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What Happens To Nutrient Dynamics When You Get Land Management Right: The East Anglia, England Success Story

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ABSTRACT

Nutrient status, availability, reachability are the basis of soil fertility studies in agricultural soils. The East Anglia experience evaluated soil nutrient dynamics from the following parameters: whole ecosystem and soil respiration, microbial carbon , soil total carbon, soil total nitrogen, soil C:N ratio, soil temperature and soil water filled pore spaces. The following land management practices were evaluated: grassland under permanent pasture on 5 y ley before stocking; grassland under permanent pasture sown with red clover a y before stocking; grassland under permanent pasture treated with N fertilizer a y before stocking; arable land under barley; with deciduous woodland as control. Each site was replicated four times and revisited at each time of sampling. Whole ecosystem respiration was measured once a day per month with portable environmental gas monitor. At the same time soil samples were collected for actual measurement of soil respiratory activity in the laboratory; together with soil water filled pore spaces. Significant differences were observed in whole ecosystem and soil respiration amongst land management practices with grassland under permanent pasture treated with N fertilizer a year before stocking giving the highest whole ecosystem and soil respiration, 67.8 and 33.9 mmol m^{-2} h^{-1} respectively. Respiratory activity was highest over the summer months and lowest over the winter months. Whole ecosystem and soil respiration were dependent on soil microbial C (R^2 = 0.6 and 0.73 respectively). It pays to get it right when land management and nutrient dynamics are at stake.

Introduction

Sustainable agricultural production is anchored on sustainable soil nutrient dynamics, which is also anchored on sustainable land management practices. Soil fertility studies for ages will always remain incomplete without reference to microbial community, population and diversity; nitrogen, carbon, C:N ration, temperature and moisture. The microbial community mediates degradation of organic and inorganic constituents of the soil. Their level of viability and activity in the soil is first from the point of their respiratory activity which are common to both heterotrophic and autotrophic organisms. Whole ecosystem respiration is a combination of both. In whole ecosystem respiration it is established that plant parts namely: leaves, stems, roots all contribute to global C flux in addition to that of microbial communities especially the autotrophs and heterotrophs. In the course of their activities essential nutrients are released namely: nitrogen, phosphorus, potassium amongst others that are vital for plant growth and productivity. The ratio of carbon to nitrogen explains the rate of mineralization of organic fractions and the stress imposed on soil microbial communities at the instance of carbonaceous materials. Soil microbial carbon is a quick index for quantifying soil microbial community (IPCC, 2001; RCEP, 1996; Houghton, 2003; Buringh, 1984; Coleman and Jenkinson, 1996; Probert *et al*, 1998)

Nutrient dynamics and land management vary from ecosystem to ecosystem: temperate, tropical, semi-tropical, arid, semi-arid; grassland, forest, woodland, arable, pasture, agroforestry, silviculture, pastoral, legumes, cereals, horticultural crops, plantation crops, root crops, tuber crops. The East Anglia Region of England have rich history of agrarian culture that cut across grassland and arable farming; especially wheat, barley, corn, dairy and cattle/sheep fattening. The region remains one of the food basket of England in particular and United Kingdom as a whole (Chambers and Mingay, 1966; Pretty, 2002; Briggs and Courtney, 1989; Davies *et al*, 1992; Fowler, 1983; Rackam, 1986; Dent *et al*, 1966; Simmons and Dooley, 1981).

How do the farmers in this region get it right in land management?. There are strict codes for air, water and soil resources in England that are implemented to the letter (DEFRA, 2006). The region was rewarded for hard work with several universities and colleges; especially University of Essex and Writtle College who have several decades of novel research in agriculture and land management in the region. For this study, Writtle college with its extensive over 209 ha of agricultural land for arable, pasture and horticulture to reflect the farming history of the region was selected for getting land management right. Infact, Writtle College is the gateway for latest agricultural techniques and practices in England. They have enviable record on land management practices that meets the test of England and the world (Writtle College, 2006). Details of this rich agricultural culture is described in predicting carbon sequestration under land management practices for six periods of English agriculture using CENTURY 4.0 Model (Igboji, 2015; Parton et al, 1993, 1987, 1996).

For this nutrient dynamics study; their land management practices were: grassland under permanent pasture on 5 y ley before stocking; grassland under permanent pasture sown with red clover a y before stocking; grassland under permanent pasture treated with N fertilizer a y before stocking; arable land under barley and deciduous woodland as control. They were assessed for whole ecosystem and soil respiration, microbial carbon, total nitrogen, total carbon, C:N ratio, temperature and

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moisture and their various roles in soil fertility stability. The arable land gave a clue to scenarios under constant tillage and pulverization, as well as crop uptake of nutrients; the grassland pastures enhanced the understanding of nutrients released by red clover (basically nitrogen via nitrogen fixation) and the other scenario the trend when inorganic N fertilizer is applied; all in the course of rye-grass rejuvenation prior to stocking of herds of cattle and sheep. The woodland was a baseline to nutrient status of the Hanslope soil outside perturbations like tillage, inorganic fertilizer mineral enrichment and herding.

Materials and Methods

Site description

Writtle College Research and Teaching Farm is located 68 km east of London (51° 44¹, 0° 26¹, 32 OD). The soil is Hanslope of Chalky Boulder Clay parent material. The land management types are as decribed in introduction. Each site had four replicate sampling points which were revisited on each sampling occasion. Grassland under permanent pasture is located in the Daws N (Terminal 10); arable land under barley is located in the Cudhams (Terminal 9); while the deciduous woodland is adjacent to Sturgeon farm (Terminal 25) – Writtle College (2006); Neath (1979).

Field methods and laboratory protocols

Soil physical properties

Gravimetric soil water content was determined in the laboratory. By the aid of soil auger (5 cm diameter, volume 209.27 cm^{-3}) soil samples were taken at each location for various periods at a depth of 0 – 20 cm. For the determination of gravimetric soil water content 50 g of soil was placed in an oven at 105°C for 24 h. After incubation the soil was cooled in a desiccators and reweighed to obtain the water content of the soil. The result was expressed relative to the mass of oven dry soil. Water filled pore space was calculated as:

$WFPS = SWC \times Db (1 – Db/PD)$

Where, SWC is soil water content (kg kg^{-1}); Db is bulk density (mg m^{-3}) and PD is particle density (2.65 mg m^{-3}) – Franzluebbers *et al* (2002); Doran *et al*, (1998). Soil bulk density was determined by calculating using the mass of oven dry soil and volume of core

Soil chemical properties

Soil pH was measured as follows: Air dry soil (10 g) was weighed into a bottle with a srew cap. Water from a measuring cylinder was added (25 ml) and shaken for 15 min on a mechanical shaker with a stirrer. The pH electrode was inserted and the suspension swirled over the electrodes. The pH was recorded after 30 s. Total C and S was measured using an automated CHNS/O analyser (Perkin Elmer), loaded in the CHNS/O automated analyser wells and set to run the normal cycle as prescribed for the analyser. The total carbon and nitrogen per air dry soil was calculated automatically by the analyser with reference to individual soil sample weight in % and this was further transformed to g kg^{-1} by multiplication of each value by 10 (ASA-CSSA-SSSA, 1998).

Estimation of microbial carbon

Microbial C was estimated using the fumigation-incubation method (Jorgensen, 1998; Rowell, 1994). Moist soil (50 g) was placed in a vacuum dessicator along with a beaker containing 25 ml of ethanol-free chloroform. The dessicator was evacuated with a pump until the chloroform boiled vigorously for 5 min. The soils were left in the chloroform vapour for 24 h. After fumigation respiration was measured during a 10 d dark incubation at 25°C (Jorgensen, 1998; Rowell, 1994; Jenkinson and Powlson, 1976). According to these workers biomass C (mg CO_2-C g^{-1}) in neutral soils has been found to be 2.2 x F, where F is the C respired by the fumigated soil during a 10 d incubation period at 25°C minus that respired by the unfumigated control (Rowell, 1994; Jenkinson and Ladd, 1981).

Ecosystem respiration and soil temperature measurement

Whole ecosystem respiration was measured with a portable environmental gas monitor (EGM-1, PP Systems, UK) – Sowerby, *et al*, (2000). Each individual measurement took 4 – 5 min and was carried out by placing the respiration chamber over the grassland pasture, arable land following different circles of the management (land preparation, sowing of barley, fertilization, harvesting) and the woodland under various litter from the various plants as described in earlier mentioned prediction of C sequestration under land management practices for six periods of English agriculture using the CENTURY 4.0 model by Igboji (2015). Respiratory activity was calculated from the CO_2 accumulation rate within the chamber as described by the manufacturers (Anon, 1990) and expressed as mmol CO_2 m^{-2} h^{-1}. At the same time soil temperature at a depth of 10 cm was also recorded. The measurements were done once per month for 2 y covering winter months (Dec – Feb); spring months (Mar – May); summer months (June – Aug) and autumn months (Sep – Nov).

Laboratory measurement of soil respiratory activity

Laboratory measurement of soil respiratory activity was estimated using protocols described by Rowell (1994) and Alef (1998). Soil (50 g) at various water filled pore spaces (WFPS) was placed into a sealed conical flask (500 ml) containing 0.3 M NaOH (10 ml suspended mid way in the flask). Flasks were incubated in the dark for 7 d. At the end of the incubation period the amount of CO_2 present in the NaOH was determined by titration using 0.1 M HCl with phenolphthalein as the indicator. The end point was marked by the change of colour of the titrate from pink to colourless (Rowell, 1994). For comparison with whole ecosystem results laboratory values in g CO_2 g^{-1} s^{-1} was converted to mmol CO_2 m^{-2} h^{-1} (44 g CO_2 is contained in 1 mol or 1000 mmol or 106 µmol CO_2) following the detailed procedure by Rowell (1994). The soil incubation was done at various natural moisture content of soil translated to WFPS and 25°C.

Statistical and data analysis

The values of all variables studied were subjected to two way analysis of variance (ANOVA) in randomized complete block design (RCBD). Effects at $P \leq 0.05$ was considered significant while that at $P \leq 0.01$ was considered to be highly significant. For regression analysis mmol m^{-2} h^{-1} was used for soil respiration and mg kg^{-1} for microbial carbon. Further regression analysis were done on the relationships between the following variables: whole ecosystem and actual soil respiration (though without separation of root respiration); soil temperature, water filled pore spaces (WFPS), total carbon, total nitrogen, soil pH (SXSTAT11.EXE version 1.0.7. Goodness of fit from predictions with each of the regression equations against actual values were expressed with the coefficient of determination (R^2). An exponential function was used to fit the data for all dates, sites to enhance actual values of tested variables. Multiple regression was done on whole ecosystem and soil respiration, temperature and WFPS. WFPS of the 0 – 20 cm depth was used as the moisture variable in all analysis as this property integrates porosity and moisture variables (Franzluebbers *et al*, 2002; Franzluebbers, 1999; Doran *et al*, 1998; Zar, 1999)

Results and Discussions

Whole ecosystem respiration

There were significant differences ($P \leq 0.05$) in whole ecosystem respiration in 5 months in the first y. On day 46

(February), F = 14, FLSD = 23.4); Day 64 (March), F = 16, FLSD = 23.4); Day 187 (July), F = 28, FLSD = 75). The highest whole ecosystem respiration across five sites was at day 79 (March) of first y, 133.4 mmol m^{-2} h^{-1} and day 277 (October), 133.4 mmol m^{-2} h^{-1} as well. The lowest whole ecosystem respiration across the five sites was at day 163 (June) of y 1, 29.5 mmol m^{-2} h^{-1} and day 316 (November) of y 2, 50 mmol m^{-2} h^{-1}. The highest whole ecosystem respiration across days of the year was in grassland under permanent pasture treated with N fertilizer a y before stocking in first y, 67.8 mmol m^{-2} h^{-1} and deciduous woodland in second y, 126.6 mmol m^{-2} h^{-1}. When whole ecosystem respiration between yrs was compared no significant difference (P≤0.05) was observed.

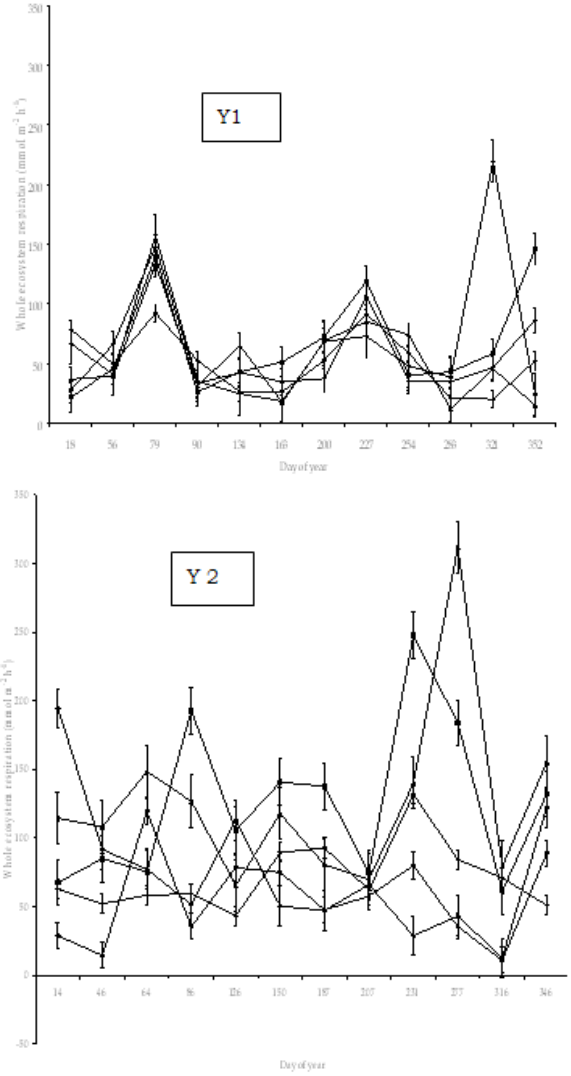

Fig 1. Changes in whole ecosystem respiration (mmol m^{-2} h^{-1}) in ♦ grassland under permanent pasture on 5 y ley before stocking; ● grassland under permanent pasture sown with red clover a y before stocking; ▬ grassland under permanent pasture treated with N fertilizer a y before stocking; ■ arable land under barley and ▲ deciduous woodland. Each value is mean of 4 replicates. Bars represent standard error of means.

Laboratory soil respiration

Significant differences (P≤0.05) in soil respiration were observed on day 283 (October), F = 21, FLSD =31), day 352 (December), F = 58.9, FLSD = 85 of first y; day 231 (September), F = 71.1, FLSD = 72 of second y. The highest respiratory activity across sites occurred at day 79 (March), 119 mmol m^{-1} h^{-1} in y 1 and day 231 (September), 116.4 mmol m^{-2} h^{-1} of y 2. The lowest respiratory activity across sites was on day 321 (November), 4.4 mmol m^{-2} h^{-1} of y 1 and day 14 (January), 29 mmol m^{-2} h^{-1} of y 2. Generally soil respiration across days of the y was in arable land under barley in y 1, 49.9 mmol m^{-2} h^{-1} and in deciduous woodland, 105 mmol m^{-2} h^{-1} in y 2. There was no significant difference (P≤0.05) between yearly soil respiration.

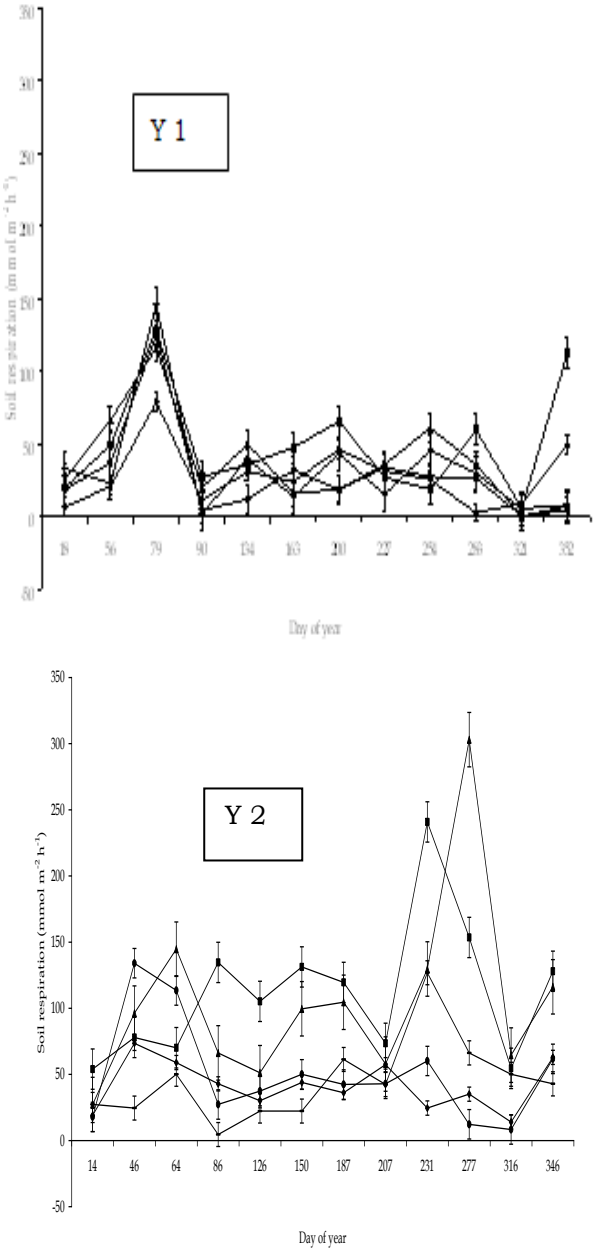

Fig 2. Changes in laboratory soil respiration (mmol m^{-2} h^{-1}) under various types of land management as described in Fig 1. Each value is mean of 4 replicates. Bar represent standard error of means

Soil microbial C

The highest microbial C across sites was at day 283 (October), 3734 mg CO_2-C g kg^{-1} of y 1 and day 126 (May), 4322 mg CO_2-C kg^{-1} in y 2. Lowest microbial C across sites was on day 321 (November), 488 mg CO_2-C kg^{-1} in y 1 and day 46 (February), 486 mg CO_2-C kg^{-1}. The highest microbial C across days was in soil from the arable land under barley in y 1, 2897 mg CO_2-C kg^{-1} and in y 2, 2087 mg CO_2-C kg^{-1}. No significant difference was observed in yearly soil microbial C. Soil microbial C was linearly related to both whole ecosystem and soil respiration, R^2 = 0.6, n = 12 and R^2 = 0.73, n = 12 for the 2 yrs.

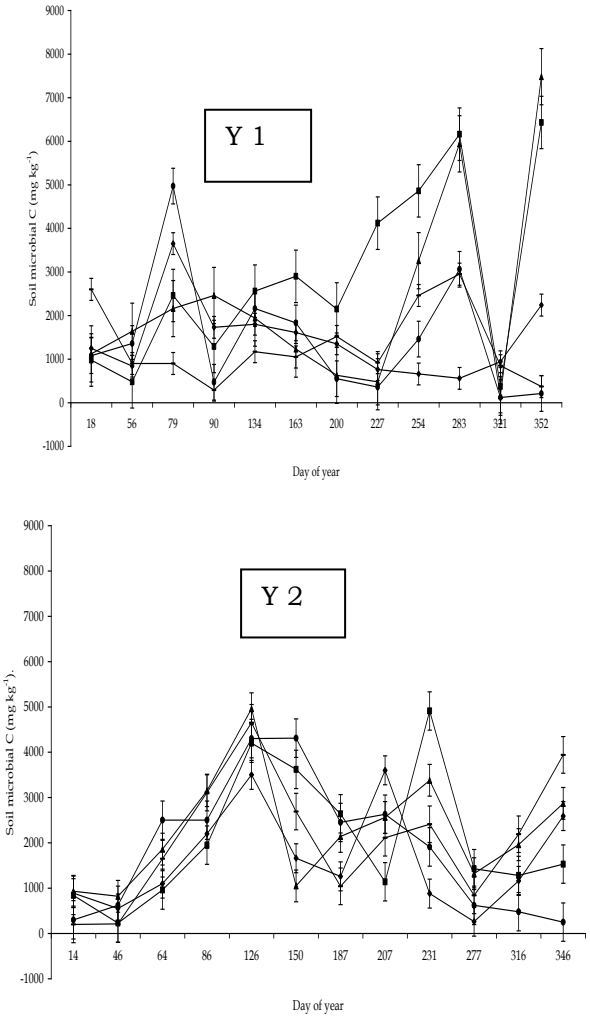

Fig 3. Changes in soil microbial C (mg CO_2-C kg^{-1}) under various land management as described in Fig. 1. Each value is mean of 4 replicates. Bars represent standard error of means

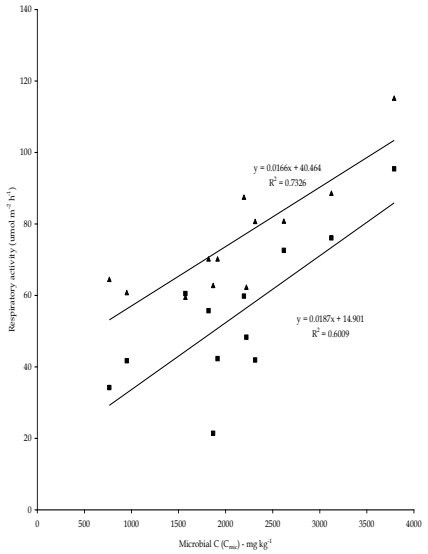

Fig 4.The relationship between whole ecosystem and soil respiration (mmol m^{-2} h^{-1}) and soil microbial carbon (mg kg^{-1}) as expressed by regression equation and coefficient of determination ($R^{2)}$ in y 2; ■whole ecosystem respiration; ▲soil respiration. Each value is mean of 20 observations (5 sites x 4 seasons)

Soil total carbon

Soil total C was highest across sites on day 254 (September) in y 1, 30.6 g kg^{-1} and lowest on day 352 (December) of same y 1, 8.5 g kg^{-1}. During the 2nd y, soil total C was highest across sites on day 277 (October), 42 g kg^{-1} and lowest on day 86 (April), 5.8 g kg^{-1}. In the first y, the highest soil total C across months was in deciduous woodland, 28 g kg-1 while the lowest was in arable land under barley, 8.5 g kg^{-1}. In y 2, the highest soil total C across months was in deciduous woodland, 40.8 g kg^{-1}; the lowest in arable land under barley, 14 g kg^{-1}. No significant difference was observed between yearly soil total C. Soil total C was linearly related to whole ecosystem respiration (R^2 = 0.61, n = 12) and to soil respiration, R^2 = 0.88, n = 12 in y 2.

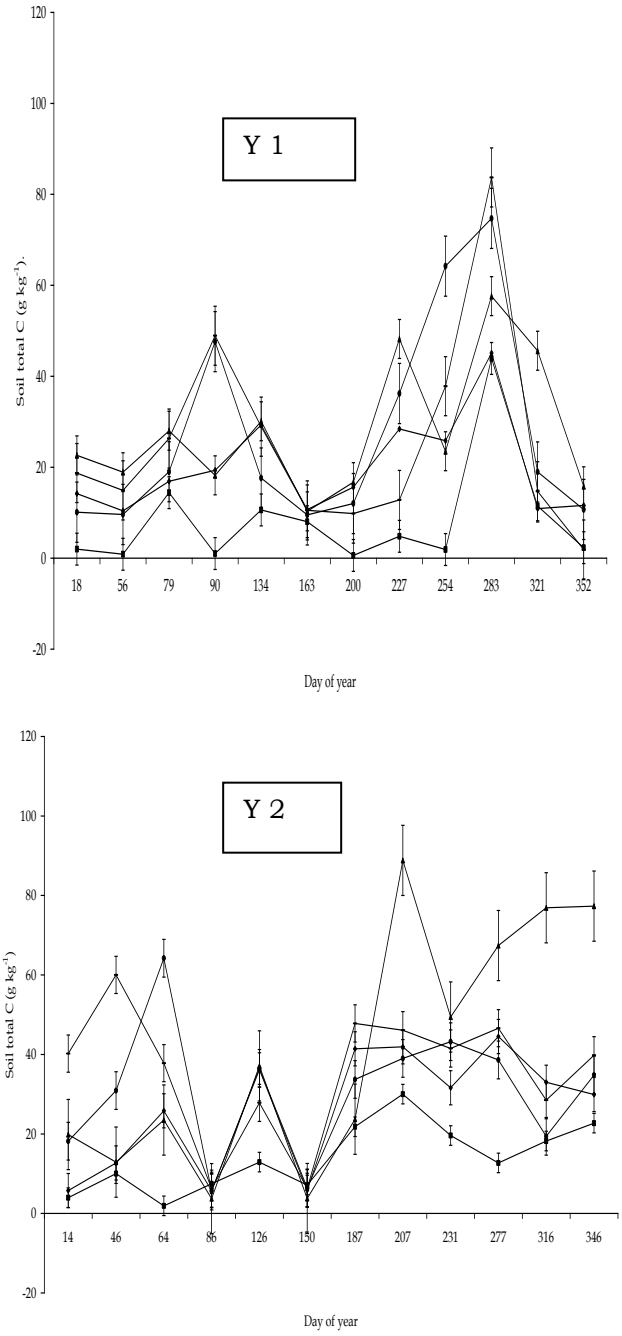

Fig 5.Changes in soil total C (g kg^{-1}) under various land management as described in Fig 1: Each value is mean of 4 replicates. Bars represent standard error of means

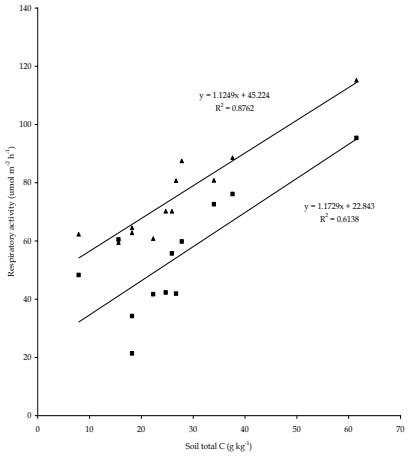

Fig 6. A, the relationship between whole ecosystem respiration (mmol m^{-2} h^{-1}) and soil total C (g kg^{-1}) and that between soil respiration (mmol m^{-2} h^{-1}) and soil total C (g kg^{-1}) as expressed by regression equation and coefficient of determination (R^2) in y 1; ■whole ecosystem respiration; ▲soil respiration. Each value is mean of 12 months for 5 sites

Soil total N

The highest soil total N across sites was recorded on day 283 (October) of y 1, 5.4 g kg-1 and day 277 (October) of y 2, 4.72 g kg^{-1}. The highest total N across months was in soils under permanent pasture sown with red clover a year before stocking, 2.5 g kg^{-1} and soil from grassland under permanent pasture treated with N fertilizer, 3.94 g kg^{-1} in y 2. The lowest soil total N for both yrs was in arable land under barley, 0.8 and 1.4 g kg^{-1} respectively

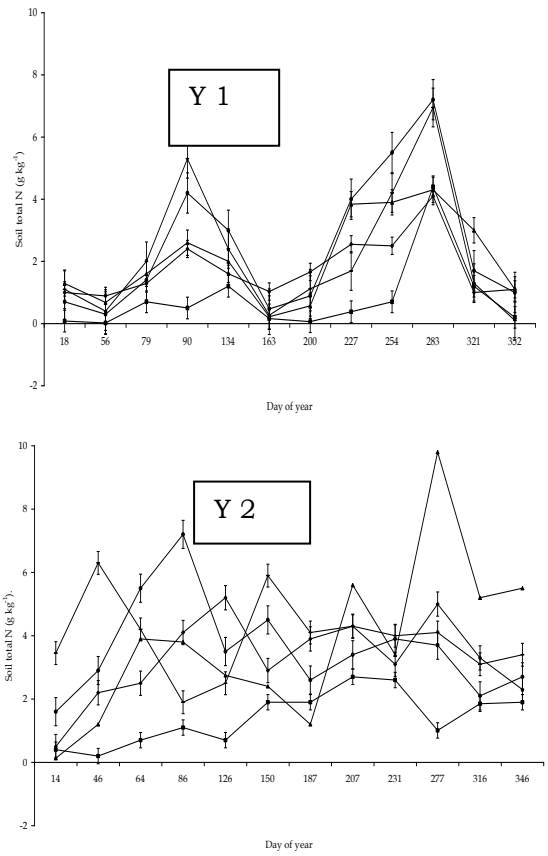

Fig 7. Monthly time course soil total N (g kg^{-1}) under various land management as described in Fig. 1. Each value is mean of 4 replicates. Bars represent standard error of means

Soil C:N ratio

Temporally the C:N ratio across sites was highest on day 227 (August) in y 1, 10.6; day 187 (July) in y 2. Lowest C:N ratios were recorded in soils on day 254 (September) in y 1 and day 64 (March) of y 2. The highest C:N ratio across months was in deciduous woodland in y 1, 16.3 and y 2, 13.6. Lowest C:N ratio were recorded in grassland under permanent pasture on a 5 y ley before stocking in y 1 and 2; 11.6 and 9.7 respectively. No significant difference was observed in yearly C:N ratio.

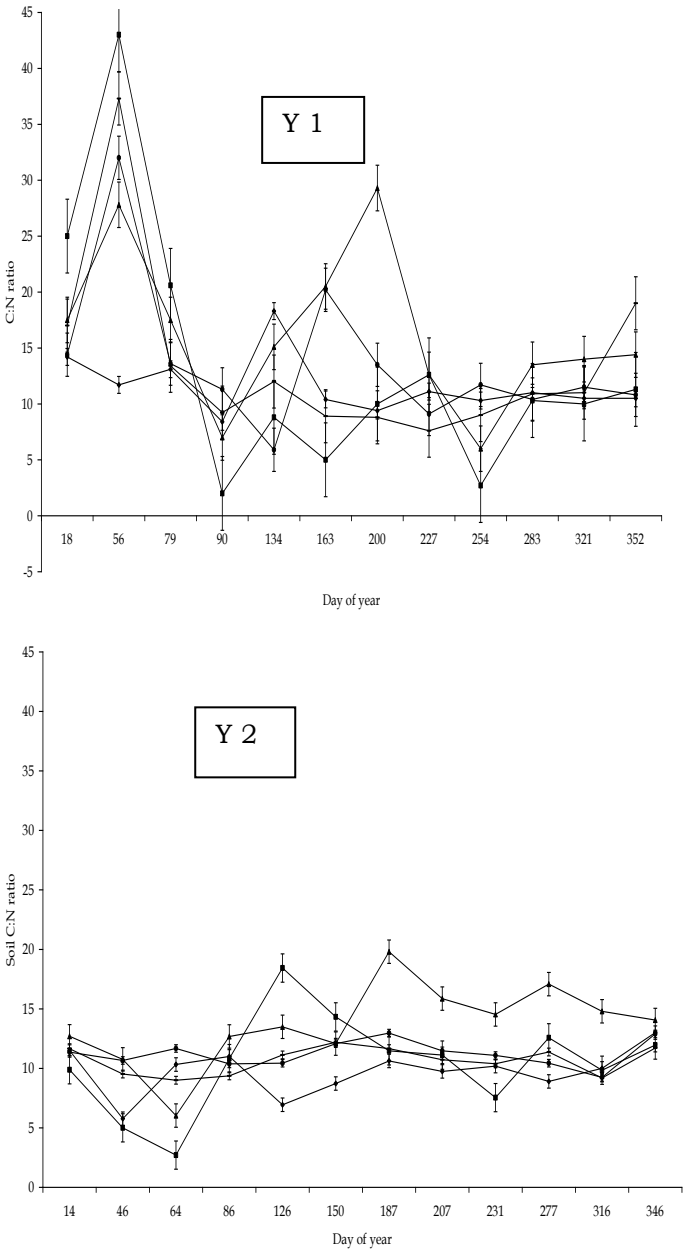

Fig 8. Monthly time course soil C:N ratio under various land management as described in Fig. 1. Each value is mean of 4 replicates. Bars represent standard error of means

Soil pH

The highest pH across sites was on day 163 (June) of y 1, 6.66 and day 316 (November) of y 2, 6.08. The lowest pH was on day 79 (March) of y 1, 6.33 and day 277 (October), of y 2, 5.18. The highest pH across months was in arable land under barley for both yrs, 7.60 and 7.4 respectively. The lowest pH was in deciduous woodland for both yrs, 4.46 and 3.78 respectively. No significant difference in yearly pH

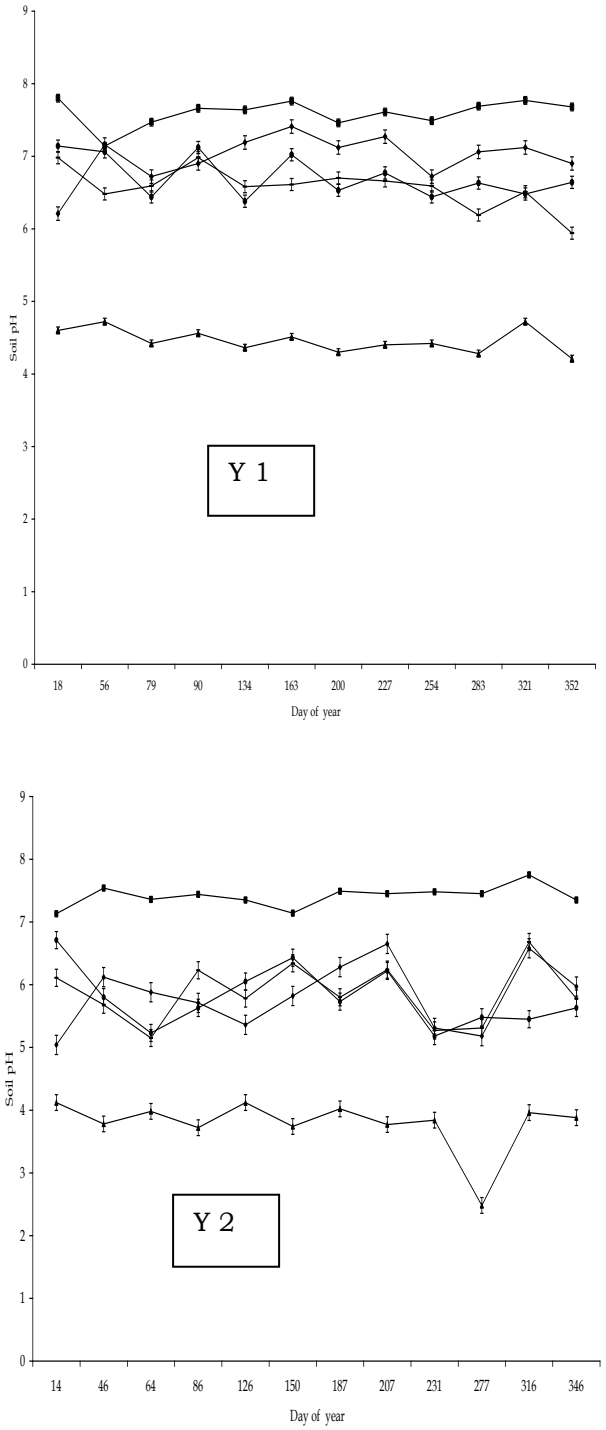

Fig 9. Monthly time course soil pH under various land management as described in Fig 1. Each value is mean of 4 replicates. Bars represent standard error of means

Changes in soil temperature

The highest soil temperature across sites was on day 227 (August) of y 1, 16.76°C and day 187 (July) of y 2, 20.74°C. The lowest soil temperature was on day 18 (January of y 1, 3.2°C and day 346 (February) of y 2, 3.02°C. The highest soil temperature across days of the y was in grassland under permanent pasture on a 5 y ley before stocking in y 1 and 2, 10.9 and 12.9°C respectively; while the lowest was in deciduous woodland in y 1 and 2, 10.3°C respectively. Whole ecosystem respiration was positively related to soil temperature (R^2 = 0.52) in y 1.

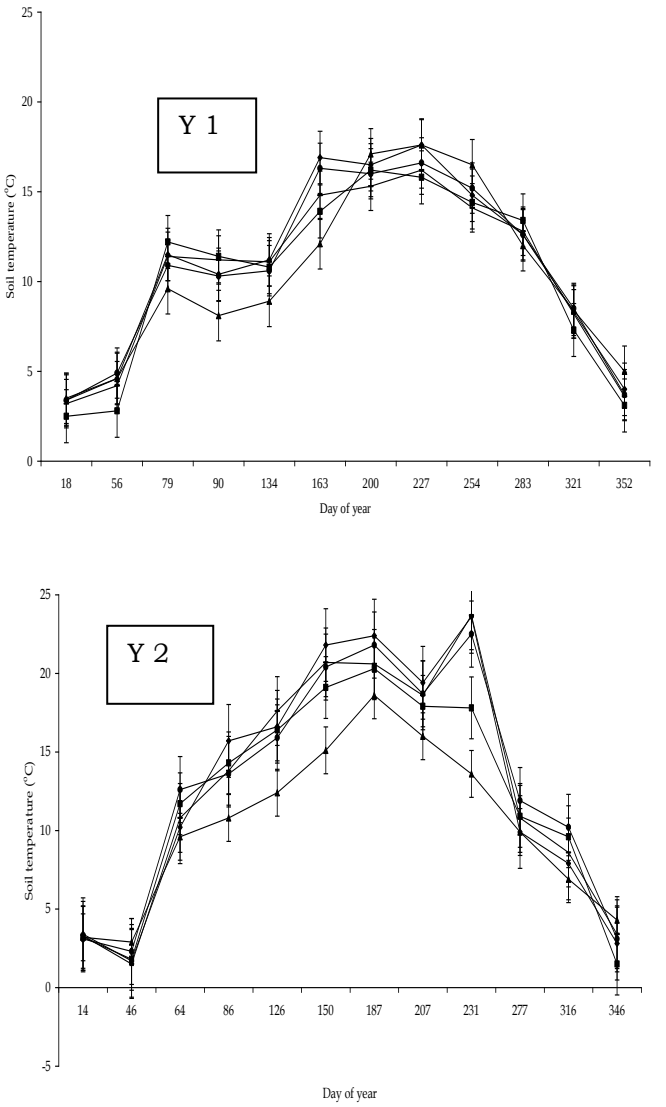

Fig 10. Monthly time course soil temperature (°C) under various land management as described in Fig 1. Each value is mean of 4 replicates. Bars represent standard error of means

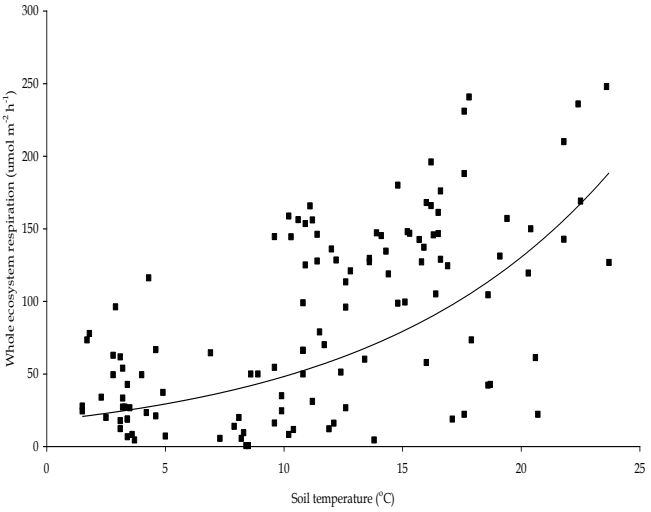

Fig 11. The relationship between whole ecosystem respiration (mmol m^{-2} $h^{-1)}$ and soil temperature (°C) in y 1. The fitted function is: C-Flux = 17.831 x $e^{(0.0995 \text{ x temp})}$, R^2 = 0.52, P≤0.05. No of points = 240 (5 sites x 4 replicates x 12 months). No relationship was established in y 2

Water filled pore spaces (WFPS)

Looking at temporal changes in WFPS across sites, the highest WFPS, 0.7 m^3 m^{-1} was on day 79 (March) in y 1 and 0.62 m^3 m^{-3} on day 126 (May) of y 2. The lowest WFPS was on day 283 (October) of y 1, 0.1 m^3 m^{-3} and day 207 (August) of y 2, 0.2 m^3 m^{-3}. The highest WFPS across months was in deciduous woodland in y 1, 0.5 m^3 m^{-3} and grassland under permanent pasture on 5 y ley before stocking in y 2, 0.5 m^3 m^{-3}. The lowest and same level of WFPS was in arable land under barley and grassland under permanent pasture sown with red clover a y before stocking in y 1, 0.3 m3 m-3. The same red clover plot had the lowest WFPS in y 2. A strong relationship was observed between whole ecosystem respiration and WFPS (R^2 = 0.61) and weak relation between soil respiration and WFPS (R^2 = 0.1).

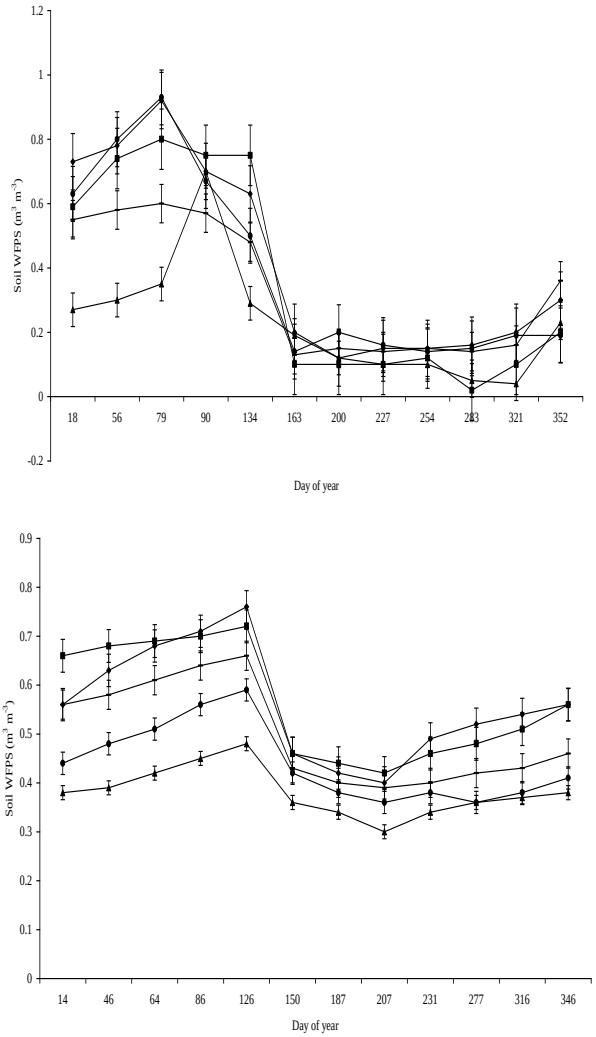

Fig 12. Monthly time course soil WFPS (m^3 m^{-3}) under various land management as described in Fig 1. Each value is mean of 4 replicates. Bars represent standard error of means

Discussion

Whole ecosystem respiration

The significant differences in whole ecosystem respiration over the months of Feb, Mar, Sep and Oct can be attributed to environmental variables. These periods coincided with winter, summer and autumn, each with distinct features. The winter is marked by adequate moisture but low temperature, spring has both optimum moisture and temperature; summer has low moisture but high temperature and autumn has optimum moisture and temperature.

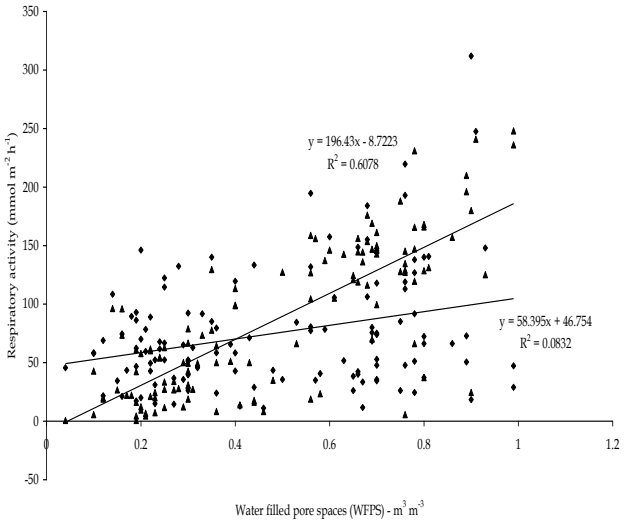

Fig 13. The relationship between whole ecosystem respiration (mmol m^{-2} h^{-1}) with soil WFPS (m^3 m^{-3}) as expressed by regression equation and coefficient of determination (R^2) in y 1. No of points = 240 = 5 sites x 4 replicates x 12 months. ▲whole ecosystem respiration; ■soil respiration. No relationship was established in y 2

These two variables, moisture and temperature appear to have played key role. Other factors were soil microbial C, total C. It was seen that an increase in soil microbial C and total C led to increase in whole ecosystem respiration. This suggests that soil microbial C has significant impact on activities of decomposer organisms and subsequent C-flux. Evidence exists that radiation, particularly during summer can lead to increased production of photosynthates and translocation belowground (rhizosphere deposition of C) –Grahammer et al (1991); Franzluebbers et al, (1995;2002). Franzluebbers et al (2002) added physiological processes like C-fixation and allocation on plant growth. Many of these workers emphasize the role of soil C in whole ecosystem respiration as it is a substrate for heterotrophic activity. This factors may be true of grassland under permanent pasture treated with N fertilizer in y 1, suggesting the effects of above and belowground biomass and N and in deciduous woodland in y 2, suggesting the effects of litter, biomass and N. The deciduous woodland was high in total porosity and low in bulk density throughout the y, while the soil from grassland under permanent pasture treated with N fertilizer a y before stocking was high in soil bulk density and low in total porosity due to effects of grazing (baseline studies done) The stocking and carrying capacity was light as classified by Parton et al, 1993.

The respiratory activity in Mar of y 1 may be due to several factors: optimum moisture, temperature and nutrient concentrations. Vanhala (2002) attributed the high respiratory activity in spring to the presence of readily utilizable C compounds released following the soil thaw. Most of these factors influenced respiratory activity in Sept in y 2 (autumn). This time was recommended for sampling by Vanhala (2002) in view of its respiratory activity. However, in this study the summer months gave the highest soil respiration rate.

Soil respiration

Since soil respiration was determined under constant temperature (25°C) and natural WFPS, it is likely that moisture and nutrient were the major factors influencing the outcome. Many workers have observed temperature and moisture when

kept constant makes variation in CO_2 flux to other changes in the physical and chemical properties of the soil e.g SOC, SON, pH; WHC –Singh and Gupta, 1977; Howard and Howard, 1993; Vanhala, 2002). Vanhala (2002) demonstrated effects of pH and moisture determine soil respiration at constant moisture. When the moisture content was kept constant, the amount of OM, majorly N and microbial C and pH made the difference. When respiration rate was calculated on the basis of the N concentration, the variation was mainly explained by pH only. This makes scientist incredible and wonderful people. They way they get into the route of the problem are amazing. This is civilization. This fact may be true for the grassland under permanent pasture treated with N fertilizer and deciduous woodland that led in soil respiratory activity for the 2 y. The levels of microbial C, total C and N in these types of land management support these results. Another factor that may have contributed to the soil respiration may be respiration due to root portions which was not separated in the laboratory in this investigation (Boone *et al*, 1998; Widen and Majdi, 2001) Pumpanen et al, (2003) detected differences between measured and predicted CO_2 effluxes during the autumn and the spring to seasonal proportion of root respiration and in the temperature response. Savage and Davidson (2003) reported similar effects on soil respiration as a result of distribution of roots, soil carbon substrates, soil temperature and water content, all of which vary spatially and temporally. Davidson et al (1998) saw variation in soil temperature for most of the seasonal and dual variation in soil CO_2 efflux but cautioned that temperature effect is not always consistent and other factors like soil water content, are more important. In their work, an exponential function relating CO_2 fluxes to soil temperature accounted for 80% of the seasonal variation in fluxes across all sites studied (Q_{10} = 3.9) but the Q_{10} ranged from 3.4 to 5.6. According to these workers, the Q_{10} function can yield reasonably good predictions of annual fluxes of CO_2, but it is a simplification that masks response of root and microbial processes to variation in temperature and water content throughout the soil.

In Curiel-Yuste et al (2003) temperature was the dominant factor over soil respiration during most of the year in temperature maritime forest. However, during spring and summer when the soil water was limiting soil respiration was insensitive to temperature. Other works have linked soil respiratory to environmental conditions and soil nutrients include: Jenkinson et al; 1976; Shen et al, 1997 who referred strong link of soil respiration and microbial C; Wang (2003) linked soil respiration to moisture and temperature and Franzluebbers et al (1999a,b) note close relations between soil respiration and microbial CO_2-C determined using the chloroform fumigation technique. Nevertheless, Sato and Seto (1999) and Wang et al (2003) failed to establish any relationship between soil respiration and microbial C

Soil microbial C

The high microbial C in deciduous woodland may be related to level of organic carbon especially following litter accumulation in autumn. The same applies for grassland under permanent pasture on 5 ley before stocking which had deposits of livestock dung throughout the sampling period. The autumn and early winter is a period marked with high levels of litter in the soil. These litters played three key roles namely: supply of substrates, conservation of soil moisture and temperature

Santruckova *et al* (2002) showed microbial C as a living component of SOC with a short turnover time. The proportion of microbial C in the total C pool does not only reflect the potential to transform organic C input into SOC and CO_2 but also the fraction of SOC that is immediately susceptible to fluctuations of environmental factors, soil disturbance and stress. Thus, soils with high microbial C have a greater potential to transform organic material but also a higher susceptibility to fluctuations in environmental factors

Soil total C and N

The level of soil total C and N during the months of Sept to Nov may be attributed to the increase in OM resulting from autumn litter. The same applies for the sites namely: deciduous woodland; grassland under permanent pasture sown with red clover a y before stocking and grassland under permanent pasture treated with N fertilizer a y before stocking. The steady input of OM into the deciduous woodland has resulted in a soil high in OM while the N fertilization a y before stocking and part irrigation during y 2 summer of the grassland under permananent pasture treated with N fertilizer may have provided the nutrient and moisture required for mineralization of SOM.

Solomon et al (2002) reported that agricultural management of virgin soil induces a drastic change in the equilibrium of SOM attained under undistrurbed conditions and thereby affects the quantity and quality of SOM especially in the near surface layers. In their study, the amounts of both total SOM and N in the surface soils significantly decreased, $P \leq 0.05$ following land use changes. For example, at Wushwush, forest clearing and 25 y of continuous low-input cropping led to depletion of 55% of the total SOC and 25% of total N, whereas 30 y of cultivation at the Munesa site resulted in a 63 and 60% reduction of the SOC and N in the bulk soils respectively. These results are comparable to those reported by Skjemstad et al (1986) for cultivated subtropical vertisols of Australia and with that of cultivated luvisols of northern Tanzania (Solomon et al, 2002). It is also comparable to the results from the calcareous pedosol of Writtle especially those under arable land under barley where total C and N were generally low for the seasons assessed.

Solomon *et al* (2002) also reported the depletion of SOM in continuously cultivated soils to drastic reduction in OM input and to tillage practices which frequently expose aggregates to physical disruption by rapid wetting and rain drop impact. The net effect is loss of SOM through the simulation of oxidation and exposure of the originally inaccessible OM to attack by soil micro organisms. This may be true in the arable land under barley which recorded high microbial activity during spring, summer and autumn. This plot was regularly tilled in the course of seed bed preparation. The high oxygen demand of this plot clearly led to depletion of available SOM. Lebron et al (2002) saw a decrease in SOM from Las Animas soils before and after reclamation from 1.4 to 0.77%. This decrease was consistent with highly coloured effluent obtained during the leaching of the soil. Podwojewski et al (2002) attributed high C content in paramo soils to specific OM originating from the decomposition of grasses, a statement supported by other works e.g Shoji et al (1990) and Barrois *et al* (1998).

Other suggestions for the decrease in OM included the cold conditions (cryic soil temperature regime) which inhibit microbiological activity (Shoji et al, 1993) and the physical and chemical protection of mineralization by organometalic complexes (Boudot *et al*, 1986). Podwojewski and his colleagues discovered that the soil total C in paramo soils decreased in the surface horizon from the humid, 100 g kg^{-1} to 70 g kg^{-1} soil which corresponds to a decrease of C storage in the surface horizon from 10 kg m^{-2} to 8 kg m^{-2} with very low values in the arenal area which supports little vegetation. Apart from the decrease in soil total C related to the precipitation gradient they also noted a strong decrease caused by soil degradation

with over grazing. For example, in permanent grazed places in humid paramo covered by recolonisation vegetation soil C storage was maintained at high levels, over 10 kg m^{-2} in the upper horizon. Similar view was supported by Hofstede and Rossenaar (1995). In the over grazed areas SOC in the surface horizon fell from 100 to 60 g kg^{-1} in the paramo area and from 70 to 40 g kg^{-1} in the dry paramo which corresponded to a decrease of C storage in the top 15 cm from 10 to 8 kg m^{-2} and from 8 to 5 kg m^{-2} respectively. The authors attributed the decrease in C content to substantial changes in the soil components and their micro-organisation.

A comparison of paramo work with current work show that grassland under permanent pasture was not affected by depletion of organic C except in arable land under barley. Prior to the work SOC in this soil was between 15 and 40 g kg^{-1}. After the y 1 and 2 total C rose to 50.8 g kg^{-1} except in arable land under barley where levels of 2.8 to 5.3 g kg^{-1} were recorded during winter and spring but which increased to 24.2 g kg^{-1} in autumn. There was no evidence of overstocking of the pasture. There was no problem of surface soil erosion which could leach SOM. The observed decrease in SOM in arable land during winter and spring may be attributed to crop uptake of nutrients by the winter barley and to crop removal during summer. Most of the biomass removed was not returned to the soil. However, the incorporation of residues of previous barley to the arable land during tillage by autumn in preparation for winter barley raised the total C in this plot at this time.

Soil pH

The low pH of the soils taken from deciduous woodland may have been due to the higher level of humic acid as described in Humic acid generated by ^{13}CNM Spectroscopy in this place (Igboji, 2015). In a study conducted in sub-humid Ethiopian Highlands influenced by deforestation and agricultural management, Solomon et al (2002) reported soil pH of 6.4 – 7.6 in natural forest, 5.7 – 7.4 in tea and cupressus plantation and 5.6 – 5.7 under cultivation. They also recorded a soil cation exchange capacity (CEC) of 37 – 52 cmol kg^{-1} under the natural forest, 25 – 40 cmol kg^{-1} under tea and cupressus plantation and 26 – 27 cmol kg^{-1} under cultivation. In Solomon *et al* (2002) the natural forest age was disclosed but the tea and cupressus plantations were 35 and 25 yrs respectively while the fields were cultivated for 30 yrs. In current work the deciduous woodland is over 200 years of age, the grassland under permananent pasture is over 50 years, while the arable land has been tilled for over 30 years. In a similar study of three saline-sodic soils in their natural condition from Madera, California and Arkansas valley, a pH of 7.06, 7.64 and 8.10 were obtained from the Hanford Soil Series (coarse loamy, mixed, superactive, non-acid, thermic Typic Xerorthents), Madera Soil Series (fine, smectic, thermic, abruptive Durixeralfs sandy clay loam and Las Animas Soil Series (coarse-loamy, mixed, superactive, calcareous, mesic Typic Fluvaquents silty loam) respectively – Lebron et al (2002). The Writtle soil is a Hanslope Soil Series (chalky boulder, slightly mottled, calcareous pedosol).

Soil temperature and WFPS

The low temperature in deciduous woodland may be due to to the mulching effects of the litter and shading effects of trees. The highest soil temperature in summer and lowest in winter is in line with the radiation recorded at these times of the y. A similar trend was observed with WFPS where the grassland under permament pasture on 5 y ley before stocking had the highest WFPS during the first y perhaps as a result of mulching effects of the grass and dungs. The high WFPS in arable land under barley in the second y may be due to the high porosity in this plot for most seasons of the y as a result of tillage. By virtue of its clay status it was able to retain sufficient moisture. For deciduous woodland the higher WFPS over the spring is also normal as it's litter enhanced water retention, added over the spring months with highest precipitation in the area. Podwojewski et al, (2002) did not observe any effect of grazing on soil total porosity. Several workers have reported the effects of different land management practices on soil temperature and moisture (Singh and Gupta, 1977; Doran et al, 1988; Oberbauer *et al*, 1992; Raich and Schlesinger, 1992; Howard and Howard, 1993; Hanson et al, 1993; Raich and Potter, 1995; Davidson *et al*, 1998; Franzluebbers *et al*, 1999; 2002; Vanhala, 2002; Raich *et al*, 2002; Curiel-Yuste *et al*, 2003; 2004).

Conclusion

Novel things happen when you get land management right. As can been seen each land management practice favoured either or combination of the physico-chemical properties evaluated. It has added to global discourse on nutrient dynamics of agricultural and non agricultural soils. The story of the East Anglia England is worth encouraging.

References

Alef, K. 1998. Soil respiration. In: Alef, K and P. Nannipieri, P., (Eds.). Methods in Applied Soil Microbiology and Biochemistry. 2nd edition. Academic Press Ltd, London; pp. 214 – 219.

Anon; 1990. Operators Manual, Version 1.8, PP Systems, Hitchens, UK.

American Society of Agronomy-Soil Science Society of America-Crop Science Society of America (ASA-SSSA-CSSA); 1998. Publications Handbook Style Manual, Madison, WI, pp. 154

Barrois, I., Dubroeucq, D., Rojas, P., and Lavelle, P.; 1998. Andosol-forming process linked with soil fauna under the perennial grass (Mulhembergia macroura) Geoderma 86: 241 - 260.

Boone, R. D.; Nadelhoffer, K. J.; Canary, J. D.; Kaye, J. P.; 1998. Roots exert a strong influence on the temperature sensitivity of soil respiration. Nature 396, 570 – 572.

Boudot, J. P., Hadj, A. B., and Chone, T.;1986. Carbon mineralization in andosols and aluminium-rich highland soils. Soil Biology and Biochemistry 4: 457 - 461

Briggs, D. J., Courtney, F. M., 1989. Agriculture and Environment: The physical geography of temperate agricultural systems. Longman Scientific and Technical.

Buringh, P.; 1984. Organic carbon in soils of the world. In: Woodwell, G. M., (Ed.), The role of terrestrial vegetation in the global carbon cycle: measurement by remote sensing. SCOPE 23. John Wiley and Sons, Ltd, New York: pp. 91 – 109.

Chambers, J. D and G. E. Mingay. 1966. The Agricultural Revolution (1750 – 1880). B. T. Batsford Ltd, London: 222 pp.

Coleman, K., Jenkinson, D. S.; 1996. RothC-26.3 - a model for the turnover of carbon in soil. In: Powlson, D.S., Smith, P., Smith, J. U., (Eds.), Evaluation of soil organic matter models, NATO ASI Series, Vol.138. Spinger, Berlin: 237 -246.

Curiel-Yuste, J., Janssens, I. A.; Carrara, A.; Meiresonne, L.; Ceulemans, R.; 2003. Interactive effects of temperature and precipitation on soil respiration in a temperate maritime forest. Tree Physiology 23, 1263 – 1270.

Curiel-Yuste, J.; Janssens, A.; Carrara, A.; Ceulemans, R.; 2004. Annual Q_{10} of soil respiration reflects plant phenological patterns as well as temperature sensitivity. Global Change Biology 10, 161 – 169.

Davidson, E. A.; Belk, E.; Boone, R.; 1998. Soil water content and temperature as independent or confounded factors

controlling soil respiration in a temperate mixed hardwood forest. Global Change Biology 4, 217 – 227.
Davis, B., Walter, B., Ball, N., Fitter, A.; 1992. The soil: The new naturalistic survey of British Natural History, Harper Collins
DEFRA.; 2006. The UK's Third National Communication under the United Nations Framework Convention on Climate Change. Dept for Environment, Food and Rural Affairs: 121 pp.
Dent, J. M., Russell, E. J., 1966. A history of agricultural science in Great Britain. George Allen and Unwin
Doran, J. W., Mielke, L. N., Stamatiadis, S.; 1998. Microbial activity and N cycling as regulated by soil water filled pore space. In: Tillage and traffic in crop production. Proceeding of 11th International Soil Tillage Research Organization, Edinburgh, Scotland 1, 11 – 15 July. Organizing Committee of the 11th International Soil Tillage Research Organization, Penicuik, Midlothian, Scotland, p. 49 – 54.
Doran, J. W., Safley, M., 1997. Defining and assessing soil health and sustainable productivity, p. 1 – 28. In: C. E. Pankurst (Ed.). Biological indicators of soil health. CAB Int., New York.
Fowler, P. J., 1983. The farming of prehistoric Britain. Cambridge University Press.
Franzluebbers, A. J.; Hons, F. M.; Zuberer, D. A.; 1995. Tillage and crop effects on seasonal soil carbon and nitrogen dynamics. Soil Science Society of American Journal, Vol. 59, 1618 – 1624.
Franzluebbers, A. J.;1999. Microbial activity in response to water filled pore space of variably eroded southern piedmont soils. Applied Soil Ecology 11, 91 – 101
Franzluebbers, A.J., Haney, R. L., Hons, F. M., 1999a. Relationship of chloroform- fumigation-incubation to soil organic matter pools. Soil Biology and Biochemistry 31: 395-405.
Franzluebbers, A.J., Haney, R. L., Hons, F. M., Zuberer, D. A., 1999b. Assessing biological soil quality with chloroform fumigation - incubation: why subtract a control?. Canadian Journal of Soil Science 79: 521-528.
Franzluebbers, K., Franzluebbers, A. J., Jawson, M. D.; 2002. Environmental controls on soil and ecosystem respiration from a tallgrass prairie. Soil Science Society of America Journal 66, 254 – 262
Grahammer, K., Jawson, M. D., Skopp, J.; 1991. Day and night soil respiration from a grassland. Soil Biology and Biochemistry 23, 77 – 81.
Hanson, P. J.; Wullschleger, S. D.; Bohlman, S. A.; Todd, D. E.; 1993. Seasonal and topographic patterns of forest floor CO_2 flux from an upland oak forest. Tree physiology 13, 1 – 15.
Hofstede, R. G. M., and Rossenaar, A. G. M.; 1995. Biomass of grazed, burned and undisturbed paramo grasslands. Colombia II: Root mass and aboveground:below ground ratio. Arctic and Alpine Research 27: 13 - 18.
Houghton, R. A.; 2003. Why are estimates of the terrestrial carbon balance so different. Global Change Biology 9, 500 – 509.
Howard, D. M., Howard, P. J. A.; 1993. Relationships between CO_2 evolution, moisture content and Humic substances in soil, sediment and water, Wiley, New York: 329.
Intergovernment Panel on Climatic Change (IPCC), 2001. Impacts, adaptability, and vulnerability. Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climatic Change. Cambridge University Press, UK.
Jenkinson, D. S., Ladd, J. N.; 1981. Microbial biomass in soil: measurement and turnover. In: Paul, E. A., Ladd, J. N. (Eds.). Soil Biochemistry 5, Marcel Dekker Ltd, New York: pp. 415 – 471
Jenkinson, D. S., Powlson, D. S., 1976. The effects of biocidal treatments on metabolism in soil – I. Fumigation with chloroform. Soil Biol. Biochem. 8: 167 – 177.
Jenkinson, D. S., Powlson, D. S., Wedderburn, R. W. M.; 1976. The effects of biocidal treatments on metabolism in soil III. The relationship between soil biovolume measured by optical microscopy and the flush of decomposition caused by fumigation. Soil Biology and Biochemistry 8: 189 – 202
Joergensen, R. G., 1998. The fumigation incubation method, p. 376 – 381. In: Methods in applied soil microbiology and biochemistry, Alef, K., Nannipieri, P.,(eds), Academic Press, London.
Lebron, I., Suarez, D. L., and Yoshida, T.; 2002. Gypsum effect on the aggregate size and geometry of three sodic soils under reclamation. Soil Sci. Soc. Am. J. 66 (1): 92 - 98.
Neate, D., 1979. Writtle agricultural college wildlife and landscape survey: Report and recommendations, Sept., 78 pp.
Oberbauer, S. F.; Gillespie, C. T.; Cheng, W.; Gebauer, R.; Sala-Serra, A.; Tenhunen, J. D.; 1992. Environmental effects on CO_2 efflux from riparian tundra in the northern foothills of the Brooks Range, Alaska, USA. Oecologia 92, 568 – 577.
Parton, W. J., Anderson, D. W., Cole, C. V., Stewart, J. W. B.; 1983. Simulation of soil organic matter formation and mineralization in semi-arid agroecosystems. In: Lowrance, R. R., Todd, R. L., Asmussen, L. E., Leonard, R. A., (Eds.). Nutrient cycling in agricultural ecosystem. The University of Georgia, College of Agriculture Experiment Stations, Special Publ. No. 23, Athens, Georgia.
Igboji, P. O; 2015. Predicting carbon sequestration under land management practices for six periods of English agriculture. Submitted to Elixir Publishers.
Igboji, P.O, 2015. Effect of land management on humic acid spectra generated using ^{13}CNM Spectroscopy. Submitted to Elixir Publishers.
Parton, W. J., McKeown, R., Kirchner, V., Ojima, D., 1992. Users guide for the CENTURY model. Colorado State University.
Parton, W. J., Metherell, A. K., Harding, L. A., Cole, C. V.; 1993. CENTURY: Soil organic matter model environment. Technical documentation, agroecosystem version 4.0. Great Plains System Research Unit, Technical Report No. 4, USDA-ARS, Fort Collins, Colorado.
Parton, W. J., Schimel, D. S., Cole, C. V., Ojima, D. S., 1987. Analysis of factors controlling soil organic levels of grasslands in the Great Plains. Soil Sci. Soc. Am. J. 51: 1173 – 1179.
Podwojewski , P., Poulenard, J., Zambrana, T., and Hofstede, R. ; 2002. Overgrazing effects on vegetation cover and properties of volcanic ash soil in the paramo of Llangahua and La Esperanza (Tungurahua, Ecuador). Soil Use and Mgt 18 (1) : 45 – 55.
Pretty, J.; 2002. Agriculture: Reconnecting people, land and nature. 1st Edition. Earthscan Publishers Ltd, London, UK, pp. 261
Probert, M.E., Dimes, J. P., Keating, B. A., Dalal, R. C., Strong, W. M., 1998. APSIM's water and nitrogen modules and simulation of the dynamics of water and nitrogen in fallow systems. Agricultural Systems 56: 1-28.
Pumpanen, J.; Ilvesniemi, H.; Hari, P.; 2003. A process based model for predicting carbon dioxide efflux and concentrations. Soil Science Society of America Journal 67, 402 – 413.

R.S.C.; 2001. Pollution: Causes, effects and control. Royal Society of Chemistry, Cambridge: 557 pp.

Rackham, O., 1986. The history of the countryside. London, Dent: 445 pp. + xvi

Raich, J. W.; Potter, C. S.; 1995. Global patterns of carbon dioxide emissions from soils. Global Biogeochemical Cycles 9, 23 – 36.

Raich, J. W.; Potter, C. S.; Bhagawati, D.; 2002. Interannual variability in global soil respiration, 1980 – 94. Global Change Biology 8, 800 – 812.

Raich, J. W.; Schlesinger, W. H.; 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44B, 81 – 99.

Rowell, D. L.; 1994. Soil Science: Methods and Applications. 1st Edition. Longman Scientific and Technical, UK, p. 116 – 121

Royal Commission on Environmental Pollution – RCEP. ; 1996. Sustainable use of soil. In: Houghton, J. (Chairman). 19th Report presented to Parliament by Command of Her Majesty, HMSO

Santruckova, H., Bird, M. I., Kalaschnikov, Y. N., Grund, M., Elhottova, M., Simek, S., Grigoryev, S., Gleixner, G., Arneth, A., Schulze, E.D., Lloyd, J., 2002. Microbial characteristics of soils on a latitudinal transect in Siberia. Faculty of Biological Sciences, University of Bohemia, Czech Republic: 32 pp.

Savage, K. E.; Davidson, E. A.; 2003. A comparison of manual and automated systems for soil CO_2 flux measurements: trade-offs between spatial and temporal resolution. Journal of Experimental Botany, Vol. 54, No 384, 891 – 899.

Shen, S.M., Brookes, P. C., Powlson, D. S., 1997. Effect of long-term straw incorporation on soil microbial biomass and C and N dynamics. Pedosphere 7: 297-302.

Shoji, S., Kurebayashi, T., and Yamada, I.; 1990. Growth and chemical composition of Japanese pampas grass (Miscanthus sinensis) with special reference to the formation of dark-colored andisols in north eastern Japan. Soil Science and Plant nutrition 36:105 - 120.

Simmons, I., Tooley, M. 1981. The environment in British prehistory.

Singh, J. S., Gupta, S. R.; 1977. Plant decomposition and soil respiration in terrestrial ecosystems. The Botanic Review 43, 449 – 528

Skjemstad, O. J; Dalal, R. C., and Barron, P. F.; 1986. Spectroscopic investigations of cultivation effects on organic matter of vertisols. Soil Sci. Soc. Am. J. 50: 354 – 359

Solomon, D; Fritzsche, F., Tekalign, M., Lehmann, J., and Zech, W.; 2002. Soil organic matter composition in the subhumid ethiopian highlands as influenced by deforestation and agricultural management. Soil Sci. Soc. Am. J. 66 (1): 68 - 82.

Sowerby, A., Blum, H., Gray, T. R. G., Ball, A. S.; 2000. The decomposition of Lolium perenne in soil exposed to elevated CO_2: comparisons of mass loss of litter with soil respiration and soil microbial biomass. Soil Biology and Biochemistry 32, 1359 – 1366

Joergensen, R. G., Brookes, P. C., Jenkinson, D. S., 1990. Survival of the soil microbial biomass at elevated temperatures. Soil Biol. Biochem. 22: 1129 - 1136.

Vanhala, P.; 2002. Seasonal variation in the soil respiration rate in coniferous forest soils. Soil Biology and Biochemistry 34, 1375 – 1379.

Wang,W.J; Dalal, R. C.; Moody, P. W., and C.J. Smith, C. J.; 2003.Relationships of soil Respiration to microbial biomass, substrate availability and clay content. Soil Biology and Biochemistry 35: 273 – 284.

Widen, B.; Majdi, H.; 2001. Soil CO_2 efflux and root respiration at three sites in a mixed pine and spruce forest:seasonal and diurnal variation. Canadian Journal Forest Resources 31, 786 – 796.

Writtle College, 2006. Crop production handbook: Farm data and general information (2003 – 2004), 93 pp.

Zar, J. H.; 1999. Biostatistical analysis. 4th Edition. Prentice Hall, New Jersey, pp. 663 + xii