Impact of addition of various resource quality inputs on soil CO_2 flux and C balance in a tropical dryland agroecosystem

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Abstract

Management strategies in agroecosystems may influence C balance in soil through variation in C input to soil and also by causing variation in C output from soil. In a two year study we evaluated the effect of application of soil inputs with varying resource quality viz: high quality (C:N 16; HQR), low quality (C:N 82; LQR) and mixed quality (HQR +LQR; MQR) inputs having equivalent amount of N, on the soil CO_2 flux, % C build-up, soil C balance and crop productivity in a tropical dryland rice-barley-summer fallow agroecosystem. Addition of LQR singly resulted in high probability of C retention capacity compared to other treatments, however lower levels of soil C build-up, and crop productivity was observed. On the other hand, although in HQR treatment the C balance approached almost unity, the C build-up and crop productivity was comparable to that of the LQR treatment. Combining the two inputs resulted in significant build-up of soil C and enhancement of crop productivity and also indicated high C sequestration capacity. It is concluded that for sequestration of C, the resource quality of the input i.e., the form of C, labile or recalcitrant, is more important than the absolute amount of C added to the soil through exogenous inputs.

Key Words

Resource quality, agroecosystem, soil CO_2 flux, C balance, C build-up, crop yield.

Introduction

Agroecosystems has become very important not only for its role in achieving food security but also in mitigation of the climate change due to atmospheric enrichment of CO_2 and other greenhouse gases (IPCC 2001). The mechanism and potential of C sequestration in soil are still not well understood, and predictions made for world-wide carbon (C) balance remain uncertain (Rustad 2006). Since soil can serve both as a source or sink for atmospheric CO_2 depending upon the agricultural management practices employed, any change in management strategies may influence soil C cycle (Lal 2004). Maintenance of soil organic C is essential for the long-term sustainability of agroecosystems in general and particularly dryland agroecosystems. Achieving agricultural sustainability is the prime need for India where about 68% of total agricultural land (85×10^6 ha) is under dryland farming conditions, receiving moisture supply only through highly seasonal rainfall. In the contemporary global change scenario, the evaluation of the impact of agricultural management practices on both the emission of CO_2 from soil and C sequestration capacity in soil has been emphasized. However, limited information is available on the maintenance and sequestration of C in soils of rice field in general and particularly in tropical dryland agroecosystems (Singh *et al.* 2009). In drylands the application of soil organic amendments (e.g. crop residues, green manures), among other measures, is generally recommended for efficient management of soil organic matter and moisture availability (Singh *et al.* 2007). It is important to emphasize on not only the quantity of organic amendments, but its resource quality as well. There is a need to evaluate the impact of management strategies, which manipulate the quality of exogenous inputs, on soil CO2–C flux in tropical dryland agroecosystems, an aspect scantily explored so far. The broad objective of the present work was to examine the influence of resource quality on soil CO_2 flux in the context of agricultural sustainability and global change. The specific objectives of the present study, carried out in a Indian tropical dryland agroecosystem having rice-barley-summer fallow annual sequence, subjected to varying quality soil inputs, were: (1) to evaluate the effect of quality of exogenous inputs on soil CO_2 flux, microbial biomass and crop root biomass, (3) to quantify soil C build-up and increment in crop yield and (4) to estimate the C balance in soil through C input and C output.

Material and method

The experiments were conducted in Banaras Hindu University campus at Varanasi (25°18' N lat. And 83°1' E long., 76 m above the mean sea level. This region has a tropical moist sub-humid climate, characterized by strong seasonal variations with respect to temperature and precipitation. The long term average annual rainfall is about 1100 mm. The soil belongs to the order inceptisol, showing pale brown colour, sandy loam

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texture and a neutral reaction. The experimental design involved application of various soil amendments having equivalent amount of N (80 Kg N) but with contrasting chemical composition viz. chemical fertilizer (FER) and three organic inputs in form of high quality resource (*Sesbania aculeata* shoot, N 3.03%, C:N 16, lignin:N 3.2, polyphenol + lignin:N 4.2, HQR),low quality resource (wheat straw, N 0.61%, C:N 82, lignin:N 34.8, polyphenol + lignin:N 36.8, LQR), and high and low quality resource combined (*Sesbania*+wheat straw, MQR) besides control (cropped, no inputs, CON). Every year the exogenous inputs were applied only once, 1 or 2 d before the sowing of the rice crop. The experimental plots were laid down in a random block design using three replicates per treatment. The plot size was 3 m _3 m. A strip of 1 m was left to separate each block.

During the two year study the flux of CO_2 from soil surface was determined 32 times at regular intervals under field condition using alkali absorption method. (Singh and Shekhar 1986). Each year the flux was estimated seven times during the both the crop periods which corresponded with seedling, pre-grain-forming, grain-forming, post-grain-forming and maturity stages of crops and twice during summer fallow. Cumulative soil CO_2 flux was calculated as the sum of CO_2 evolved during different sampling intervals. The sum of rice and barley yields was represented as annual crop yield (CY). Crop yield increment (%) was estimated as: (CY of treatment – CY of control) x100 / CY of control. Soil organic C (SOC) was estimated by dichromate oxidation and titration method during summer fallow. C build-up (%) was estimated as: C build-up (%)= (SOC in treatment – SOC in control) x 100 / SOC in control. C content of plant materials were estimated by CHN Analyzer. Soil C balance was estimated as: C input in soil - C output from soil, where, C input was accounted as sum of C added through exogenous inputs, crop roots and crop stubbles and C output was accounted from soil CO_2 flux (using conversion formula, C = CO_2 /3.67).

Result and discussion

A distinct seasonal variation in CO_2 flux was recorded in all treatments, flux being higher during rice period, and much reduced during barley periods (Table 1). During rice period the mean CO_2 flux was greater in LQR and MQR treatments; however, during barley and summer fallow periods differences among treatments were small. The variability in annual cumulative soil CO_2 flux was strongly related to various indices of resource quality of the exogenous inputs, i.e. C:N (r = 0.96), lignin:N (r = 0.92) and polyphenol+lignin:N (r = 0.92) ratios.

Table 1. Variation in soil CO_2–C flux and Cumulative CO_2–C flux following various soil amendments.

	CO_2 flux (mg CO_2/m^2/h ± SE)			Cumulative CO_2 flux (g CO_2/m^2/y)
Treatments	Rice (112 days)	Barley (139 days)	Summer Fallow (60 days)	Annual
1st Annual Cycle				
CON	180.7 ± 15.5	94.2 ± 6.0	129.4 ± 4.5	972 ± 30.3
FER	138.1 ± 11.3	94.8 ± 7.3	131.7 ± 5.3	889 ± 20.2
LQR	427.1 ± 28.2	91.4 ± 6.5	132.8 ± 7.5	1606 ± 6.6
HQR	164.8 ± 15.6	98.7 ± 7.0	138.5 ± 9.2	982 ± 21.3
MQR	361.6 ± 22.1	100.2 ± 6.7	135.3 ± 4.5	1480 ± 6.1
2nd Annual Cycle				
CON	142.3 ± 10.9	86.8 ± 5.2	133.8 ± 8.2	889 ± 14.0
FER	151.2 ± 17.8	94.1 ± 5.8	139.5 ± 3.0	944 ± 19.2
LQR	406.7 ± 25.8	101.3±5.3	141.8 ± 5.6	1633 ± 9.0
HQR	213.3 ± 18.2	92.1 ± 5.2	132.8 ± 4.7	1083 ± 12.5
MQR	366.1 ± 24.7	99.7 ± 5.2	143.6 ± 4.3	1518 ± 7.7

Although, the cumulative CO_2 flux was higher in LQR and MQR treatments yet, on considering CO_2 flux per unit C added the ratio was lower indicating the possibility of high C retention in soil despite of huge loss of C (in terms of CO_2) from these treatments. A reverse trend was found in CON, FER and HQR treatments with lower cumulative CO_2 flux with an overall net loss of C (Table 2). CO_2 flux per unit C added may give a better indication of C dynamics compared to cumulative CO_2 flux alone.

Table 2. Variation in total C input to soil, CO_2 flux per unit C added, C build up and crop yield increment as influenced by various soil amendments.

Parameters	Treatments				
	CON	FER	LQR	HQR	MQR
C input (g C/m^2/y)	108 ± 1.9	163 ± 1.8	819 ± 9.2	292 ± 6.0	566 ± 2.1
Cumulative CO_2 flux per unit C added (g CO_2/gC/y)	2.2± 0.14	1.6 ± 0.08	0.5 ± 0.05	1.0 ± 0.03	0.7 ± 0.05
C build up (%)		8	18	15	33
Crop yield increment (%)		45	32	38	49

In any system when C input to the soil exceeds the C output from the soil, a positive imbalance occurs which subsequently results in sequestration of C in soil (Jastrow *et al.* 2007). In our study difference between C input and output in soil was found to be positive in the treatments where LQR was added either singly or in combination (Figure 1). Jacinthe *et al.* (2002) reported that soil mulching through the incorporation of wheat straw has beneficial effect on soil C sequestration. Paustian *et al.* (1997) also suggested that crop residues with higher C:N ratio play important role in C sequestration. Although LQR showed high C sequestration capacity in terms of C balance yet, the huge input of C in soil could not be translated to C storage either in the form of soil organic C build-up, or crop productivity (Table 2). Due to the slow rate of its decomposition of wheat straw C and other nutrients remained immobilized in undecomposed or partially decomposed portions of wheat straw (Singh *et al.* 2007), and was perhaps not available immediately after its application. The recalcitrant component of LQR may be incorporated in the passive pool of soil organic matter in long term as indicated by the balance of C input and output.

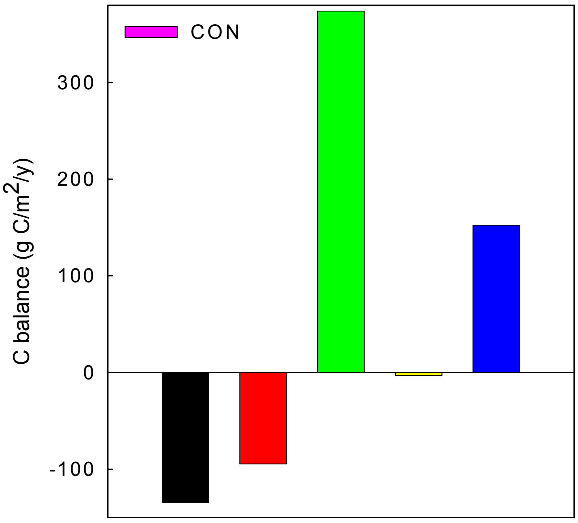

Figure 1. Impact of soil inputs on C balance during second annual cycle.

On the other hand, although in HQR treatment the C output was almost balanced by C input, the C build-up and crop productivity was comparable to that of the LQR treatment inspite of one-third C input (cf. wheat straw). Rapid decomposition of HQR resulted in release of the readily mineralizable labile C and other nutrients which perhaps were utilized for the accumulation of labile pool of soil organic matter and not for build-up of C or enhancement of crop productivity. Since C balance is near unity, this level of C may be maintained for long time. Addition of HQR to LQR altered the rate of decomposition resulting in prolonged release of nutrients which in turn supported the enhanced crop productivity and so also the C build up. In addition, some C which remained in the soil as recalcitrant partially decomposed mass may lead to C sequestration in the long term as evident from balance between C input and output. In case of CON and FER treatments the system seemed to be most unbalanced as the input of C exceeded C output.

Conclusion

In this two year study combining the high and low quality inputs resulted in significant increment in C build-up and crop yield in addition to high C balance. The soil C retention capacity however varied significantly, mostly influenced by the recalcitrant or labile nature of the inputs. It is suggested that appropriate mixing of high and low quality inputs may contribute to improved crop productivity and soil fertility in terms of soil C sequestration, which in turn will help mitigate atmospheric CO_2.

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