Position Paper

Potassium and CO_2 Sequestration

Background

The Kyoto Protocol imposed limits to industrial emission of six greenhouse gases (GHGs), mostly CO_2, by the years 2008–2012. Concomitantly, it recognized three mitigation actions, all associated with land-use, and known as the land-use, land-use change, and forestry actions. Within the land-use category, tillage, crop residue, and nitrogen management effects on carbon sequestration have been studied and evaluated (e.g. Schlesinger, 2000; Allmaras *et al*., 2004). Similarly, the capacity of global forests to sequester CO_2 has also been assessed but, due to variability in tree cover and biotic conditions, the current estimates are at best qualitative. No attempt has been made so far to evaluate the impact of plant nutrition on CO_2 sequestration, although this approach is embodied in the land-use mitigation category. Potassium is of particular interest since crops are very responsive to it. Additionally, it requires considerably less energy than nitrogen for fertilizer manufacture and at an adequate level in plants can enhance N-use efficiency (NUE). This improving effect of potassium on NUE thus optimizes N management, while contributing to a lowering in emission of CO_2 and other GHGs.

In 2001, the Soil Science Society of America drafted a position paper that included the following statement: “Worldwide, SOC (soil organic carbon) in the top 1 meter of soil comprises about 3/4 of the earth's terrestrial carbon; nevertheless, there is tremendous potential to sequester additional carbon in soil”.

In order to explore this potential further, a group of soil scientists working together with the International Potash Institute (IPI) are currently studying the contribution of potassium fertilization to sequester additional SOC. The study comprises mathematical modeling and comparison of the results from this modeling with experimental findings. In addition, the interpretation of this information is expressed in terms of the contribution of potassium to carbon sequestration.

About this paper

This paper was prepared by Agriecology. Agriecology is dedicated to assessing and solving problems related to agriculture, environment and their interface. This position paper was written by Prof. J. Ben Asher (soil physics) and Dr. B. Bar-Yosef (soil chemistry). The authors recently retired from The Ben-Gurion University and Volcani Center, Agricultural Research Organization (ARO), Ministry of Agriculture and Rural Development, Israel, respectively.

The IPI position

The unique IPI approach links two systems: (i) a soil-crop-atmosphere model, and (ii) the modeling of soil processes involving carbon sequestration. The integration of these two systems will be of particular value in assessing the beneficial effect of raising the K nutritional status of crops to increase carbon sequestration in the soil. The IPI approach is the attainment of increased crop production for the benefits of economic productivity, as well as for increased carbon sequestration at a global level. The IPI position can be realized by applying currently recognized best nutrient management practices based on a combination of modeling and scientific experience.

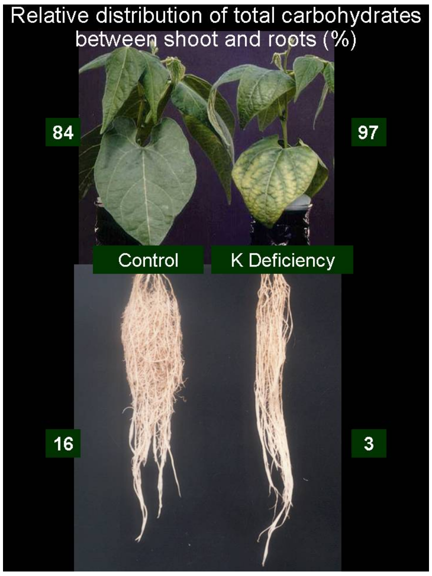
How potassium affects C sequestration

No till farming in Brazil. Brachiaria (Braquiaria ruziziensis) grown after a maize crop. Both crops contribute to elevating OM in the soil. Photo by IPI.

Raising the potassium status of the plant to an adequate level affects CO_2 sequestration in two ways, namely by: (i) stimulating photosynthetic activity thereby increasing dry matter (DM) production of all plant organs, including roots; (ii) increasing the root:shoot ratio as a consequence of activating shoot-root transport of photosynthates and thus also C allocation to the roots. Carbon released from roots into the soil as occurs, for example, when roots are sloughed off and decomposed to SOM is, to a large extent, sequestered in the soil. The processes of carbon mineralization and transport of soil CO_2 are well understood (Simunek and Suarez, 1993; Pumpanen *et al*., 2003) and are included in the comprehensive model which is described below.

A model for assessing the role of K in C sequestration

The modeling approach is based on the measured effects of K-fertilizer on dry matter yields of tops and roots of major crops across the world. The model is modular in that it is based on a progressive build up of CO_2 sequestration. It starts from calculating the gross potential carbon sequestration (GPCS). This is the total carbon present in the DM production i.e. the sum of roots and tops. It then determines the role of potassium fertilization and the potential carbon sequestration (PCS), which is based on the calculated DM accumulation in the roots. The actual carbon sequestration (ACS) is then further calculated using more detailed data pertaining to the specific soil conditions as they affect mineralization and other soil-related processes. It should be mentioned here that the model (as any model) is incomplete because it accounts only for the three major elements (N, P and K) and neglects crop response to other nutrients. The basis of the approach is that when K supply is inadequate, the root:shoot ratio will be low because the consequent low concentration of leaf K will impair photosynthate loading into the phloem and translocation to the roots. Raising the K supply will overcome this effect providing that other nutrients are not growth limiting. Moreover, the higher supply of K will not only increase the root:shoot ratio but also increase the absolute root weights and thus CO_2 sequestration. Magnesium is also particularly important as adequate amounts must be present because, in common with K, it is required both in photosynthesis and in the loading of photosynthates into the phloem and hence their translocation to the root (Cakmak and Kirkby, 2008).



Relative distribution of total carbohydrates under low K compared to control in bean (Phaseolus vulgaris) plants. Source: Cakmak, I. 1994: Activity of ascorbate-dependent H_2O_2-scavenging enzymes and leaf chlorosis are enhanced in potassium deficient leaves. J. of Exp. Botany 45, 1259-1266. With permission from I. Cakmak.

Model description

The GPCS calculations are based on a widely used soil-crop model known as DSSAT (Decision Support System for Agro-technology Transfer). It has been modified to account for crop response and CO_2 budget to combine with NPK application by coupling it with the QPAIS model (Zhang *et al.*, 2007). Its output is the PCS. The ACS calculation is the third stage of the model. This uses PCS results as an input and takes into account mineralization and transport of soil carbon from the major sources. Currently the integrated model is tested and calibrated and parametric values are assigned based on literature data.

Example of calculations

The simulated total corn dry matter (DM) weight in an arbitrary control (N, P and K=200, 100 and 0 kg/ha. respectively) is 15,515 kg/ha (Table 1). Applying 100 kg/ha K (at N=200 and P=100) increases the DM yield to 20,357 kg/ha. The calculated GPCS in the control and K amended soils are of 7,137 and 9,364 kg/ha, respectively. Hence the application of 100 kg/ha K resulted in an additional 2,227 kg/ha C bound in the plant material (equivalent to ~8,166 kg/ha CO_2), or 22.3 kg/ha of C per 1 kg of K. This contribution of 100 kg/ha K to C sequestration is the calculated GPCS and is equivalent to 81.8 kg/ha CO_2/kg K.

Table 1. Example of model aided evaluation of the potential impact of K on the GPCS, PCS and ACS in maize. Data was obtained by the model assuming conventional N and P fertilization of maize under Mediterranean climate and clay soil. The model calculated range of ACS/PCA resulted from different soil organic C pools (SOC), pH, etc.

	Application rate (kg/ha)		
Nitrogen (N)	200	200	200
Phosphorus (P)	100	100	100
Potassium (K)	0	100	200
	DM and carbon potential		
Total DM (kg/ha)	15,515	20,357	21,720
GPCS (kg C/ha)	7,137	9,364	9,991
Root DM (kg/ha)	1,875	2,852	3,163
PCS (kg C/ha)	863	1,312	1,455
ACS (kg C/ha)	259-604	394-918	436-1018

The PCS (i.e. binding of carbon only in the root system under zero CO_2 efflux from soil) can be also evaluated from Table 1. Here, root DM increased from 1,875 to 2,852 kg/ha in the K amended soil. Hence the application of 100 kg/ha K resulted in 449 kg/ha C being bound in the roots (equivalent to 1,646 kg/ha CO_2), or 7.6 kg/ha CO_2/kg K. The model assumes that ACS is 30-70 per cent of the PCS, which leads to the calculation of ACS.

In summary

Carbon credits are a key component of national and international attempts to mitigate the increase in GHGs. We demonstrate here that potassium fertilization may assist in mitigation of GHGs, and possibly even provide some credits to users. The IPI approach uses a model to reliably estimate potential and actual carbon sequestration by crops in various soils and agro-climatic conditions, through a specific model-based calculation process.

Further reading

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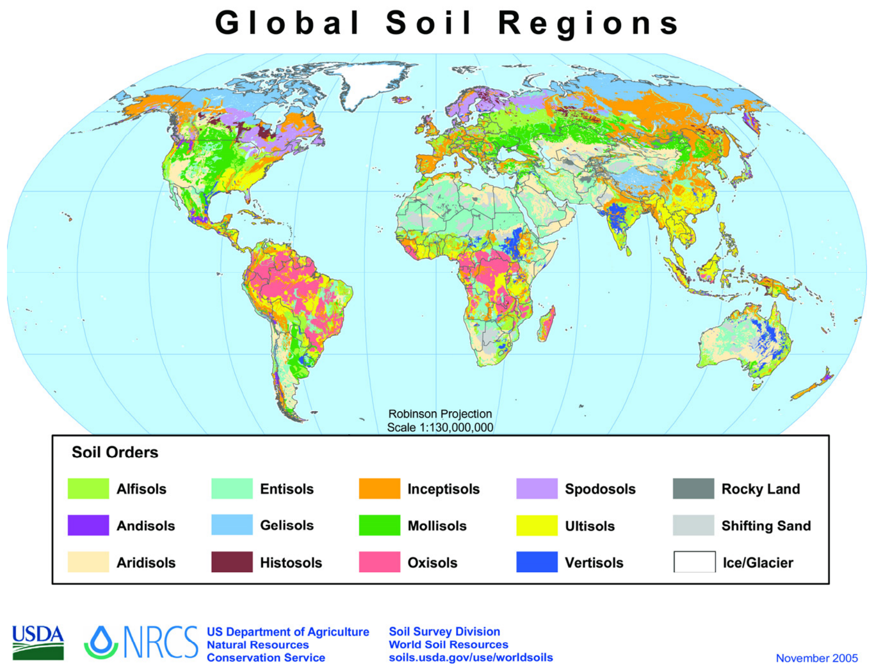
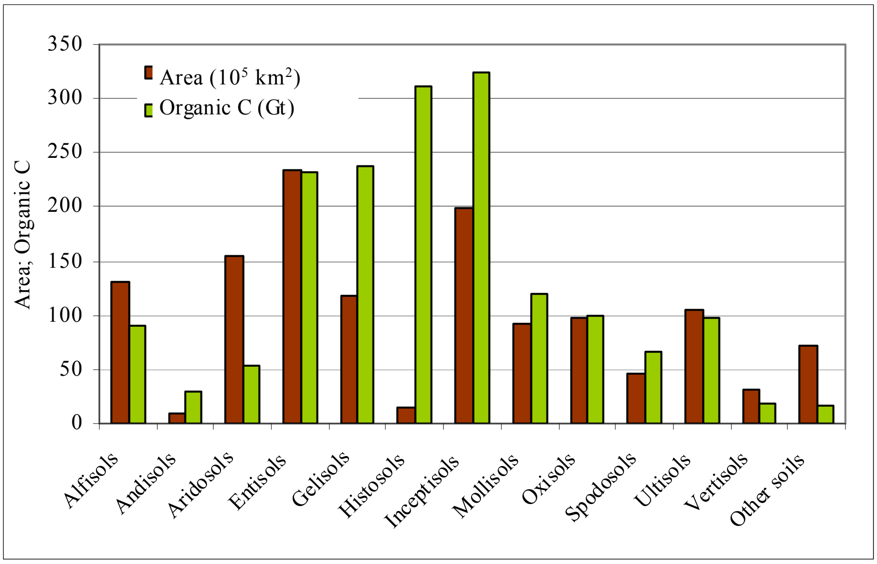
The position paper “Potassium and CO_2 Sequestration” appears also at:

IPI Position Papers.

Soil orders and their estimated carbon content



soils.usda.gov/use/worldsoils/mapindex/order.html



Estimated mass of carbon in the world’s soils. *Source*: USDA. After Hillel and Rosenzwig, CSA News June 2009. www.agronomy.org/publications/csa-news.