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Effect of vegetation change from forest to herbaceous vegetation cover on soil moisture and temperature regimes and soil water chemistry

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ABSTRACT

Objective of this study was to compare the effects of forest and herbaceous vegetation covers on soil temperatures (average daily maximum, minimum, and mean daily temperatures), soil moisture, and chemical content of the soil water. Soil moisture and soil temperature were monitored at three different soil depths (40, 80 and 120 cm) and rain water samples and soil water samples from 40 cm and 80 cm soil depths were collected for 20 weeks on a weekly basis depending on precipitation events. Soil water samples were analyzed for total alkalinity, total nitrogen, calcium hardness, chloride, electrical conductivity, organic matter, pH, potassium, sodium, sulfate, and total hardness. Experiment was as a 3-way factorial in a split plot design with whole plots in blocks and repeated measures with two replications. Data were analyzed by using ANOVA and means were separated with Tukey test. Soils under the forest and herbaceous vegetation covers showed significant difference in terms of overall mean daily maximum, minimum, and average daily temperatures. Overall average daily maximum and minimum temperatures were 9.94 °C and 9.75 °C, respectively for the soils in the forest plot while they were 11.08 °C and 10.87 °C for those in the herbaceous plot. Woody vegetation removal significantly increased overall mean daily temperature from 9.84 °C to 10.98 °C and overall mean daily volumetric soil moisture content of the soils from 32% to 48%. Chemical content of the soil water from both study sites were similar except for chloride and sulfate content. Soil water from forestland had a lower chloride but higher sulfate content than the soils from herbaceous vegetation covered area. On the other hand, chemical content of the soil water from forestland did not show significant changes with soil depth while total alkalinity, calcium hardness, electrical conductivity, pH, sodium, sulfate, and total hardness increased significantly with soil depth in the soils under herbaceous vegetation cover.

1. Introduction

Watersheds includes several landuse types that have important impacts on quality and quantity of the streamwater (Huang et al., 2013). Among the land use types, forest ecosytems provide the best quality fresh water in a sustainable manner (Neary et al., 2009) but they consume much more water than other ecosystems due to interception and transpration losses (Grelle et al., 1999; Kosugi and Katsuyama, 2007; Özhan et al., 2010; García-Santos, 2012). Since the presence of forest cover has an important effect on microclimate and the amount of precipitation reaching soil surface, land cover changes from forest to herbaceous vegetation can affect quality and quantity of the streamwaters in the watersheds. In arid and semiarid regions, plant growth can be limited due to low soil moisture availability and high soil temperatures. Therefore, there is heightened interest for removing trees to increase soil moisture in the semiarid regions around the world (Hungerford and Babbitt, 1987; Fleming et al., 1998; Garduño et al., 2010). Additionally, vegetation transformation from one type to another increases as a result of human intervention due to population growth and demand for forest resources (Song et al., 2013). In general, the greatest changes in the soil moisture content and soil temperature occur after forest vegetation removal because of increased solar radiation on the soil surface and decreased transpration and interception capacities of the forest canopy (Hungerford and Babbitt, 1987; Carlson and Groot, 1997; Bhatti et al., 2000; Smit and Retman, 2000; Ritter et al., 2005; Scharenbroch and Bockheim, 2007). Morecroft et al. (1998) reported that much smaller range of temperatures was measured in the soils under forest cover compared to soils under grass cover. Woody vegetation clearance affects not only moisture availability in the soil but also chemical content of the soil water and soil temperature. On the other hand, climate change is a reality and natural phenomen. Due to global warming, vegetation pattern can be altered and this case can result in permanent vegetation and soil losses and changes in soil moisture and temperature and hence soil chemisrty. Soil moisture and temperature are important ecological factors which play important roles in chemical, hydrological, and biological processes in the soil (Bhatti et al., 2000). For instance, soil moisture and temperature

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influence organic matter decomposition, nutrient availability, and soil thermal dynamics (Yi et al., 2009), ecosytem stability and fertility (Lucas-Borja et al., 2010), runoff generation, erosion, nutrient flux, and plant growth and distribution patterns (Cornaglia et al., 2005; Wang et al., 2013). Vegetation attributes such as density and heigth affect soil temperature and moisture level. Morecroft et al. (1998) compared the soil temperatures at high forest, coppice and grassland and found that grassland soils had the highest maximum temperature while coppice soils had the lowest maximum temperatures. Song et al. (2013) reported that reduction in plant heigth and density caused significant increases in the soil temperature. Similarly, Garduño et al. (2010) found higher soil temperatures between dead trees (without leaves) compared to under the canopy of the live trees (with leaves) in New Mexico, USA. Ritter et al. (2005) investigated effect of gap formation on soil moisture and temperature and found higher soil temperatures and soil moisture content in the gaps than in the forestland. Pinyon-Juniper harvesting increased soil moisture content and mean soil temperature at the 15-cm depth in the Shoshone Mountain range of central Nevada (Everett and Sharrow, 1985). Zeng et al. (2009) investigated impact of landcover change on soil moisture content in Inner Mongolia and they found that soil moisture content of the soils in savanna ecosytems was higher than Mongolian pine plantation in May and November. Similarly, Scharenbroch and Bockheim (2007) measured higher soil moisture content and soil temperatures in herbaceous vegetation covered soils than nearby forest vegetation covered soils.

Since chemical content of the soil water is the result of several ecological processes including decomposition of plant litter, nutrient uptake by plants, evapotranspiration, cation exchange, and weathering and leaching of minerals, soil water chemistry can be considered as a useful tool for monitoring the changes taking places within ecosytems (Avila et al., 1995). Also, changes in the soil water chemistry, soil temperature and soil moisture content can reflect the effect of vegetation cover change in a short term following vegetation transformation. Furthermore, these parameters can be considered as indicators for recovery of disturbed ecosystems. There are some studies showing effect of vegetation changes on soil temperature and moisture as cited before but they were carried out under different climatic and ecologic conditions. That is why, further studies are needed conducted under different ecologic and climatic scenarios. Compared to other parts of the world, there is limited information about effect of vegetation conversion on the soil temperature, soil moisture and soil water chemistry in southeastern Europe where climate changes from sub humid Mediterranean to arid Middle East. Therefore, main objectives of this study were to compare the effect of oak-beech mixed deciduous forest cover with the effect of herbaceous vegetation cover on soil temperature, soil moisture, and soil water chemical content under subhumid climatic conditions in North Western Turkey and provide useful information to policy makers and people who is responsible for management of vegetation resources to show how disturbance of forest ecosystems influences ecological conditions especially in the fresh water producing watersheds.

2. Material and methods

2.1. Study site

Two forest sites together with two adjacent forest openings, which were cleared about 40 years ago (100 m by 50 m) and covered completely with herbaceous vegetation, were selected in an oak-beech mixed broadleaf forest ecosystem in Belgrad Forest (41°13′00″–41°14′13″ N latitude, 28°54′25″-28°56′37″ E longitude). Forest cover was composed of coppice originated trees including *Quercus petraea* (Mattuschka) Lieb, *Q. frainetto* Ten., *Q. cerris* L., and *Fagus orientalis* Lipsky with approximately 60–70 years age and together with low proportion of other tree and shrub species such as *Populus tremula* L., *Alnus glutinosa* L., *Carpinus betulus* L., *Acer trautvetteri* Med., *Acer campestre* L., *Castanea sativa* Mill., *Ulmus campestris* L., and *Sorbus torminalis* Crantz., *Erica arborea* L., *Erica verticillata* Forssk., *Cistus creticus* L, *Cistus salviifolius* L., *Cistus villosus* L., *Rubus* spp., and *Spartium junceum* L. (Yaltırık, 1966). Herbaceous vegetation in the forest gaps were dominated by mostly grass species such as *Brachypodium pinnatum* (L.) Beauv., *Carex* spp., *Stellaria holostea* L., *Dactylis glomerata* L., *Holcus lanatus* L., *Avena sativa* L., *Bellis perennis* L., *Agropyron repens* (L.) Beauv., and *Osyris alba* L. The forest site has a mull type forest floor with around 4–6 cm depth while grass covered site had no litter accumulation on the soil surface. The soil type in the site was Vertic Xerochrept developed from Neocene deposits and carboniferous clay schists (USDA, 1996) and contains FeO, Fe_2O_3, Al_2O_3, MgO, CaO, and K_2O (Özhan, 1977). Soils were moderately deep with good permeability rates, organic matter content over 3%, field saturation capacity about 40% in the topsoil and 25% in the subsoil (Özhan, 1977). The site has an undulate topography and elevation ranging from 95 m to 190 m. According to the Thornthwaite classification method, climate of the study site is a humid, mesothermal and maritime with a moderate water deficit in summer months. Mean annual precipitation is about 1129 mm and most of it falls from October to April. Average annual potential evapotranspiration changes between 752 and 833 mm (Özhan et al., 2010). Average annual temperature is about 12.3 °C and August is the warmest month with a mean monthly temperature of 21.7 °C, while February is the coldest month with a mean monthly temperature of 4.2 °C in the study area (Özhan et al., 2008).

2.2. Sampling and analyses

Two forest plots and two adjacent herbaceous vegetation covered plots were established and soil pits were dug and instrumented with Campbell Scientific model 107-L temperature probes and Campbell Scientific model CS616 soil water content reflectometer probes (Campbell Scientific Inc., 2016) at three soil depths (40, 80, and 120 cm) for each of four plots. Soil moisture and temperature data were recorded hourly and temperature data were checked to separate daily maximum and minimum temperatures. Soil moisture and temperature were monitored for 5 months from January to May in order to detect the changes distinctly from dormant season to growing season. To sample soil water, double porous plastic suction cup type lyzimeters were placed at 40 cm and 80 cm soil depths for each sampling plot (Eijkelkamp Soil and Water, 2016). Thus, a total of 16 lyzimeters were used for soil water sampling in this study. Soil water samples were collected on weekly basis and soil water was sampled for 20 week depending on availability of precipitation events. During the sampling, contents of the two lyzimeters from the same depth at the same plot were mixed and one subsample was taken as a representative of each soil depth and each plot. When the amount soil water was insufficient due to limited precipitation soil water was not sampled. Soil water samples were usually analyzed when samples arrived at the laboratory at the same day of collection for total alkalinity ($CaCO_3$), total N, calcium hardness ($CaCO_3$), chloride (Cl^-), electrical conductivity (EC), organic matter, pH, potassium (K^+), sodium (Na^+), sulfate $(SO4)^{2-}$, and total hardness ($CaCO_3$). The water samples were analyzed with respect to the standard methods of the American Public Health Association (A.P.H.A., 1998). The EC and pH measurements were made by using methods 4500-HB and 2510 B, respectively with the WTW Multiline *P*4 Universal Meter (WTW, Weilheim, Germany). Total alkalinity and calcium hardness were determined according to 2320 B titration method and 2340C EDTA titrimetric method, respectively. Cl^- was analyzed with 4500-*C*1-B argentometric method. Total N was analyzed based on 4500-Norg C semi-microkjeldahl method using a Velp UDK 132 distillation unit. $(SO_4)^{2-}$ was analyzed by 4500-SO4 E turbidimetric method, K^+ by 3500 K C Potassium-selective electrode method using Thermo-orion 720 A ion meter, Na^+ by AOAC official method 976.25 (AOAC International, 1990), and organic matter according to TS 6288 EN ISO 8467 (Turkish Standard Institute, 1998). Experiment was as a 3-way factorial (cover type, sampling depth and sampling month) in a split