Temperature responsiveness of soil carbon fractions, microbes, extracellular enzymes and CO_2 emission: Mitigating role of texture

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The interaction of warming and soil texture on responsiveness of the key soil processes i.e. organic carbon (C) fractions, soil microbes, extracellular enzymes and CO_2 emissions remains largely unknown. Global warming raises the relevant question of how different soil processes will respond in near future, and what will be the likely regulatory role of texture? To bridge this gap, this work applied laboratory incubation method to investigate the effects of temperature changes (10-50°C) on dynamics of labile, recalcitrant and stable C fractions, soil microbes, microbial biomass, activities of extracellular enzymes and CO_2 emissions in sandy and clayey textured soils. The role of texture (sandy and clayey) in the mitigation of temperature effect was also investigated. The results revealed that the temperature sensitivity of C fractions and extracellular enzymes was in the order recalcitrant C fractions > stable C fractions > labile C fractions and oxidative enzymes > hydrolytic enzymes. While temperature sensitivity of soil microbes and biomass was in the order bacteria > actinomycetes > fungi ≈ microbial biomass C (MBC) > microbial biomass N (MBN) > microbial biomass N (MBP). Conversely, the temperature effect and sensitivity of all key soil processes including CO_2 emissions were significantly ($P < 0.05$) higher in sandy than clayey textured soil. Results confirmed that under the scenario of global warming and climate change, soils which are sandy in nature are more susceptible to temperature increase and prone to become the CO_2-C sources. It was revealed that clayey texture played an important role in mitigating and easing off the undue temperature

influence, hence, the sensitivity of key soil processes.

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Running Title: **Sensitivity of soil C and biological properties**

ABSTRACT

The interaction of warming and soil texture on responsiveness of the key soil processes i.e. organic carbon (C) fractions, soil microbes, extracellular enzymes and CO_2 emissions remains largely unknown. Global warming raises the relevant question of how different soils and their key processes will respond in near future, and what will be the likely regulatory role of texture? To bridge this gap, this work applied laboratory incubation method to investigate the effects of temperature changes (10-50°C) on dynamics of labile, recalcitrant and stable C fractions, soil microbes, microbial biomass, activities of extracellular enzymes and CO_2 emissions in sandy and clayey textured soils. The role of texture (sandy and clayey) in the mitigation of temperature effect was also investigated. The results revealed that the temperature sensitivity of C fractions and extracellular enzymes was in the order recalcitrant C fractions > stable C fractions > labile C fractions and oxidative enzymes > hydrolytic enzymes. While temperature sensitivity of soil microbes and biomass was in the order bacteria > actinomycetes > fungi ≈ microbial biomass C (MBC) > microbial biomass N (MBN) > microbial biomass P (MBP). Conversely, the temperature effect and sensitivity of all key soil processes including CO_2 emissions were significantly ($P < 0.05$) higher in sandy than clayey textured soil. Results confirmed that under the scenario of global warming and climate change, soils which are sandy in nature are more susceptible to temperature increase and prone to become the CO_2-C sources. It was revealed that clayey texture played an important role in mitigating and easing off the undue temperature influence, hence, the sensitivity of key soil processes.

Keywords: Soil C fractions, soil microbes and biomass, extracellular enzymes, CO_2 fluxes, temperature sensitivity, warming, texture

List of abbreviations: TOC: total organic C, MBC: microbial biomass C, MBN: microbial biomass N, MBP: microbial biomass P, RCP: recalcitrant C pool, LCP: labile C pool, SCP:

stable C pool, ROC: recalcitrant organic carbon, WHC: water holding capacity, LFOC: light fraction of organic carbon, RMC: readily mineralizable carbon, DOC: dissolved organic carbon, POC: particulate organic carbon, EOC: easily oxidizable carbon, ROC: recalcitrant organic carbon, CFU: colony-forming unit

INTRODUCTION

The world's soils store substantially more carbon (C) than present in the atmosphere (Badgery et al. 2020; Paustian et al. 2019). The estimated global soil C pool at one-meter depth is >1500 GT and two-meter depth is >2500 GT, which is 3.2 and 4 times the size of combined atmospheric and biotic C pool (Zomer et al. 2017). Being a gigantic pool, terrestrial C is receiving increasing attention both as a potentially large and uncertain source of CO_2 and also as a natural sink to reduce atmospheric CO_2 (Badgery et al. 2020; Zomer et al. 2017). It has been estimated that soils emit ≥11 times CO_2-C than fossil fuel combustion which is roughly about 68-100 Pgy^{-1} (Zhang et al. 2018). Conversely, even a 0.4% annual increase in soil C has the potential to significantly halt the yearly atmospheric CO_2 increase (Amundson and Biardeau, 2019). Therefore, it is of utmost importance to examine soil C and its divergent fractions, and their likely sensitivity and response towards temperature increase for future feedbacks and predictions.

Due to continuous movement in the soil systems, soil C is constantly disintegrating and changing into divergent pools (Yang et al. 2021; Zomer et al. 2017). The three major pools of soil C, are recalcitrant C pool (RCP), labile C pool (LCP), and stable C pool (SCP) respectively (Zhang and Zhou, 2018). The LCP is composed of newly incorporated plant residues, amino acids, simple carbohydrates, root exudates, and simple C fractions (Lian et al. 2018). Whereas, RCP is made of detritus, decomposed plant and microbial byproducts, and C fractions e.g., recalcitrant organic carbon (ROC) which is resistant to decomposition (Zhang and Zhou, 2018).

Whereas, the total organic C (TOC) which is a heterogeneous mixture of diverse compounds (e.g., residues, humin, humic acid, aromatic and hydrophobic compounds) with several hundred years of a mean age and accounts for 90% of stable fraction is also known as SCP (Lian et al. 2018). These C fractions are of utmost importance, owing to their direct and strong role in soil structure, C cycling and production and fluxes of CO_2 (Badgery et al. 2020; Zomer et al. 2017). The C fractions are extremely susceptible to abiotic variables, and multiple earlier studies have demonstrated that the future C balance of terrestrial ecosystems is highly dependent on the consequences of global warming (Wang et al. 2016; Qi et al. 2016; Biswas et al. 2018). Qi et al. (2016) observed a significant reduction in soil labile organic C fractions in response to warming, while Karhu et al. (2010) reported a decline in stable organic carbon fractions. Nonetheless, the temperature sensitivity of C fractions is a highly controversial and vague topic to date (Davidson and Janssens 2006; Sierra et al. 2017). Therefore, it is the need of the day to quantify and establish the temperature sensitivity of C fractions of labile, recalcitrant, and stable pools.

Soil microbes i.e., bacteria, fungi, and actinomycetes, owing to their vast metabolic diversity play diverse and critical roles in all-major biogeochemical cycles and ecosystem services (Walker et al. 2018; Nottingham et al. 2019). They also play a key role in regulating the C decomposition, emission of CO_2, and overall C cycle of the ecosystem (Qu et al. 2020). Alike, soil enzymes are major components of biological processes which participate in all biochemical reactions (Hassan et al. 2013a). Soil enzymes play an important role in the biological catabolism, decomposition of organic matter and C cycling (Hassan et al. 2013b; Aislabie and Deslippe, 2013). They also perform catalysis of reactions that are necessary for the life processes of microorganisms (Walker et al. 2018; Hassan et al. 2013b). Soil microbial community and enzymes respond to changes in soil and environmental factors much faster than do other

variables (Nottingham et al. 2019; Aislabie and Deslippe, 2013). Soil microbial community and enzymes are sensitive to a number of environmental factors, among them temperature is of utmost ascendancy (Walker et al. 2018). Under the scenario of global warming, it is indeed important to test the temperature sensitivity of the soil microbial communities (bacteria, fungi, and actinomycetes) and extracellular enzymes (oxidative and hydrolytic).

Temperature is rightly known as one of the primary bio-controller, because it influences soil reactions, biological processes and the inter-spheric gas exchange between the soil and atmosphere (Thakur et al. 2016; Fang et al. 2016). Due to its control over energy shifts, microbial communities, and extracellular enzyme activity, it regulates OM mineralization rates and storage, and hence the production of CO_2 in soils is also temperature-dependent (Hassan et al. 2014; Thakur et al. 2016; Walker et al. 2018). Therefore, the temperature has a great influence on the ability of soils to act as a C sink or source (Walker et al. 2018; Thakur et al. 2016; Fang et al. 2016). For example, Zhou et al. (2013) found that a six-year warming period enhanced the activities of β-glucosidase and N-acetylglucosaminidase, which were connected with changes in microbial biomass C. Under warming conditions, changes in the soil LOC fractions have been shown to drive changes in soil enzyme activity (Zhou et al., 2013; Qi et al. 2016). However, according to Li et al. (2018), microbial responses to climate change may be influenced by soil properties.

The texture is one of the most important properties of soil because it determines characteristics and biophysical properties that shape and regulate the overall behavior and response of soils (Fang et al. 2016; Ding et al. 2014; Hassan et al. 2013a). The texture is associated with porosity, moisture, gaseous exchange, nutrient cycling, and substrate availability to microbiota along with other important functions and services in soils (Oertel et al. 2016;

114 Hobley et al. 2014; Hamarashid et al. 2010). Moreover, it also provides physical protection to
115 soil microbiota, organic matter, and C from harsh climatic conditions i.e., temperature anomalies
116 (Frøseth and Bleken, 2015; Hassan et al. 2013a). Therefore, it affects the microbial and
117 enzymatic activity, decomposition of organic matter, nutrients and C cycling, and eventually
118 CO_2 production (Ding et al. 2014; Feng et al. 2013). Soil texture can modulate the effects of
119 temperature and climate change and thus production and emission of gases (e.g., CO_2) through
120 its strong influence on biochemical processes and C cycling and storage (Zhang et al. 2015; Feng
121 et al. 2013). The main reason for the strong influence of texture on key soil processes and
122 activities is diverse and divergent characteristics of its relative particle's i.e., fine and coarse
123 (Frøseth and Bleken, 2015; Hamarashid et al. 2010). The fine particles (i.e., clay) have large
124 surface areas, numerous reactive sites, strong ligand exchange, and polyvalent cation bridges
125 than coarse ones i.e., sand (Fang et al. 2016; Ding et al. 2014; Hassan et al. 2013a). However, the
126 interaction of warming and soil texture on responsiveness of the key soil processes remains
127 largely unknown.

128 Therefore, it is indeed important to quantify the role of texture in regulating the
129 temperature sensitivity of key soil processes for correct future inventories and feedbacks. We
130 hypothesized that, warming would increase decomposition of recalcitrant and stable soil C pools
131 via microbial activities and extracellular enzymes. These changes will be more pronounced in
132 sandy textured soils while clayey soils will mitigate the effects of warming. Thus, the purpose of
133 this study was (1) to determine the temperature influence and responsiveness of labile,
134 recalcitrant, and stable C fractions, as well as CO_2 emission from divergent textured soils (2)
135 quantify the effect of temperature on soil microbial counts (bacteria, fungi, and actinomycetes),
136 microbial biomass, and extracellular enzymes (oxidative and hydrolytic) activities and their

response towards temperature increase in divergent textured soils and (3) identify and establish the potential role of texture in climate change mitigation.

MATERIAL AND METHODS

Soil sampling

The study area has a moderately continental climate, the maximum and minimum mean annual temperatures are 14.03°C and 6.72°C and average annual precipitation is 24.97 mm. Soil samples (0-30 cm depth) were collected randomly using a hand auger from ten points within the selected agricultural fields at Dahlem and Rhinluch, Berlin, Germany (52°27" N and 13°18" E) in April 2017. Winter wheat and maize was grown in rotation. Soils were Albic Luvisol and Arenosol with glacial till and periglacial sand parent materials. Samples (field fresh) were sieved (< 2mm) and separated into two subsamples. One part of the subsample was used to conduct the incubation experiment while the other was used for microbial and enzymatic analyses. The remaining soil was used for physicochemical and C fractional analyses after air-drying at room temperature (25°C) for 7 days by using methods as described by Hassan et al. (2014). The basic physicochemical properties of experimental soil are given in Table 1A.

Experimental layout

For incubation, 400 g dry soil was incubated in 1000 ml glass jars under different temperature and moisture regimes for 84 days in a randomized block design. Soil samples were wetted to maintain 60% of water holding capacity (WHC) and equilibrated overnight at 4°C, before being placed in incubators. The five treatments in triplicate were developed and expressed as T1 (10°C), T2 (20°C), T3 (30°C), T4 (40°C), and T5 (50°C). To keep the soils at their prescribed WHC, moisture loss in the jars was determined after every 2 days by weighing the jars and the

159 water loss was replenished with distilled water throughout the incubation (Elliott et al. 1994).
160 Soil samples were collected from each jar after incubation, for the determination of labile,
161 recalcitrant and stable C fractions, microbial community and enzymes.

162 **Quantification of Carbon dioxide (CO_2) emission**

163 The emission of CO_2 from the incubated soil (as described above) was estimated by the alkali
164 trap method as described by Witkamp, (1966). The evolved CO_2 was trapped in 25 ml of 0.1 M
165 KOH. After exposure, the KOH solution was removed, and any carbonate formed precipitated
166 with saturated $BaCl_2$ to form $BaCO_3$; the remaining KOH was then titrated with an equivalent
167 strength of HCl using phenolphthalein as an indicator. A jar without soil, containing the same
168 amount of KOH, was run simultaneously as a blank. The evolved CO_2 was measured at 7, 21, 42,
169 63 and 84 days during incubation. The evolved and cumulative CO_2 was calculated, by using the
170 method of Hassan et al. (2014).

171 **Determination of soil C fractions**

172 **Total organic carbon**

173 Total soil carbon of the soil before and after the experiment was determined by potassium
174 dichromate ($K_2Cr_2O_7$) oxidation at 170-180˚C followed by titration with 0.5 mol L^{-1} $FeSO_4$
175 (Walkley and Black 1934).

176 **Light fraction of organic carbon**

177 Light fraction of organic carbon was measured by wet oxidation ($K_2Cr_2O_7$). Fleetingly, 50 ml
178 NaI solution (1.70 g cm^{-3} density) along with soil sample (25 g) was placed into a centrifuge
179 tube and was shaken (200 rpm) for 15 minutes. The floating material was extracted in triplicate

and transferred to a filter paper and rinsed every time with $CaCl_2$ (0.01M) and distilled water, and then dried (60˚C) for 48 hours (Gregorich and Ellert, 1993).

Readily mineralizable carbon

Readily mineralizable carbon was estimated after extraction with K_2SO_4 (0.5 M) followed by wet digestion with dichromate. Briefly, soil (10 g), after precipitating the Fe^{2+} with 1 ml of $FeCl_3$ (2.5% solution) and 4 ml of 6 N NaOH, was extracted with 40 ml of K_2SO_4 (0.5 M) after shaking for 1 hour at a rotary shaker. After allowing the precipitate to settle down (4°C) clear supernatant (aliquots) were titrated with $FeH_8N_2O_8S_2$ (0.04 N) by using 2 to 3 drops of diphenylamine (DPA) indicator after wet digestion with H_2CrO_4 (Mishra et al. 1997).

Dissolved organic carbon

For dissolved organic carbon fresh soil (10 g) was extracted with the 2.0 M KCl (1:4 soil/water) after shaking (250 rpm) the soil samples for 30 minutes. The supernatant was then centrifuged (15,000 rpm) for 10 minutes and filtered (0.45 µm cellulose ester filters) and analyzed at a TOC (Multi N/C 2100, Germany) analyzer (Zsolnay, 2003).

Particulate organic carbon

The particulate organic carbon was quantified after dispersing the soil sample (10 g) with 30 ml of hexametaphosphate (5 g l^{-1}) in a reciprocating shaker (90 rpm) for 18 hours. The soil suspension was transferred into another clean and empty container under a continuous flow of distilled water over a sieve (53-µm) to ascertain the separation. The remaining soil on the sieve was dried at 55-60˚C for 48 hours after shifting to a glass dish, and ground to powder with a ball mill, and measured (wet digestion) for POC by using $K_2Cr_2O_7$ (Camberdella and Elliott, 1992).

201 **Reducing sugar carbon**

202 The content of reducing sugar carbon was determined using a phenol reagent. One ml of soil
203 extract was mixed with 1 ml of the phenol solution (5% w/v in distilled water), then 5 ml of 18.4
204 M H_2SO_4 (1.84 d) was added under continuous shaking. The mixture was left for 10 minutes,
205 thereafter, incubated in a water bath at 25˚C for 20 minutes and the absorbance was read
206 colorimetrically with a standard curve of glucose at 490 nm by following Badalucco et al. (1992)
207 with slight modification.

208 **Easily oxidizable carbon**

209 For easily oxidizable carbon soil (3 g) was centrifuged (2000 rpm) for 5 minutes along with 25
210 ml of $KMnO_4$ (333 mM) and the absorbance of the supernatant and standards was read
211 spectrometrically at 565 nm. Likewise, the blank samples (no soil + standard) were also analyzed
212 in each run. The change in the concentration of $KMnO_4$ was used to assess the amount of C
213 oxidized by assuming that 1 mM MnO_4 is consumed for the oxidation of 0.75 mM or 9 g of C
214 (Blair et al. 1995).

215 **Recalcitrant organic carbon**

216 The recalcitrant organic carbon was determined by the acid hydrolysis (18 hours) of soil (1 g)
217 with HCl (6 M). The repeated evaporation and filtration were done in order to remove the HCl
218 and separate the soluble materials. The residue was washed with de-ionized water (20 ml) and
219 dried at 55˚C. After drying, the residue was ground and passed through a screen (180 mm), and
220 combusted to CO_2 (Paul et al. 2001).

221 **Analysis of soil microbial colony counts and biomass**

The total number of bacteria, fungus, and actinomycetes was determined using the dilution plate count technique on nutritional agar, as described previously by Hassan et al (2013b). The dilution plate technique is based on the assumption that each colony is created by a single cell, referred to as a colony-forming unit (CFU). In a flask containing 90 ml distilled water and glass beads, 10 g of fresh soil was added (0.5 mm). For 30 minutes, the flask was shaken at 28°C and 180 rpm. 0.1 ml of the suspension was put to a small tube containing 0.9 ml distilled water after shaking. The tube was gently shaken and used to perform the remaining dilutions. To count bacteria, dilutions of 10^{-1}-10^{-8} were utilized. Conversely, a range of 10^{-1}-10^{-6} was used for the determination of fungi and actinomycete. Each dilution was repeated three times In an incubator, the plates were incubated at 28°C (301.15 K). Bacteria, fungi, and actinomycetes were identified four, five, and seven days after plating, respectively (Hassan et al. 2013b). The chloroform fumigation-extraction method was used to determine the microbial biomass, i.e., MBC, MBN, and MBP. For this purpose, 10 g fresh soil was fumigated with alcohol-free chloroform for 24 hours at a temperature of 25°C in a desiccator. The soils (fumigated and non-fumigated) were then extracted for an hour using a horizontal shaker (200 rpm), filtered with Whatman No. 40 filter paper, and finally spectrophotometrically measured and computed (Hassan et al. 2013b).

Examination of enzymes activity

Phenoloxidase and peroxidase activity

The phenoloxidase and peroxidase activity was measured by incubating (25˚C) the soil (0.5 g), in a shaking environment (100 rpm), with acetate buffer (3 ml) and 2 ml of 10 mM L-3,4-dihydroxyphenylalanine (L-DOPA), followed by centrifugation for 10 minutes at 5˚C. For peroxidase, an addition of 0.3% H_2O_2 (0.2 ml), just before incubation, was made. Then the

absorbance of the dopachrome (reaction product) was read at 475 nm spectrophotometrically and activity of both enzymes was expressed as µmol dopachrome g^{-1} h^{-1} (Dick, 2011).

Catalase activity

The catalase activity was measured by titrating residual H_2O_2 in the filtrate with $KMnO_4$ (0.1 N), after mixing the soil (1 g) with 3% H_2O_2 (1 ml) and H_2SO_4 (5 ml) after shaking (20 minutes), followed by filtration. The activity was expressed as µmol H_2O_2 g^{-1} h^{-1} (Roberge, 1978).

Invertase activity

The activity of invertase was determined by incubating (24 hours at 37˚C) the soil (5 g) with sucrose solution (15 ml), phosphate buffer (35.6 g Na_2HPO_4 + 700 ml distilled H_2O + adjust pH to 5.5 with HCl + volume to 1 liter) and toluene (4-5 drops), followed by filtration. The activity (color density) was measured spectrophotometrically at 508 nm, after mixing the filtrate (1 ml) with 0.5% $C_7H_4N_2O_7$ (2 ml), heating (5 minutes) in a boiling water bath and colling (3 minutes) it down under running water and making the final volume to 25 ml with deionized H_2O and described as µmol glucose g^{-1} h^{-1} (Dick, 2011).

β-glucosidase activity

The β-glucosidase activity was estimated by incubating and treating (1 hour at 37˚C) the soil (1 g) with 0.25ml toluene, 0.25mn *p*-nitrophenol phosphate (*p*-NPP), 4ml MUB (Modified universal buffer), 1 ml of glucoside, 1 ml of $CaCl_2$ (0.5 M) and 4ml of o.1 M THAM (Tris-hydroxymethyl-aminomethane) solution. After filtration (Whatman No. 2V) the activity was determined through spectrophotometer at 400 nm and described as µmol *p*-nitrophenol g^{-1} h^{-1} (Eivazi and Tabatabai, 1988).

265 **Cellulase activity**

266 The cellulase activity was measured after incubating (24 hours, 50°C), centrifuging (2500xg, 10
267 min) and treating the soil (10 g) with 5ml acetate buffer (11.2 M, pH 5.5), carboxymethyl
268 cellulose sodium (7 g) and cellulose substrate (0.7%). After filtration the activity was determined
269 through spectrophotometer at 690 nm and described as µmol glucose g^{-1} h^{-1} (Schinner and Von
270 Mersi, 1990).

271 **Statistical Analysis**

272 The statistical software Statistix 8.1 (Statistix, USA), and Excel 2016 were used for data
273 analysis. Parametric statistics of ANOVA analysis was carried out to estimate the effect of
274 temperature on the soil microbes, microbial biomass, enzymes, C fractions and CO_2 production
275 and emissions under divergent textures. Mean separations were achieved by using the least
276 significant difference (LSD) test at $p < 0.05$. Data presented are means ± standard deviation (SD)
277 of three replicates of each treatment. Correlation coefficients (R^2) between soil C fractions of
278 labile, recalcitrant, and stable pools, CO_2 emissions and cumulative CO_2, microbial community,
279 microbial biomass, oxidative and hydrolytic enzymes and temperature were developed by using
280 the same software.

281 **RESULTS**

282 **Labile C fractions**

283 The response and decomposition of labile C fractions viz LFOC, DOC, RMC, RSC, POC, and
284 EOC under a range of elevated temperature (T1-T5) regimes in sandy and clayey soil is
285 presented in Fig. 1. The response and decomposition of labile C fractions increased significantly
286 ($P < 0.05$) with the increase in the temperature (per 10°C rise). However, the temperature

response and decomposition of labile C fractions were significantly ($P < 0.05$) higher in sandy than the clayey soil. Therefore, in sandy soil, the maximum increase in the LFOC (2.92-fold), DOC (3.34-fold), RMC (4.07-fold), RSC (4.54-fold), POC (3.51-fold), and EOC (4.02-fold) was observed at the highest temperature i.e., T5 compared to lowest temperature (T1). Conversely, in clayey soil, maximum increase in the LFOC (2.41-fold), DOC (2.05-fold), RMC (3.17-fold), RSC (2.98-fold), POC (2.71-fold), and EOC (3.03-fold) was observed at the T4 compared to lowest temperature (T1). Whereas, the minimum sensitivity and decomposition of labile C fractions were observed at the lowest temperature i.e., T1. Furthermore, owing to higher temperature impact and decomposition, the sandy soil exhibited significantly lower labile C fractions i.e., LFOC (1.14-fold), DOC (1.17-fold), RMC (1.14-fold), RSC (1.15-fold), POC (1.16-fold), and EOC (1.17-fold) compared to the clayey soil. Mainly the effect of temperature on the labile C fractions in the sandy soil was in the order T4 > T5 > T3 >T2 >T1. Conversely, the influence of temperature on the labile C fractions in the clayey soil was in the order T5 > T4 > T3 >T2 >T1.

Recalcitrant C fractions

The response and decomposition of recalcitrant C fraction viz ROC under a range of elevated temperature (T1-T5) regime in sandy and clayey soil is illustrated in Fig. 2. The response and decomposition of ROC enhanced markedly ($P < 0.05$) with the temperature increase (per 10˚C rise) in both textured soils. Unlike the labile C fractions, the increase in temperature caused a significant and continuous increase in the response and decomposition of ROC under both textured soils. Therefore, the maximum increase in the ROC (3.16-fold and 3.72-fold) was observed at the highest temperature i.e., T5 in sandy and clayey soil respectively compared to lowest temperature (T1). Whereas, the minimum response and decomposition of ROC were

observed at the lowest temperature i.e., T1. Due to the higher temperature effect and decomposition, the decrease in the ROC was higher (1.15-fold) in sandy compared to clayey soil. In general, the effect of temperature on the ROC in both soils was in the order T5 > T4 > T3 > T2 > T1 endorsing, the fact that ROC likely has higher sensitivity to temperature (T1-T5) increase than the labile C fractions.

Stable C fractions

The response and decomposition of stable C fractions viz TOC under a range of elevated temperature (T1-T5) regime in sandy and clayey soil is presented in Fig. 3. The response and decomposition of TOC enhanced greatly ($P < 0.05$) with the temperature increase (per 10˚C rise) in both textured soils. Unlike the labile and stable C fractions the increase in temperature significantly ($P < 0.05$) decreased the TOC. Therefore, the maximum decrease in the TOC (3.89-fold and 3.60-fold) was observed at the highest temperature (T5) in both sandy and clayey soil respectively compared to lowest temperature (T1). Highlighting that TOC has a strong ($P < 0.05$) antagonistic association to the temperature increase (T1-T5). Whereas, the minimum response and decomposition of TOC were observed at the lowest temperature i.e., T1. Owing to the higher temperature effect and decomposition, the decrease in the TOC was higher (1.14-fold) in sandy compared to the clayey soil. In general, the effect of temperature on the TOC decomposition and sensitivity was in the order T5 > T4 > T3 > T2 > T1.

Microbial community

The response of soil microbes i.e., bacteria, fungi, and actinomycetes under a range of elevated temperature (T1-T5) regimes in sandy and clayey soils is exhibited in Fig. 4. The response of the soil microbes increased significantly ($P < 0.05$) with the temperature increases (per 10˚C rise) in

both textured soils. However, the temperature sensitivity and response of the soil microbes were significantly ($P < 0.05$) variable. The bacteria showed the maximum temperature response (2.22-fold and 2.57-fold) at the highest temperature (i.e., T5) in sandy and clayey soils correspondingly compared to lowest temperature (T1). Conversely, the maximum increase in the response of actinomycetes (2.01-fold and 2.52-fold) and fungi (1.64-fold and 1.73-fold) were found at T4 and T3 in sandy and clayey soils respectively compared to lowest temperature (T1). Indicating the fact that among soil microbes the temperature sensitivity order is bacteria > actinomycetes > fungi. Whereas, the minimum sensitivity and response of soil microbes were observed at the lowest temperature i.e., T1. Besides, owing to higher temperature effect and sensitivity, the sandy soil showed a markedly lower soil microbes count i.e., bacteria (1.34-fold), fungi (1.12-fold), and actinomycetes (1.14-fold) compared to clayey soil. In general, the effect of temperature on the bacterial counts was in the order T5 > T4 > T3 > T2 > T1. Whereas the temperature sensitivity of actinomycetes and fungi were in an order of T4 > T5 > T3 > T2 > T1 and T3 > T4 > T5 > T2 > T1 respectively.

Microbial biomass

The response of microbial biomass i.e., MBC, MBN, and MBP under a range of elevated temperature (T1-T5) regimes in sandy and clayey soils is presented in Fig. 5. The response of microbial biomass increased significantly ($P < 0.05$) with the temperature surge (per 10˚C rise) in both textured soils. However, like soil microbes colony counts, the temperature sensitivity of microbial biomass was also significantly ($P < 0.05$) variable. The MBC exhibited the maximum temperature sensitivity and increase (1.97-fold and 2.21-fold) at the highest temperature (i.e., T5) in sandy and clayey soils correspondingly compared to lowest temperature (T1). On the contrary, the maximum increase in the MBN (2.11-fold and 2.22-fold) and MBP (1.84-fold and 2.31-fold)

were found at T4 and T3 in sandy and clayey soils respectively compared to lowest temperature (T1). Indicating the fact that among microbial biomass the temperature sensitivity order is MBC > MBN > MBP. Whereas, the minimum sensitivity and response of microbial biomass were observed at the lowest temperature i.e., T1. Moreover, due to the higher temperature effect and sensitivity the sandy soil exhibited a significantly lower microbial biomass i.e., MBC (1.23-fold), MBN (1.29-fold), and MBP (1.43-fold compared to the clayey soil. The temperature sensitivity order for MBC was T5 > T4 > T3 > T2 > T1. Whereas the temperature sensitivity order for MBN and MBP was T4 > T5 > T3 > T2 > T1 and T3 > T4 > T5 > T2 > T1 respectively.

Oxidative enzymes

The response and activity of oxidative enzymes viz PO, PEO, and CAT under a range of elevated temperature (T1-T5) regimes in sandy and clayey soil are shown in Fig. 6. However, unlike the hydrolytic enzymes, a significant ($P < 0.05$) and continuous increase in the activity of oxidative enzymes was observed with the increase in the temperature (per 10˚C rise). As a result, the maximum increase in the activity of PO (2.61-fold and 4.07-fold), PEO (3.08-fold and 6.77-fold), and CAT (2.18-fold and 2.71-fold) were found at the highest temperature i.e., T5 in sandy and clayey soils respectively compared to lowest temperature (T1). Whereas minimum response and activity of oxidative enzymes were observed at the lowest temperature i.e., T1. Establishing the fact that oxidative enzymes have decidedly higher responsiveness to temperature increase than the hydrolytic enzymes. Furthermore, owing to the higher temperature effect, the sandy soil showed a markedly lower activity and values of oxidative enzymes i.e., PO (1.69-fold), PEO (1.48-fold), and CAT (1.24-fold) compared to the clayey soil. The overall effect of temperature on the sensitivity and activity of oxidative enzymes was in the order T5 > T4 > T3 > T2 > T1.

Hydrolytic enzymes

The response and activity of hydrolytic enzymes viz INV, BGL, and CELL under a range of elevated temperature (T1-T5) regimes in sandy and clayey soils are depicted in Fig. 7. Generally, an increasing trend was observed in the activity of hydrolytic enzymes under elevated temperature (per 10°C rise). However, unlike the oxidative enzymes, the maximum increase in the activity of INV (1.71-fold and 2.01-fold), BGL (1.85-fold and 2.22-fold), and CELL (1.81-fold and 2.23-fold) were found at T4 in sandy and clayey soils respectively compared to lowest temperature (T1). After that, an abrupt decrease in the activity of hydrolytic enzymes was examined at the highest temperature i.e., T5 compared to lowest temperature (T1). Whereas, the minimum activity of hydrolytic enzymes was observed at the lowest temperature (T1). Additionally, due to the higher temperature effect, the sandy soil depicted a significantly lower activity and values of hydrolytic enzymes i.e., INV (1.25-fold), BGL (1.23-fold), and CELL (1.29-fold) compared to the clayey soil. The overall effect of temperature on the response and activity of hydrolytic enzymes was in the order T4 > T5 > T3 > T2 > T1.

Emissions and cumulative CO_2

The response and changes in the emissions and cumulative CO_2 under a range of elevated temperature (T1-T5) regimes in sandy and clayey soils are illustrated in Fig. 8. Overall, an increasing trend was found in the emissions and cumulative CO_2 for each 10°C rise in temperature. However, the temperature responsiveness and changes in emissions and cumulative CO_2 were significantly ($P < 0.05$) higher in sandy than the clayey soil. Therefore, in sandy soil, the maximum increase in the emissions (1.84-fold) and cumulative CO_2 (1.81-fold) were observed at the highest temperature (T5) compared to lowest temperature (T1). Conversely, in clayey soil, higher emissions (1.45-fold) and cumulative CO_2 (1.36-fold) were observed at the T4 compared to lowest temperature (T1). After that, in clayey soil, a decrease in the response and

thus values of emissions and cumulative CO_2 were examined at the highest temperature i.e., T5. Whereas, the minimum sensitivity and changes in emission and cumulative CO_2 were observed at the lowest temperature (i.e. T1). Furthermore, unlike other key soil processes, the sandy soil showed greater increase in the emissions (1.22-fold) and cumulative CO_2 (1.23-fold) owing to higher temperature effect, decomposition rate and changes than the clayey soil. Underscoring the fact that CO_2 production and emissions and cumulative CO_2 have positive feedback with the augmentation in the temperature, and sandy soil are more vulnerable than the clayey ones. Mainly the effect of temperature on the sensitivity and emissions and cumulative CO_2 in the sandy soil was in the order T5 > T4 > T3 > T2 > T1. Conversely, the influence of temperature on the sensitivity and emission and cumulative CO_2 in the clayey soil was in the order T4 > T5 > T3 > T2 >.

Regression analysis

Regression analysis showed that C fractions of labile, recalcitrant, and stable pools, CO_2 fluxes, and cumulative CO_2 correlated well with the temperature in both sandy and clayey soils (Table 1B). Nonetheless, overall, temperature accounted for 93% and 79% variability in the C fractions of labile, recalcitrant, and stable pools in the sandy and clayey soils correspondingly (Table 1B). Whereas, temperature accounted for 91% and 94% variability in the CO_2 fluxes and cumulative CO_2 in the sandy soil. Conversely, temperature described for 78% and 75% alterability in the CO_2 fluxes and cumulative CO_2 in the clayey soil (Table 1B). Furthermore, temperature accounted variability was significantly higher for C fractions of recalcitrant and stable pools compared to labile pools in both sandy and clayey soils (Table 1B). Regression analysis showed that overall, temperature accounted for 85% and 72% variability in the microbial community in the sandy and clayey soils (Table 2A). The temperature accounted variability was significantly

higher for bacteria (R^2 = 0.97 and 0.91) than actinomycetes (R^2 = 0.92 and 0.81) and fungi (R^2 = 0.68 and 0.46) in both sandy and clayey soils (Table 2A). Moreover, the temperature described alterability was markedly higher in sandy soil than clayey soil (Table 2A). Whereas, temperature designated for 88% and 78% variability in the microbial biomass in the sandy and clayey soils (Table 2A). The temperature accounted alterability was significantly higher for MBC (R^2 = 0.98 and 0.92) than MBN (R^2 = 0.91 and 0.80) and MBP (R^2 = 0.75 and 0.63) in both sandy and clayey soils (Table 2A). Moreover, the temperature designated changeability was markedly higher in sandy soil than clayey soil (Table 2A). Regression analysis showed that overall, temperature accounted for 93% and 86% variability in the oxidative enzymes in the sandy and clayey soils (Table 2B). Whereas, temperature accounted for 73% and 66% variability in the hydrolytic enzymes in the sandy and clayey soils (Table 2B). The temperature described alterability was significantly higher for oxidative enzymes than hydrolytic enzymes. Moreover, the temperature accounted variability was markedly higher in sandy soil than clayey soil (Table 2B).

DISCUSSION

The responsiveness and decomposition of labile C fractions increased significantly ($P < 0.05$) with the temperature increase (per 10˚C) in both textured soils (Fig. 1). Yang et al. (2021) and Qi et al. (2016) assessed that temperature increase significantly alters the fractions of soil labile organic C (RSC, MBC, DOC, and POC) by increasing their response and rate of decomposition. However, response to the temperature and decomposition of labile C fractions were significantly ($P < 0.05$) higher in sandy soil than the clayey soil (Fig. 1). Temperature accounted variability for labile C fractions was significantly higher in sandy soil than clayey soil (Table 1B). Wankhede et al. (2020), Rittl et al. (2020), Takriti et al. (2018), Ghosh et al. (2016), Frøseth and

447 Bleken, (2015) and Hobley et al. (2014) found that temperature impacts on labile C fractions was
448 higher in coarse (sandy) than fine (clayey) soils owing to low physical protection, small specific
449 areas, fewer reactive sites, and weak ligand exchange bridges, where soil C could be sorbed and
450 protected. In present study, unlike the labile C fractions, the increase in temperature (T1-T5)
451 caused a significant ($P < 0.05$) and continuous increase in the sensitivity and decomposition of
452 recalcitrant (ROC) and stable (TOC) C fractions (Figs. 2 and 3) in both soils. Whereas, the
453 temperature impacts and thus decomposition of ROC (1.15-fold) and TOC (1.14-fold) were
454 significantly higher in sandy soil at T5 i.e. 50°C (Figs. 2 and 3). Wankhede et al. (2020) and
455 Zheng et al. (2019) examined that in sandy (coarse) soils the temperature response of recalcitrant
456 and stable C fractions was much higher due to weak physical protection, fewer cations bridges,
457 unstable moisture availability, and their low storing ability. The response of C fractions to
458 temperature was in the order recalcitrant C fractions > stable C fractions > labile C fractions
459 (Figs. 1-3). In both sandy and clayey soils, temperature accounted variability was significantly
460 higher for C fractions of recalcitrant and stable pools compared to labile pools (Table 1B). Zhang
461 and Zhou, (2018) and Dai et al. (2017) found that recalcitrant and stable C fractions have
462 decidedly extra sensitivity than the labile fractions to the temperature increase (5°C-30°C) in
463 divergent coarse and fine textured Chinese soils. The results of current study also endorsed the
464 fact that recalcitrant and stable C fractions have a higher sensitivity to temperature (T1-T5)
465 increase than the labile C fractions (Figs. 1-3). Higher R^2 were found for recalcitrant and stable
466 C fractions than labile ones in both sandy and clayey soils (Table 1B). Biswas et al. (2018), Lian
467 et al. (2018), Fang et al. (2016) and Nguyen et al. (2010) confirmed that recalcitrant and stable C
468 fractions have higher responses to temperature than the labile C fractions in coarse and fine
469 textured soils.

The response of soil microbial counts and microbial biomass increased markedly ($P < 0.05$) with the temperature increase (per 10˚C rise) in both sandy and clayey textured soils. However, the temperature responses of microbial colony counts i.e., bacteria (1.34-fold), fungi (1.12-fold), and actinomycetes (1.14-fold) and biomass i.e., MBC (1.23-fold), MBN (1.29-fold), and MBP (1.43-fold) were higher in sandy soil (Figs. 4 and 5). Overall, in sandy soil, temperature accounted for significantly higher variability in microbial population (85%) and microbial biomass (88%) than in clayey soil (Table 2A). Qu et al. (2020), Nottingham et al. (2019), Hutchins et al. (2019), Zhang et al. (2016), Fang et al. (2016), and Hassan et al. (2013a) examined that microbial counts (bacteria, fungi, and actinomycetes) and biomass (MBC, MBN, and MBP) had higher sensitivity to temperature increase and their sensitivity increased many folds in coarse (sandy) soils owing to less favorable conditions, predation, desiccation, and substrate availability. The results further, revealed that temperature sensitivity and response of soil microbes colony counts and biomass were significantly variable (Figs. 4 and 5). Cavicchioli et al. (2019), Zhang et al. (2016) and Fang et al. (2016) also examined variations in the activity, behavior, and response of microbial community and biomass towards experimental warming and temperature increase. The temperature response of soil microbes colony counts and biomass were in the order bacteria > actinomycetes > fungi and MBC > MBN > MBP (Table 2A). Therefore, the maximum activity and response of bacteria, actinomycetes and fungi and MBC, MBN, and MBP were observed at temperatures T5, T4 and T3 in both soils respectively (Figs. 4 and 5). Zheng et al. (2019), Dubey et al. (2019), Walker et al. (2018), and Zhang et al. (2016) found a strong association between temperature increase and responses of soil microbes colony counts and biomass and stated that temperature sensitivity of bacteria and MBC is much higher followed by actinomycetes and fungi and MBN and MBP in diverse textured soils (coarse and

fine). The temperature accounted variability was significantly higher for bacteria (R^2 = 0.97 and R^2 = 0.91) than actinomycetes and fungi in both sandy and clayey soils (Table 2A). Romero-Olivares et al. (2017), Zhang et al. (2016), García-Palacios et al. (2015), and Wang et al. (2014) also stated that among microbes and biomass, bacterial community and MBC have decidedly higher sensitivity, contrarily, fungi are less sensitive to changes in temperature owing to the chitinous cell walls that make them highly resilient. The temperature accounted variability was significantly higher for MBC (R^2 = 0.98 and R^2 = 0.92) than MBN and MBP in both sandy and clayey soils (Table 2A). Melillo et al. (2017), and Crowther et al. (2016) also found a significant association between the increase in temperature (warming), temperature sensitivity, and reduction in the microbial biomass and stated that temperature sensitivity of MBC is markedly higher.

The extracellular enzymes (i.e., oxidative and hydrolytic) response and activity increased significantly ($P < 0.05$) with the temperature increase (per 10°C rise) in both textured soils. However, the temperature response of oxidative enzymes i.e., PO (1.69-fold), PEO (1.48-fold), and CAT (1.24-fold) and hydrolytic enzymes i.e., INV (1.25-fold), BGL (1.23-fold), and CELL (1.29-fold) were markedly higher in sandy soil (Figs. 6 and 7). The temperature accounted variability for oxidative and hydrolytic enzymes was markedly higher in sandy soil than clayey soil (Table 2B). Wankhede et al. (2020), Cavicchioli et al. (2019), Zheng et al. (2019), Thakur et al. (2016), and Fang et al. (2016) assessed a significant increase in the sensitivity and response of extracellular enzymes i.e., oxidative and hydrolytic with the temperature increase and stated that temperature sensitivity increases strongly in sandy (coarse) soils due to less favorable conditions, unstable moisture, and substrate availability. The results of present study further revealed that the temperature sensitivity of extracellular enzymes was in the order oxidative enzymes > hydrolytic

516 enzymes (Figs. 6 and 7). The temperature accounted variability was significantly higher for
517 oxidative enzymes (93% and 86%) than hydrolytic enzymes (73% and 66%) in both sandy and
518 clayey soils (Table 2B). Establishing the fact that oxidative enzymes have higher temperature
519 sensitivity than the hydrolytic enzymes in both sandy and clayey soils. Meng et al. (2020), Tang
520 et al. (2019), Walker et al. (2018), Allison et al. (2018), Cheng et al. (2017), and Fang et al.
521 (2016) examined a strong synergistic association between extracellular enzymes sensitivity and
522 temperature and revealed that oxidative enzymes (e.g., PO, PEO, and CAT) have decidedly
523 higher temperature sensitivity than the hydrolytic (e.g., DEH, URE, INV, BGL, and PHP)
524 enzymes.

525 Overall, an increasing trend was found in the emissions and cumulative CO_2 under
526 elevated i.e., each 10˚C rise in temperature in both sandy and clayey soils (Fig. 8). However, the
527 temperature effect and changes in emissions and cumulative CO_2 were significantly ($P < 0.05$)
528 higher in sandy than the clayey soil. Temperature accounted for 91% and 94% variability in the
529 CO_2 emissions and cumulative CO_2 in the sandy soil (Table 1B). Sánchez-Cañeteet al. (2018),
530 Zomer et al. (2017), Ekwurzel et al. (2017), Fang et al. (2016) and Frøseth and Bleken, (2015)
531 examined a significant increase in the emissions and cumulative CO_2 with the temperature rise
532 and stated that coarse i.e., sandy soils have much higher temperature effect thus emissions and
533 cumulative CO_2 than the fine (clayey or silty) soils. Therefore, in sandy soil, the maximum
534 increase in the CO emissions (1.84-fold) and cumulative CO_2 (1.81-fold) was observed at the
535 highest temperature (T5). Furthermore, the sandy soil showed significantly ($P < 0.05$) higher
536 CO_2 emissions (1.22-fold) and cumulative CO_2 (1.23-fold) owing to higher temperature effect,
537 response and decomposition rate than the clayey soil (Fig. 8). Significantly higher correlation
538 coefficients were observed between CO_2 emissions ($R^2 = 0.91$) and cumulative CO_2 ($R^2 = 0.94$)

539 and temperature in sandy soil than clayey soil (Table 1B). Wachiye et al. (2020), Badagliacca et
540 al. (2017), Frøseth and Bleken, (2015) and Ding et al. (2014) found a significantly higher
541 responsiveness of CO_2 emissions and cumulative CO_2 to temperature in the sandy soils and
542 established that this was due to high rate of C decomposition, low humification, and small
543 specific areas in sandy soils, where soil C could be sorbed, secured and stored. Underscoring the
544 fact that CO_2 production and emissions and cumulative CO_2 have a strong synergistic association
545 with the temperature augmentation, and sandy soils have much higher temperature sensitivity
546 and vulnerability to become CO_2-C sources than the clayey ones (Fig. 8 and Table 1B).
547 Temperature accounted for significantly lower variability for the CO_2 fluxes (78%) and
548 cumulative CO_2 (75%) in clayey soil compared to sandy soil (Table 2). Oertel et al. (2016),
549 Frøseth and Bleken, (2015), Zhang et al. (2015) and Six and Paustian, (2014) inspected that the
550 sandy soils are more sensitive to temperature increase and the main reason of sandy/coarse soils
551 to foster higher CO_2 production and emissions and cumulative CO_2 is high decomposition rate,
552 low humification and availability of C sorption, and attachment sites.

553

554 **CONCLUSION**

555 The study concluded that the temperature sensitivity of soil C fractions, microbial colony counts,
556 microbial biomass, extracellular enzymes, and CO_2 fluxes increased with the upsurge in
557 temperature. However, the recalcitrant and stable C fractions have decidedly higher responses
558 than labile C fractions. Alike, among microbes, microbial biomass, and extracellular enzymes,
559 bacteria, MBC, and oxidative enzymes (PO, PEO, and CAT) have markedly higher sensitivity. It
560 was concluded that the temperature effect and variability for all measured key soil processes
561 along with CO_2 fluxes were markedly higher in sandy textured soil. Conversely, clayey texture
562 performed a significant role in the mitigation of undue temperature influence, hence, the

sensitivity of key soil processes and CO_2 fluxes. The study also suggests between sandy and clayey textured soils, the soils which are sandy in nature under the scenario of global warming, are more vulnerable to become CO_2-C sources therefore must be managed and treated wisely. Furthermore, in future research and models instead of generalizing effects of global warming, temperature sensitivity of individual key soil processes must also be considered carefully. The findings of the study will be helpful in alleviating the controversy of the temperature sensitivity of key soil processes in sandy and clayey soils. And enabling the scientists and environmentalists to formulate measures and devise recommendations to reduce the excessive increase in CO_2-C fluxes from divergent textured soils.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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Author contribution

WH conceptualized and conducted the study and led the writing. TS analyzed the data and prepared figures and tables under WH's supervision. LY, and JW reviewed and improved the manuscript. All authors contributed to this work and approved the final manuscript prior to submission.

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764 **Figure captions**

765 **Fig 1.** Effect of temperature on labile C fractions under sandy and clayey texture

766 LFOC, light fraction of organic carbon; DOC, Dissolve organic carbon; RMC, readily
767 mineralizable carbon; RSC, reducing sugar carbon; POC, Particulate organic carbon; EOC,
768 easily oxidizable carbon

769 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

770 **Fig 2.** Effect of temperature on recalcitrant C fraction under sandy and clayey texture

771 ROC, recalcitrant organic carbon

772 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

773 **Fig 3.** Effect of temperature on stable C fraction under sandy and clayey texture

774 TOC, total organic carbon

775 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

776 **Fig 4.** Effect of temperature on microbial community under sandy and clayey texture

777 Units: Bacteria, CFU×10^6 g^{-1}; Fungi, CFU×10^4 g^{-1}; Actinomycetes, CFU×10^5 g^{-1}

778 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

779 **Fig 5.** Effect of temperature on microbial biomass under sandy and clayey texture

780 MBC, microbial biomass carbon, MBN, microbial biomass nitrogen; MBP, microbial biomass
781 phosphorous

782 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

783 **Fig 6.** Effect of temperature on oxidative enzymes activity under sandy and clayey texture

784 PO, phenol oxidase; PEO, peroxidase; CAT, Catalase

785 Units: PO and PEO, µmol dopachrome g^{-1} h^{-1}; CAT, µmol H_2O_2 g^{-1} h^{-1}

786 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

787 **Fig 7.** Effect of temperature on hydrolytic enzymes activity under sandy and clayey texture

788 INV, Invertase; BGL, β-glucosidase; CELL, cellulose

789 Units: INV, µmol glucose g^{-1} h^{-1}; BGL, µmol *p*-nitrophenol g^{-1} h^{-1}; CELL, µmol glucose g^{-1} h^{-1}

790 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

791 **Fig 8.** Effect of temperature on CO_2 emissions and cumulative CO_2 under sandy and clayey
792 texture

793 Unit: CO_2 emission, mg kg^{-1} h^{-1}; Cumulative CO_2, mg kg^{-1}

794 Vertical bars represent means ± SD (n = 3). ANOVA significant at $p \leq 0.05$

795

796

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799

800

Figure 1

Effect of temperature on labile C fractions under sandy and clayey texture

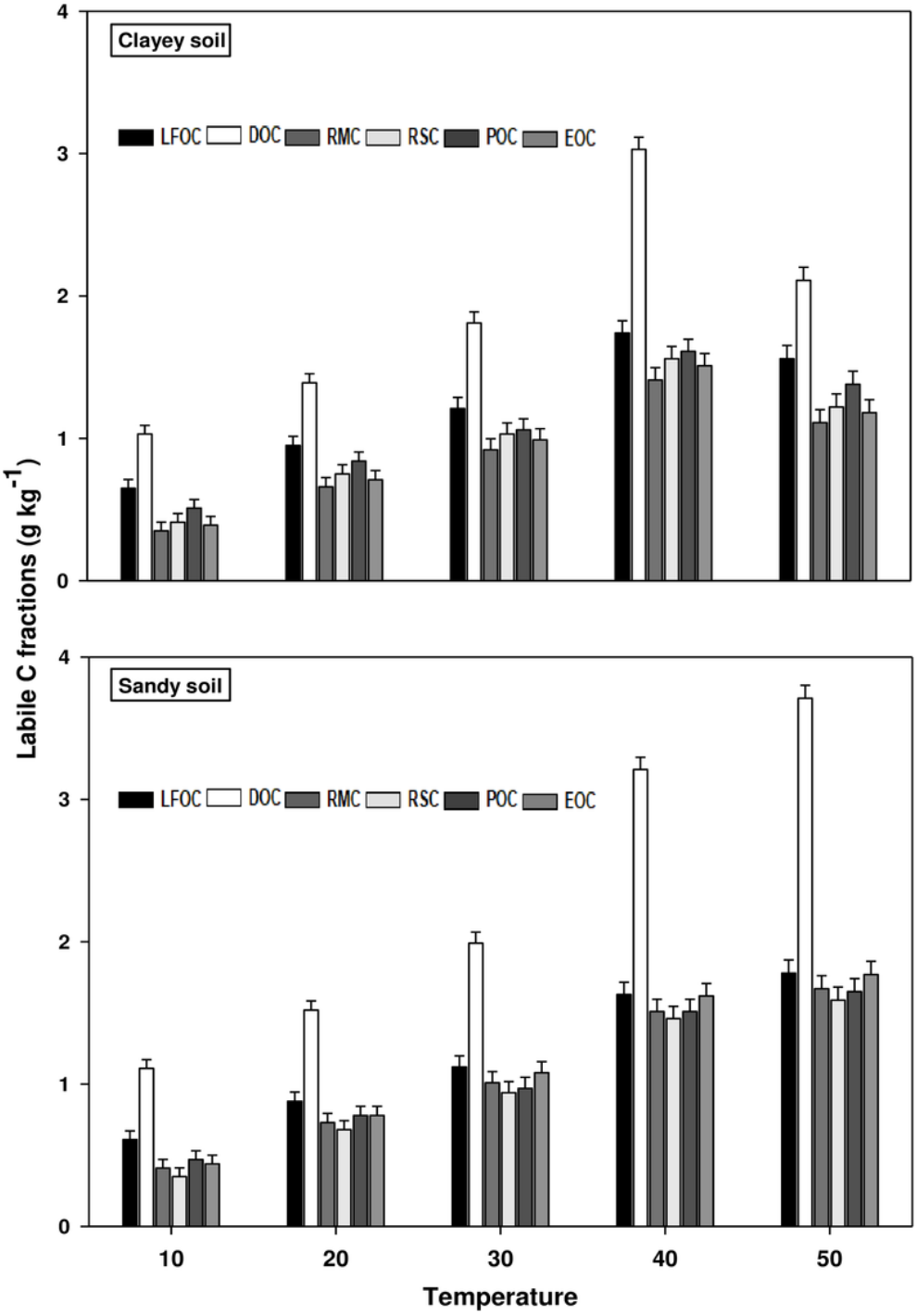

Clayey soil
LFOC
DOC
RMC
RSC
POC
EOC
Sandy soil
Labile C fractions (g kg-1)
Temperature
0
1
2
3
4
10
20
30
40
50

Fig. 1

Figure 2

Effect of temperature on recalcitrant C fraction under sandy and clayey texture

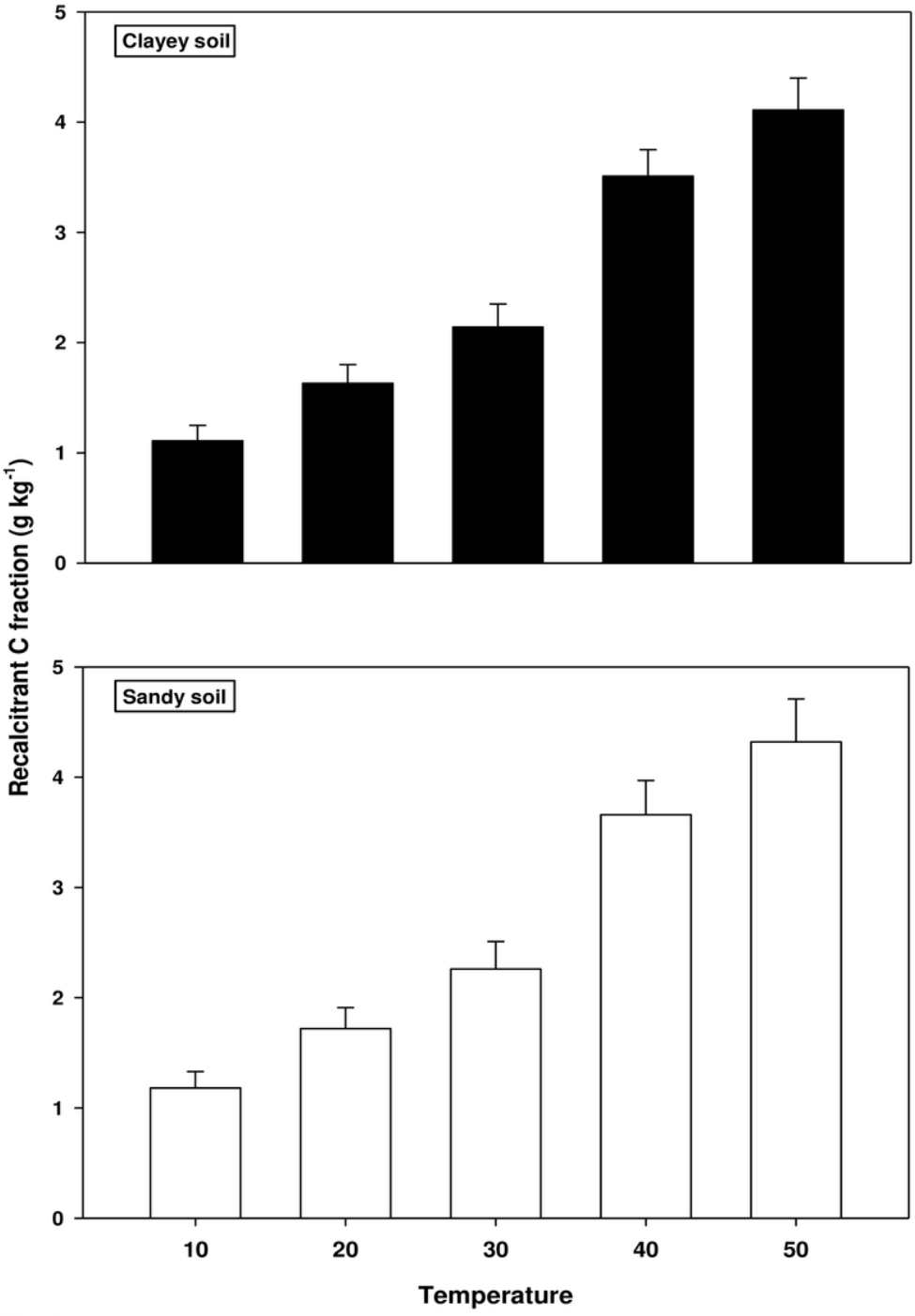

Clayey soil
Sandy soil
Recalcitrant C fraction (g kg-1)
0
1
2
3
4
5
10
20
30
40
50
Temperature

Fig. 2

Figure 3

Effect of temperature on stable C fraction under sandy and clayey texture

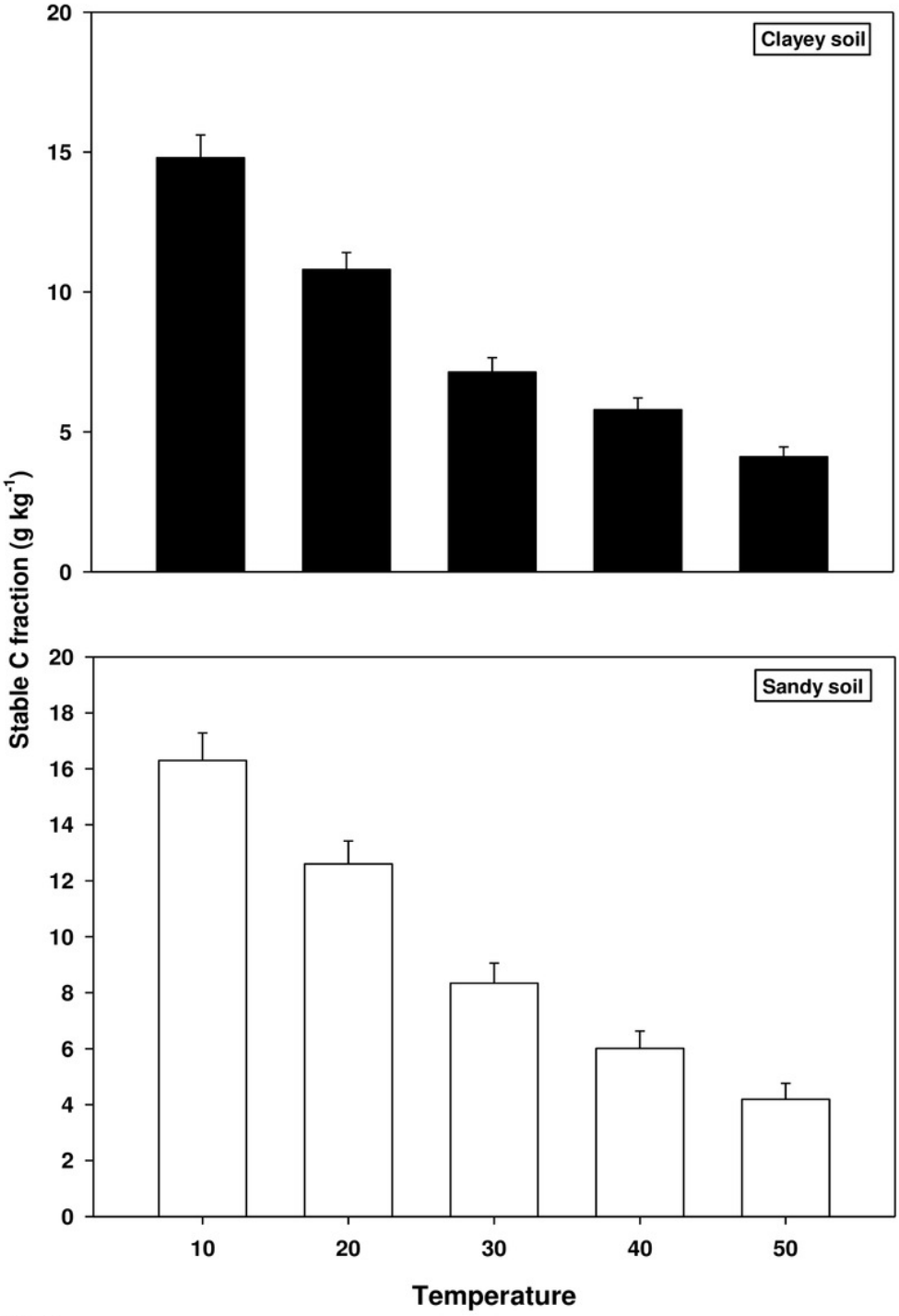

Clayey soil
Sandy soil
Stable C fraction (g kg-1)
Temperature
0
5
10
15
20
2
4
6
8
12
14
16
18
10
20
30
40
50

Fig. 3

Figure 4

Effect of temperature on microbial community under sandy and clayey texture

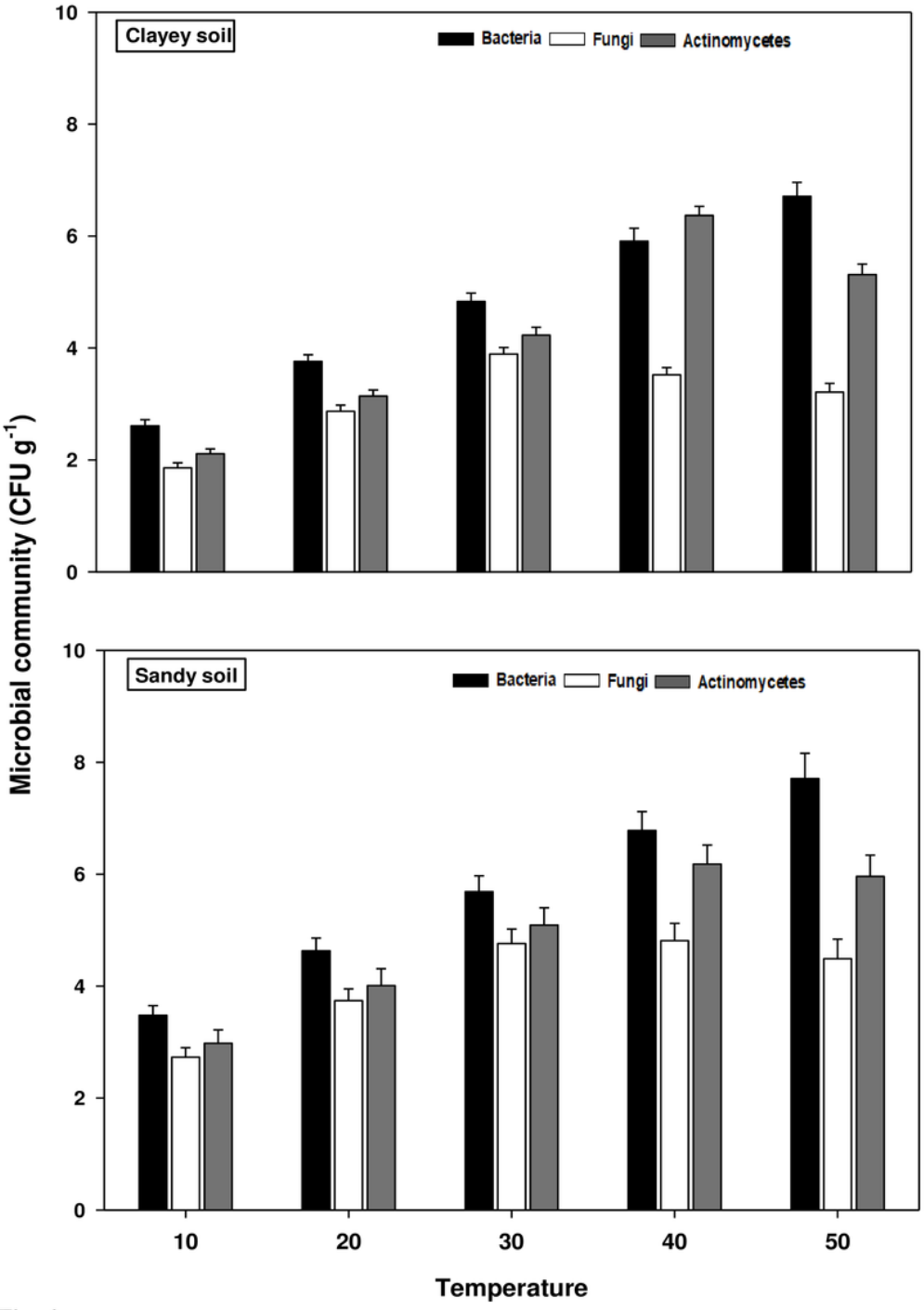

Clayey soil
Bacteria
Fungi
Actinomycetes
Sandy soil
Bacteria
Fungi
Actinomycetes
Microbial community (CFU g-1)
0
2
4
6
8
10
10
20
30
40
50
Temperature

Fig. 4

Figure 5

Effect of temperature on microbial biomass under sandy and clayey texture

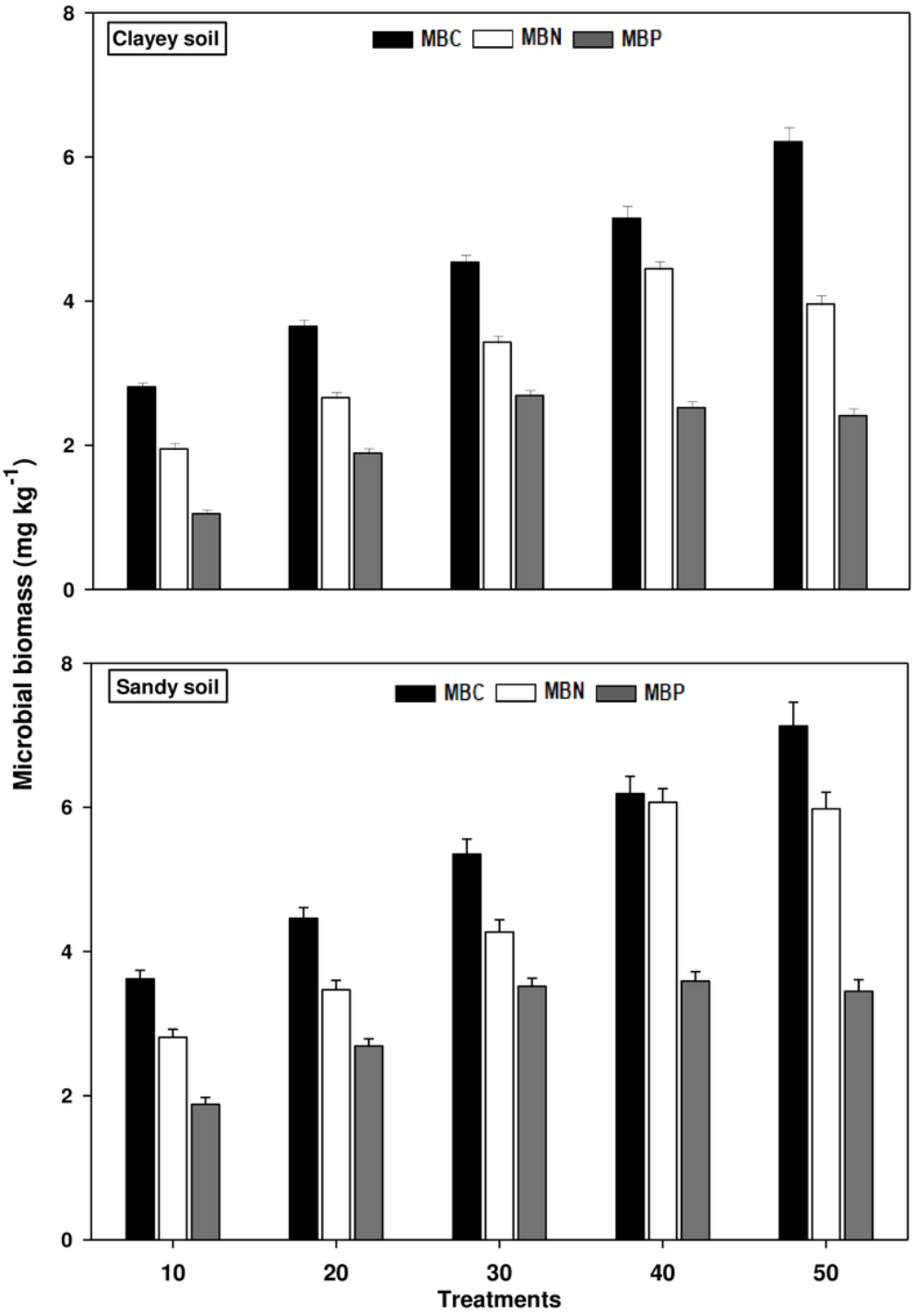

Clayey soil
MBC
MBN
MBP
Sandy soil
MBC
MBN
MBP
Microbial biomass (mg kg-1)
0
2
4
6
8
10
20
30
40
50
Treatments

Fig. 5

Figure 6

Effect of temperature on oxidative enzymes activity under sandy and clayey texture

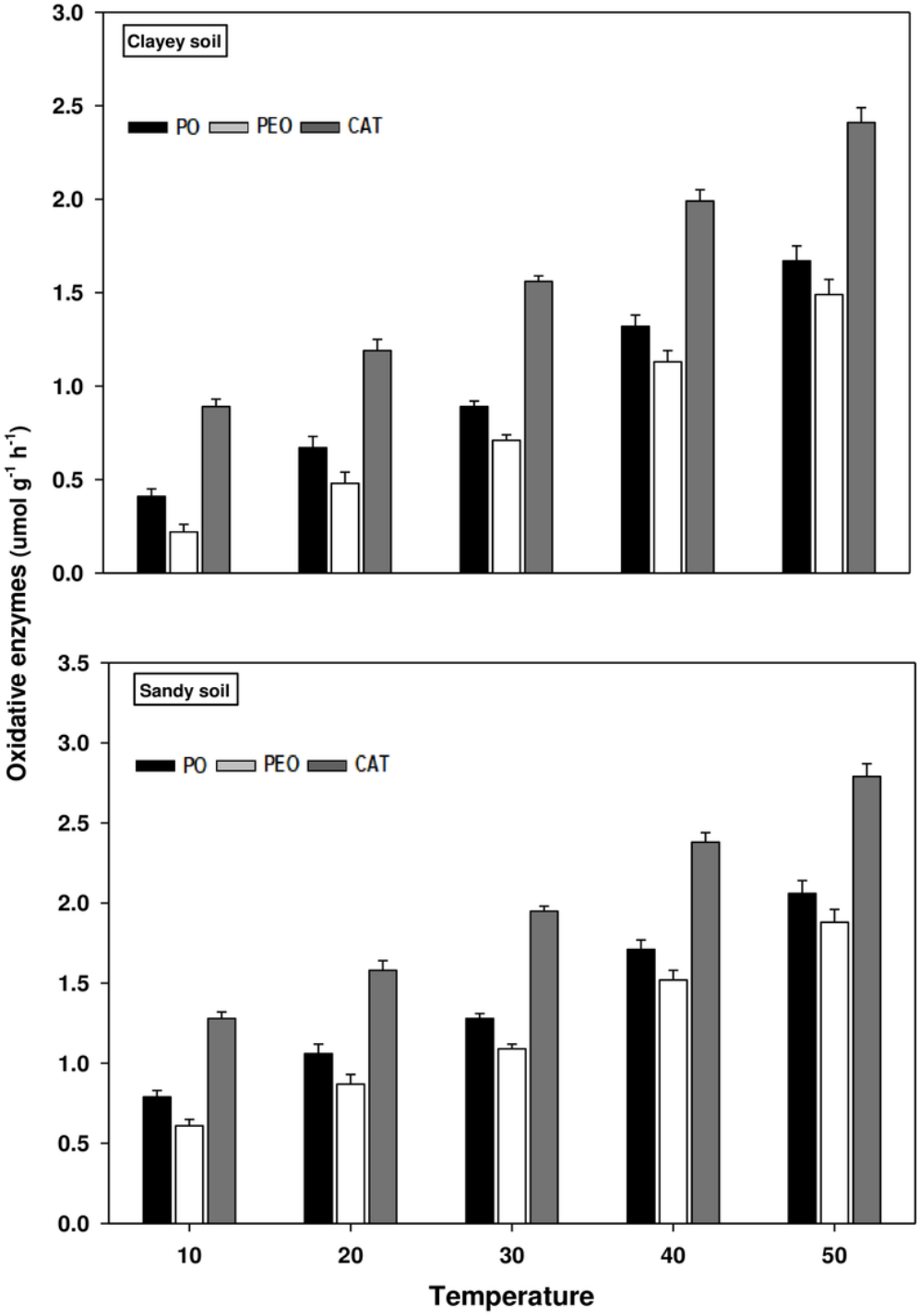

Clayey soil
PO
PEO
CAT
Sandy soil
PO
PEO
CAT
Oxidative enzymes (umol g-1 h-1)
Temperature
10
20
30
40
50

Fig. 6

Figure 7

Effect of temperature on hydrolytic enzymes activity under sandy and clayey texture

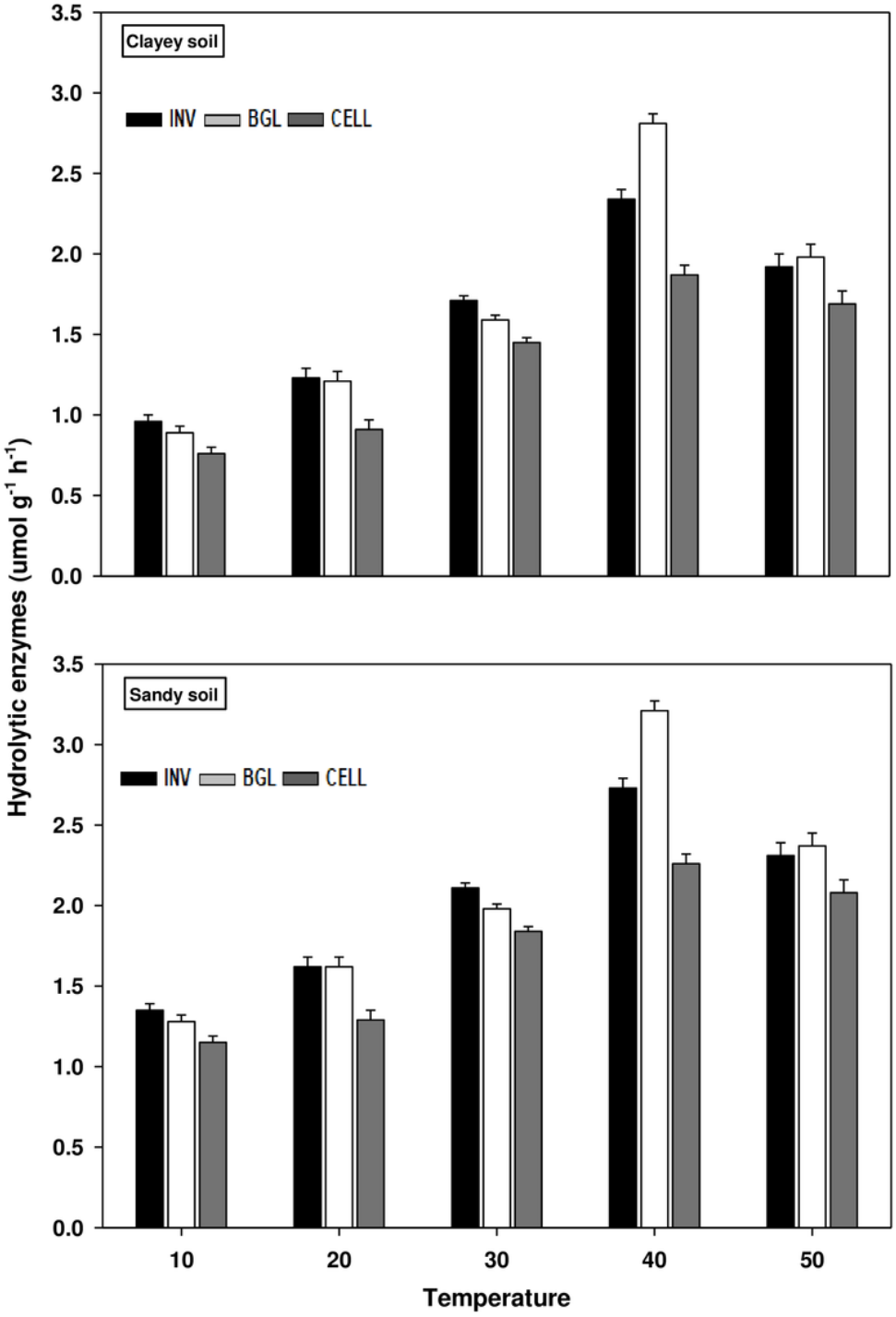

Clayey soil
INV
BGL
CELL
Sandy soil
INV
BGL
CELL
Hydrolytic enzymes (umol g-1 h-1)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
10
20
30
40
50
Temperature

Fig. 7

Figure 8

Effect of temperature on CO_2 emissions and cumulative CO_2 under sandy and clayey texture

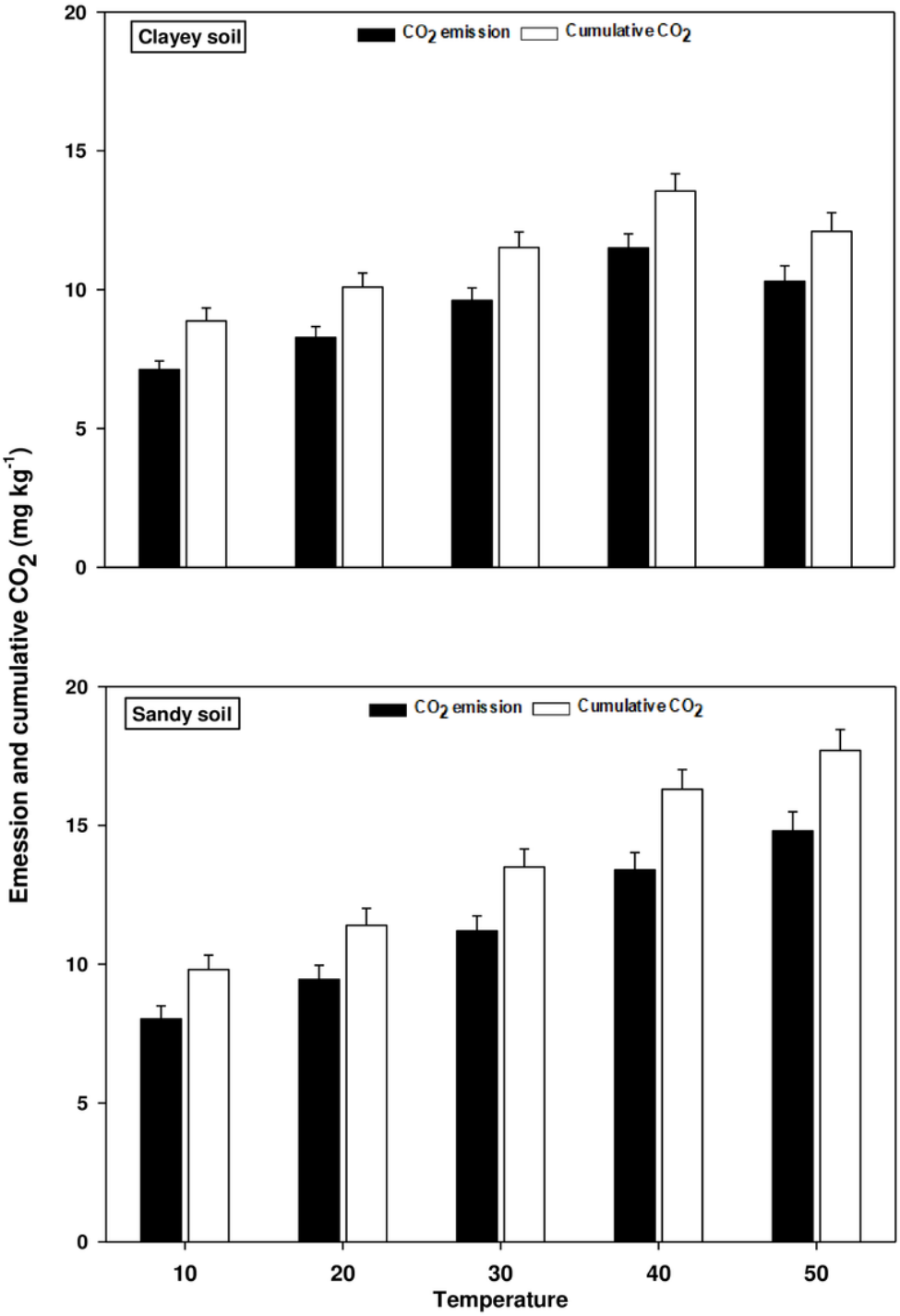

Clayey soil
CO2 emission
Cumulative CO2
Sandy soil
CO2 emission
Cumulative CO2
Emession and cumulative CO2 (mg kg-1)
0
5
10
15
20
10
20
30
40
50
Temperature

Fig. 8

Table 1(on next page)

Table 1A and 1B

Table 1A. Physico-chemical properties of experimental soils; **1B.** Correlation coefficient (R^2) between C fractions, CO_2 emissions, cumulative CO_2 and temperature

Table 1A. Physico-chemical properties of experimental soils; **1B.** Correlation coefficient (R^2) between C fractions, CO_2 emissions, cumulative CO_2 and temperature

Properties	Textural class	
	Sandy loam	Clay loam
Sand	539.3	232.4
Silt	251.2	286.3
Clay	209.5	481.3
pH (1:2.5)	7.11	7.24
EC (μS cm^{-1})	149.8	169.5
CEC (C mol_c kg^{-1})	7.32	8.35
Bulk density (g cm^3)	1.58	1.28
Available N (mg kg^{-1})	5.61	6.91
Available P (mg kg^{-1})	4.63	6.49
Available K (mg kg^{-1})	170.5	201.8
Total P (g kg^{-1})	0.18	0.32
Total N (g kg^{-1})	0.37	0.53

Table 1B.

Parameters	R^2 (Sandy soil)	R^2 (Clayey soil)
LFOC	0.93**	0.85**
DOC	0.94**	0.62*
RMC	0.92**	0.75*
RSC	0.91**	0.76*
POC	0.92**	0.71*
EOC	0.93**	0.84**
[a]Total R^2	**0.92****	**0.75***
ROC	0.97**	0.91**
TOC	0.96**	0.89**
[b]Total R^2	**0.97****	**0.90***
CO_2 emission	0.91**	0.78*
Cumulative CO_2	0.94**	0.75*

[a]Total R^2, Correlation coefficient from all labile C fractions, [b]Total R^2, Correlation coefficient from recalcitrant and stable C fractions, * Significant at $P < 0.05$. ** Significant at $P < 0.01$.

[b]Total R^2, Correlation coefficient from all microbial biomass

* Significant at $P < 0.05$. ** Significant at $P < 0.01$.

Table 2(on next page)

Table 2A and 2B

Table 2A. Correlation coefficient (R^2) between microbial community and biomass and temperature; **2B.** Correlation coefficient (R^2) between oxidative and hydrolytic enzymes and temperature

Table 2A. Correlation coefficient (R^2) between microbial community and biomass and temperature; **2B.** Correlation coefficient (R^2) between oxidative and hydrolytic enzymes and temperature

Parameters	R^2 (Sandy soil)	R^2 (Clayey soil)
Bacteria	0.97**	0.91**
Fungi	0.68*	0.46*
Actinomycetes	0.92*	0.81*
[a]Total R^2	**0.85****	**0.72***
MBC	0.98**	0.92**
MBN	0.91**	0.80*
MBP	0.75*	0.63*
[b]Total R^2	**0.88****	**0.78***

[a]Total R^2, Correlation coefficient from all microbial community

[b]Total R^2, Correlation coefficient from all microbial biomass

* Significant at $P < 0.05$. ** Significant at $P < 0.01$.

Table 2B.

Parameters	R^2 (Sandy soil)	R^2 (Clayey soil)
PO	0.96**	0.88**
PEO	0.93**	0.86**
CAT	0.91**	0.84**
[a]Total R^2	**0.93****	**0.86****
INV	0.76*	0.69*
BGL	0.64*	0.58*
CELL	0.81*	0.73*
[b]Total R^2	**0.73***	**0.66***

[a]Total R^2, Correlation coefficient from all oxidative enzymes

[b]Total R^2, Correlation coefficient from all hydrolytic enzymes

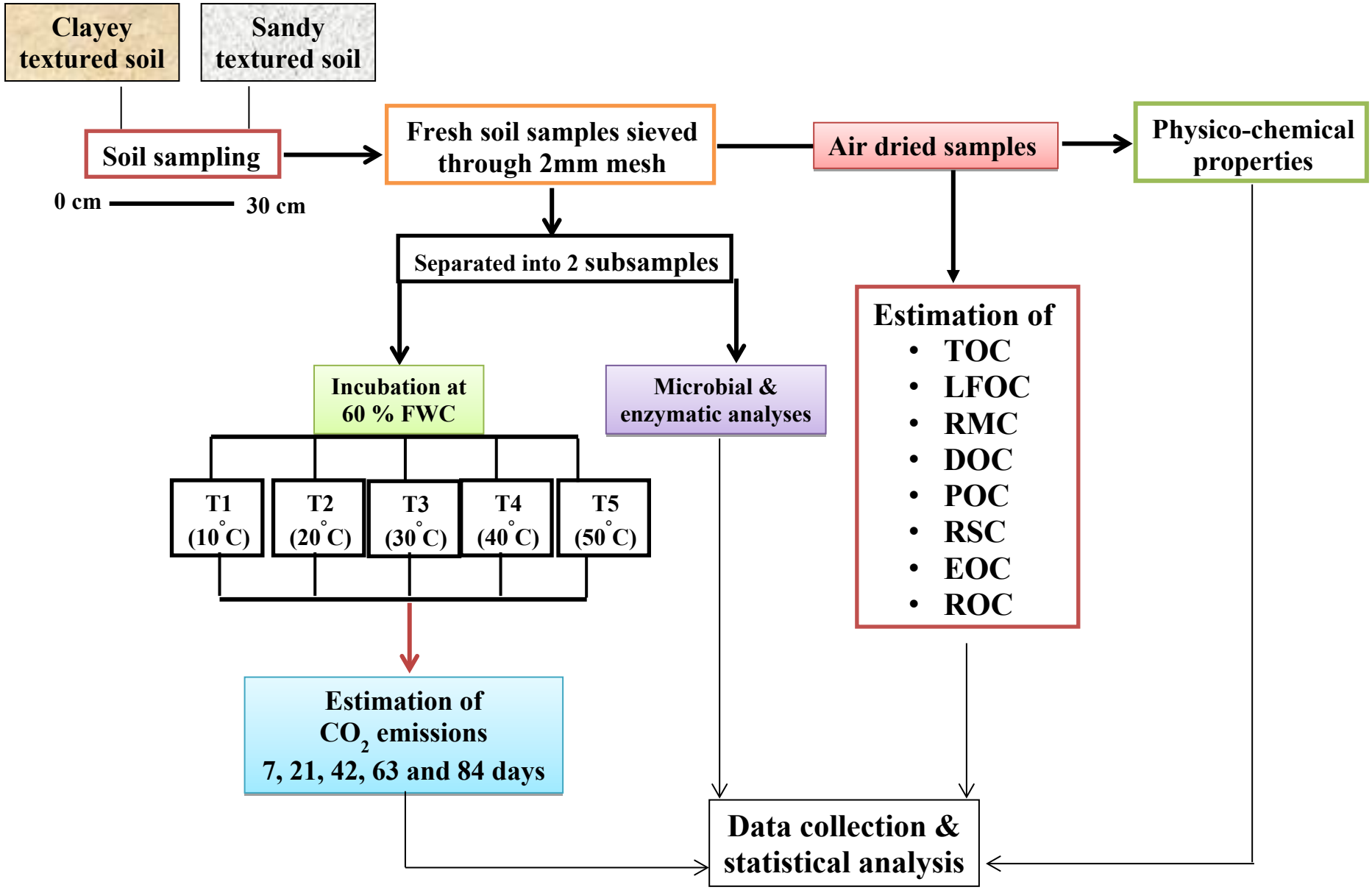
* Significant at $P < 0.05$. ** Significant at $P < 0.01$.

Table 3(on next page)

Methods Graphical Representation

Graphical Representation of methods

1


Clayey textured soil
Sandy textured soil
Soil sampling
0 cm
30 cm
Fresh soil samples sieved through 2mm mesh
Air dried samples
Physico-chemical properties
Separated into 2 subsamples
Incubation at 60 % FWC
Microbial & enzymatic analyses
Estimation of
TOC
LFOC
RMC
DOC
POC
RSC
EOC
ROC
T1 (10 °C)
T2 (20 °C)
T3 (30 °C)
T4 (40 °C)
T5 (50 °C)
Estimation of CO2 emissions 7, 21, 42, 63 and 84 days
Data collection & statistical analysis