Nat. Volatiles & Essent. Oils, 2021; 8(5): 7458 - 7480

Soil ecology and possible and possible effects of soil texture microbial assisted Co2 sequestration

[1*]Ansa Rebi, [2]Muhammad Ibrar Ahmed [3]Ammara Saeed, [3]Talha Rehman, [3]Malik Noman Mansha, [2]Shahrish Nawaz, [4]Akram Ali, [3]Aqsa Waseem, [5]Ali Afzal, [6]Mehwish Farooq, [7]Mamoona Naz, [8]Muhammad Ubaid Ullah khan

[1]*Soil and water conservation and desertification combating, Beijing Forestry University China*
[2]*Soil and Water Testing Laboratory, Sargodha 40100, Punjab, Pakistan*
[3]*Institute of Soil and Environmental Science, University of Agriculture -38040, Faisalabad, Pakistan.*
[4]*Department of Agronomy, University of Agriculture -38040, Faisalabad, Pakistan.*
[5]*Institute of soil chemistry and environmental sciences, kala shah kaku, Sheikhpura, Punjab.*
[6]*National Institute of Food Science and Technology, University of Agriculture -38040, Faisalabad, Pakistan*
[7]*Institute of Horticulture, University of Agriculture -38040, Faisalabad, Pakistan*
[8]*Institute of plant breeding and biotechnology, Muhammad Nawaz Shareef University of Agriculture-60000, Multan*
*Corresponding Author: 2013ag3549@uaf.edu.Pk

Abstract

Soil is an important component that gives room for saprophytic organisms to decompose materials and nutrients for recycling, as well as for plants to use as a rooting medium. Soil ecology is the study of interactions between soil organisms (both microbes and fauna) and their physical and chemical surroundings. The diversity of bacteria, fungus, and microscopic and macroscopic soil animals is supported by the soil habitat's variability. The decomposition of organic materials, the outflow of carbon dioxide from soils, and the cycling of nutrients within soils are all driven by these organisms. The diversity of soil organisms is reflected in their functional qualities, with species influencing ecosystem parameters ranging from soil physical properties to nutrient dynamics rates. Much of these ecosystem activities are governed by tropic interactions in soil food webs.

Introduction

Soil is a significant carbon (C) deposit in the earth ecosystem, storing roughly 2000 Pg C, three times more than plant reserves (Bond-Lamberty et al., 2018). The worldwide C flux from soil to atmosphere is 68–98 pgc y 1, and soil respiration is a significant source of this carbon (Jian et al., 2018). Soil respiration emits 10 times more carbon dioxide (CO2) than human activity (e.g., fuel use), and there is a strong link between soil seawater and CO2 levels in the environment (Joo et al., 2012; Raich and Tufekciogul, 2000).

Soil respiration has a big impact on CO2 levels in the atmosphere, and even tiny adjustments can have a big impact on global CO2 levels (Adchi et al., 2017).

Many factors, including land use changes (Shi et al., 2019; or Yao et al.,) soil erosion (Yu et al., 2019a), and climate change (Barryman et al., 2018), have been demonstrated to alter soil respiration and soil concentration in previous research. and agricultural management techniques (Chen et al.) One of the most important elements impacting soil breathing is changes in land use (Shi et al., 2019b).

The rate of organic matter input and degradation, as well as the physical and biological characteristics of the soil, are all affected by land use interchange, resulting in microbial activity (Assefa et al., 2017; Villarino et al., 2017) Soil C sequestration will be reduced as a result of unsustainable land use management. According to Llorente et al. (2010), deforestation might result in a 60 percent loss in N. soil. Sustainable land use structures, on the other hand, can increase soil storage (Machmller et al. 2015).To reduce carbon (C) capture and climate change, soil organic matter (SOM) content must be maintained and improved (Paustian et al., 2016).. Plant manure is a significant component in the creation of SOM, in addition to root extraction (Kogel Nabner, 2002). Root turnover, bioturbation, and dissolved organic matter are all ways for waste to reach the soil (DOM). On the centennial and millennial time scales, some of the C acquired from trash is transformed to mineral CO2, while the rest is finally retained in the soil and broken down (Lehman et al., 2020).

Internal parameters such as lignin to nitrogen (N) ratio, C / N ratio, or phosphorus concentration (Prescott, 2010), as well as microbiological, control sewage rot under stable environmental circumstances, such as steady temperature or humidity. Cepakov" a and Frouz (2015) found that higher quality litters (i.e., with low lignin/N or C/N ratios) degrade more quickly. After entering the soil, this dirt or organic matter can be employed for hereditary restoration, aggregation, and/or mineral-related organic matter (MAOM v. Van Lutzo et al.) 2006.

Mineral-related organic matter (Kleber et al., 2006; von Lützow et al., 2006), which attaches to mineral surfaces via ligand exchange, electrostatic interactions, or cation bridges, is frequently regarded the most stable type of SOM. The stability of these organo mineral complexes can be further strengthened when they are part of the MAOM aggregate, which inhibits microbial access to endogenous organic matter (G. Angst et al., 2017).

Nonetheless, these investigations were carried out in soils with a dirt structure, in which (new) organic matter can be predicted to have a better potential to breakdown minerals due to the presence of mineral particles (dirt and dust). There's a lot of money to be made. MAOM and aggregate.

Because the number of reaction surfaces for the synthesis of MAOM and aggregates in coarse structural soils is naturally limited (Blume et al.2015), the retention of litter C may be decreased (e.g., Hicks Pries et al., 2017).

Furthermore, different soil textures can harass different microbial communities (Satin et al., 2020) with varying C use efficiencies, i.e., the ratio of anabolic (growth) to catabolic (energy production) processes (Manzoni et al., 2012), and capacity to degrade different components of organic matter (Xia et al., 2020). As a result, while the actual, quantitative linkages in this process have yet to be established, the transfer of litter C and its retention in a soil may differ significantly depending on soil texture. The soil–atmosphere C cycle is also greatly influenced by vegetation restoration. Soil respiration increased after plant restoration, owing to increased root biomass, improved soil structure, and increased microbial biomass and activity, as well as increased root secretion and litter (Barba et al., 2018; Xiao et al., 2019; Yu et al., 2019b). The impacts of vegetation restoration on soil respiration rate and carbon supply in eroded parts of China's Loess Plateau are less well understood.

So we'll see how soil texture affects microbial-assisted CO2 sequestration in this investigation.

Soil work in greenhouse gases dynamics

(Law and Harmon, 2011, Willson and Brown, 2008) found that Individual countries' political goals and international initiatives announce greenhouse gas (GHG) neutrality by 2050, for example.

If such announcements can be made and whether they should be perceived realistically cannot be a concern in this examination. Nonetheless, it is critical to analyse soil as a source of GHGs with precision and to gain a better understanding of the source and sinking processes of this critical environmental item. Climate-related trace gases include carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Total C roughly 1500 1500 Pg and entire N 136 (92–140) Pg in the uppermost metre of the total soil layer Safe, which is the greatest groundwater carbon and nitrogen reservoir, despite being highly unequally distributed (order intensity 3–4). (Batjes, 1996, Kutsch et al., 2009, Nieder and Benbi, 2008, Schaufler et al., 2010, Schlesinger and Andrews, 2000). Changes in soil structure, on the other hand, might impact its source and sink functions, and total storage capacity is limited (Jungconst and Fidler, 2007). The European groundwater GHG balance, for example (Schulze et al. Agricultural CH4 and N2O emissions are largely due to the depletion of CO2 in grasslands and forests).

The scientists do warn, however, that the trend toward deeper agriculture and logging will "possibly make Europe's land surface a key producer of greenhouse gases." According to Bahn et al. (2010), who collated and evaluated global data on plant species and biomes, soil emits roughly 98 Pg C a-1. This is significantly higher than carbon dioxide emissions from fossil sources. With 68–77 PGC-1, older sources show a lower flow (Reich and Potter, 1995, Reich and Schlesinger, 1992). Bahn and colleagues (2010) Despite numerous assumptions and increased efforts, there remains a high level of uncertainty. Because the relative total annual emissions of 35 percent CO2, 47 percent CH4, 53 percent N2O, and 21 percent nitric oxide (NO) are related to soil dusting, GHG emissions from the soil need to be better quantified for the global budget (IPCC, 2007). Global NO emissions from soil are comparable to NO emissions from fossil fuel combustion on an annual basis (Butterbach Behl et al. 2009). Since the commencement of industrialization in the mid-18th century, the increase in GHG emissions from soil has been primarily attributable to CH4 and N2O, and has been caused by agricultural activities (Forster et al., 2007). As a result, GHG emissions have become a hot topic in discussions about global warming, climate research, and agriculture and forestry management.

In the nineteenth century (Bosingalt and Levy, 1853), soil CO2 emissions were first measured in laboratories, impacted by soil respiratory tracer function for soil fertility (Russell and Applied, 1915). The study of CO2, N2O, and CH4 behaviour is now dominated by topics relating to climate change (Cox et al. 2000). Because of its function in acid rain, ozone generation, and destruction, nitric oxide (NO) has been researched. (Campfell and colleagues, 2007). In the early twentieth century, field measurements with chambers were introduced (Lindgard, 1927) Other trace gas emissions were measured subsequently, as gas analyzers became accessible (N2O in the 1950s: Arnold, 1954; NO in the 1970s: Galbally et al., 1987; CH4 in the 1980s: Holzapfel-Pschorn et al., 1985).

No	Name of Microorganisms	Soil Type	Vegetation	Duration	Co_2 Release or sequestered	Other	Outcome	Reference
1	Studied were the fungal grazers *Aphelenchoides saprophilus* and *Aphelenchus* sp. in combination with the fungi *Chaetomium globosum, Aspergillus terreus* or *Cryptococcs terreus* as well as the bacterial grazers *C. elegans* and *Acrobeloids buetschlii* in combination with the bacteria *Pseudomons putida,*	The dominant soil type is loamy haplic Luvisol, composed of approximately 7% clay, 87% silt and 6% sand.	Controlled semi-natural soil environment	72h	Reduction in respiration (evolved CO2		The presence of nematodes caused a reduction in respiration (evolved CO2), thus a decline in microbial activity. The formation of chemical and/or morphological defense is likely a reason for that reduced prey activity.	Richter et al. (2019)

	Kitasatospa sp. or *Sphingomos trueperi* ematode *Caenorhabditis elegans*							
2		he soil is a Willamette silt loam	egume, red clover (*Trifolium prutense L.)*	2 years	itrogen fertilization caused a general increase in qCOz, CO1-C and Cmic.		he results documented a significant improvement of soil aggregation and maintenance of organic C pools with a soil management system that provides greater root activity and C input	iller et al. (1995)
3	nicrocosm experiment	oils (from pure oak, mixed and pure pine stand		licrocosms were incubated over a 54-day period in temperature ontrolled incubators maintained in darkness at 20°C (maximum mean monthly temperature in soils	lediterranean forest soils to sequester C	oil processes leading to increases of available N (via e.g. mineralization, nitrification)	irst, there was an acceleration in soil organic matter (SOM) turnover after microbial – especially bacterial– growth ceased to be so intensely inhibited by needle litter (ecotone soils), resulting in lower fungal to bacterial ratios; and second, N mineralization was stimulated once pine-derived SOM was no longer present in soils (pure oak forest soils), resulting in further acceleration of SOM turnover, suppression of CH4 consumption and an increase in gram negative bacteria.	ernández-Alonso et al. (2018)

				at 10-cm depth for the period 2014–2017,				
4	Microbial biomass	Sand rich Clay rich Forest floor	ndiangrass; *Sorghastrum nutans* (L.) Nash	186-day incubation	After the six-month incubation, the %mass and %C remaining were highest or tended to be highest for the litter incubated in the clay soil	ower amounts of litter C respired as $CO2$ in in clay vs. sand and forest floor material	The soil rich in clay provided conditions favorable for a more efficient microbial utilization of the litter material (high pH and high C use efficiency) as compared to the sand-rich soil and the forest floor.	Angst, G et al.(2021)
5	*Chlorella vulgaris* was the dominant microalgal specie in the soil.	Dystrophic Red-Yellow Latosol is the predominant soil type.	*Pennisetum glaucum* Millet	60 days	CO_2 emissions significantly increased in microalgal biofilm treatment	he biofilm allowed for higher CO_2 and N_2O emissions,	Establishment of a microalgal biofilm in the soil favored lower nitrogen loss through N— NH_3 volatilization and increased OM content and CEC in the soil.	de Siqueira et al. (2017)
6	Microbial biomass	The dominant soil type in the study area is	The vegetation in the area is dominated	15 years	Roots were the main source of soil respiration in cropland,	Soil respiration in the dry	The results showed that soil respiration in the rainy season was significantly higher than that in the dry season	Shi p et al. (2021)

		loessial soil vith a fine silt texture	by *Robinia pseudoacacia* (Leguminosae), *Caragana korshinskii* (Leguminosae), *Hippophae rhamnoides* (Elaeagnaceae), *Astragalus adsurgens* (Leguminosae), and *Medicago sativa* (Leguminosae).		which contributed >70% of CO_2 emissions	season was as follows: shrubland (1.04 μmol m^{-2} s^{-1}) > cropland (0.72 μmol m^{-2} s^{-1}) > forestland (0.44 μmol m^{-2} s^{-1}) > grassland (0.33 μmol m^{-2} s^{-1}).	owever, grass and forestland had significantly higher soil respiration than shrub and cropland in the rainy season	
/	Microbial biomass	oil is a sandy loam (dystric Cambisol) with a soil texture of 69% sand, 24% silt and 7% clay,	hree crops starting with winter barley (*Hordeum vulgare*) in September 1999–June	-years	levated CO_2	he fungal-to-bacterial ratio is superior to C_{mic} in	he enhancement of the bacterial respiratory activity with increasing tendency over time most probably reflects the increasing C availability due to enhanced rhizodepositions into the soil.	nderson T H.(2011)

			2000, followed by a rye grass mixture (*Lolium*) as cover crop from July 2000 to October 2000, then sugar beet (*Beta vulgaris*) from April 2001 to September 2001, and finally winter wheat (*Triticum aestivum*) from November 2001 to July 2002.			responding to elevated CO_2		
	gram-negative bacteria	oils are cambisols with a granite bedrock. The textures are silty clay loam in the oak forest, silt loam in the	ine forests ak forests ixed forest	years	igh CO2 production igh nutrient availability may have a positive effect on plant growth leading to an	oil processes leading to increases of available N	irst, there was an acceleration in soil organic matter (SOM) turnover after microbial – especially bacterial– growth ceased to be so intensely inhibited by needle litter (ecotone soils), resulting in lower fungal to bacterial ratios; and second,	ernández et al (2018)

		mixed forest and sandy loam in the pine orest.			increase in C sequestration in aboveground compartments.	(via e.g. mineralization, nitrificatio)	N mineralization was stimulated once pine-derived SOM was no longer present in soils (pure oak forest soils), resulting in further acceleration of SOM turnover, suppression of CH4 consumption and an increase in gramnegative bacteria.	
	Micobioal biobass	he soil is classified as a mountain red earth	hinese fir plantation	-year field experiment	he high intensity forest regeneration approach (II) simultaneously produced more biomass and emitted more CO_2 than low intensity approach (I).	he temperature sensitivity of soil respiration (Q_{10}) of autotrophic respiration is relatively higher than that of heterotrophic resp	ur results suggest that high intensity forest regeneration approach has a higher soil CO_2 emission and lower production of biomass.	ai et al (2020)

						iration		
0	icrobial biomass	hree major soil conservation practices i.e., no-tillage, manures, and biochar.	heat, rice, maize		ig-manure had the greatest impact on crop yield while emitting the least CO_2 emissions.	he addition of biochar significantly reduced CO_2 and N_2O emissions under both rainfed and irrigated conditions,	one of the manures were able to reduce GHGs emissions, with poultry manure being the largest contributor to all GHGs emissions	hakoor A et al. (2020)
1	acteria and archaea (including CH_4-cycling organisms	rimary rainforest, cattle pasture, and secondary forest oils are red-yellow podzolic latosol with sandy clay loam texture,	egetation type is open moist tropical forest with palms			attle pasture soils exhibit high and variable rates of CH_4 emission.	asture soils emit high levels of CH_4 hile forest soils on average emit CH_4 at modest rates econdary forest soils tend to consume CH_4	eyer K M. (2020)
2	icrobial biomass		ropical dry forests	– 6month dry	oil C pools are highly variable in		ound that rewetting of dry soils produced an	aring at al (2016)

				season lasting from January till may	space and time in these dry forests		immediate and dramatic pulse of CO2, accompanied by rapid immobilization of nitrogen into the microbial biomass.	
13	Microbial biomass	Fluvo-aquic loamy soil	maize (*Zea mays* L.)	June 9, 2006 to September 23, 2006.	Soil CO_2 emissions in the N-unfertilized soil (CK0) and unplanted soil treated with 150 kg N ha^{-1} (CKNL) treatments were estimated		Our results suggest that the effects of N fertilization on soil respiration mainly depended on the concentration of easily decomposed organic carbon in soil and N fertilization possibly reduced soil respiration in the planted soils when N released from the decomposition of native soil organic carbon roughly met the demand for maize growth.	Ding W et al (2010)
14	Microbial biomass	The soils are podzolic, with mor-type humus and shallow organic layer	The dominant vegetation in the region is black spruce (*Picea mariana*)	2015, 2016	Elevated CO_2 did not significantly affect these community measures, Warming also had a significant positive effect on diversity	Annual variability in weather conditions can influence soil fauna response to climate change	The enhanced response of soil communities in the second year of experimental treatment was due to greater than normal precipitation, suggesting that annual variability in weather conditions can influence soil fauna response to climate change.	Meehan M L et al (2020)

15	Microbial abundance of both **bacteria and fungi groups** differed significantlybetween soil types under bare soil (natural soil > topsoil > waste)	Soils comprise red shallow stony soils on hills and ranges and sands on plains with predominance of Red Kandosols, Red Ferrosols, and Leptic Rudosols	Vegetation is predominantly composed of hummock grasslands, tussock grasslands, sclerophyll shrublands, and shrublands and woodlands with a tussock grass understorey. Natural shrub–grassland ecosystem dominated by *Triodia* spp. and *Acacia* spp	1971–2000 period)	Between vegetated and nonvegetated patches, only OC and C:N were significantly different higher values of both indicators were observed in areas covered with vegetation.	Values of OC and N were significantly higher in natural soils and topsoil compared to the waste for both the vegetated sites and bare soil sites	Vegetation has a positive effect on restored soils, improving soil functions and processes through increasing microbial activity and diversity, and levels of organic C and the C:N ratio (connected to nutrient cycling processes	Muñoz-Rojas M. et al (2016)
16	Microbial biomass	The four study peatlands Histosol	Zone Dominant cover type Hemiboreal: Mosses (*Sphagnum* sp.) Temperate :	1–3 years	In all incubations, burned peat showed a brief initial period of higher emissions than	Peat from sites with frequent fires (NC,	Laboratory incubations show lower CO2 emissions from peat subjected to low-severity fire and predict lower cumulative CO2 emissions from burned peat after 1–3 years	Flanagan

			Ericaceous shrubs (Lyonia, Ilex sp.) ub-Tropical : Sedge (*Cladium jamaicense*) ropical Palm :(*Mauritia flexiosa)*		unburned peat	FL) showed lower O/C ratios than peat from sites with relatively infrequent fires (MN, PERU), indicating lower carbohydrate and carboxylic contents of organic matter		
.7	necic earthworm species	ypic Fluvaquent		90-day	fter removal of earthwor	oil with h	hat the main effect of earthworm activity on N2O emissions	izhiya E et al. (2007)

	Aporrectodea longa (Ude) vs. the epigeic species *Lumbricus rubellus* (Hoffmeister)	pasture soil with silt loam texture			ms, a drying/wetting and freezing/thawing cycle resulted in significantly higher emissions of N2O and CO2 from soil with prior presence of L. rubellus.	prior presence of *L. rubellus* also had higher potential denitrification.	is through mixing residue into the soil, switching residue decomposition from an aerobic and low denitrification pathway to one with significant denitrification and N2O production. Furthermore, A. longa activity resulted in more stable soil organic matter than L. rubellus.	

Co2 fluxes

At the Hlglwald location, the total type of soil respiration has the largest CO2 flow over the years with a lower annual average temperature and higher N2O emissions (e.g. cold 1995/1996 and cold 2005/2006). Winters and springs are a part of life (Lu Luo et al., 2012). The Harvard Forest Site had similar results (Phillips et al., 2010). As a result, the annual soil respiration rate in temperate natural habitats can be determined by climatic conditions during the dormant or early growing season.

It's also possible that the rise in soil respiration rate is related to the integration of plant carbon and sewage output from the previous year (Luo et al., 2012). Their findings also revealed that gross domestic product and soil respiration had a close association. Annual soil respiration rates have decreased in all three locations due to years of summer dryness.

The effects of soil moisture and temperature on soil CO2 efflux

Changes in soil temperature are frequently blamed for changes in CO2 movement in the soil. Longdoz et al., 2000; Drewitt et al., 2002; Dilustro et al., 2005), soil moisture alone (Linn and Doran, 1984; Kelliher et al., 1999), or both (Linn and Doran, 1984; Kelliher et al., 1999) (Davidson et al., 1998; Subke et al., 2004).

We found that soil CO2 efflux was highly linked with soil temperature in the previous work, and that the relationship between soil CO2 efflux and soil temperature could be accurately depicted using an exponential equation.

Soil temperature was responsible for 44–68% of the seasonal variance in CO2 efflux in the soil. During the maize growing season, the temperature sensitivity of soil respiration fluctuated between 1.90 and 3.81, according to the exponential equation. Unplanted and N-unfertilized soil (CK0) had a value of 1.90–2.01, which was somewhat lower than 2.12–2.33 in unplanted and N-fertilized soil (CKNL. Despite the fact that N addition marginally / reduced the effect of soil temperature on soil CO2 outflow, this shows that N loading increased values for unplanted soils via enhancing native SOC breakdown. However, regardless of N fertilisation, these values were lower than in planted soils. In planted and N-fertilized soil (NL and NH), rhizosphere respiration was as high as 8.35–12.67, but only 3.63–5.21 in planted and N-unfertilized soil (NL and NH) (N0). The value for root respiration was 4.6, according to Boone et al. (1998). Our data, combined with earlier research, suggest that fertilisation practises have a significant impact on both basal and rhizosphere respiration, and that the presence of maize plants appears to improve soil respiration responses to soil temperature. Root respiration and microbial respiration triggered by root exudates make up the rhizosphere respiration. Then increased root respiration may improve the utility of soil respiration. As a result, ecosystem process models for predicting the seasonal cycle of soil respiration utilised in this study (Reich et al., 1991) may have reflected soil basal respiration. When root respiration contributes to soil respiration, the model's default value should be modified. When soil water content was above the wilting point threshold, Dilustro et al. (2005) discovered that soil CO2 efflux was substantially connected to soil moisture in sandy soils, but not in clayey soils. When soil temperature changed in a small range, Kelliher et al. (1999) found that soil CO2 outflow was associated with soil moisture during the rainless period of July 13–27, 1996. Soil CO2 efflux was considerably affected by soil moisture in late spring and summer when soil temperature was over 15 °C, but not by soil temperature in the fall, winter, and early spring in a desert grassland in eastern Washington (Wildung et al., 1975).

According to Kucera and Kirkham (1971), soil CO2 outflow was lowered only when soil moisture content reached extremes such as permanent wilting point and field capacity, which were required to effect microbial activity.

Role of microorganism

The Interconnection of Plants with Soil Microbes

Although plant physicists often consider soil to be the only source of nutrients for plants, it is actually a complex ecosystem that supports bacteria, fungus, Protestants, and animals (Bonkowski et al. 2009 Mul Mller et al. Plants interact with soil organisms in a variety of ways, allowing them to adapt to a variety of different environments (competitive, exploitative, neutral, shared, reciprocal). \

Most interaction investigations in recent plant science have focused on removing harmful effects such herbs and infections (Strange and Scott, 2005; Zhang et al., 2013) or reducing abiotic stress conditions (Yaish et al., 2016; Meena et al., 2017) However, there has long been a need to highlight beneficial environmental interactions that encourage plant growth.

For example, since the second half of the nineteenth century, both mycorrhizal fungi and bacteria found in nodulated fruits have been recognised as signs of roots (Morton, 1981). To boost development and productivity, agricultural seeds were coated with bacterial cultures (Azotobacter chroococcum or Bacillus megaterium) as early as the 1950s (Brown, 1974). Many different bacterial strains, primarily Pseudomonas but also Azospirillum, were documented as having plant growth stimulating properties until the 1980s (Burr et al., 1978; Teintze et al., 1981; Lin et al., 1983).

Since the early 2000s, research has evolved away from identifying particular bacteria strains and toward using metagenomics to document the richness and diversity of the root microbiome. The findings of a study of such a series demonstrate that the rhizospheric niche is a hotspot of environmental abundance, with a diverse range of microbial taxa inhabiting the roots of plants (Bulgarian et al.2013) Research has progressed rationally in recent years. . Has progressed toward the formation of synthetic communities (SynComs), which comprise strains representing dominant rhizospheric vaccinations, with the goal of recapitalizing beneficial microbial functions under controlled experimental circumstances (Busby et al., 2017). One of the main goals of this branch of research is to figure out how soil microorganisms help plants grow and defend themselves, and then utilise that information to construct the optimum microbial communities for certain tasks.

Factors affecting microbes

Environmental factors

The bacterial community is influenced by numerous environmental conditions. When compared to assets that the microbial community requires for growth, some of these factors are considered modulators (Balser et al.2001) (e.g. carbon, nitrogen). The distinction between a modulator and a resource is that organisms compete for resources actively, whereas they cannot compete for a modulator. Temperature, PH, water capacity, and salinity, for example, are examples of modulators. In response to modulator modifications, microbes can achieve homeostasis. The inner pH will be maintained if, for example, the exterior pH changes. Similarly, bacteria will vary their inner solute latent in reaction to changes in soil salinity, or change the composition of their membrane fatty acids in response to a change in temperature (Russel and Fukunaga, 1990). However, maintaining cell uprightness after a modulator change requires energy, and the resulting strain may have an impact on the soil community. The altered selection pressure may eventually result in a shift in community composition, resulting in a new community that is better adapted to the new environmental conditions.

Temperature

Microorganisms can survive in a wide range of temperatures, from the freezing temperatures of the Arctic to the near-boiling temperatures of geysers. These bacteria have varied temperature associations with cardinal points (minimum, optimal, maximum) associated to environmental variables depending on the different temperature regimes. The rates of biological, chemical, and physical processes in the soil are all influenced by the temperature. The Q10 connection, i.e. the factor by which activity increases when the temperature rises by 10°C, has long been used to characterise this. For every 10°C rise in temperature within a narrow range of temperatures, the rates of biological and chemical processes normally increase two to three times. The speeds of biological and chemical processes normally increase two to three times for every 10°C increase in temperature within a narrow range of temperatures. Q10, on the other hand, is said to grow with decreasing temperature, from roughly 2.5 at 20°C to more than 8 at 0°C (Kirschbaum, 1995; 2000). Because the bacterial community's turnover rate is linked to temperature and increases until the optimal temperature is attained, one might expect that temperature will affect other processes as well, such as the bacterial community's adaptation rate following a perturbation event.

pH

There are various environmental conditions that influence the role of microorganisms in the soil, but pH is the most essential. Lynch and Hobbie (Lynch and Hobbie, 1988). pH does not usually alter over time. Because the accessible carbon in acidic soils becomes vulnerable to microbial assault when the pH is raised (Skyllberg, 1993), liming was discovered by measuring plate count (e.g. Ivarson, 1977; Nodar et al., 1992; Shah et al., 1990). (Curtin et al., 1998; Persson et al., 1991; Shah et al., 1990). Because when the pH of acidic soils is elevated, the available carbon becomes exposed to microbial attack (Curtin et al., 1998; Persson et al., 1991; Shah et al., 1990). After liming, increased soil microbial activity is measured as soil respiration rate (Ivarson, 1977; Illmer and Schinner, 1991) and [3 H]-thymidine incorporation rate (Bth and Arnebrant, 1994). Liming will eventually alter the bacterial community's makeup, resulting in a population adapted to more alkaline environments (Bth et al., 1992; Bth and Arnebrant, 1994).

Co2 cycle independently

Human activities during the industrial period mostly disrupted the carbon cycle by increasing carbon dioxide levels in the atmosphere by burning more fissile flues and converting agricultural land from natural ecosystems. The impact of human actions on global weather is still debatable, in part due to our faulty understanding of soil respiration and its representation in soil system models. 38–40 Microbial contributions to climate change via carbon cycle feedbacks are complicated by straight and roundabout properties, as well as interactions with other factors (also reviewed in (wardle et al. 2021) and (Singh et al.2011)

Microbial activity, and as a result organic carbon decomposition and CO2 released by respiration, may be accelerated in reaction to increased warmth, which is an example of a simple direct affirmative response to global warming. Analyses of meadow data from around the world show a relationship between increased land respiration flux and rising temperatures. Carbon fertilisation of prime (photosynthetic) production, which accelerates photosynthesis (wang et al. 2020) and the release of root exudates, resulting in increased labile carbon accessible for microbial breakdown and respiration, is an example of a roundabout positive feedback to high CO2. Furthermore, increased root deposition of just existing exudates may 'prime' the return of a less readily available SOM element that would not otherwise be decomposed (Janssens et al.2009)

One of the biggest uncertainties in understanding the coupled carbon–climate system is how the balance between earthly ecosystem sinks (photosynthesis) and sources (respiration, including microbial respiration) of atmospheric CO2 would be modified in a high CO2 world (Lindén et al. 2014)

When soil nitrogen and plant availability are included, the likelihood increases, despite contrary evidence. 64 Some studies suggest that the terrestrial ecosystem will move from a sink to a source of atmospheric CO2, owing to better microbial respiration; on the other hand, these models are still in the early stages of development (Adolfsson et al. 2015)

Questions about the true temperature sensitivity of soil (microbial) respiration, as well as how this sensitivity is adapted by new environmental factors such as changes in soil humidity during droughts, nutrient boundaries, and the physical protection of organic matter in aggregates or by sorption, remain unanswered. This issue is exacerbated by the diversity of soil ecosystems seen around the world, which differ in function due to changes in the variables that shape them: parent material, terrain, climate, species, and time. Concerns have been expressed regarding peat lands and permafrost soils, where climatic conditions that allow for the accumulation or protection of organic material may not be suitable in the future, resulting in the release of large amounts of carbon into the atmosphere. More research in this area is essential if we are to calculate the implications and feedbacks between climate change and the global carbon cycle.

Discussion at soil texture

Effect of soil texture on soil microbial populations:

Bacteria and fungus were counted according to Zak et al. (1994), who noted that bacteria and fungi are the most common forms of soil microorganisms and play an important role in nutrient transformations and litter decomposition rates. The average counts of bacteria and fungi in various soil textures are reported as log CFU per 1 g dry soil (Table 5). Bacteria had a CFU count of 6.07–8.77 per 1 g dry soil, while fungus had a CFU count of 4.09–4.49 per 1 g dry soil. Clay loam and silty clay loam soils had the highest bacterial populations, with 8.77 log CFU per g air dry soil and 8.03 log CFU per g air dry soil, respectively. In sandy loam and silty laom soils, however, the lowest levels of bacterial populations were found (6.07 and 6.42 log CFU per g dry soil, respectively).Previous studies showed that soil types influence the structure of microbial communities, especially bacterial population among soils of different textures (Garbeva et al., 2004 and Fang et al., 2005). On the other hand, no significant differences were noticed among average counts of soil fungi due to soil textures

Previous research has shown that differing soil textures affect the structure of microbial communities, particularly the bacterial population (Garbeva et al., 2004 and Fang et al., 2005). However, due to soil textures, there were no significant changes in average counts of soil fungi.

It has been suggested that average counts of microorganisms correspond to usual counts of microbes in arable soils (Paul, 2007), and similar results in evaluating both groups of microorganisms in different soil types have previously been obtained (Critter et al., 2002; Popeláová et al., 2008). A possible explanation for the higher number of bacteria in soil with clay contents was documented by Carney and Matson (2005), who stated that fine textured soils support

Carbon Mineralization:

CO2 effluxes from bacterial consumption of carbon substrate in plant residue change significantly (p0.01) between clay loam, loam, and silty clay loam textures during incubation period, according to numerical study. They had larger CO2 effluxes than silty loam, sandy loam, and loamy sand textures, which did not differ significantly. The availability of soil water, pore size distribution, nutrient availability, and surface area all influence litter decomposition (Scott, 1996). The CO2-C evolution patterns in soil treated with the same plant residues were identical throughout time. The amount of CO2-C released quickly during the first 7 days, then gradually dropped over the balance of the incubation period. The results showed that soil texture had a substantial impact on cumulative CO2, with fine textural soil samples having considerably greater cumulative CO2-C (P0.01) than coarse textural soil samples.

It has been suggested that average counts of microorganisms correspond to usual counts of microbes in arable soils (Paul, 2007), and similar results in evaluating both groups of microorganisms in different soil types have previously been obtained (Critter et al., 2002; Popeláová et al., 2008). A possible explanation for the higher number of bacteria in soil with clay contents was documented by Carney and Matson (2005), who stated that fine textured soils support

According to Heritage et al. (2003), the dispersion of microbes in different soil textures may be connected to soil moisture and nutrient content. Sandy soils, for example, are unable to store water and drain quickly. Clay loam, on the other hand, retains water and nutrients for longer.

For the microbiota that live in it, soil provides a highly varied environment, with different microhabitats provided by different soil components (sand, silt, clay, and organic matter). Native soil organisms are subjected to abiotic and nutritional circumstances that can differ on a micrometre scale (Garbeva et al., 2004). Chemical and physical disturbances of soil organic matter have been hypothesised as methods for increased CO2 flushes related with soil characteristics and microorganisms, which are key in crop waste breakdown (Jensen et al., 1996). Total nitrogen (r=0.59, r=0.42), organic matter (r=0.6, r=0.09), soluble chloride (r=0.56, r=0.79), and bicarbonate (r=0.41, r=0.56) are among soil chemical components that are positively correlated with bacterial and fungal population in all soil textures. Additionally, in all soil samples, soluble calcium, potassium, and sodium (r=-0.4, r=-0.44, p0.01) are inversely linked with bacteria and fungus population (r=-0.4, r=-0.44, p0.01). The availability and quantity of substrates and nutrients are all factors that limit microbial activity in soils, according to this research. The C-mineralization process resulted in a positive association with soil organic matter and total nitrogen concentrations (r=0.62, r=0.61, p0.001), confirming this trend. T This is consistent with the findings of Wright and Reddy (2001), who found that adding substrates containing C, N, and P promoted heterotrophic microbial activity. Soil texture, along with pH, cation exchange capacity, and organic matter content, is one of the most important factors influencing the structure of microbial communities. Soil texture can directly affect microbial community structure by providing a suitable habitat for specific microorganisms, resulting in a maximum degradation process (Girvan, et al., 2003). Finally, interactions between soil organic matter and total nitrogen concentrations, as well as soil texture, may promote soil microbial populations and their activities for plant waste decomposition. As a result of the current findings, soil textures and chemical qualities are the most important elements influencing the extent of decomposition.

Conclusion

Almost by definition, soil ecology is a multidisciplinary field. Some of the most important breakthroughs in agronomy, ecosystem ecology, microbiology, and environmental science can be connected to research exploring the interactions between soil organisms and their environment, as seen by the range and extent of successes in soil ecology. Additionally, the rise of global climate change, biodiversity loss, and agricultural sustainability as global challenges has brought soil ecology to the fore. Soil ecologists must consider where the field sits in relation to other scientific disciplines as the subject obtains prominence and more recognised for its contributions to society. There is an increasing desire for a deeper grasp of fundamental theories in soil ecology, if recent articles (Barot et al., 2007, Andrén et al., 2008) are any clue. We agree with this sentiment in general and have highlighted numerous lines of evidence that imply unifying principles in soil ecology are more widespread than we might believe. Consistency in microbial communities and soil organic matter dynamics across a wide range of environments is one example of this evidence. Constraints on the physiology and metabolic activity of soil communities account for a major part of this consistency. Organic matter, usually plant material, undergoes modifications in the microbial 'funnel' that decrease chemical structural differences. The effects of physical and chemical processes in soils, as well as their overriding effects on organic matter stabilisation, contribute to this consistency.

Naturally, no two soils are alike, and some of the observed changes in soil biota and biological processes over time and space will be unpredictable. Soil ecologists now have a set of methods for researching microbial communities, organic matter dynamics, and nutrient cycling that could yield important new information. Future study aimed at establishing "unifying principles" in soil ecology will invariably lead to quantitative and conceptual advances in the subject if these techniques are properly applied (Wall et al., 2005, Filley and Boutton, 2006). We may draw on notions in soil ecology to establish an integrated set of hypotheses to understand soil biological and biogeochemical processes across time and space, rather than piecing together results from research that may not be directly comparable to one another.

References

1. Adachi, M., Ito, A., Yonemura, S., Takeuchi, W., 2017. Estimation of global soil respiration by accounting for land-use changes derived from remote sensing data. J. Environ. Manag. 200, 97–104. https://doi.org/10.1016/j.jenvman.2017.05.076.
2. Angst, S, ˇ Cajthaml, T., Angst, G., Simackova, H., Brus, J., Frouz, J., 2017. Retention of dead standing plant biomass (marcescence) increases subsequent litter decomposition in the soil organic layer. Plant and Soil 418, 571–579. https://doi. org/10.1007/s11104-017-3318-6.
3. Assefa, D., Rewald, B., Sandén, H., Rosinger, C., Abiyu, A., Yitaferu, B., Godbold, D.L., 2017. Deforestation and land use strongly effect soil organic carbon and nitrogen stock in Northwest Ethiopia. Catena 153, 89–99. https://doi.org/10.1016/j. catena.2017.02.003.
4. Allison, S.D., Lu, Y., Weihe, C., Goulden, M.L., Martiny, A.C., Treseder, K.K., Martiny, J. B.H., 2013. Microbial abundance and composition influence litter decomposition response to environmental change. Ecology 94, 714–725. https://doi.org/10.1890/ 12-1243.1
5. Barba, J., Lloret, F., Poyatos, R., Molowny-Horas, R., Yuste, J.C., 2018. Multi-temporal influence of vegetation on soil respiration in a drought-affected forest. iForest 11, 189. https://doi.org/10.3832/ifor2448-011.
6. Bond-Lamberty, B., Bailey, V.L., Chen, M., Gough, C.M., Vargas, R., 2018. Globally rising soil heterotrophic respiration over recent decades. Nature 560, 80. https://doi.org/ 10.1038/s41586-018-0358-x
7. Blume, H.-P., Fleige, H., Horn, R., Kandeler, E., Kogel-Knabner, ¨ I., Kretzschmar, R., Stahr, K., Wilke, B.-M., 2015. Soil Science, first ed. Springer Berlin Heidelberg, Berlin Heidelberg.
8. Cepakova, S., Frouz, J., 2015. Changes in chemical composition of litter during decomposition: a review of published 13C NMR spectra. Journal of Soil Science and Plant Nutrition 15, 805–815. https://doi.org/10.4067/S0718-95162015005000055.
9. Frouz, J., Hrˇckova, ´ K., L´ ana, J., Kriˇstůfek, V., Mudr´ ak, O., Lukeˇsov´ a, A., Mihaljeviˇc, M., 2011. Can laboratory toxicity tests explain the pattern of field communities of algae, plants, and invertebrates along a toxicity gradient of post-mining sites? Applied Soil Ecology 51, 114–121. https://doi.org/10.1016/j.apsoil.2011.09.007
10. Hicks Pries, C.E., Bird, J.A., Castanha, C., Hatton, P.J., Torn, M.S., 2017. Long term decomposition: the influence of litter type and soil horizon on retention of plant carbon and nitrogen in soils. Biogeochemistry 134, 5–16. https://doi.org/10.1007/ s10533-017-0345-6
11. Kleber, M., Eusterhues, K., Keiluweit, M., Mikutta, C., Mikutta, R., Nico, P.S., 2015. Mineral-organic associations: formation, properties, and relevance in soil environments. Advances in Agronomy. Elsevier {BV}, pp. 1–140. https://doi.org/ 10.1016/bs.agron.2014.10.005.
12. Jian, J., Steele, M.K., Thomas, R.Q., Day, S.D., Hodges, S.C., 2018. Constraining estimates of global soil respiration by quantifying sources of variability. Glob. Change Biol. 24, 4143–4159. https://doi.org/10.1111/gcb.14301.

13. Joo, S., Park, S.U., Park, M.S., Lee, C.S., 2012. Estimation of soil respiration using automated chamber systems in an oak (Quercus mongolica) forest at the Nam-San site in Seoul, Korea. Sci. Total Environ. 416, 400–409. https://doi.org/10.1016/j.scitotenv.2011.11.025.
14. Kogel-Knabner, ¨ I., 2002. The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter. Soil Biology and Biochemistry 34, 139–162. https://doi.org/10.1016/S0038-0717(01)00158-4.
15. Lehmann, J., Hansel, C.M., Kaiser, C., Kleber, M., Maher, K., Manzoni, S., Nunan, N., Reichstein, M., Schimel, J.P., Torn, M.S., Wieder, W.R., Kogel-Knabner, ¨ I., 2020. Persistence of soil organic carbon caused by functional complexity. Nature Geoscience 13, 529–534. https://doi.org/10.1038/s41561-020-0612-3
16. Machmuller, M.B., Kramer, M.G., Cyle, T.K., Hill, N., Hancock, D., Thompson, A., 2015. Emerging land use practices rapidly increase soil organic matter. Nat. Commun. 6, 6995. https://doi.org/10.1038/ncomms7995.
17. Manzoni, S., Taylor, P., Richter, A., Porporato, A., Ågren, G.I., 2012. Environmental and stoichiometric controls on microbial carbon-use efficiency in soils. New Phytologist 196, 79–91. https://doi.org/10.1111/j.1469-8137.2012.04225.x.
18. Parro, K., Köster, K., Jõgiste, K., Seglinš, K., Sims, A., Stanturf, J.A., Metslaid, M., 2019. Impact of post-fire management on soil respiration, carbon and nitrogen content in a managed hemiboreal forest. J. Environ. Manag. 233, 371–377. https://doi.org/10.1016/j. jenvman.2018.12.050
19. Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G.P., Smith, P., 2016. Climatesmart soils. Nature 532, 49–57. https://doi.org/10.1038/nature17174.
20. Prescott, C.E., 2010. Litter decomposition: what controls it and how can we alter it to sequester more carbon in forest soils? Biogeochemistry 101, 133–149. https://doi. org/10.1007/s10533-010-9439-0.
21. Raich, J.W., Tufekciogul, A., 2000. Vegetation and soil respiration: correlations and controls. Biogeochemistry 48, 71–90. https://doi.org/10.1023/A:1006112000616.
22. Seaton, F.M., George, P.B.L., Lebron, I., Jones, D.L., Creer, S., Robinson, D.A., 2020. Soil textural heterogeneity impacts bacterial but not fungal diversity. Soil Biology and Biochemistry 144, 107766. https://doi.org/10.1016/j.soilbio.2020.107766
23. Shi, P., Zhang, Y., Ren, Z., Yu, Y., Li, P., Gong, J., 2019c. Land-use changes and check dams reducing runoff and sediment yield on the loess plateau of China. Sci. Total Environ. 664, 984–994. https://doi.org/10.1016/j.scitotenv.2019.01.430
24. Villarino, S.H., Studdert, G.A., Baldassini, P., Cendoya, M.G., Ciuffoli, L., Mastrángelo, M., Piñeiro, G., 2017. Deforestation impacts on soil organic carbon stocks in the semiarid Chaco region. Argentina. Sci. Total Environ. 575, 1056–1065 https://doi.org/ 1056–1065. https://doi.org/10.1016/j.scitotenv.2016.09.175
25. von Lützow, M., Kogel-Knabner, ¨ I., Ekschmitt, K., Matzner, E., Guggenberger, G., Marschner, B., Flessa, H., 2006. Stabilization of organic matter in temperate soils: mechanisms and their relevance under different soil conditions - a review. European Journal of Soil Science 57, 426–445. https://doi.org/10.1111/j.1365- 2389.2006.00809.x

26. Xiao, L., Liu, G., Li, P., Xue, S., 2019. Direct and indirect effects of elevated CO2 and nitrogen addition on soil microbial communities in the rhizosphere of Bothriochloa ischaemum. J. Soils Sediments https://doi.org/10.1007/s11368-019-02336-0.
27. Xia, Q., Rufty, T., Shi, W., 2020. Soil microbial diversity and composition: links to soil texture and associated properties. Soil Biology and Biochemistry 149, 107953. https://doi.org/10.1016/j.soilbio.2020.107953.
28. Yu, Y., Wei, W., Chen, L., Feng, T., Daryanto, S., 2019b. Quantifying the effects of precipitation, vegetation, and land preparation techniques on runoff and soil erosion in a loess watershed of China. Sci. Total Environ. 652, 755–764. https://doi.org/10.1016/j. scitotenv.2018.10.255.
29. Law, B. E., & Harmon, M. E. (2011). Forest sector carbon management, measurement and verification, and discussion of policy related to climate change. *Carbon Management*, *2*(1), 73-84.

30. Willson, R. W., & Brown, K. D. (2008). Carbon neutrality at the local level: Achievable goal or fantasy?. *Journal of the American Planning Association*, *74*(4), 497-504.
31. Batjes, N. H. (1996). Total carbon and nitrogen in the soils of the world. *European journal of soil science*, *47*(2), 151-163.
32. Kutsch, W. L., Bahn, M., & Heinemeyer, A. (Eds.). (2009). *Soil carbon dynamics: an integrated methodology*. Cambridge University Press.
33. Nieder, R., & Benbi, D. K. (2008). *Carbon and nitrogen in the terrestrial environment*. Springer Science & Business Media.
34. Schaufler, G., Kitzler, B., Schindlbacher, A., Skiba, U., Sutton, M. A., & Zechmeister-Boltenstern, S. (2010). Greenhouse gas emissions from European soils under different land use: effects of soil moisture and temperature. *European Journal of Soil Science*, *61*(5), 683-696.
35. Schlesinger, W. H., & Andrews, J. A. (2000). Soil respiration and the global carbon cycle. *Biogeochemistry*, *48*(1), 7-20.
36. Galbally, I. E., Freney, J. R., Muirhead, W. A., Simpson, J. R., Trevitt, A. C. F., & Chalk, P. M. (1987). Emission of nitrogen oxides (NO x) from a flooded soil fertilized with urea: Relation to other nitrogen loss processes. *Journal of Atmospheric Chemistry*, *5*(3), 343-365.
37. Holzapfel-Pschorn, A., Conrad, R., & Seiler, W. (1985). Production, oxidation and emission of methane in rice paddies. *FEMS Microbiology Ecology*, *1*(6), 343-351.
38. Longdoz, B., Yernaux, M., & Aubinet, M. (2000). Soil CO2 efflux measurements in a mixed forest: impact of chamber disturbances, spatial variability and seasonal evolution. *Global Change Biology*, *6*(8), 907-917.
39. Drewitt, G. B., Black, T. A., Nesic, Z., Humphreys, E. R., Jork, E. M., Swanson, R., ... & Morgenstern, K. (2002). Measuring forest floor CO2 fluxes in a Douglas-fir forest. *Agricultural and Forest Meteorology*, *110*(4), 299-317.
40. Dilustro, J. J., Collins, B., Duncan, L., & Crawford, C. (2005). Moisture and soil texture effects on soil CO2 efflux components in southeastern mixed pine forests. *Forest Ecology and Management*, *204*(1), 87-97.
41. Linn, D. M., & Doran, J. W. (1984). Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and nontilled soils. *Soil Science Society of America Journal*, *48*(6), 1267-1272.
42. Kelliher, F. M., Lloyd, J., Arneth, A., Lühker, B., Byers, J. N., McSeveny, T. M., ... & Schulze, E. D. (1999). Carbon dioxide efflux density from the floor of a central Siberian pine forest. *Agricultural and Forest Meteorology*, *94*(3-4), 217-232.
43. Davidson, E. A., Belk, E., & Boone, R. D. (1998). Soil water content and temperature as independent or confounded factors controlling soil respiration in a temperate mixed hardwood forest. *Global change biology*, *4*(2), 217-227.
44. Subke, J. A., & Tenhunen, J. D. (2004). Direct measurements of CO2 flux below a spruce forest canopy. *Agricultural and forest meteorology*, *126*(1-2), 157-168.
45. Boone, R. D., Nadelhoffer, K. J., Canary, J. D., & Kaye, J. P. (1998). Roots exert a strong influence on the temperature sensitivityof soil respiration. *Nature*, *396*(6711), 570-572.
46. Reich, P. B., Walters, M. B., & Ellsworth, D. S. (1991). Leaf age and season influence the relationships between leaf nitrogen, leaf mass per area and photosynthesis in maple and oak trees. *Plant, Cell & Environment*, *14*(3), 251-259.
47. Dilustro, J. J., Collins, B., Duncan, L., & Crawford, C. (2005). Moisture and soil texture effects on soil CO2 efflux components in southeastern mixed pine forests. *Forest Ecology and Management*, *204*(1), 87-97.
48. Kelliher, F. M., Lloyd, J., Arneth, A., Lühker, B., Byers, J. N., McSeveny, T. M., ... & Schulze, E. D. (1999). Carbon dioxide efflux density from the floor of a central Siberian pine forest. *Agricultural and Forest Meteorology*, *94*(3-4), 217-232.
49. Wildung, R. E., Garland, T. R., & Buschbom, R. L. (1975). The interdependent effects of soil temperature and water content on soil respiration rate and plant root decomposition in arid grassland soils. *Soil Biology and Biochemistry*, *7*(6), 373-378.
50. Kucera, C., & Kirkham, D. R. (1971). Soil respiration studies in tallgrass prairie in Missouri. *Ecology*, *52*(5), 912-915.

51. Strange, R. N., & Scott, P. R. (2005). Plant disease: a threat to global food security. *Annu. Rev. Phytopathol.*, *43*, 83-116.
52. Zhang, Y., Lubberstedt, T., & Xu, M. (2013). The genetic and molecular basis of plant resistance to pathogens. *Journal of Genetics and Genomics*, *40*(1), 23-35.
53. Yaish, M. W., Al-Lawati, A., Jana, G. A., Vishwas Patankar, H., & Glick, B. R. (2016). Impact of soil salinity on the structure of the bacterial endophytic community identified from the roots of caliph medic (Medicago truncatula). *PLoS One*, *11*(7), e0159007.
54. Meena, K. K., Sorty, A. M., Bitla, U. M., Choudhary, K., Gupta, P., Pareek, A., ... & Minhas, P. S. (2017). Abiotic stress responses and microbe-mediated mitigation in plants: the omics strategies. *Frontiers in plant science*, *8*, 172.
55. Burr, T. J., Schroth, M. N., & Suslow, T. (1978). Increased potato yields by treatment of seed pieces with specific strains of Pseudomonas fluorescens and P. putida. *Phytopathology*, *68*(9), 1377-1383.
56. Teintze, M., Hossain, M. B., Barnes, C. L., Leong, J., & Van der Helm, D. (1981). Structure of ferric pseudobactin: a siderophore from a plant growth promoting Pseudomonas. *Biochemistry*, *20*(22), 6446-6457.
57. Lin, W., Okon, Y., & Hardy, R. W. (1983). Enhanced mineral uptake by Zea mays and Sorghum bicolor roots inoculated with Azospirillum brasilense. *Applied and Environmental Microbiology*, *45*(6), 1775-1779.
58. Russell, N. J., & Fukunaga, N. (1990). A comparison of thermal adaptation of membrane lipids in psychrophilic and thermophilic bacteria. *FEMS Microbiology Letters*, *75*(2-3), 171-182.
59. Kirschbaum, M. U. (1995). The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic C storage. *Soil Biology and biochemistry*, *27*(6), 753-760.
60. Lynch, J. M., & Hobbie, J. E. (1988). *Micro-organisms in action*. Blackwell Scientific Publications.
61. Skyllberg, U. (1993). Acid-base properties of humus layers in northern coniferous forests. Swedish University of Agricultural Sciences, Department of Forest Ecology. *Soil Science Section, Dissertation, Umeâ*.
62. Ivarson, K. C. (1977). Changes in decomposition rate, microbial population and carbohydrate content of an acid peat bog after liming and reclamation. *Canadian Journal of Soil Science*, *57*(2), 129-137.
63. Bååth, E., & Arnebrant, K. (1994). Growth rate and response of bacterial communities to pH in limed and ash treated forest soils. *Soil biology and Biochemistry*, *26*(8), 995-1001.
64. Nodar, R., Acea, M. J., & Carballas, T. (1992). Microbiological response to Ca (OH) 2 treatments in a forest soil. *FEMS Microbiology Letters*, *86*(3), 213-219.
65. Curtin, Denis, C. A. Campbell, and Abdul Jalil. "Effects of acidity on mineralization: pH-dependence of organic matter mineralization in weakly acidic soils." *Soil Biology and Biochemistry* 30, no. 1 (1998): 57-64.
66. Persson, T., Wirén, A., & Andersson, S. (1991). Effects of liming on carbon and nitrogen mineralization in coniferous forests. In *Management of Nutrition in Forests under Stress* (pp. 351-364). Springer, Dordrecht.
67. Shah, Z., Adamst, W. A., & Haven, C. D. V. (1990). Composition and activity of the microbial population in an acidic upland soil and effects of liming. *Soil Biology and Biochemistry*, *22*(2), 257-263.
68. Ivarson, K. C. (1977). Changes in decomposition rate, microbial population and carbohydrate content of an acid peat bog after liming and reclamation. *Canadian Journal of Soil Science*, *57*(2), 129-137.
69. Illmer, P., & Schinner, F. (1991). Effects of lime and nutrient salts on the microbiological activities of forest soils. *Biology and fertility of soils*, *11*(4), 261-266.
70. Bååth, E., & Arnebrant, K. (1994). Growth rate and response of bacterial communities to pH in limed and ash treated forest soils. *Soil biology and Biochemistry*, *26*(8), 995-1001.
71. Bååth, E., Frostegård, Å., & Fritze, H. (1992). Soil bacterial biomass, activity, phospholipid fatty acid pattern, and pH tolerance in an area polluted with alkaline dust deposition. *Applied and Environmental Microbiology*, *58*(12), 4026-4031.
72. Arnold, P. W. (1954). Losses of nitrous oxide from soil. *Journal of Soil Science*, *5*(1), 116-128.
73. Declaration, L. (2015). Annex to the Leaders' Declaration G7 Summit 7-8 June 2015.

74. Benndorf, R., Bernicke, M., Bertram, A., Butz, W., Dettling, F., Drotleff, J., ... & Zietlow, B. (2013). *Treibhausgasneutrales Deutschland im Jahr 2050*. Umweltbundesamt.
75. Wardle, D. A., Bardgett, R. D., Klironomos, J. N., Setälä, H., Van Der Putten, W. H., & Wall, D. H. (2004). Ecological linkages between aboveground and belowground biota. *Science*, *304*(5677), 1629-1633.

76. Singh, R. D. (2011). Singh. *Anindita, electrocatalytic activity of binary and ternary composite films of Pd, MWCNT and Ni, Part II: methanol electrooxidation in*, *1*, 2052-2057.
77. Wang, S., Zhang, Y., Ju, W., Chen, J. M., Ciais, P., Cescatti, A., ... & Peñuelas, J. (2020). Recent global decline of CO2 fertilization effects on vegetation photosynthesis. *Science*, *370*(6522), 1295-1300.
78. Janssens, I. A., & Luyssaert, S. (2009). Nitrogen's carbon bonus. *Nature Geoscience*, *2*(5), 318-319.
79. Lindén, A., Heinonsalo, J., Buchmann, N., Oinonen, M., Sonninen, E., Hilasvuori, E., & Pumpanen, J. (2014). Contrasting effects of increased carbon input on boreal SOM decomposition with and without presence of living root system of Pinus sylvestris L. *Plant and soil*, *377*(1), 145-158.
80. Adolfsson, L., Solymosi, K., Andersson, M. X., Keresztes, Á., Uddling, J., Schoefs, B., & Spetea, C. (2015). Mycorrhiza symbiosis increases the surface for sunlight capture in Medicago truncatula for better photosynthetic production. *PLoS One*, *10*(1), e0115314.
81. Richter, A., Kern, T., Wolf, S., Struck, U., & Ruess, L. (2019). Trophic and non-trophic interactions in binary links affect carbon flow in the soil micro-food web. *Soil Biology and Biochemistry*, *135*, 239-247.
82. Miller, M., & Dick, R. P. (1995). Dynamics of soil C and microbial biomass in whole soil and aggregates in two cropping systems. *Applied Soil Ecology*, *2*(4), 253-261.
83. Fernández-Alonso, M. J., Yuste, J. C., Kitzler, B., Ortiz, C., & Rubio, A. (2018). Changes in litter chemistry associated with global change-driven forest succession resulted in time-decoupled responses of soil carbon and nitrogen cycles. *Soil Biology and Biochemistry*, *120*, 200-211.
84. Angst, G., Pokorný, J., Mueller, C. W., Prater, I., Preusser, S., Kandeler, E., ... & Angst, Š. (2021). Soil texture affects the coupling of litter decomposition and soil organic matter formation. *Soil Biology and Biochemistry*, *159*, 108302.
85. de Siqueira Castro, J., Calijuri, M. L., Assemany, P. P., Cecon, P. R., de Assis, I. R., & Ribeiro, V. J. (2017). Microalgae biofilm in soil: Greenhouse gas emissions, ammonia volatilization and plant growth. *Science of the Total Environment*, *574*, 1640-1648.
86. Shi, P., Qin, Y., Liu, Q., Zhu, T., Li, Z., Li, P., ... & Wang, F. (2020). Soil respiration and response of carbon source changes to vegetation restoration in the Loess Plateau, China. *Science of the Total Environment*, *707*, 135507.
87. Anderson, T. H., Heinemeyer, O., & Weigel, H. J. (2011). Changes in the fungal-to-bacterial respiratory ratio and microbial biomass in agriculturally managed soils under free-air CO2 enrichment (FACE)–A six-year survey of a field study. *Soil Biology and Biochemistry*, *43*(5), 895-904.
88. Fernández-Alonso, M. J., Yuste, J. C., Kitzler, B., Ortiz, C., & Rubio, A. (2018). Changes in litter chemistry associated with global change-driven forest succession resulted in time-decoupled responses of soil carbon and nitrogen cycles. *Soil Biology and Biochemistry*, *120*, 200-211.
89. Bai, S., Qiu, W., Zhang, H., Wang, Y., & Berninger, F. (2020). Soil respiration following Chinese fir plantation clear-cut: Comparison of two forest regeneration approaches. *Science of The Total Environment*, *709*, 135980.
90. Shakoor, A., Dar, A. A., Arif, M. S., Farooq, T. H., Yasmeen, T., Shahzad, S. M., & Ashraf, M. (2020). Do soil conservation practices exceed their relevance as a countermeasure to greenhouse gases emissions and increase crop productivity in agriculture?. *Science of The Total Environment*, *805*, 150337.
91. Meyer, K. M., Morris, A. H., Webster, K., Klein, A. M., Kroeger, M. E., Meredith, L. K., ... & Bohannan, B. J. (2020). Belowground changes to community structure alter methane-cycling dynamics in Amazonia. *Environment International*, *145*, 106131.
92. Waring, B. G., & Powers, J. S. (2016). Unraveling the mechanisms underlying pulse dynamics of soil respiration in tropical dry forests. *Environmental Research Letters*, *11*(10), 105005.

93. Ding, W., Yu, H., Cai, Z., Han, F., & Xu, Z. (2010). Responses of soil respiration to N fertilization in a loamy soil under maize cultivation. *Geoderma*, *155*(3-4), 381-389.
94. Meehan, M. L., Barreto, C., Turnbull, M. S., Bradley, R. L., Bellenger, J. P., Darnajoux, R., & Lindo, Z. (2020). Response of soil fauna to simulated global change factors depends on ambient climate conditions. *Pedobiologia*, *83*, 150672.
95. Muñoz-Rojas, M., Erickson, T. E., Dixon, K. W., & Merritt, D. J. (2016). Soil quality indicators to assess functionality of restored soils in degraded semiarid ecosystems. *Restoration Ecology*, *24*, S43-S52.
96. Flanagan, N. E., Wang, H., Winton, S., & Richardson, C. J. Low-Severity Fire as a Mechanism of Organic Matter Protection in Global Peatlands.
97. Rizhiya, E., Bertora, C., van Vliet, P. C., Kuikman, P. J., Faber, J. H., & van Groenigen, J. W. (2007). Earthworm activity as a determinant for N2O emission from crop residue. *Soil Biology and Biochemistry*, *39*(8), 2058-2069.