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Develop Agricultural Strategies to Increase Soil Carbon Sequestration and Reducing Greenhouse Gases Emission

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A B S T R A C T

Soils are one of our most important resources. Better management of our soils can increase Soil Organic Carbon (SOC) and improve the overall environment. Changing farming/ forestry practices can reduce emissions. Many practices will reduce emissions and at the same time increase SOC. These farming/forestry practices have been studied for a long time and are being used in many areas of the world but they have not been accepted and or used to the necessary extent. What is needed are strategies that will lead to the adoption of practices that lead to SOC sequestration and a reduction of GHG's. Strategies are not the practices per se but the policies and or carrot and sticks that get the known practices on the ground. Strategies need to be developed that overcome the resistance to changes in farming/forestry practices for the ones doing the work on the ground. Strategies cannot be developed without input from the farmers/foresters. These strategies need to allow profitability as part of the equation and they need to be environmentally friendly.

Keywords: mitigation, climate change

Desenvolvimento de Estratégias Agrícolas para Aumentar o Sequestro de Carbono e Reduzir Emissões de Gases de Efeito Estufa

R E S U M O

O solo é uma dos nossos mais importantes recursos naturais. Melhor manejo dos nossos solos pode aumentar o carbono orgânico e melhorar o ambiente de modo geral. Mudanças nas práticas agrícolas/florestais podem reduzir as emissões. Muitas além de reduzir emissões aumentam a matéria orgânica do solo. Essas práticas agrícolas/florestais têm sido estudadas por um longo período de tempo e vem sendo usadas em muitas áreas no mundo, mas elas não tem sido aceitas ou usadas na extensão necessária. O que é preciso são estratégias que levem a adoção de práticas que resultem em sequestro de carbono orgânico no solo e reduzam a emissão de GEE. Estratégias não são as práticas per se, mas as políticas de incentivo e penalização que as implementam. Devem ser desenvolvidas estratégias que superem as resistências a mudanças nas práticas agrícolas/florestais para aqueles que trabalham na terra. Essas estratégias não podem ser desenvolvidas sem a participação d e fazendeiros e florestais. Elas devem permitir lucratividade como parte da equação e devem ser ambientalmente amigáveis.

Palavras - chave: mitigação, mudanças climáticas.

1. Introduction

Soils are one of our most important natural resources; they are where we grow the crops that feed the world. We are in a world with a rapidly increasing population, that we must feed, using a shrinking resource, our soils. As urban areas increase more of the most productive lands are taken out of agriculture and used for housing, land fills, industrial sites and paved over for infrastructure. Therefore, we must be able to increase production to continue to feed the peoples of the world. This will lead to the

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need for new policies and strategies within the agriculture sector to increase yields and to feed the ever-growing needs for more and more food and fiber. Not just as a feed source but also for the production of biofuel to reduce the demand on non-renewable resources (oil, gas, and coal) a finite resource that is being exploited more and more without much concern for the future. Farming has exploited the soils for years without putting back what is removed or burned up (oxidation of the soil organic carbon (SOC) and nutrients contained in the Soil's Organic Matter. Early civilizations, in most cases, developed in areas where there were productive soils. Over time the SOC in these soils was reduced by 50% or more with little consideration for the future, the soils were productive at the time yet the farming practices, policies, and strategies in place did not look to the future. Many people felt the soils were not being changed and would remain productive forever. However, yields dropped over time and the next strategies were geared to adding more inorganic nutrients to maintain yields or increasing yields by introducing hybrid varieties. This shift in strategy resulted in a soil resource that was even more degraded, soil structure was broken down by many tillage operations and in many areas soil was lost to wind and water erosion. The net effect was LOW SOIL CARBON AGRICULTURE and for soils we are not interested in "Low Carbon Agriculture" we are interested in "HIGH Carbon Agriculture" with LOW carbon emissions. The round table this paper is being written for is titled; "Experience of Low Carbon Agriculture". What is needed is high soil carbon agriculture and low agriculture carbon emissions. Is this a new concept or are we just going back to the way many early farmers farmed with additions of organic manner and even slash and burn, which released nutrients to the soil and in many cases even, increased SOC.

In many areas of the world, all of the biomass is removed to feed livestock or to be burned as a fuel source. This now has led to degraded soils in much of the world. The sad thing is we do not learn from the past but now, and in some cases of necessity, blindly go ahead with only looking at yields.

The following quote has been used by me in the past (Kimble, 2006).

Up to the present, the policy – if it can be called a policy – has been to exhaust the supply, rather than maintain it by regular additions according to the demands of the crops produced or the soil fertility removed. To continue very long this practice will mean a further sharp drop in crop yields.

This showed the importance of soil carbon and this was in the *1938 Year Book of Agriculture* (Albrecht, 1938). Here we are, 53 years later, still talking about strategies to increase SOC and reduce Greenhouse Gases (GHG's). We need to link SOC to strategies that will increase SOC through carbon sequestration, improve food security and agriculture sustainability, and reduce soil

erosion and other practices that degrade our soils. The bottom line is we need strategies that address farming/forestry practices that will sequester carbon and at the same time reduce carbon emissions so help ensure we live in a world with low carbon emissions.

2. Developing

When we develop strategies we need to consider the soil, in the past most cropping strategies did not focus on the soils they focused on improving yields. Soil was a place to grow crops, add fertilizer and generally, little or no concern was shown with regard to building the SOC; nor was there concern demonstrated by the policy makers who developed farming programs. Policy makers over many years have addressed soil erosion but not with the idea of increasing SOC. Increasing yields can lead to increases in SOC but what are really needed are changes in tillage and other farming practices. We need to maintain and improve the ecological function of the soils and the best way to do this is to increase the SOC content. In areas such as Brazil with large areas of low activity clays in the Oxisols and Ultisols with low CEC's, the SOC is needed to provide the necessary exchange sites for NPK and other nutrients. We also must It must be remembered that farming is a profit driven business and if the farmer does not make a profit, he will not make changes to improve the way the land is managed.

Where do we really stand on strategies for increasing SOC and reducing emissions?

In the late 1980's a group in the United States became very active on subjects related to SOC organizing meetings related to soil, carbon sequestration, and fieldwork to look at changes to soils under different farming systems.

Many books and papers were produced on the topic with some specifically related to SOC management and GHG's (Follet *et al*., 2001; Kimble, *et al*., 2007; Kimble, *et al*., 2003; Kimble, *et al*., 2002; Lal, *et al*., 2001; Lal, *et al*., 2000; Lal, *et al*., 2000; Lal, *et al*., 1999; Lal, et al., 1998; Lal, *et al*., 1995; Lal, *et al*., 1995). In many of these publications there were areas of needed research identified and developed, and suggested policies and strategies that needed to be adopted to translate our suggestions into workable policies. Over 20 years later, we still are working to develop strategies and/or policies. Scientists wrote most of these for scientists and they are long and have a great deal of good scientific information. The problem is policy makers do not read such information. The work of scientists and policy makers seems to be disconnected worlds putting fourth our scientific expertise and the politicians (ones who develop strategies and policies) seem more interested in what will get them re-elected. Many times the farmers, foresters, and other land managers are not included in the mix. Small groups of people used most the books with usually less than 2000 copies published. In 1999, we produced

the book *The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect* (Lal, *et al*., 1999). This book was written for another audience, i.e. policy makers. The Under Secretary of Agriculture requested this book after I had met Debbie Reed, then the Agriculture Staffer for Senator Robert Kerry, and she pushed me into interacting with the policy people. The book was short with simple chapters and recommendations. It went beyond the normal scientific writing and was written not for other scientists (though many read it and made comments) but for use in the policy arena. It sold over 10,000 copies with several additional printings. The problem was a change in administration and a shift of policies. The book is out there and still draws comments many years later; there may still be changes that will positively affect SOC and GHG's emissions.

Shortly after this communication with many of the different commodity groups and many of the farmers in these groups to try to express what could be done to change the levels of SOC, and at the same time decrease emissions of carbon and also NOx'. The farmers also said not many people were doing real on-farm research and I asked if any of them were interested in having soils work done on their farms and many were projects on farms in Ohio, Virginia, Indiana , Nebraska, and Idaho were established to looked at soil changes with no-till and compared them to conventional tillage and to native lands and also linked them to the large project we had been doing to look at the effects of the Conservation Reserve Program.There are many papers published on these projects documenting the changes to SOC and how SOC affects other soil properties.

There were many other books and papers produced that were related to SOC and carbon sequestration and it became the topic of interest in many scientific circles and in the farming community. Three books should be cited here; *Soil Organic Matter in Sustainable Agriculture* (Magdoff and Weil, 2004); *Soil Management: Building a Stable Base for Agriculture* (Hatfield and Saucer, 2011) and *Soil Carbon Sequestration and the Greenhouse Effects* (Lal; Follett, 2009). All of these have sections on strategies and or policies. There is much more information out there today then in years past.

A Google search in July 2011 on "soil carbon strategies" and got 1,590,000 hits in 0.2 seconds. There is a lot of information out there. In fact, there is way too much to be useful. We are in an age of information overload. Much work is being done on Biochar an idea based on the early work of Wim Sombroke and others in Brazil. There is a large volume of information on biomass for biofuel. Searching the www on the topic of biofuel, there was just fewer than 6,000,000 hits, again information overload. The question I would ask is how many of these www hits have had input from farmers? Many are from

non-farmers looking for a way to exploit the most important soil resource (plant organic matter) without looking at its effect on the soil.

Lengthy discussions of the topics raised are still taking place in many different meetings and forums, however not many are being put into practice as policies. One part of the equation was still missing, the farmers, foresters, and other land use managers. Because of this, there has not been a lot of progress in reducing emissions nor has SOC increased in many areas. We still till the soils, grow monocultures, and do not use cover crops or other conservation practices on many soils of the world. Soils are just there and most people do not recognize how important a role they play in feeding the world's population. Soil degradation and exploitation of the SOC is still done for short-term yield increases. This is not to say that a large number of farmers have not changed their farming practices; many have, and the amount of land in no-till keeps increasing but this is not because of policies or strategies but because farmers have come to see the benefits of no-till. Another factor that has led to the increase in no-till has been increasing fuel prices, which has affected what farmers do and no-till does cut down fuel usage.

We need to get beyond technical, statistically supported studies and work with famers to show them how we can sequester SOC and reduce emissions. One of the problems with this is that scientists are rated on their scientific publications for promotions and many times scientific studies are not geared to practical matters that do not satisfy the drive for promotion or tenure. I know this as I was told during my last rating in NRCS, done by ARS that I was not doing research but instead doing too much practical or applied research. The farmers I worked with were happy and sad to see me retired and many are still in touch with me and still want help.

It may seem to many that I am not talking about how to develop strategies and policies but more on the problems of developing strategies and that is my intent. However, to me the most important aspect is not how to develop strategies but why are those strategies that are already out there not used. The major point to be made is we really do have many strategies that scientists have proven will work in increasing SOC and reducing emissions but these have not been linked to practices or adopted by the farming community. It is clear the need for scientists to interact more with farmers/foresters and policy makers. We need to leave our ivory towers and work in the real world. We need to find out why farmers do not use no-till and show them how to overcome their concerns. We also need to determine what their concerns are. Some of the most rewarding work was talking a group of farmers to a hearing in the US Senate to let them explain there experiences with no-till to the Senators and staffers. They were all worried that what

they said was not important but it was what the senators/staffers really needed to hear, real concerns and real successes from real farmers. They were asked many questions showing there was an interest in what they were saying, in fact many more questions than are asked of scientists in such meetings. One reason that scientists may not be asked many questions is they answer in their scientific language and change the answer by saying more studies are needed and more money needs to be provided for the research. What we need to remember is that policies will be developed and that we need to give our best answers. If future research suggests that changes are needed to policies, then make these suggestions at a later day. Too often, our strategies come from think tanks and people in research positions with little understanding of what farming is about.

The World Bank did a report *Brazil Low-carbon Country Case Study* (Gouvello, 2010). This report has much useful information, but does it show how and what strategies really will work? Does it show which proposed items are understandable to the farmers, foresters, and land managers who are working the land? After reading it, I would say no.

In a discussion with a friend and colleague from the mid 60's a Nigerian working for the International Fertilizer Development Center for many years, and then head of the UN University in Africa. He was invited to a meeting in Washington, DC to discuss food security in Africa and he was the only person from Africa the rest were from NGOs etc., but with little expertise in Africa and a lack of understanding of the soils and problems related to food security. This happens all too often in the development of strategies. Groups with good intentions come up with ideas but they base them on the knowledge they have which is more related to the developed world. He was frustrated but gave it his best shot and was more than willing to give his input.

Fearnside (2009) discusses the outside influences that can affect scientific projects. It must be remembered that political and diplomatic decisions are not always made based on what is good for everyone but with the idea that the decisions will be good for the single country from which the diplomats come from. Bottom line here is that diplomacy is what is good for the country for which the diplomat represents. This is not to say that scientists should not interact with politicians, policy makers and diplomats, they should do so in such a way that these people will have the best information at that point in time to make informed decisions even if in the end they do not use the scientific information.

Brazil has communicated it anticipated mitigation actions in UN-FCCC/AWGLCA/2011/INF.1. 2011. Several of these are related to forestry and agriculture. The next question is how to translate these actions into strategies/policies

that will work and still allow farming and forestry operations to be profitable and have a positive impact on the environment. An example is no-till farming. Most of us here would say that no-till is a good option, but what policies are needed to overcome the farmers concerns and worries about the cost of new equipment? How does this really apply to small landholders?

One basic concern is why the work done fobyr scientists has not been used in policy development and policy in policy development is where the strategies we know will work are not being used. We need policies that reward the early adopters and in many cases, the ones who developed no-till farming. In some of the rules, which are written to put the policies in place, the ones who have been doing the best farming are not rewarded for sequestering soil carbon but the ones who exploited the land are rewarded. Moreover, it might even be profitable to get carbon credits to till the land again and then go back to no-tilling, which is a very perverse way of doing things. We have policies to cover yield losses and natural disasters such as flooding but none to save our soils. Soils are right under out feet but still forgotten, many people call soil DIRT, ignore it, and do not treat it, as it should be; as a valuable resource. this meeting title is Low Carbon Agriculture , a soil scientist wants to maintain or increas e SOC and high carbon in soils and low carbon emissions.

We have used ever-increasing amounts of commercial fertilizers and in the process increased yields when linking them to intensive tillage operations. In many areas over 50% of the native SOC has been lost. With this we have lost the biodiversity in the soil, the amounts and numbers of micro- and other biological organisms contained in a handful of soil is more varied than the above ground part of the rain forest along the Amazon. We worry about cutting forests and losing biodiversity as we can see those changes; however, we do not see the biological changes that occur when a soil is tilled. It is hard to get people to understand that soils can be changed and such changes are important and critical to the entire ecosystem it supports.

A farmer's concern in Central Nebraska related to notill and conventional tillage was the thickness of the mollic layer. It was > 50 cm in the native site about 25 cm in the no-till site and about 10 cm in the conventional tilled field with CRP between the native and no-till. The soil structure was much better in the Native > CRP > no-till > conventional tillage. The farmers comment was, "*It still looked black to me, when I tilled I had no idea how much of the good top soil was lost*." The best part was that the following year he switched to no-till, a win-win for him, the soil, and the entire ecosystem.

It used to be said for some professors in agricultre that Crops can be grown anywhere if we have fertilizers (also need water). Soils in the period of the green revolution were not

always part of the equations; it was plant breeding and fertilization with out concern for the role soils played. This led to more degradation of the soil resources.

We are now going into a period where there is more and more discussion of biomass removal for biofuel, up to 90 % of the surface litters are emitted as CO_2. This may be true but what is not taken into consideration is that when soil organisms break down the litter they release nutrients into the soil and build and/or maintains the soil structure. When the soil litter is removed, the soil losses out and it cannot perform its natural functions. We call it litter maybe we should call it the food for the soil! Litter has had a negative connotation of something bad that needs to be disposed. However, the overall soil function depends on the litter!

The questions to be addressed when considering biofuel produced from biomass are more scientific than just the reduction in the use of the fossil fuels. Some of these concerns are as follows. What is the value of N in stover? What is its value to the next crop and what is its overall value to the soil and the environment? Specifically how much of the N is lost through biomass removal or if left on the field is lost by leaching and denitrification and how much is utilized by the following crops? Many farmers say they are able to reduce the amount of added N fertilizers and even P & K over time as their length of time with their fields in no-till increases if they leave their biomass to build the soil. However, it is hard to find definitive studies that show the changes in N usage under no-till and how it varies with the length of time a field has been in no-till.

What is the consequence of selling above ground biomass as an alternative crop without considering the value of the biomass to the soil and the overall environment? We need to learn to look beyond just the nutrient value of N and other plant nutrients in the biomass that is removed. Are the environmental benefits of leaving the biomass worth more than the nutrients removed? In talking to some farmers in the Imperial, NE. area some have said they would not sell their biomass, as they want it to improve their soil and help reduce wind and water erosion, and reduce irrigation needs. They see a value beyond that of selling the biomass. They feel the value of biomass to the ecosystem as a whole is greater than they would obtain by selling the biomass. The value is not just in the N or other nutrients being removed with the biomass, but also in the effect, the biomass has on soil quality and the sustainability of the farming system.

2.1 Strategies

Having said all that what are the possible strategies? The ones we know work and know their benefits are simply listed below: (are the ones in Red removed, they are needed

Management Practices

Conservation Tillage

Crop Rotations

Carbon inputs

Residue Management/Biomass removal
Reduced Tillage/No-till/ Zero Till
Organic Amendments
Cover crops
Forest Management Practices

Now is the time to become proactive and to make the case for soil carbon sequestration. With no-till we do see increases in SOC; the amount of increase will vary with different crops. If we go to a monoculture of soybeans we are putting back very little litter and roots to build the soil but if crop rotations are used this can be overcome. The bottom line is that practices need to be combined to make them work effectively. No-till provides a major reduction in tillage operations that is accompanied by reduced emissions and improved profitability. Not only yield havce to be onsidered, but what is profitable, improves SOC, and reduces emissions for any strategy to be useful and adopted by farmers.

In National Geographic (2011) there was an article on the FOOD ARC in the special series on "Seven Billion" people to be fed and clothed. The loss of food varieties has been grown during the last century has decreased from 307 to now only 27 corn varieties for example. This will have an impact on the soils as the varieties used were selected for yield and not for how they affect the soil. Breeding is not done to increase the amount of roots and or biomass returned to feed the soil. Monocultures over time change the soil critters and make them less effective. A telling comment by Dr. Worede in the article was "The people doing the planning are aware the first green revolution failed over time. There are some intelligent ideas but they are still placing too much emphasis on a narrow range of varieties". It is necessary to link soils into what will be the next green revolution! We do not want SOC sequestration to fail! The SOC is and has to be part of the solution to reducing emissions and increasing soil carbon!

3. Conclusion

As scientists we know of many methods to show how to increase SOC, and in many cases, they are economically viable and environmentally friendly, yet not adopted in large areas of the world. So why are these strategies not adopted that is the question we need to answer. It is necessary to interact with the policy makers to make sure the techniques that lead to soil carbon sequestration are part of the package developed to reduce emissions and improve the environment while increasing SOC. Soil is one of our most important natural resources and we need to treat it as such. We need to look at the role that soil can play in helping to mitigate the increase of GHG's in the atmosphere and see soil as major contributor to improving the environment and feeding the increasing number of people in the world. Soils have been exploited for 1000's of years we need to stop the exploitation and treat soils better in the future. Looking at and developing strategies that increase SOC there are many

benefits. Many of these same strategies also reduce methane and nitrous oxides other GHG's.

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