Mitigating global warming by improving terrestrial biotic carbon flux

BK Sinha[A], A Hembrom[B], M Mahto[C] and S Choudahry[D]

[A]Department of Zoology, S S M College, Ranchi University, Ranchi, 834 008, Jharkhand, India. Email b_kishoresinha@yahoo.co.in
[B]Rajiv Gandhi National Fellow, Department of Zoology, Ranchi University, Ranchi, Jharkhand, India.
[C]Research Scholar, Department of Zoology, Ranchi University, Ranchi.
[D]Department of Psychology, P P K College, Bundu, Ranchi, India.

Abstract
There is global growing concern over increasing atmospheric CO_2, making Earth warmer and increasing frequency of extreme weather effects. Global carbons are pooled in five carbon pools and terrestrial carbon pool - a major pool - has a potential function to dampen increasing atmospheric concentration. The pedospheric mesofauna promote carbon sequestration by redistributing carbon through soil profile. A study of selected reclaimed overburden dumps, of different age, of mine spoils and a natural forest floor pedosphere ecosystem was carried out in Jharkhand. Quadrates of 1m x 1m x 0.05m were selected and soil corers were used for collection of samples for biotic and abiotic factors. Field data were analyzed using PAST software. We observed that there is a higher amount of soil organic carbon (SOC) in newly reclaimed over burden dumps (OBDs) than in older OBDs and natural forest, SOC and nitrogen are significantly correlated with soil mesofauna, there is significant positive correlation between above ground mesofauna and below ground mesofauna and there is higher soil mesofauna /kg in older reclaimed OBD and natural forest ecosystem. These results are indicative that there is a detrimental relationship between soil mesofauna and carbon sequestration – as there is lowering of SOC and soil organic matter/kg in older OBDs and forest.

Key words
Below-ground, arthropods, disequilibrium, non-equilibrium, ecosystem

Introduction
There is a growing concern that increasing levels of carbon dioxide in the atmosphere will change the climate, making the earth warmer and increasing the frequency of extreme weather effects (Schimel *et al.* 2001; Schlesinger and Licher 2001; Neff *et al.* 2002; Lal 2004; Bradford *et al.* 2007). The last two decades of the 20th century were the hottest in 400 years. It is expected that earth's mean temperature may increase by 1.5 – 5.8^{0}C in the 21st century (IPCC 2001). These climate changes are reportedly caused by emission of green house gases (GHGs) through anthropogenic activities (Lal 2007) and natural phenomena. Increase in GHGs coupled with increase in human population has cascading effect on the environment implicitly shifting ecosystem processes and functions (Running 2006; Westerling *et al.* 2006; Greene and Pershing 2007). Stakeholders, planners and environmentalist wish to stabilise the atmospheric abundance of carbon dioxide and other GHGs to mitigate the risk of global warming (Kerr 2007; Kintisch 2007b; Kluger 2007). According to Lal (2007) there are three ways of lowering carbon dioxide emissions; (1) Reduction in global energy use (2) Development of low or no carbon fuel (3) Sequestering CO_2 through natural or engineering techniques. The present paper's scope is limited to the third point and will emphasize the role of soil arthropods in carbon sequestration. The case study of rehabilitated mine spoils may be a model for the sink of atmospheric CO_2 for scaling up as there is no empirical data available to estimate the magnitude of carbon sequestration by soil insects. The environmental condition prevailing in the deep soil profile has detrimental role in the decomposition of soil organic matter (Gill *et al.* 1999; Gill and Broke 2002). The terrestrial ecosystems contain c2100 Gt of carbon (Schulze 2006), of which over two-thirds are stored in soils (Jobbagy and Jackson 2000; Amundson 2001). Part of this soil carbon pool is highly variable in space and time, while a large inert carbon pool may become active when exposed to new environmental condition (De Deyn *et al.* 2008). The large carbon storage capacity of soils suggests a potential function for soil to dampen increasing atmospheric concentrations (De Deyn *et al.* 2008). Soil carbon pools are balanced between carbon input via primary productivity and output via decomposition, leaching, burning and volatilization of organic compounds (Amundson 2001). The maximal potential of soil to sequestered carbon is determined by intrinsic abiotic soil factors, but soil carbon dynamics are essentially driven by biota and their interaction with climate (De Dedyn 2008). Soil mesofauna above ground as well as below ground promote carbon sequestration by redistributing carbon through the soil profile by channelling, mixing organic and mineral soil components, and by forming relatively stable soil aggregates and casts (De Deyn *et al.* 2008).

Materials and methods

The present study was carried out in the Kathara Coalfield area situated at 23^{O} 47' N latitude and 85^{O} 57' E longitude above 210 meters from mean sea level, in the district of Bokaro, Jharkhand, India. The average annual rainfall ranges between 157 cm - 195 cm and temperature oscillates between 2°C in winter to 45°C in summer. The soil is lateritic to acidic. Mine spoils are composed of coarse rocks generated due to deep coal mining operations and associated coal processing with low moisture and high temperature of the surface barring the natural growth of vegetation. Five sites were selected – three OBDs (spreading fly ash mixed with soil to give support for vegetation) of 5, 15, 30 years age of plantation, one derelict patch of fifty years age (approx.) with natural growth, and one natural forest. Samples of soil and litter arthropods – mesofauna were collected at regular monthly interval by standardized soil corers (0.05m) from randomized quadrates of 1m x1m covering an area of 100 sq. m. Each 250 - 300 gm litre sample was placed in a separate Berlese-Tullgren funnel and the arthropods were extracted. Data were analyzed using PAST software.

Results

We analyzed soil for its biotic and abiotic constituents. The abiotic physical properties of the soil are presented in Table 1. Results indicate that the SOC is higher in the newer reclaimed OBDs rather than in the older OBDs and in the forest (Figure 1). There are negative correlations between below-ground mesofauna and SOC (-0.5465), N (-0.5501), P (-0.956) and K (-0.9582), whereas there are positive correlations between above-ground mesofauna and SOC (0.5507), N (0.5447) P (0.0623) and K (0.0832).The linear regression between SOC and SOM expresses a highly (0.001) significant positive correlation (Figure 2). Principal component analysis (PCA) based on the soil mesofauna and nutrients (organic carbon, nitrogen, phosphate and potash) showed that at 63.05% (five years old, Figure 3) had strong association with soil mesofauna and SOC (component 1 and component 2). Similar trends were observed at 44.83%, 45.9%, and 39.28% for fifteen years, thirty years and fifty years respectively. SOM and nitrogen of the soil were also found positively correlated with each other in PCA.

Table 1. Soil profile of sites.

Sites	SOC/kg/h	N*/kg/h	P#/kg/h	K!/kg/h
I	1.5	808.3	41.7	165.8
II	1.4	766.7	40.2	160.5
III	0.9	503.3	38.9	161.1
IV	0.5	316.7	37.0	150.3
V	0.5	319.0	27.8	118.7

*N= nitrogen, #P= phosphate, !K= potash

Conclusions

Higher amount of SOC and SOM in freshly reclaimed OBDs of mine spoils may be because the ecosystem in disarray due to mining. The higher Shannon diversity index (DI) may be because ruderals and r-selects having higher reproductive capacity (Krebs 2004), which are exploratory meso-arthropods and are yet to adapt to a new habitat. On the contrary the lower DI and SOM in the older sites and forest reflect the presence of K - select species. The comparison of five to fifty years and a natural forest gives the impression that the system is in gradual change - switching from disequilibrium (Howard and Fisk 1911, Hembrom *et al.* 2008) to non-equilibrium (Krebs 2004; Sinha 2008) as no ecosystem is in equilibrium on the earth. Small disturbances put them in non-equilibrium state and it is the homeostatic and power of resilience that restores systems and provides opportunities for succession. But a larger disturbance exceeds the capacity of resilience of the system.

The results indicate that the systems have gone beyond their capacity of resilience, at the same time the available SOC and SOM are facilitating restoration processes. The positive correlation between above and below-ground arthropods (Hooper *et al.* 2000) is indicative of the restoration and improvement of habitat, which will improve the DI and vice-versa consequently. It was difficult to measure the missing carbon, in the pedosphere ecosystem as we were not able to account for all carbon in soil. But, the lowering of both soil mesofauna (below ground) and SOC are indicates that the residual carbon may be present in other supporting systems of the soil. Further, the microbes and mesofauna also immobilize organic carbon present in the soil as biomass (SOM). The SOM accumulates nutrients, which is important for above ground floral diversity (Devi and Yadav 2009). According to an estimate ten per cent of CO_2 flux to atmosphere through soil every year, which is more than ten times the CO_2, released from fossil-fuel combustion (Raich and Potter 1995). The large pool of mineralizable carbon in soil may be exploited by improved land management systems

(Kumar *et al.* 2009). Adopting conservation principles in general and improving soil meso arthropods taxonomic diversity in particular can mitigate GHG.

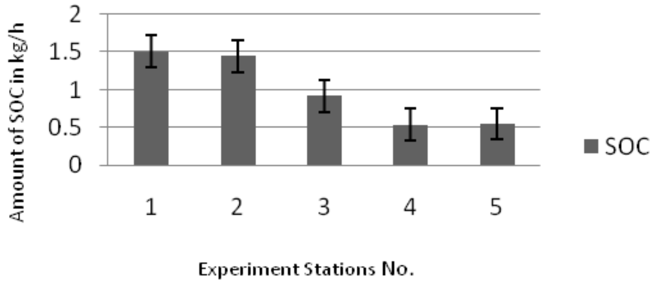

Figure 1. Soil organic carbon in different ages of reclaimed OBDs and natural forest of Jharkhand.

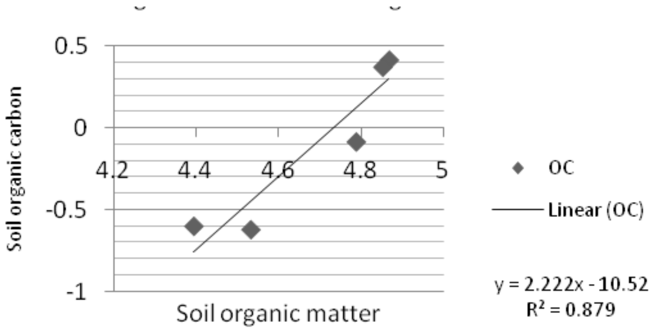

Figure 2. Linear positive correlation between soil organic matter and soil organic carbon.

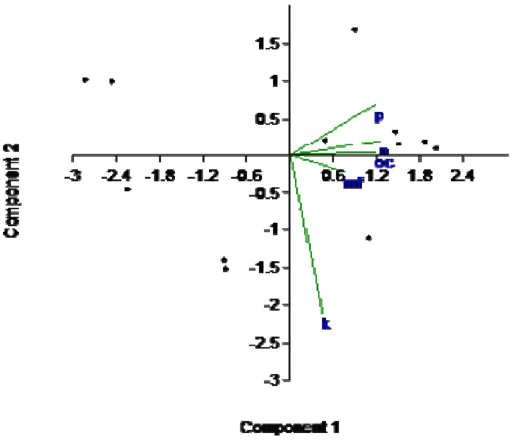

Figure 3. PCA between soil mesofauna OC, N, P, K of 5 years old OBD.

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References

Amundson R (2001) The carbon budget in soils. *Annu. Rev. Earth Planet. Sci.* **29**, 535-562.

Bradford MA, Tordoff GM, Black HIJ *et al*. (2007) Carbon dynamics in a model grassland with functionally different soil communities. *Functional Ecology* **21**, 690-697.

De Deyn GB, Cornelissen JHC and Bardgett RD (2008) Plant functional traits and soil carbon sequestration in contrasting biomes. *Ecology Letters* **11**, 516-531.

Devi NB, Yadav PS (2009) Emission of CO_2 from the soil and immobilization of carbon in microbes in a subtropical mixed oak forest ecosystem, Manipur, Northeast India. *Current Science* **96(12)**, 1627-1630.

Gill R, Burke IC, Miluchunas DG, Lauenroth WK (1999) Relationship between root biomass and soil organic matter pools in the shortgrass steppe of eastern Colorado. *Ecosystems* **2**, 226-236.

Gill RA and Burke IC (2002) Influence of soil depth on the decomposition of Bouteloua gracilis roots in the shortgrass steppe. *Plant Soil* **241**, 233-242.

Greene CH and Pershing AJ (2007) Climate drivers sea change. *Science* **315**, 1084-1085.

Hembrom A, Sinha BK and Mahto M (2008) What Species to be Conserved for Restoration of Derelict Pedosphere Ecosystem? In 'Proceedings of International Conference on Biodiversity Conservation and Management (BIOCAM 2008)*'*. (Eds. P Natrajan, KV Jayachandran, A Augustine), pp. 548-552. (Rajiv Gandhi Chair Proffesor Cochin University of Science and Technology, Cochin, India).

Hooper DU, Bignell DE *et al.* (2000) Interactions between above ground and below ground biodiversity in terrestrial ecosystem: Patterns, mechanisms and feedbacks. *BioScience* **50(12)**, 1049-1061.

Howard LO and Fisk WF (1911) The importation into the United States of Parasites of the Gypsy-moth and Brown-tail moth. US. Bureau of Entomology Bulletin 91, Deptt of Agriculture.

IPCC (2001) Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change. Cambridge University Press, UK.

Jobbagy EG, Jackson RB (2000) The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecol. Appl.* **10**, 423-436.

Kerr RA (2007) Scientists tell policy makers we're all warming the world. *Science* **315**, 1481.

Kintisch E (2007b) New congress may be warming up to plans for capping emissions. *Science* **315**, 444.

Kluger J (2007) Global warming: what now? Our feverish planet badly needs a cure. *Time Magazine* **9**, 50-109.

Krebs CJ (2004) Ecological methodology. Fourth Edition, p 332.

Kumar GP, Murkute AA, Gupta S, Singh SB (2009) Carbon sequestration with special reference to agro forestry in cold deserts of Ladakh. *Current Science* **97**(7), 1063-1068.

Lal R (2004) Soil carbon sequestration Impacts on Global Climate Change and Food Security. *Science* **304(5677)**, 1623-1627.

Lal R (2007) Carbon sequestration. *Phil. Trans. R. Soc. B.* **363**, 815-830.

Neff JC, Townsend AR, Gleixner G, Lehman SJ, Turnbull J, Bowman WD (2002) Variable effects of nitrogen additions on the stability and turnover of soil carbon. *Nature* **419**, 915-917.

Raich JW and Potter CS (1995) Global patterns of carbon dioxide emissions from soil. *Global Biogeochem. Cycle* **9**, 23-36.

Running SM (2006) Is global warming causing more large wildfires? *Science* **313**, 927-928..

Schimel DS, House JI, Hibbard KA *et al*. (2001) Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Science* **414**, 169-172.

Schlesinger WH and Lichter J (2001) Limited carbon storage in soil and litter of experimental forest plots under increased atmospheric CO_2. *Nature* **411**, 466-469.

Schulze ED (2006) Biological control of the terrestrial carbon sink. *Biogeosciences* **3**, 147-166.

Sinha BK (2008) Ecological Modeling for Derelict Ecosystem. In '*Proceedings of International Conference on Biodiversity Conservation and Management (BIOCAM 2008)'*. (Eds P Natrajan, KV Jayachandran, A Augustine) pp. 654-660. (Rajiv Gandhi Chair Proffesor Cochin University of Science and Technology, Cochin, India).

Westerling AL, Hidalgo HG, Cayan DR and Swetnam TW (2006) Warming and earlier spring increase western U. S. Forest wildfire activity. *Science* **313**, 940-943. (doi: 10. 1126/science.1128834).