SOILS AND FERTILIZER MANAGEMENT FOR CARBON SEQUESTRATION

R. Lal

Carbon Management and Sequestration Center, The Ohio State University,

2021 Coffey Road, Columbus, OH 43210

ABSTRACT

In comparison with the geologic and oceanic options, C sequestration in soils and terrestrial ecosystems has numerous ancillary benefits (Lal, 2008a). For example, increase in soil C pool improves soil quality and agronomic/biomass productivity; enhances water quality by reducing erosion and non-point source pollution; increases soil biodiversity; improves use efficiency of agronomic input and enhances the environment quality (Lal,2004a). Soil C sequestration (SCS) is based on the natural process of photosynthesis and conversion of biomass C into soil C pool. Therefore, the rate of SCS depends on the rate of soil application of biomass C along with those of N, P, K, S and other components essential to humification (Lal, 2008b). While C is supplied through application of biosolids, it is also essential to maintain a positive nutrient budget through judicious application of fertilizers and integrated nutrient management.Therefore, net rate of SCS must account for the hidden C costs of tillage, irrigation, fertilizers, pesticides and other energy-based input. Most of these inputs are manufactured through energy produced from fossil fuel. Hidden C costs range from ~1kg C/kg of N to 5 to 7 kg C/kg of active ingredients of pesticides. Primary tillage operations also require 30 to 40 kg C/*h*a (Lal, 2004b). Transfer of atmospheric CO_2 into other pools with a larger residence time(C sequestration)has several technological options. Geologic sequestration involves capture, purification, compression transport and injection of industrially-produced (point source) CO_2 into geologic strata about 1000 m deep into stable geologic strata or a saline aquifer. Compressed CO_2 can also be injected into old oil wells to enhance oil recovery (EOR), into unmineable coal seams to increase yield of coal bed methane (CBM), or deep in the ocean floor where it forms a CO_2 lake. Stagnating and declining crop yields, especially in South Asia's rice-wheat system, are attributed to decline in soil quality caused by removal or burning of crop residues, low rate or unbalanced application of fertilizers, indiscriminate/excessive grazing of stubbles, and inappropriate use of irrigation water (Lal, 2008c). Most cropland soils of South Asia, similar to those of Sub-Saharan Africa (IFDC, 2006), have a negative nutrient budget (Roy, 2003). The problems of soil degradation, water pollution and contamination by fertilizers and pesticides, low and declining crop yields, and poor environment quality can be partly addressed by restoring degraded ecosystems through increasing soil C pool (Lal, 2008d). However, land managers must be compensated for the ecosystems services of value to humans (Lal, 2008e). Sequestration of C in soils and ecosystems depends on use of precious input(e.g.,crop residues,fertilizers,animal manure and compost,irrigation) for which farmers must be compensated. Undervaluing soil C, as is the case by trading C at $2.50/ton of CO_2 through voluntary market, is counter productive. The value of soil C for ecosystem services is as much as $250/ton of C. Thus, farmers must be compensated appropriately and justly as an incentive to adopt restorative land use and recommended management practices. Trading credits of C sequestered in soils, by creating another income stream for farmers, provides the necessary incentive to invest in soil restoration and adoption of recommended management practices.

KEY WORDS Carbon trading, Hidden carbon costs, Nutrient mining, Soil exhaustion, Carbon budgeting, Ecosystem carbon budget, Soil carbon sequestration

REFERENCES

IFDC 2006. African soil exhaustion. Science 312:31.

Lal, R. 2004a. Soil carbon sequestration to mitigate climate change. Geoderma 123: 1-22.

Lal, R. 2004b. Carbon emissions from farm operations. Env. Intl. 20: 981-990.

Lal, R. 2008a, Sequestration of atmospheric CO_2 in global C pools. Energy and Env. Sci. 1: 86-100.

Lal, R. 2008b. Caron sequestration in soil. CAB Reviews (http://www.cababstracts.org/cabreviews).

Lal, R. 2008c. Soil and India’s food security. J. Ind. Soc. Soil Sci. 56(2): 351-367.

Lal, R. 2008d. Food insecurity’s dirty secret. Science 322: 673-674.

Lal, R. 2008e. Promise and limitation of soils to minimize climate change. J. Soil Water Cons. 63: 113-118.

Roy, A. H. 2003. Fertilizer need to enhance production: challenges facing India. In R. Lal, D. Hansen, N. Uphoff and S. Slack (Eds) “Food Security and Environmental Quality in the Developing World”. Lewis Publishers, Boca Raton, FL: 53-67.

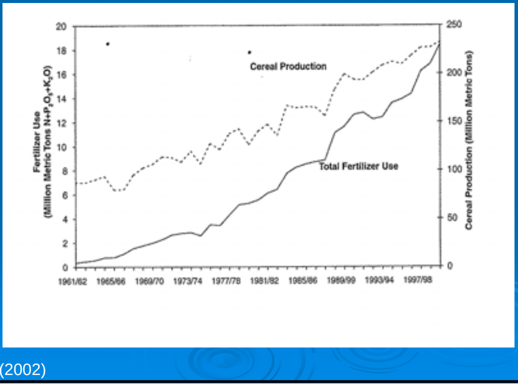
Soils and Fertilizers

R. Lal
Carbon Management and Sequestration Center
The Ohio State University, Columbus, OH
43210 USA

Nutrients and Residue Required to Sequester 100 kg of Soil Carbon

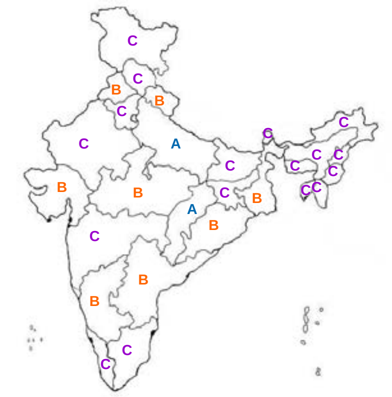
N. . . . . 8.33 kg
P. . . . . 2.0 kg
S. . . . . 1.43 kg
C. . . . . 1000 kg (10% efficiency, 2500 kg of residue

Growth in Cereal Production and Fertilizer Use - India



Roy (2002)

Annual Soil NPK Depletion

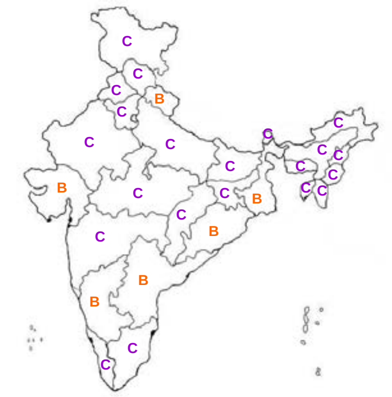


NPK Depletion (kg/ha)

A	< 20
B	41-80
C	> 80

Roy (2002)

Annual Soil K_2O Depletion



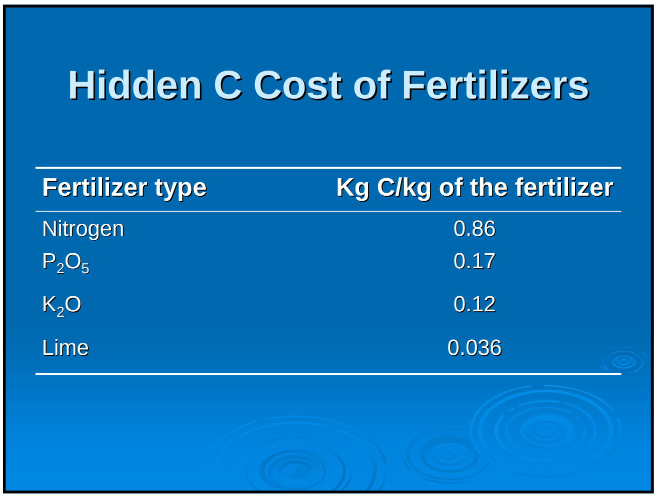
K_2O Depletion (kg/ha)

A	< 20
B	20-40
C	41-80

Roy (2002)

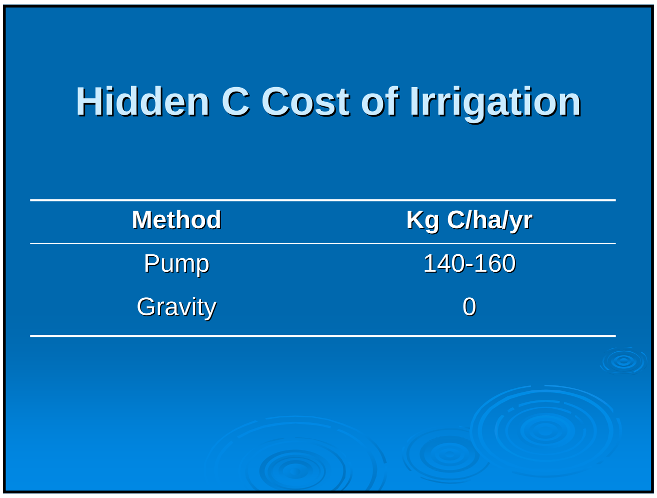
Hidden C Costs of Tillage Methods

Method	Kg C/ha/yr
Conventional tillage	62-72
Minimum tillage	40-45
No tillage	20-23



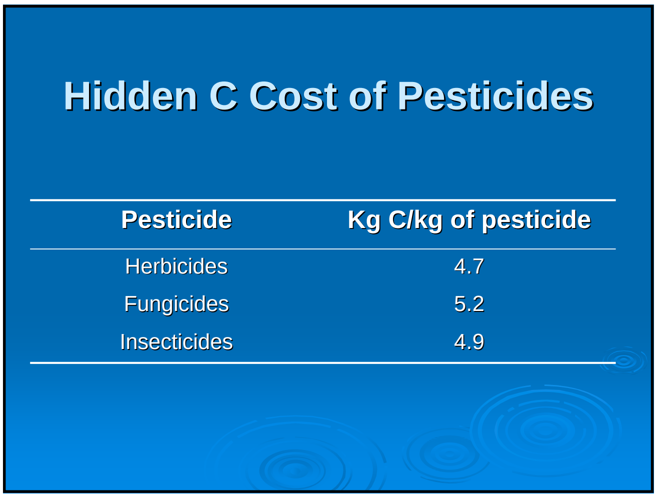
Hidden C Cost of Fertilizers

Fertilizer type	Kg C/kg of the fertilizer
Nitrogen	0.86
P_2O_5	0.17
K_2O	0.12
Lime	0.036



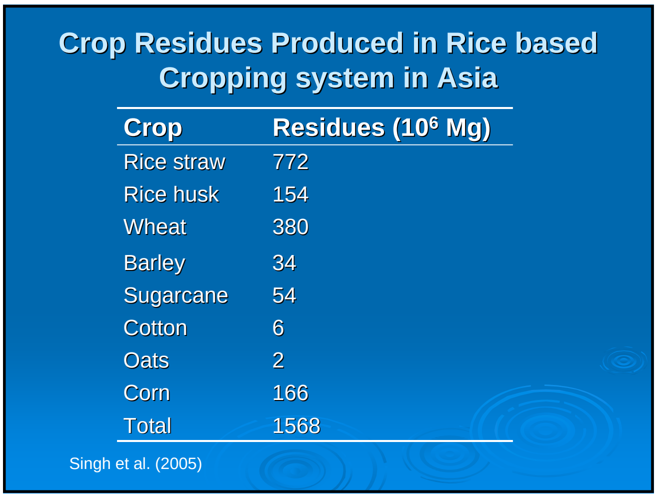
Hidden C Cost of Irrigation

Method	Kg C/ha/yr
Pump	140-160
Gravity	0



Hidden C Cost of Pesticides

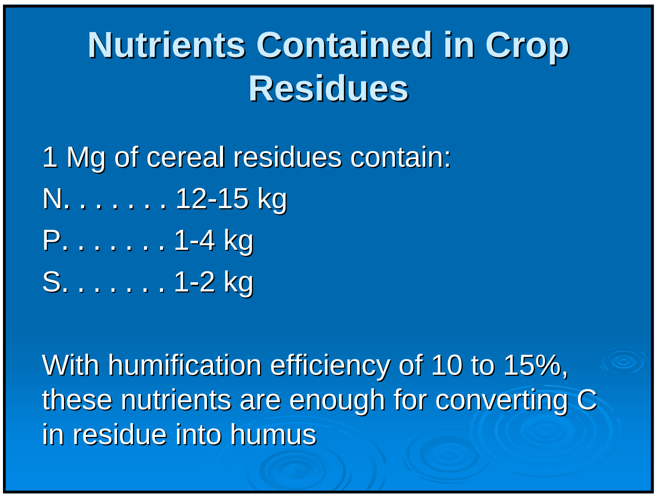
Pesticide	Kg C/kg of pesticide
Herbicides	4.7
Fungicides	5.2
Insecticides	4.9



Crop Residues Produced in Rice based Cropping system in Asia

Crop	Residues (10^6 Mg)
Rice straw	772
Rice husk	154
Wheat	380
Barley	34
Sugarcane	54
Cotton	6
Oats	2
Corn	166
Total	1568

Singh et al. (2005)



Nutrients Contained in Crop Residues

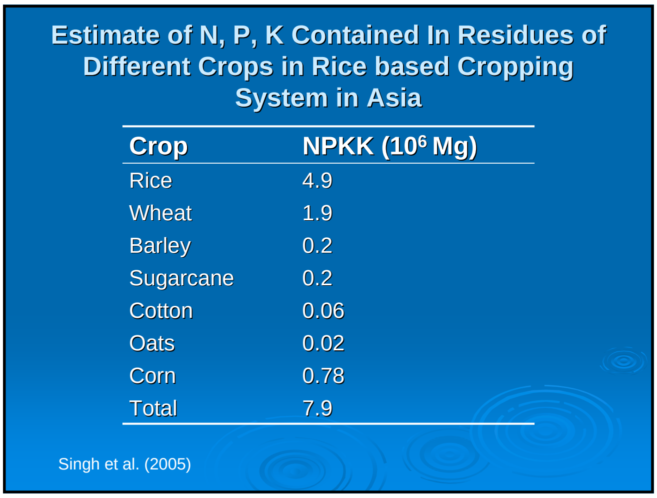
1 Mg of cereal residues contain:

N. . . . . . . 12-15 kg

P. . . . . . . 1-4 kg

S. . . . . . . 1-2 kg

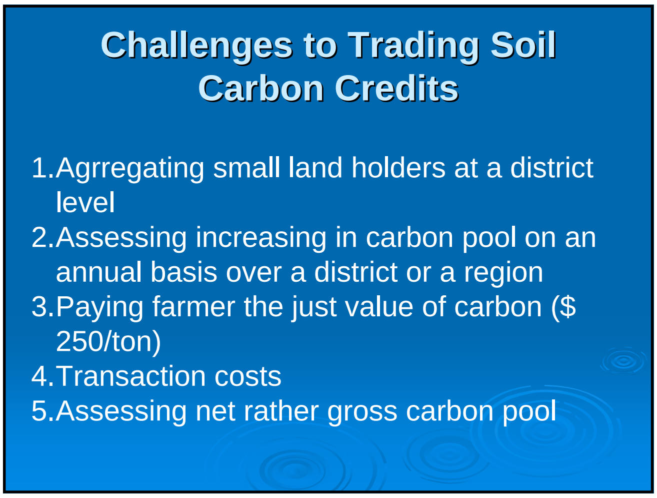
With humification efficiency of 10 to 15%, these nutrients are enough for converting C in residue into humus



Estimate of N, P, K Contained In Residues of Different Crops in Rice based Cropping System in Asia

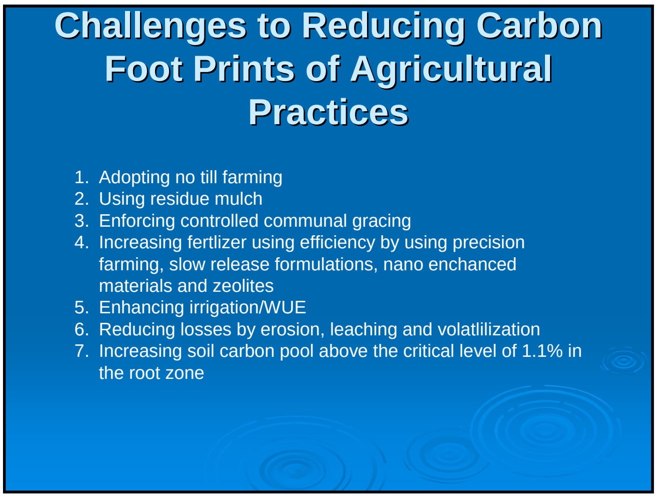
Crop	NPKK (10^6 Mg)
Rice	4.9
Wheat	1.9
Barley	0.2
Sugarcane	0.2
Cotton	0.06
Oats	0.02
Corn	0.78
Total	7.9

Singh et al. (2005)



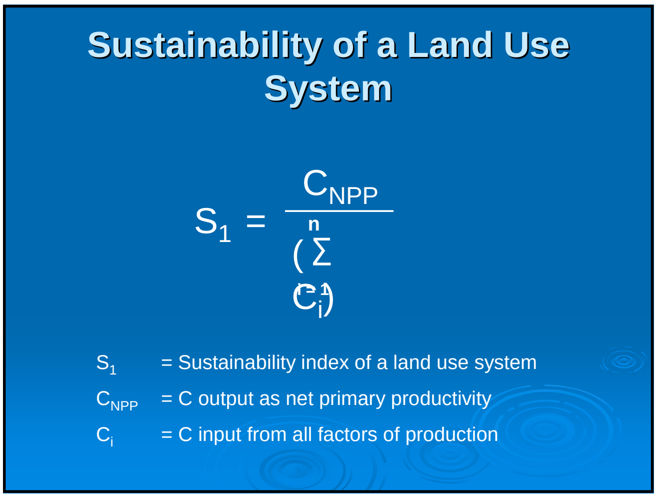
Challenges to Trading Soil Carbon Credits

1. Agrregating small land holders at a district level
2. Assessing increasing in carbon pool on an annual basis over a district or a region
3. Paying farmer the just value of carbon ($ 250/ton)
4. Transaction costs
5. Assessing net rather gross carbon pool



Challenges to Reducing Carbon Foot Prints of Agricultural Practices

1. Adopting no till farming
2. Using residue mulch
3. Enforcing controlled communal gracing
4. Increasing fertlizer using efficiency by using precision farming, slow release formulations, nano enchanced materials and zeolites
5. Enhancing irrigation/WUE
6. Reducing losses by erosion, leaching and volatlilization
7. Increasing soil carbon pool above the critical level of 1.1% in the root zone



Sustainability of a Land Use System

$$S_1 = \frac{C_{NPP}}{\left(\sum_{i=1}^{n} C_i\right)}$$

S_1 = Sustainability index of a land use system

C_{NPP} = C output as net primary productivity

C_i = C input from all factors of production