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SmartLessons

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Assessing the Carbon Benefits of Improved Land Management Technologies

Ensuring food security under changing climate conditions is one of the major challenges of our era. Agriculture must not only become increasingly productive, but must also adapt to climate change while reducing greenhouse gas emissions. Soil carbon sequestration, the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils, can support these goals. First, soil carbon enhances agricultural productivity, which reduces rural poverty; second, it limits greenhouse gas concentrations in the atmosphere; and third, it reduces the impact of climate change on agricultural ecosystems. This SmartLesson describes the potential benefits of selected land management technologies that sequester carbon.

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Background

Agriculture is the economic foundation of many developing countries, employing up to two-thirds of the workforce and contributing between 10 and 30 percent of gross domestic product (GDP). For the poorest people, GDP growth originating in agriculture is about four times more effective in raising incomes than GDP growth originating from other sectors (World Bank, 2010). Yet agricultural growth rates have declined significantly over the last decade, and food insecurity remains pervasive. Food production must increase by 70–100 percent by 2050 to meet the demands of a world with 9 billion people and changing diets.

Agriculture is highly vulnerable to climate change and needs to adapt to it. Under optimistic lower-end projections of temperature rise, climate change may reduce crop yields by 10 to 20 percent, whereas increased incidence of droughts and floods may lead to a sharp increase in prices of some of the main grain crops by the 2050s. While agriculture is the sector most susceptible to climate change, it is also a major cause of it, directly contributing about 14 percent of greenhouse gas emissions, or approximately 30 percent when considering land-use change, including deforestation driven by agricultural expansion for food, fiber, and fuel. The net increase in agricultural land during the 1980s and 1990s was more than 100 million hectares across the tropics. About 55 percent of this new agricultural land came at the expense of intact forests, while another 28 percent came from the conversion of degraded forests (Gibbs et al. 2010).

With effective policies, agriculture can also be a part of the solution to climate change. Climate-smart agriculture (CSA) seeks to increase productivity in an environmentally and socially sustainable way, strengthen farmers' resilience to climate change, and reduce agriculture's contribution to it by reducing greenhouse gas emissions and increasing soil carbon storage. Historically, agricultural soils have lost more than 50 billion tons of carbon. Some of this carbon, however, can be recaptured through improved land management practices.

There is a growing global momentum to rapidly scale up CSA, but there is a more urgent need to improve the knowledge base for facilitating investments in land management technologies that increase the storage of soil organic carbon. The Economic and Sector Work (ESW) on Soil Carbon

Assessment (P124234) was carried out to fulfill this need. The study involved:

1. A meta-analysis to provide better estimates of soil carbon sequestration rates;

2. An ecosystem simulation modeling technique to predict future carbon storage in global cropland soils; and

3. An assessment of the cost-effectiveness of the land management technologies in mitigating climate change.

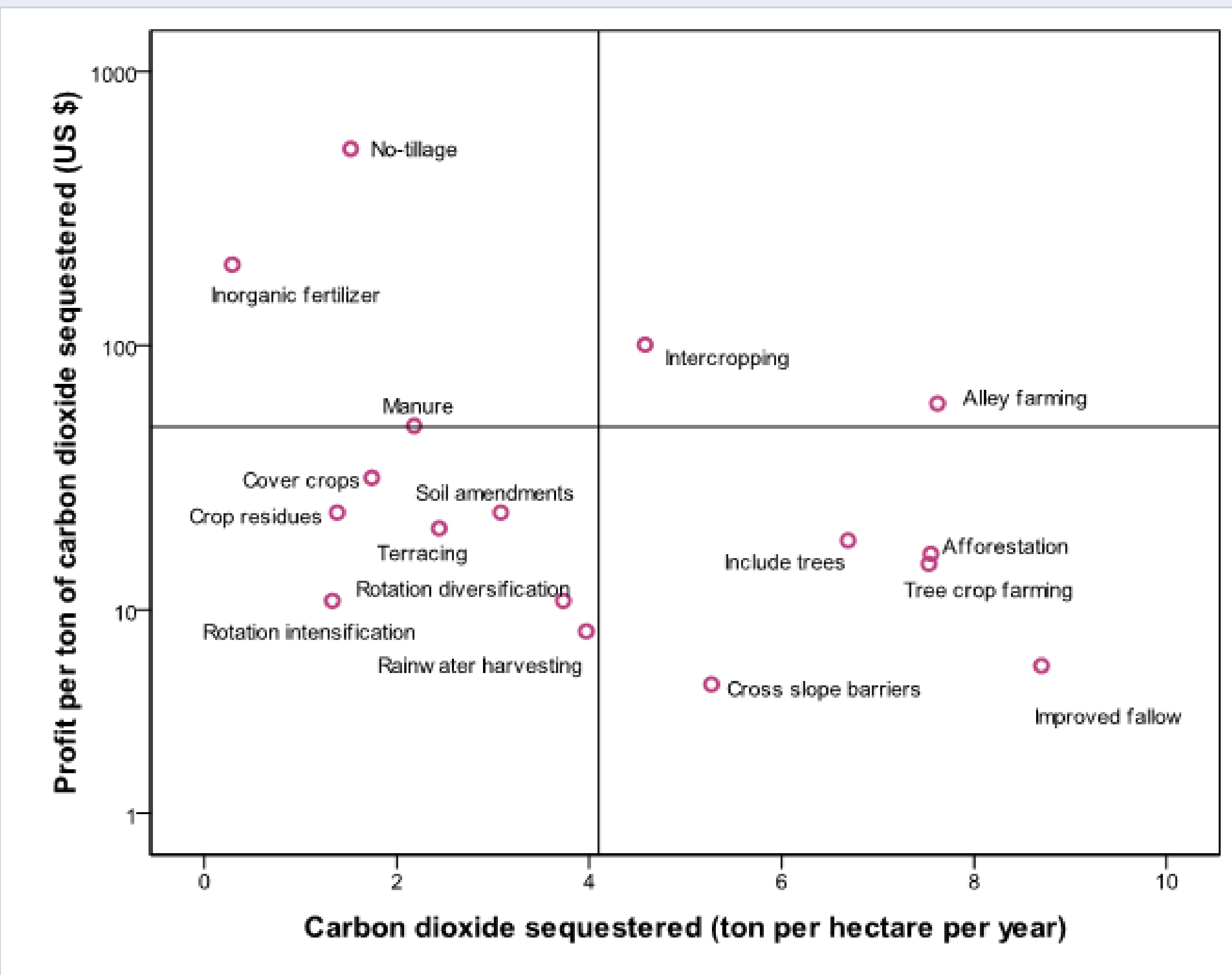
The ESW began in October 2010 and will be disseminated in January 2012.

Lessons Learned

Lesson 1: Soil carbon sequestration is profitable to the farmers.

In addition to storing soil carbon, sustainable land management technologies can be beneficial to farmers because they can increase yields and reduce production costs. Such technologies include integrated nutrient and water management, mulching and residue management, no-tillage, crop rotation, cover crops, and agroforestry — the integrated land use system combining trees and shrubs with crops and/or livestock. Increases in crop yields derive from the ability of the land management technologies to maintain soil organic matter and biological activity at levels suitable for soil fertility. The pattern of increase in yield, however, varies from crop to crop. The profitability of no-tillage systems derives primarily from less labor requirement for seedbed preparation and other tillage operations compared to conventional tillage systems. In Zambia, yields have doubled for maize and increased 60 percent for cotton compared to the conventional tillage system. Farmers also frequently reported significant crop yield increases for maize, sorghum, millet, cotton, and groundnut in agroforestry systems, but relatively high labor inputs are required to reduce the competition effects of trees from negatively impacting crop growth. Inorganic fertilizers also show relatively high profits because they provide nutrients that can be readily absorbed by plants. They are less environmentally friendly, however, due to nitrous oxide emissions associated with high application rates of nitrogen fertilizers, and fossil fuel-based emissions associated with

Figure 1: Tradeoffs between profitability and carbon sequestration of sustainable land management technologies. Thresholds for classification were $50 profit and 4.1 tons of sequestered carbon dioxide.



fertilizer production and transportation.

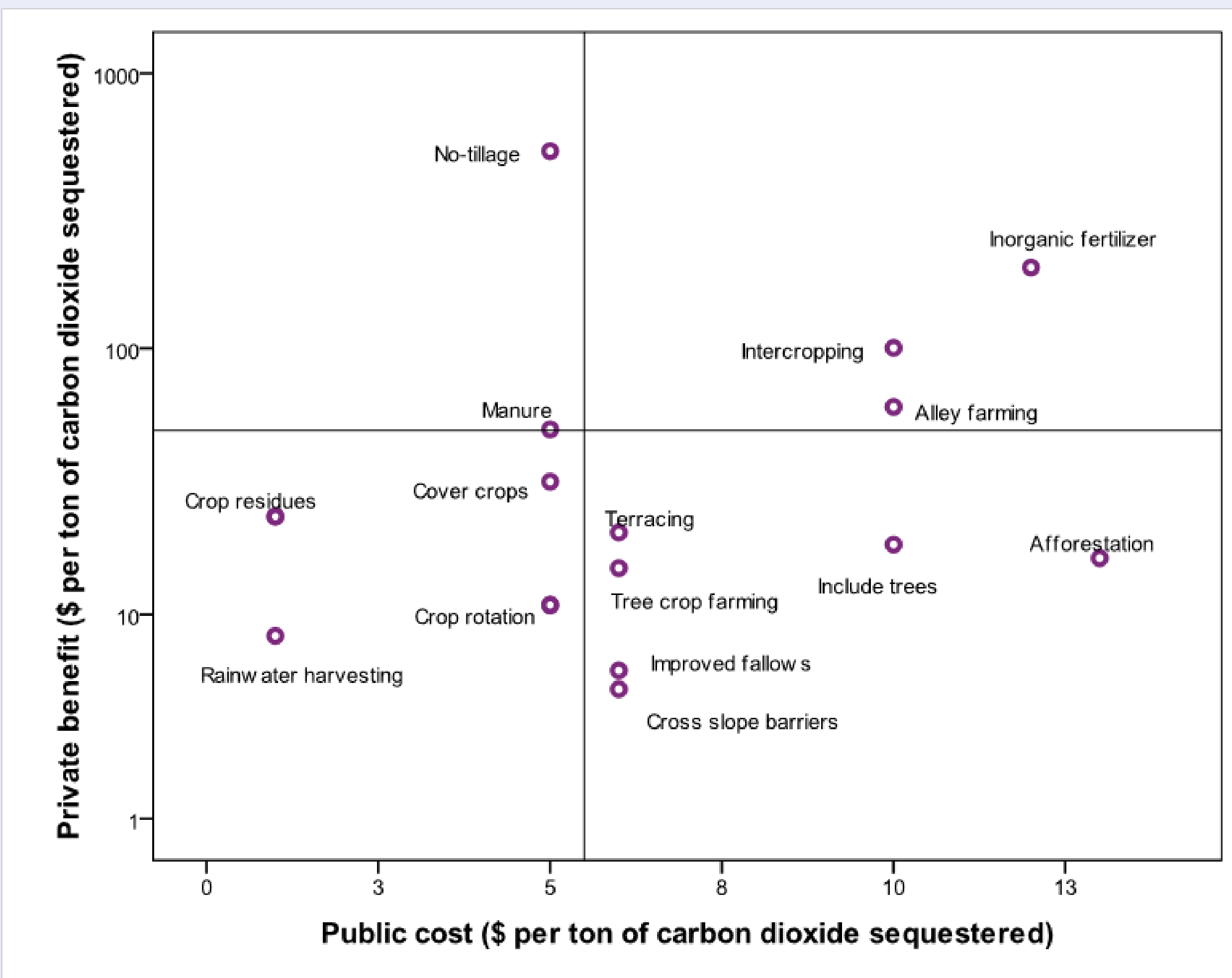
Lesson 2: Soil carbon sequestration can be maximized by managing trade-offs and synergies.

Tradeoff occurs when attempts to increase carbon storage reduces productivity (profitability). On the other hand, synergy implies a positive correlation between carbon sequestration and profitability. Increasing food security under a changing climate requires the analysis and identification of the land management technologies that maximize synergies and minimize tradeoffs. Synergies between profitability and mitigation are found in two agroforestry systems: intercropping and alley farming (top right quadrant of Figure 1). Intercropping is growing crops near existing trees, whereas alley farming is growing crops simultaneously in alleys of perennial, preferably leguminous trees or shrubs. Both are important strategies for increased productivity and resilience of the farming system.

Land management technologies in the lower right quadrant of Figure 1 have high mitigation potentials but are modestly profitable. Afforestation, improved fallow involving the use of fast-growing trees to accelerate soil rehabilitation, including trees in croplands, and establishing barriers across sloping areas tend to take land out of production for a significant period of time. They reduce the amount of land available for cultivation in the short run, but can lead to overall increases in productivity and stability in the long run. The time-averaged, above-ground biomass of crop residues and other technologies in the lower left quadrant of Figure 1 is relatively small compared to that of agroforestry systems (see photos below). Also, the biomass of crop residues does not accumulate easily, resulting in lower mitigation benefits (see photos below).

Judicious fertilizer application counters soil nutrient depletion, reduces deforestation and expansion of cultivation to marginal areas, and increases crop yields. Yields also increase with manure application and accumulation of soil carbon, but with patterns that depend on crop type. Manure is less profitable than inorganic fertilizer because of the labor costs associated with collecting and processing manure (top left quadrant of Figure 1). Manure also has quite low nutrient contents relative to inorganic fertilizers, so a large amount needs to be applied on relatively small fields. This explains why manure works well for small-scale intensive and high-value

Figure 2: Relationship between private benefits and public costs. Thresholds for classification were \$50 profit and \$5.50 for public costs.



vegetable gardening. Manure systems are also associated with high methane emissions. The relatively high profitability of no-tillage derives primarily from the decrease in production costs after the establishment of the system.

Lesson 3: Sustainable land management practices generate benefits to the farmers, but at varying costs to the public.

Carbon sequestration provides private benefits to the farmers through enhancement of soil fertility that leads to increases in crop yields and more efficient production. However, other benefits, such as improved air quality, water quality, and biodiversity, are public goods that accrue to society but not to the farmers engaged in market transactions alone. Without government intervention, poor agricultural land management will intensify land degradation and contribute additional greenhouse gases in the atmosphere.

Public cost refers to government support toward the implementation of land management practices. This includes investments in seeds and seedlings, input subsidies, extension services, and other administrative costs. The pattern of public support is as crucial as the amount of support for the full realization of productivity, mitigation, and adaptation benefits in agriculture. Public support measures that focus

Maize growing under Faidherbia trees.

Photo credit: World Agroforestry Center

Crop harvesting. The residues are left on the soil surface as mulch.

Photo credit: Curt Carnemark

Table 1: Relative importance of different factors for adopting improved land management practices. Synthesized from Liniger et al. (2011).

Land management technology	Inputs/ Credits	Market access	Training/ Education	Land tenure	Research	Infrastructure
Inorganic fertilizer	***	**	**	**	*	**
Manure	**	**	*	**	*	**
Conservation agriculture	**	**	***	**	**	*
Rainwater harvesting	**	**	**	***	**	**
Cross-slope barriers	**	*	**	**	**	*
Improved fallows	**	*	*	***	**	*
Grazing management	***	***	**	***	**	*

Key *= Low importance, **= Moderate importance; ***= High importance.

on research, investments in improved land management, and land tenure rather than on input support are generally more effective, benefit more farmers, and are more sustainable in the long run.

Technologies that involve significant change in land use (afforestation, improved fallows) and landscape alteration (terracing, cross-slope barriers) incur high public costs but generate low private benefits (lower right quadrant of Figure 2). The low profits suggest that farmers may be reluctant to privately invest in these technologies. Strong public involvement in these technologies is justifiable, given their relatively high mitigation potentials. Crop residues, cover crops, crop rotation, and rainwater harvesting with lower profits and also manure and no tillage that generate relatively higher profits require minimal government support (lower left and upper left quadrants of Figure 2, respectively). These technologies generally have low mitigation potentials. The relatively high public cost of inorganic fertilizer (top right quadrant, Figure 2) reflects the use of subsidies in spurring farmers' access to the technology.

Lesson 4: Adoption of sustainable land management practices faces considerable barriers despite the private benefits they generate.

Despite the fact that improved land management technologies generate private benefits, their adoption faces many socioeconomic and institutional barriers. Table 1 suggests that lack of credit and inputs and land tenure problems are by far the most important factors for adoption. However, improved availability of inputs is a necessary but insufficient condition for adoption of land management practices. Better market prices for crops and other agricultural produce are crucial. Secure land rights are a precondition for climate-smart agriculture, as they provide incentives for local communities to manage land more sustainably.

Behavioral change through education is required to enable changeover to improved land management technologies. For instance, conservation agriculture — the farming system involving no-tillage, residue management, and use of cover crops — is highly knowledge-intensive, requiring those promoting its adoption to acquire training and practical experience. Learning hubs, regional platforms, scientific research, south-south knowledge exchange, and technical support mechanisms will increase innovation and facilitate adoption of improved land management technologies. The knowledge base of land management practices at the local level can be also improved through careful targeting of capacity development programs.

There is also the need to boost financial support for early action in climate-smart agriculture. For technologies with significant private returns, grant funding or loans may be more suitable to overcome adoption barriers. For technologies such as conservation agriculture that require specific machinery inputs, the initial costs of investment can be considerable. Thus, payment for ecosystem services schemes could be used to support farmers and break the adoption barrier. There is also the potential for carbon finance to support farmers during the initial period before the trees in agroforestry systems generate an economic return. The costs to the public sector could be lower if some of the costs are borne by the private sector. For instance, the private sector may be involved in establishing tree plantations or in developing improved seeds and seedlings.

Conclusion

A new global vision that appreciates and rewards the productivity, mitigation, and adaptation benefits of soil carbon sequestration is required. Progress in agriculture is slower than most people had hoped for under the UN Framework Convention on Climate Change (UNFCCC). However, some good news came out of the recently concluded Conference of Parties (COP) in Durban, where, for the first time, it was agreed to initiate a formal work program under the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA). Placing agriculture under a firm global agreement in future could help provide a policy framework for fully incorporating agriculture into adaptation and mitigation strategies. There is a need to integrate the public sources of climate finance with those supporting food security into a single mechanism to support climate-smart agriculture. Countries must be prepared to access new and additional finance. Readiness for carbon sequestration and climate-smart agriculture can be achieved through capacity building for strengthening the institutional and implementation framework for climate-smart agricultural development, and identifying early-action investments in land management technologies for different locales.