleviates the NO_3^- leaching. Water flooding from the surrounding sites causes to significant changes in soil's spatial structure as a result of the water inputs and unidirectional flows such as base cations and organic carbon distribution and surficial soil development (Fennessy and Mitsch, 2001). Since the processes in the nitrogen cycle is sensitive to environmental conditions (Gilliam *et al.*,1999), it can be suggested that seasonal changes in nitrogen transformations are extremely rapid. Besides, as the soil physical characteristics such as water table also affects the denitrification (Hefting *et al.*, 2004) we could expect a higher denitrification period at *Fraxino carpinetum* and *Carici-Fraxinetum tipikum* sites where the water tables are very high (Table 1). As conclusion we may assume that floodplain forests provide high organic carbon and total nitrogen content in the plant nutrition. But the seasonal fluctuations should be studied in the further researches to provide a comprehensive and more precise knowledge about seasonal and year round nitrogen transformations.

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