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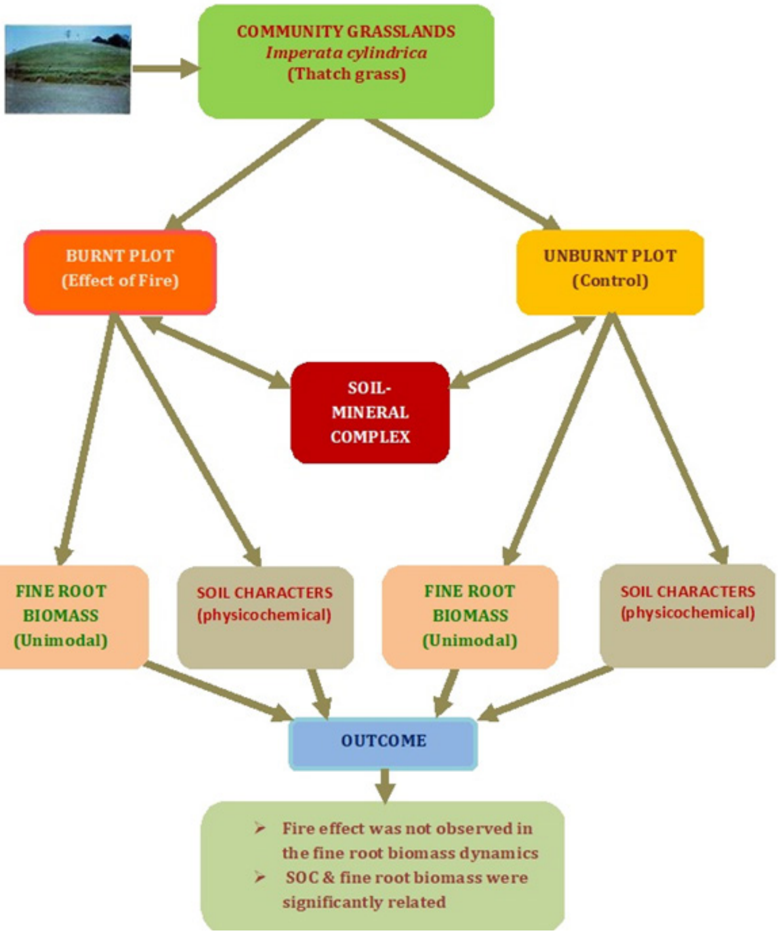
SHORT COMMUNICATION

Fine root biomass and soil properties in burnt and unburnt community grasslands of Cachar district, Assam, Northeast India

Ashim Das Astapati* and Ashesh Kumar Das



Highlights

- Fine root biomass dynamics indicated unimodal growth curve with one peak recorded during the study period.
- Fine roots of the inhabiting species were concentrated in the surface soil layer.
- Sand and clay component were inversely related to each other across the vertical depths of soil profile.
- Water holding capacity revealed gradual higher values from surface to subsurface layers.
- Organic carbon concentration and fine root dry matter were significantly related at $p < 0.001$.

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Fine root biomass and soil properties in burnt and unburnt community grasslands of Cachar district, Assam, Northeast India

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Abstract: Community grasslands, inhabited by *Imperata cylindrica,* in northeast India contribute culturally to the rural landscape in the region. A study carried out to examine the fine root biomass and soil properties of these grasslands. Using iron cores, dry matter of fine roots and some soil parameters were determined sequentially across different depths. The results revealed that fine root biomass dynamics followed unimodal growth curve with one peak during the study period. In burnt plot, fine root biomass varied from 95.8 - 199.8 gm/m^2, 47.9 - 94.2 gm/m^2 and 27.0 - 58.7 gm/m^2 in 0-10 cm, 10-20 cm and 20-30 cm depths, respectively. The corresponding values for unburnt plot were 99.9 - 206.7, 51.6 - 94.63 and 27.0 - 58.9 gm/m^2. Fine roots were concentrated in the surface soil layer and decreased down the soil profile. In terms of the temporal variations, the maximum accumulation of dry matter was reported during the winter months. High content of soil organic carbon (%) and nitrogen (%) were recorded in the topsoil in contrast to the subsoil over two plots. The data indicated that the soil organic carbon and fine root biomass were significantly correlated at $p < 0.001$. The carbon stocks of topsoil were recorded as 10.79 and 9.52 t C/ha for burnt and unburnt plots, respectively.

Keywords: Fire; *Imperata cylindrica*; fine root; belowground; bulk density

INTRODUCTION

According to Nagy et al. (2007), the grasslands of the earth surface are treated as one of the major ecosystems, with an approximate area of about 33 × 106 km^2, and contribute substantially in the overall carbon budget owing to their larger coverage. Indian grasslands occupy 24% of the geographical area and are anthropogenic as well as successional, emerged under the consequences of fire, grazing, deforestation and stress (Singh et al., 1983). The tropical community grasslands of Cachar district, Assam, northeast India originated on the fallow lands left after sugarcane cultivation (Astapati, 2008). Characteristically, the abandoned lands transformed into grasslands with the preponderance of invasive species, *Imperata cylindrica* (L.) Raeusch. (thatch grass). The grasslands are a good example of secondary succession as they are culturally managed and regulated through various management principles such as, annual clipping of matured grass leaves followed by application of controlled burning. The small scale farmers manage these grasslands for livelihood and profit earning since abandonment of these cultivated lands. The rural people follow rich traditional management practices like cutting of mature grass shoots, manual removal of weeds and burning of debris with a belief for better sprouting and yield in the next growing season. The community grasslands of the rural landscape serve as a good source of thatching material to supplement the needs of the indigenous people living in typical thatch roofed houses. Hence, these tropical grasslands are exploited by the economically poor rural folks as major bio-resource both for subsistence as well as cash earning (Astapati & Das, 2023).

The underground root system of the thriving plant species are characterized by the presence of fine roots component that exaggerate their activity in water-nutrient absorption, and thereby enabling the processes of biogeochemical cycles to operate in an ecosystem (Gordon & Jackson, 2000). Maximum density of fine roots create better adhesion between the root system and soil, increase water transport capacity and thus perform the physiological functions like transpiration, embolism repair etc. accurately (Zeppel et al., 2004). As stated by Jackson et al. (1997), return of minerals to the topsoil through fine roots decomposition is higher than the aboveground plant parts. Further, the activity of fine roots constitutes the principal route of entry of the organic content into the soil explained by Kogel-Knabner (2017) and Wang et al. (2018). Soil profile formation and development are assisted by contributing fine roots significantly through their efficient turnover rates to the soil organic complex (Persson, 1982). The present grassland ecosystems are regulated by extensive belowground accumulation and fast recycling through decomposition strategic for subsequent re-growth of the grass in the post burning period (Astapati & Das, 2010). Moreover, in grassland soils, fine roots distribution is controlled by abiotic conditions such as climate, edaphic factors, minerals, pH and bulk density (Leuschner & Hertel, 2003) as well as plant species diversity (Rawat, 2020).

Alcaniz et al. (2018) suggested soil to be the precious earth assets supporting life, and render its significant involvement in biogeochemical cycling, mineral storage, carbon sequestration, and regulating plant growth (Osman, 2013). Grassland soils contribute much in

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arresting climate change because they accumulate global carbon in their belowground organs as soil organic matter (Pasricha, 2015). Grasslands thus, render their service in minimizing the rate and magnitude of rising temperature and change of climate. Grasslands of Assam, northeast India dominated by *I. cylindrica* are often termed as non-productive lands with poor fertility and acidic pH (DENR, 1996) primarily suitable for subsistence purposes. Annual burning procedure is the major management tool adopted by smallholder farmers in these grassland systems that serves as the effective technique for proliferation of vegetative leafy portions through the rapid discharge of useful elements (Masipiquena et al., 1997). Annual burning practice of residual biomass channelized the transfer of C between the nutrient and atmospheric C pools (Thokchom & Yadava, 2016) and stimulates the profuse regeneration of annual forbs and grasses, thereby promoting accumulation of organic C, improving soil health and the ecosystem (Neary et al., 1999).

McCormack et al. (2015) proposed that fine roots mass estimation and their association with soil properties are largely taken into consideration in our understanding of belowground biomass contribution to terrestrial ecosystem processes. However, the current knowledge of biomass of fine roots in the underground systems as well as soil characters of different layers is meagerly available with respect to vegetative dry matter particularly in the community grasslands (grasslands managed by farming community) of northeast India. It is opined that the outcome of the current study will generate valuable database for future research on community grasslands and land rehabilitation of the region. Further, the managed grassland ecosystems of study area are significant in mitigating climate change by storing carbon in their belowground organs and enriching soil organic matter. Hence, our objective of study were (i) to estimate the dry matter of fine roots through different depths, under the influence of fire essential for understanding the community grassland ecosystems and (ii) to analyze the soil characteristics for developing a more lucid understanding of belowground dynamics in the managed farmers' fields. The authors hypothesize that (i) biomass of fine roots will be regulated by the changing seasons and soil layers coupled with fire effect (ii) soil physical and chemical parameters would differ across sequential depths affected by fire within the study area (iii) significant building up of biomass with the increase in organic carbon content was expected.

MATERIALS AND METHODS

Study Site

In the district Cachar of Assam, northeast India, the study location was known as Dargakona (rural area) that lies between 24°41' 56" N latitude and 92°45' 17" E longitude. Cachar district is circumscribed by Dima Hasao district on the northern side and the state of Mizoram on the southern portion. Physiographically, the district thrives in undulating hilly regions, extensive aquatic systems like beels and haors as well as the flat fertile lands. The climate of the region is marked by hot summer, lengthened monsoon with high humidity. The study period recorded total annual rainfall of 2,290 mm (meteorological data were collected from Tocklai Tea Research Centre, Silcoorie, Cachar district). Generally, the district follows all the main seasons in a year, however, the summer is short and gets merged with long rainy season. The winter is of short duration starting from November and ending with February.

The study site was a farmer-owned grassland inhabited by *I. cylindrica*. People activities such as slashing of matured old leaves and annual burning of grasslands were the key methods adopted as management strategies. Farmers are of the opinion that fire resulted in rapid sprouting of the rhizomatic thatch grass that would finally bring good yield in the next growing season. The grassland is a small sized area (0.39 ha) which was demarcated into two study plots, a burnt plot and an unburnt plot. The burnt plot was subjected to annual fire as practiced by farmers while the adjacent unburnt plot kept as control.

Fine Root Biomass Estimation

Sampling of fine roots (≤ 2 mm in diameter) on selected dates were carried out using a sharpened corer (5.6 cm inner diameter) to collect volumetric soil cores from three different depths (0-10 cm, 10-20 cm and 20-30 cm). Precautions were taken to segregate the fine roots from residual material of soil and litter on an absorbent paper. The samples were collected in months of March, May, August, November and January during the study period to cover all seasons in a year. After collection, sample cores upto 30 cm soil depths were transferred to polythene bags and brought to Ecology lab, Assam University, Silchar, northeast India and fine rootmass was determined by wet sieving method (Nadelhoffer et al., 1985). The soil cores of each depth viz. 0-10 cm, 10-20 cm and 20-30 cm were placed in a sieve of 0.5 mm mesh size followed by gentle washing in tap water to remove tiny soil particles. Next, removal of clay and dead organic matter was carried out by washing sequentially in three shallow glass containers. Finally, the samples were covered with paper and kept in oven at 65°C for drying until weight is constant.

Sampling and Analysis of Soil

Field sampling of soil was done in the selected months i.e. March, May, August, November and January with a view to cover the different seasons in a year. Similar soil protocol was used as in the case of root cores. The samples were air dried and sieved (2 mm mesh size). The dried soils were analyzed for (a) soil color was determined using soil color chart (Munsell Color, 1994), (b) Bulk density (gm/cm^3) was determined by coring method using iron corer (Brady, 1990), (c) Soil texture was analyzed using Bouyoucos soil hydrometer (Bouyoucos, 1962). The textural class was assessed using soil texture triangle based on varying mineral proportions of sand, silt and clay (Brady, 1990), (d) Water holding capacity (%) was determined using Keen's box (Piper, 1944) (e) Soil pH was measured using a pH meter (SYSTRONICS) at a 1:2.5 soil/water suspensions Jackson (1973), (f) Organic Carbon (%):was determined by wet oxidation method (Walkley & Black, 1934), (g) Total nitrogen (%) estimated with the method of Kjeldahl digestion as given in Anderson & Ingram (1993) and (h)

The SOC stocks (t C/ha) were determined multiplying the values of bulk density (gm/cm^3), SOC concentration (%) and the corresponding soil depth (cm).

RESULTS

Fine Root Biomass

The fluctuation in fine root biomass of the sampling months across soil depths were recorded and are illustrated in Fig 1. The fine root biomass of topsoil varied from 95.85 to 199.85 gm/m^2 in burnt plot and from 99.92 to 206.74 gm/m^2 in unburnt plot. The corresponding values in subsoil were 47.93 to 94.19 gm/m^2 and 51.59 to 94.63 gm/m^2 and the same in deep soil were 27.01 to 58.69 gm/m^2 and 27.02 to 58.89 gm/m^2. It was observed that the biomass initiated with a lower value and attained its peak in winter month i.e. January irrespective of two plots and soil depths thus indicating unimodal growth pattern. Comparing the two plots using t test, the dry matter accumulation was found without any significant differences between burnt and unburnt plots. Further, the maximum biomass allocation was concentrated in the surface soil that gradually declined in the subsequent lower depths of soil profile irrespective of burnt and unburnt plots.

Soil Characteristics

The physicochemical parameters of the soil in two plots are depicted in Table 1. Physical properties were studied for different depths of the soil profile. Observation revealed that the Munsell Color varied in the two plots across the sequential depths of the soil. Thus, the Munsell Color distribution indicated that the soil colors were usually different shades of gray, brown or yellow. With the increase in the soil depths, bulk density of the soils also increased successively. It ranged from 1.27 to 1.43 gm/cm^3 in the burnt plot and from 1.07 to 1.29 gm/cm^3 in unburnt plot. The data indicated marginal increase of bulk density in the burnt plot. The relative mineral fractions such as sand, silt and clay varied across the vertical gradient of soil profile irrespective of two plots with surface soil coarse textured indicating maximum sand particles. The proportions of mechanical separates like sand and clay were inversely related where sand decreased and clay increased with depths. Soil textural class in the topsoil of the profile was predominantly sandy loam while in subsurface soil layers; it was sandy clay loam in the two plots. Water holding capacity varied from 32.62 to 38.59% and 36.00 to 40.35% in burnt and unburnt plots respectively across the vertical depths.

The soil pH is acidic in nature across sequential cores and plots with a value of 4.79 in burnt plot and 4.55 in unburnt plot (topsoil). The tendency of acidity increased successively from surface to lower layers. The SOC concentration ranged from to 0.85% 0.45% in burnt plot and 0.89 to 0.47% in unburnt plot with gradual decline in lower layers. Organic carbon concentration and clay content were significantly related at $p \leq 0.01$.

Similarly, total soil nitrogen also decreased from surface to deeper layers with maximum value of 0.14% in two plots. The C was stored more in lower layers with respect to surface soil. It ranged from 10.79 to 19.30 t C/ha[1] and 9.52 to 18.19 t C/ha[1] in burnt and unburnt plots correspondingly.

DISCUSSION

The varying pattern in dry matter of fine roots was clearly noticed in the present grassland irrespective of two study plots. Such variation in biomass was attributed to the changes in edaphic conditions particularly soil moisture, soil temperature, litter accumulation and root turnover (Sundarapandian et al., 1996). The display of single peak biomass in dry winter months corroborated with the authors earlier study on coarse roots biomass in the *Imperata* grassland system (Astapati & Das, 2010). Fire seemed to have no stimulating influence on the accumulation of fine root biomass in contrary to the findings of Sundarapandian et al. (1996). The biomass estimation of the current study indicated maximum density of fine roots in the topsoil. This is in agreement with the study of Persson (1983) and

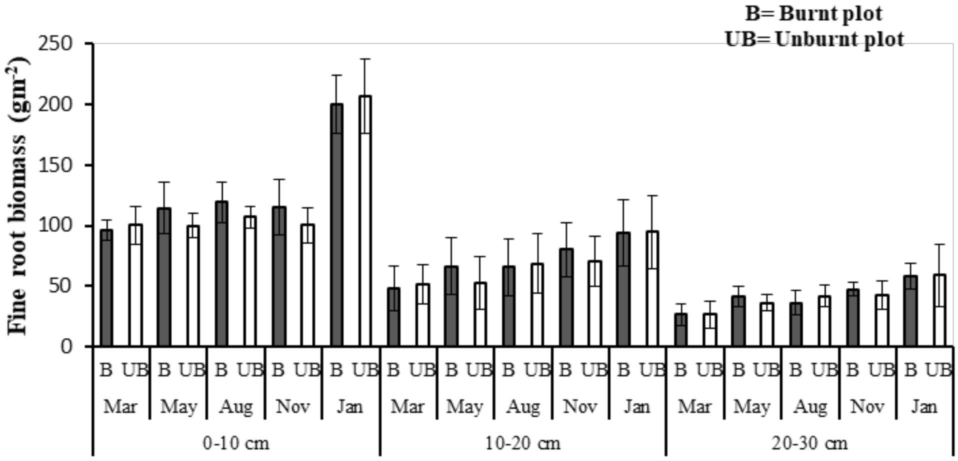

Figure 1: Bimonthly variation in the fine root biomass values (mean±SE) across the sequential soil cores at different soil depths in the burnt and unburnt community grassland. (No significant differences were detected between burnt and unburnt plots using t test)

Table 1: Assessment of physico-chemical characteristics of soil (mean±SE) across vertical depths in the burnt and unburnt community grassland.

Attributes	Soil Depth (cm)	Burnt plot	Unburnt plot
Color Munsell Matrix	0-10	Grayish brown (10YR, 5/2)	Brown (10YR, 5/3)
	10-20	Grayish brown (10YR, 5/3)	Yellowish brown (10YR, 5/4)
	20-30	Dark yellowish brown (10YR, 4/6)	Yellowish brown (10YR, 5/6)
Bulk Density (gm/cm^3)	0-10	1.27 ± 0.09	1.07 ± 0.06
	10-20	1.42 ± 0.09	1.27 ± 0.04
	20-30	1.43 ± 0.08	1.29 ± 0.06
Sand %	0-10	62.15 ± 4.32	66.05 ± 6.10
	10-20	49.60 ± 3.63	58.90 ± 5.24
	20-30	45.65 ± 4.60	55.10 ± 5.06
Silt %	0-10	24.90 ± 3.09	23.00 ± 3.66
	10-20	28.20 ± 3.11	23.55 ± 3.01
	20-30	25.05 ± 1.81	22.40 ± 3.27
Clay %	0-10	11.95 ± 3.91	10.95 ± 3.07
	10-20	22.20 ± 3.63	17.55 ± 3.81
	20-30	29.30 ± 3.27	23.20 ± 3.56
Textural Class	0-10	Sandy loam	Sandy loam
	10-20	Sandy clay loam	Sandy loam
	20-30	Sandy clay loam	Sandy clay loam
Water Holding Capacity (%)	0-10	32.62 ± 5.59	36.00 ± 6.48
	10-20	35.48 ± 6.50	38.72 ± 3.36
	20-30	38.59 ± 6.69	40.35 ± 6.19
Soil pH	0-10	4.79 ± 0.28	4.55 ± 0.27
	10-20	5.21 ± 0.15	4.99 ± 0.19
	20-30	5.86 ± 0.39	5.55 ± 0.57
SOC (%)	0-10	0.85 ± 0.11	0.89 ± 0.13
	10-20	0.58 ± 0.13	0.63 ± 0.10
	20-30	0.45 ± 0.10	0.47 ± 0.11
Nitrogen (%)	0-10	0.14 ± 0.01	0.14 ± 0.02
	10-20	0.12 ± 0.007	0.12 ± 0.01
	20-30	0.10 ± 0.01	0.11 ± 0.01
SOC stock (t C/ha^1)	0-10	10.79 ± 1.08	9.52 ± 0.95
	10-20	16.47 ± 2.98	16.00 ± 2.11
	20-30	19.30 ± 3.19	18.19 ± 2.70

Rawat (2020) where fine root mass of inhabiting plant species were more in surface layer and decreased with soil depths (Yang et al., 2004). Nambiar & Sands (1992) opined the decline of fine root mass across the sequential cores because of the increased soil strength with high bulk density and low aeration are detrimental for root growth. Thus, the studied grassland showed inverse relationship between fine root biomass and bulk density.

Soil color is a morphological characteristic and is an important criterion in description and classification of soils by the farming community (Rivas & Gerold, 2003). The grayish brown to brown color of the surface soil in the present grassland indicated minimum clay with a texture of sandy loam. Lima et al. (2011) stated that dark color soil corresponded clayey nature with enriched nutrients and favored plant growth whereas soils of pale color are not suitable for plant activity. Deep soils of the grassland were characterized by yellowish brown to dark yellowish brown with a sandy clay loam texture which may be attributed to higher clay fractions in these layers as well as the effect of burning. Soil bulk density measurements highlighted the trend of gradual increase across the lower layers of vertical depths. The surface soil is characterized by the loosened structure and thus low in bulk density while rigid nature of subsoil implied high in bulk density (Handayani et al., 2012; Verma et al., 2019). Moreover, the present findings indicated values of bulk density that lie within the range of 1.1 to 1.5 gm/cm^3. The data corresponded with the study of *I. cylindrica* grasslands of Indonesia carried out by Syahrinudin et al. (2020). The topsoil was coarsely textured with the textural class of sandy loam primarily because of the coarse texture and high sand content whereas the subsoil was comparatively finer with more clay indicating sandy clay loam texture (Snelder, 2001). Data on water holding capacity indicated fluctuations with high clay content in deeper layers of soil profile (Ramya et al., 2021).

The acidic soil pH of the present grassland may be aggravated by excessive leaching of cations and amphoteric nature of aluminum (Handayani, 2000). Further, an increase of pH in burnt plot may be due to the burning of dry mass of organic origin and assemblage of char like compounds releasing ash (Agbeshie et al., 2022). Observations of higher pH values in lower depths of the soil profile may be ascribed to low microbial activity, low organic matter content and ultimately resulted in minimum organic acids production (Jha et al., 1979). SOC and nitrogen are the limiting factors and actually determines the grassland growth and productivity (Snelder, 2001). Low organic C concentration in the present grassland may be attributed to lesser return of litter from the growth of vegetation dominated by *Imperata cylindrica* and faster decomposition (Ramakrishnan & Toky, 1981). In compliance with the above fact, Caveliar et al. (1999) stated that organic C content in grassland soils is poor than forest soils due to lesser C concentrations and thinner A and B-horizons. Organic C content and total nitrogen declined with the depth of soil profile as organic matter along with the population of microorganisms also decreased with depth (Dodd et al., 2000; Syahrinudin et al., 2020) coupled with low nitrogen built up (Ramakrishnan & Toky, 1981). The present grassland soils showed resemblance with the tropical soils of shifting agriculture in northeastern India where there is low carbon and nitrogen levels, along with an increase of soil pH after the burn (Ramakrishnan et al., 1997). In addition, the lack of woody canopy in such open grasslands is subjected to biomass removal by burning which resulted in slow decomposition rates due to lack of substrates and consequent decline of organic C and nitrogen (Handayani et al., 2012). The findings showed 23% contribution by topsoil towards the total soil C storage and 41% by deep soil. Hence, it was evident that the C storage in the deep soils was higher to a larger extent in the field of study (Syahrinudin et al., 2020).

Present study emphasized that the vertical allocation of fine root biomass was directly influenced by bulk density and soil pH. The higher bulk density and pH in the lower depth of soil horizon accounted for the decline in fine root biomass. The seasonal data of the current study indicated that the organic carbon content and fine root dry matter significantly increased in the month of January (winter season) at $p < 0.001$.

CONCLUSION

The community based *Imperata cylindrica* grassland management of Assam, northeast India indicated importance of belowground systems (roots and rhizome) in terms of global carbon accumulation and developing organic matter of soil. This feature of the grasslands in the region would certainly be valuable in mitigating the climatic variations. Additionally, it may be mentioned that the roots of dominant grass, *I. cylindrica* remain shallow and confined mostly to the topsoil thereby depositing less organic material in deeper layers. In spite of the dense lateral spreading of rhizomes, the topsoil was not rich in C stocks. In the present scenario, considering the global concern of C sequestration, it may be recommended land rehabilitation by transforming these grasslands into land use systems with greater allocation of dry matter coupled with penetration of roots at deeper depths. It is further suggested that the land use diversification may be undertaken with measures adjusted to local soil conditions.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest.

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