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Can carbon sequestration markets benefit low-income producers in semi-arid Africa? Potentials and challenges

Carlos Perez [a,*], Carla Roncoli [b], Constance Neely [c], Jean L. Steiner [d]

[a] Tropical Agriculture, Earth Institute, Columbia University, Lamont Hall 2G, 61 Route 9 W, P.O. Box 1000, Palisades, NY 10964, New York, USA
[b] Department of Biological and Agricultural Engineering, University of Georgia, Griffin, GA, USA
[c] Department of Crop and Soil Sciences, The University of Georgia, Athens, Georgia, GA, USA
[d] USDA, Agricultural Research Service, El Reno, Ok, USA

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Abstract

The Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations Framework Convention on Climate Change allows a country that emits C above agreed-upon limits to purchase C offsets from an entity that uses biological means to absorb or reduce greenhouse emissions. The CDM is currently offered for afforestation and reforestation projects, but may apply subsequently to sequestration in agricultural soils. Additionally, markets outside of the Protocol are developing for soil C sequestration.

In theory, C markets present win-win opportunities for buyers and sellers of C stocks. In practice, however, C markets are very complex. They presuppose the existence and integration of technical capacity to enhance C storage in production systems, the capacity for resource users to adopt and maintain land resource practices that sequester C, the ability for dealers or brokers to monitor C stocks at a landscape level, the institutional capacity to aggregate C credits, the financial mechanisms for incentive payments to reach farmers, and transparent and accountable governance structures that can ensure equitable distribution of benefits. Hence, while C payments may contribute to increasing rural incomes and promoting productivity enhancement practices, they may also expose resource users to additional social tensions and institutional risks.
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1. Introduction

For over a decade, evidence has been growing that the accumulation of greenhouse gases in the upper atmosphere is leading to changes in climate, particularly increases in temperature. Average global surface temperature increased by 0.6 ± 0.2 °C over the 20th century and is projected to rise by 0.3–2.5 °C in the next fifty years and 1.4–5.8 °C in the next century (Tett et al., 1999; IPCC, 2001; Mitchell et al., 2002). Global warming changes the earth's atmospheric circulation and is linked to changes in patterns of precipitation and the frequency and intensity of extreme climate events. The economic and ecological consequences of global warming will vary by region, but in the tropics, it will likely threaten production of food and fiber, and become a major cause of species extinctions (Markham, 1996; McCarty, 2001; Thomas et al., 2004).

Under the Kyoto Protocol of the United Nations Framework Convention on Climate Change, signatory countries must decrease emissions of CO_2 to the atmosphere, or increase rates of removal and storage. The Protocol's Clean Development Mechanism (CDM) allows a country that emits C above agreed-upon limits to purchase C offsets from an entity that uses biological means to absorb or reduce greenhouse emissions. The CDM is currently offered for afforestation and reforestation projects, but it is expected that in the future it will be extended to

* Corresponding author. Tel.: +1 845 6804454; fax: +1 845 6804870.
E-mail address: cperez@ei.columbia.edu (C. Perez).

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C sequestration in agricultural soils. Markets for soil C sequestration are also developing in addition to those promoted by CDM (IPCC, 2000; Ringius, 2002).

The interest in C sequestration and trading as mechanisms for both environmental protection and poverty alleviation in developing countries has increased considerably in the last decades. It is anticipated that the Clean Development Mechanism (CDM) offered by the Kyoto Protocol could result in enhanced productivity, income and food security benefits for producers, as well as local conservation of natural resources in the developing world (Woomer et al., 2004; IPCC, 1996; Hardner et al., 2000; Landell-Mills and Porras, 2002; Tschakert, 2004; Tschakert et al., 2004; Pagiola et al., 2005), including semiarid agroecosystems (Lal, 1999, 2000; Olsson and Ardö, 2002). CDM activities are also expected to enhance the economic value of the ecological services provided by forests, cropland and grazing lands, especially C storage and biodiversity conservation (Kremen et al., 2000; Portela and Rademacher, 2001). This may contribute to reducing rural poverty by providing payments to low-income resource managers who adopt C sequestration technologies (Smith and Scherr, 2002), along the lines of payments for environmental services (Ferraro, 2001; Pagiola et al., 2004, 2005).

In theory, C markets present win-win opportunities for buyers and sellers of C stocks. Buyers create a demand for C stocks by providing financial capital. Buyers include private companies but also governments (Sandor et al., 2002). Governments may provide funds for C sequestration to promote sustainable management of natural resources. Corporations, on the other hand, may do so to offset C emissions elsewhere ("right to pollute") or as part of a campaign to enhance their public image. In exchange, landholders and resource managers deliver ecosystem services and commodities that are translated into C credits. Buyers and sellers are linked via investment vehicles that draw on one or many sources of financial capital and distribute that capital to projects. Hence, a company may act as a dealer or a broker within the investment vehicle and establish a contract with many landholders. Having acquired rights to ecosystem services on various plots of land, the dealers pool small amounts of an ecosystem service associated with each project into appropriate volumes and sell that aggregation of credits to larger firms. Farmers are paid to adopt conservation practices. Payments are made either for each hectare of land on which they adopt specified practices or per unit of environmental benefit produced, for instance per ton of C sequestered (Diagana et al., this issue).

In practice, however, C markets are very complex because they presuppose the existence and integration of many conditions at multiple levels. Prerequisites include the technical capacity to enhance C storage in production systems, the capacity for farmers and other resource users to collectively adopt and maintain land resource practices that sequester C, the ability for dealers or brokers to monitor C stocks at a landscape level, the institutional capacity to aggregate C credits at levels large enough for dealers to consider worthwhile, the financial mechanisms for incentive payments to reach farmers, and transparent and accountable governance structures that can ensure equitable distribution of benefits. Attaining these conditions requires balancing and articulating often mutually contradictory goals and expectations held by multiple stakeholder groups and institutions at local, national and international levels. As a result, while C payments may contribute to increasing rural incomes and promoting productivity enhancement practices, they may also expose resource users to additional social tensions and institutional risks.

2. Enhancing soil organic carbon and productivity

C trading-related payments to farmers and pastoralists in semi-arid Africa could provide an important incentive for those producers to adopt land management practices that build soil C pools. Rainfed agriculture and pastoralism are still the main sources of livelihood in the region, and adequate levels of soil organic C content in soils enhance land productivity and food security (Sanchez, 2002; Bationo et al., this issue).The need to improve agricultural productivity and food security is particularly urgent in Sub-Saharan Africa, where 33% of the population is food insecure (http://www.fao.org/es/ess/faostat/foodsecurity/MDG/MDG-Goal1_en.pdf) and 28 million preschool children are underweight (UN Millennium Project, 2005).

Given the vastness of African drylands, which cover 44% of semi-arid, arid and dry sub-humid Africa, the opportunity for C sequestration seems substantial (FAO, 2002, 2004a). However, C sequestration is constrained by the high temperatures that prevail in many parts of Sub-Saharan Africa. Heat reduces the conversion of plant residue to humus and accelerates soil organic matter decomposition, which translate into lower levels of soil organic matter (0.5–1.0%), poor moisture retention capacity in soils, and loss of resilience related to increasing aridity and erratic rainfall (Lal, 2002a; FAO, 2004a). Prevailing land management practices, such as deep plowing, crop residue removal, biomass burning, low-input farming, reduce fallow periods and overgrazing of vegetation aggravate the depletion of the soil organic C pool (Bationo et al., this issue). Tiessen et al. (1998), for instance, estimate that between 50% and 70% of the land in West Africa is under a management system that returns very little C to the soil. The impact of these practices, combined with erosion by wind and runoff, has led to oxidation, mineralization, leaching, and removal of organic C.

Understanding of soil biophysical processes have advanced considerably during the last 30 years and have generated numerous technological practices that can slow soil C oxidation and increase C fixation and storage in African soils (Kwesiga et al., 2003). Such strategies include increasing the amount of land under permanent grassland or forest vegetation and reducing the frequency or intensity of tillage, coupled with the improved soil and water conser-

vation practices, such as cover cropping, crop rotation, application of soil amendments, and use of crop varieties that produce large root biomass and fix biological nitrogen (Reeves, 1997; Tiessen et al., 1998; Lal, 2000; Batjes, 2001; Schlesinger, 2000; Lal, 2002a; Lewandrowski et al., 2004; Bationo et al., this issue). Particular attention has been given to the application of animal manure and inorganic fertilizers, in addition to composting, inter-cropping or rotating with cover crops (especially legumes), conserving soil within field boundaries planted with grasses or bordered with stones, and conserving moisture through ridging systems. Based on research in Mali and the Gambia, for instance, Doumbia et al. (this issue) examine a promising technology to manage surface water and reduce erosion losses in crop fields by means of permanent ridges built along the contour and planted with perennial grasses. Other efforts to enhance soil C include protection of trees on farmland, mixing trees with crops, and emphasizing mixed stands of trees, which have been shown to be more efficient for C sequestration than monoculture stands (Joet et al., 1996; Montagnini and Nair, 2004).

Surprisingly, despite the abundance of technological options to increase soil C content, only a few studies have actually measured soil organic C in crop and grassland systems in the Sudan-Sahel region. One of those exceptions is the work of Tschakert et al. (2004) in the Old Peanut Basin of Senegal. The authors report 4.5 t C ha^{-1} in cultivated croplands without manure application and estimated C increases of 0.5–10.9 t C ha^{-1} with improved management. Increases are particularly high when woody species and tree based systems are introduced. Woomer et al. (2004) suggests that C sequestration rates of 0.77 t C ha^{-1} yr^{-1} may be achieved over a period of 20 years by restoring degraded grasslands to woody grasslands. Other estimates relative to the establishment of tree-based systems on degraded lands indicate vegetation C stock increases of as much as 50 Mg C ha^{-1} over a period of 20 years and soil C stocks ranging between 5 and 15 mg C ha^{-1} (Montagnini and Nair, 2004).

The actual amounts of C that can be sequestered in croplands and pastoral drylands in Africa will likely be small (estimated around 0.05–0.7 t C ha^{-1} yr^{-1}) relative to other regions of the world or to other management systems (Lal, 1999; Tschakert, 2004; Woomer et al., 2004). In addition, C sequestration in semi-arid soils may have to be discounted by the additional C emissions associated with the use of inorganic fertilizer or irrigation water required by C enhancing management practices (Schlesinger, 2000). Nonetheless, over a potential area of about 1.297 billion hectares, even small increases in soil C per unit of land would aggregate to large amounts of C sequestered. Those small amounts may be important for low-income households. For African pastoralists, for instance, even modest improvements in natural resource management may yield gains of 0.5 t C ha^{-1} yr^{-1}, which translates into \$50 yr^{-1} (estimating C at \$10 per ton). This gain would bring about a 14% increase in income for the pastoralists, at least half of whom earn less than \$1 day^{-1} (Reid et al., 2004). Therefore, there seem to be potential for C sequestration and trading to improve resource productivity and reduce poverty among rural producers of semi-arid Africa. In the following sections we outline the steps necessary to transform this potential into reality.

3. Measuring, monitoring and verifying soil carbon

The feasibility and sustainability of C credit schemes will depend on appropriate measuring and monitoring schemes. Since the ability to engage in C trading will depend on aggregating small amounts of C sequestered in large numbers of small plots to scales large enough to be tradable on C markets, there is a need for rapid, feasible, and cost-effective methods and tools for measuring soil C, modeling C offsets, and monitoring land management systems that contribute to C sequestration.

Most approaches for assessing soil C at a field scale follow the protocol outlined by Lal (2000) which includes soil mapping, soil sampling, measuring soil bulk density, preparation and analysis. While rapid assessment methods for point measures will continue to advance, there is not yet a standard methodology for scaling up soil C from point measurements to regional scales. To address this gap Lal (2002b) proposed a protocol which establishes rates of C sequestration for the main soil types in West Asia and North Africa, using spot-check ground-truth measurements, remote sensing tools to monitor land management systems, pedotransfer functions to estimate soil C content based on easily measured soil parameters (e.g. clay content); and modeling to assess soil C pool. Currently, field measurements are being used to refine biophysical models and remote sensing products, which, in combination, can improve accounting at regional scale. Models are being developed and adapted to simulate C dynamics and estimate C sequestration above and below-ground in actual and potential land management systems (Parton et al., 1988, 1994; Jones et al., 2002).

Several models have been used to project crop yields and soil C sequestration (Jenkinson and Rayner, 1977; Coleman and Jenkinson, 1995; Parton et al., 1994; Izaurralde et al., 2001, 2002; Gijsman et al., 2002; FAO, 2004b; Doraiswamy et al., this issue). Badini et al. (this issue) incorporated a grazing model into a crop model, CropSyst (Stöckle et al., 1994, 2003), to simulate pasture productivity and soil C cycling in the Sahel region. Building upon field research in Ghana, Jones et al. (this issue) applied the Ensemble Kalman Filter (EnKF), to assimilate *in situ* soil C measures into a stochastic soil C model to reduce and quantify the uncertainty associated with soil C estimates. This approach can be used to provide yearly estimates of the changes in soil C over multiple fields, the variance in those estimates, and the aggregate mean and variance values for soil C.

Remote sensing technologies play a key role in efforts to monitor C sequestration at regional scales by providing

site-specific assessments of land use and land cover. Remote sensing has been coupled with modeling to monitor the implementation of land management practices and to estimate their impact on the soil C pool and dynamics. For instance, using low and high resolution imagery, Doraiswamy et al. (this issue) developed a land use classification and applied the EPIC-Century model to project the amounts of soil C sequestered associated with alternative management of maize, millet, and sorghum production in Mali. Tappan and McGahuey (this issue) utilized remote sensing technologies to quantify improvements in environmental and agricultural conditions over multiple decades in a region of southern Mali, where intensification and diversification of cropping and improved soil and water management practices were implemented. The two studies illustrate how tools such as remote sensing and modeling can significantly advance our understanding of multi-scale processes of land use and land use cover change. Yet, application of such tools must be complemented by rigorous fieldwork for ground-truthing and contextualizing findings (Andersson and Richards, 2001).

While there have been significant advances in methodologies for measuring C sequestration, they have been largely circumscribed to biophysical and chemical soil attributes. Additional research is needed to understand the process and extent to which human intervention and changes in land use will affect C cycles, and to define how C sequestration costs are estimated (Richards, 2004; Richards and Stokes, 2004). Most models allow that C stocks may change due to natural processes independently of C sequestration efforts, but do not account for human activity influence or do so based on untested assumptions about human behavior (Richards and Andersson, 2001). There is considerable variation in models and methods for analyzing C sequestration costs, which sometimes lead to discrepancies in findings (Richards and Stokes, 2004). More precision is needed in estimating the costs of C sequestration in terms of dollars per ton and how unaccounted effects (i.e. increased use of fossil fuels) or secondary benefits (i.e. erosion control) are to be integrated into cost analyses (Richards, 2004; Richards and Stokes, 2004).

Credibility in a C market system will hinge on the existence of technical capacity within countries and regions to apply rigorous methodologies and standardized protocols for soil sampling and analysis, C measurement, monitoring and verification; and for estimating costs and benefits of C sequestration. Technical capacity will also be needed to use remote sensing and GIS tools, as well as to validate and model agricultural and ecosystem processes that affect C cycling in semi-arid Africa. Concerted efforts by governments, international organizations, and the private sector will be required to build human and infrastructural capacity, to encourage inter-institutional and intersectoral collaboration, and to ensure transparency in measuring and accounting procedures and equitable access to information, particularly by rural communities.

4. Carbon trading

Markets for buying and selling C credits are increasingly available and substantial amounts of C are being traded, both in Kyoto- and non-Kyoto countries (Lecocq, 2004; Lecocq and Capoor, 2005). Very few of those C credit markets, however, include provisions for terrestrial C sequestration activities, i.e. the so-called sinks projects. In the late 1990s there were many pioneer proactive investments in C sinks projects, particularly by private companies in the US in anticipation to C emission regulations. Given that the US did not ratify the Kyoto Protocol, however, the encouragement for private investing in the US has been reduced (Brown et al., 2000). European funding for sinks projects is also limited. Under the European Union's Emission Trading Scheme (EU ETS) countries outside the EU which are signatories of the Kyoto Protocol can be supported to meet their Kyoto targets through improvements in energy efficiency to reduce emissions (with no provisions for C sequestration). Sinks projects will not be included in the EU-ETS until 2008.

Currently, some of the most important funds for CDM sequestration projects include five out of the eight World Bank facilitated C funds (mostly with European money) and private sector companies which provide the funding similar to any venture capital effort. C credit markets for croplands and pasture in semi-arid Africa are still to be developed and, at least in the near future, will have to rely on private investments. C sequestration projects are still treading unknown territory and thus face some operational challenges. All CDM projects have to be registered with the CDM Executive Board, monitored and independently reviewed. The registration process alone can be long, costly, and complex. The administrative and organizational costs associated with aggregating sequestered C from a large number of small plots to create a marketable contract and verifying compliance with contracts are also likely to be high. These transaction costs could deter C brokers, traders and farmers from participating in C contracts. However, at the United Nations Climate Change Conference in Montreal in December 2005, the importance of strengthening the CDM mechanism was emphasized, including the need for improved methods for baseline and monitoring methodologies (http://unfccc.int/files/meetings/cop_11/application/pdf/cmp1_24_4_further_guidance_to_the_cdm_eb_cmp_4.pdf).

In the previous sections we suggest that increasing and measuring soil C storage is technically possible. We also establish that markets for C credits are emerging, albeit at slower rates than previously anticipated. Yet, the existence of biophysical potential and market opportunities does not mean that the adoption of soil C-enhancing technology and participation in C trading schemes by low-income producers will automatically ensue. In the sections that follow we consider some of the economic and institutional challenges that lay ahead to enable them not only to participate in but also to benefit from C markets.

5. Economic incentives

Under a C trading arrangement, natural resource users who adopt and/or reintroduce land management technologies that store additional C in soils and vegetation compared to existing practices would be eligible to receive payments for the C those practices sequester. Two types of payments are anticipated, namely payments for C capture and C storage (Richards, 2004). Payments for C capture entail an upfront payment, whereas payments for C storage entail annual payments proportional to average size of C stock over the year. In either case, monitoring and enforcement are critical and the entity that disburses payments to participating land managers must make provision for recouping payments if C is released. This may be easier to do if payments are spread overtime (as in the case for C storage), but this may be a disincentive to land managers, particularly if they have to make significant upfront investments in C enhancing technologies (Richards, 2004). Hence, the payment design needs to adjust compensations according to net C sequestered and the length of commitment to C sequestration (envisioned to range between 5 and 30 years).

Resource users' appraisal of the profitability of C enhancing technologies (relative to existing practices) will largely determine their willingness to adopt them and to commit to implementing them overtime (Tschakert, this issue). So far, however, empirical evidence remains scanty to enable a thorough assessment of whether C sequestration revenues from African cropland and pastures can indeed increase rural producers' incomes. In one of the few studies that do address this issue, Tschakert (2004) applied *ex-ante* cost–benefit analysis of 15 land management practices, combined with a household budget model, to assess what options are feasible and profitable for farmers in the Old Peanut Basin of Senegal. The results indicate that different management options may yield widely diverging net benefits, ranging from −\$1400 to \$9600 t C^{-1}.

Other authors have proposed that, rather than focusing on income or profits from C payments *per se*, one needs to consider the opportunity cost of adopting a C-enhancing land use practices, (Diagana et al., this issue). Resource users will invest in practices that increase C pools when the latter promise benefits that exceed those from alternatives uses of their land, labor and capital. In areas where land pressure is high, the opportunity costs of losing productive land to bunds, ridges, trees and other conservation measures have deterred farmers' from adopting them (Franzel, 1999). Conversely, if opportunity costs of land, labor and capital are low, as they are in most of Sub-Saharan Africa, there will be little incentive for producers to invest in more intensive C enhancing management practices (Diagana et al., this issue).

The article by Tschakert in this issue pushes the argument further by pointing out that assessing the potential economic benefits of C sequestration for an "average" producer is meaningless given the significant variation that exists in land managers' ability or willingness to invest resources in order to adopt new technologies and respond to market incentives (Shepherd and Soule, 1998; Place and Dewees, 1999; Kaya et al., 2000). Disparities in access to labor, land, livestock, assets, and money, as well as in their experience, education, institutional linkages, and social networks define how vulnerable resource users are to the uncertainties and risks intrinsic in technology adoption and market participation. Olsson and Ardö (2002) indicate that C sequestration activities in Senegal may be more profitable for cash crops, which are often grown by better-off farmers. Their analysis indicated that only production of cash crops such as watermelons and karkadé (Hibiscus sabdariffa) could increase net profits under carbon enhancing practices, while production costs for staple food crops (millet, sorghum, sesame, and groundnuts) exceeded prospected sale revenues.

Drawing on extensive fieldwork and farmer participatory research in Senegal, Tschakert (2004) shows that the costs of adapting C enhancing management practices were higher for poor farmers than for middle and higher income farmers. For instance, while most of management practices inventoried were shown as likely to yield profits from C trading for the two better-off groups, only one practice (conversion of cropland to grassland with live hedges) was profitable for poor farmers. All other options entailed initial investment in livestock (for manure production) and losses from foregone rents from land they were unable to cultivate, which were particularly burdensome for the poor. In such cases, C payments could provide the necessary capital to enable low-income producers to invest in improved C enhancing technologies, which they would be otherwise prevented from adopting.

In addition to social differentiation, spatial variation in resource availability means that practices that seem feasible and eligible for C payments in one location are not necessarily so in another location (Tschakert, 2004.). It is important to understand these social, spatial, and sectoral variations in potential profitability in order to design a C credit scheme that contributes to poverty reduction.

The challenge is to design C sequestration projects that maximize the returns on investment for producers in the different ranges of the economic scale, while at the same time avoiding further marginalization of disadvantaged groups. Addressing this challenge will require attention to the institutional framework, to ensure representation of all stakeholders in contractual negotiations and decisions and to promote transparency in the computation and distribution of payments. It will also call for the establishment of policy tools that enhance opportunities, remove disincentives, and mitigate risks associated with technology adoption and market participation, particularly for low-income producers.

6. Institutional and managerial capacity

Technical capacity and economic incentives to sequester C in soils may not necessarily translate into C sequestration

(or trading) programs without suitable institutional arrangements to facilitate processes of aggregation, monitoring, and verification. Mechanisms similar to contract farming or good agricultural practice certification will have to be set in place to enlist producers, to maintain or enhance stock volume and quality, and to enforce appropriate use of technologies and practices that enhance C sequestration. Contract farming assumes that it is not enough to identify activities with high "income generation" potential for rural people, but rather it is critical to provide a reliable and cost-efficient package of supports and services ranging from extension advice, seeds, fertilizers and credit to guaranteed and profitable markets for their output (Eaton and Shepherd, 2001). At the same time, under forest certification, an independent organization develops standards of good forest management and independent auditors issue certificates to forest operations that comply with those standards. This certification verifies that forests are well-managed and ensures that certain wood and paper products come from responsibly managed forests. Similarly lessons could be drawn from certification schemes for good agricultural practice that have emerged in response to food safety concerns, such as *EurepGap* (http://www.eurepgap.org).

Because of the slow rates of C accumulation, C sequestration and trading will require long-term investments in C-enhancing practices. This necessitates technical and managerial capacity to implement and improve upon such practices in ways that are profitable and sustainable in the long-run. C projects will require the organizational capacity to pool C from myriad fields scattered across the landscape. While various forms of traditional and modern forms of social organization in African rural societies may lend themselves to this task, it is important to carefully assess the possibilities and limitations of each to ensure that benefits from C projects do not result in added pressure on marginal lands and do not occur at the expense of marginal groups (Roncoli et al., 2002).

Community cohesiveness and effective leadership are key enabling factors in community-based sustainable resource management in Africa (ARD/RAISE, 2001) and will be instrumental to efforts to accumulate a large enough tradable C pool and for periods long enough (i.e. over 5 years) to build up C content. Ideally, participation in C sequestration and trading schemes will be voluntary. Individual resource users should be able to participate in ways that take into account their different level of resource endowments, risk tolerance, and opportunity costs. At the same time, resource users' ability to benefit from C trading will depend largely on their capacity to organize themselves and act as pressure groups for collective action and bargaining with C traders and with state structures that will mediate or regulate C trading.

Transparent and accountable leadership structures will be essential in facilitating processes whereby communities collectively select technologies, develop land management plans, mobilize farmers' participation, establish contracts and monitor compliance with them, create systems for equitable distribution of payments, and disburse such payments to individuals and households. In addressing the unprecedented challenges posed by participation in C markets, new forms of leadership and decision-making may emerge and replace existing ones, particularly where traditional leaders are ill equipped to deal with outsiders, understand markets, and engage in contractual agreements. To fulfill such roles, new skills will be required, including literacy, accounting, negotiation, and conflict management. The thrust towards more decentralized, democratic forms of local governance that has been embraced by several African states in the last decade has opened political space and opportunities for the formation of new leadership and institutional capacity at the local level (Ribot, 2002a,b), creating potentially favorable conditions for C sequestration projects.

Other policy trends may have less favorable implications. While agricultural extension will continue to be needed to promote improved land management practices and support farmers in their implementation and adaptation, across Sub-Saharan Africa, the viability of such services has been severely compromised by reductions in government spending mandated by the structural adjustment programs. In many countries, external donors are encouraging a shift away from traditional government extension toward a demand-driven system based on private service providers who may contract directly with individual farmers or farmers' organizations. While privatization of services may increase quality, efficiency, and responsiveness to farmers' needs, it may not favor low-income food-crop producers and long-term, broad-scale sustainable land management. This is particularly so in those cases where service provision is tied to a specific commodity crop and in the absence of strong rural organizations, which could enable poor farmers to maximize their bargaining and purchasing power (Roncoli et al., 2002).

In a similar vein, recent land reforms enacted by African governments with donors' encouragement have pushed for privatization as a way of harmonizing the different land tenure systems derived from customary and colonial law and of promoting investments in sustainable land management. Land tenure security has been shown to have a positive effect on the adoption of improved management practices, as illustrated by a review of agroforestry adoption in Africa (Pattanayak et al., 2003). Yet, land titles *per se* may be much less important to stimulate investments in land improvement than secure access to land, which can be ensured under different systems of tenure (Migot-Adhola et al., 1991; Muchena et al., 2005). At the same time, C credit payments may increase the value of common property land, much of which is currently considered "marginal" because of its low agricultural potential. Increasing the value of such land may induce powerful stakeholders to curtail access to it by disadvantaged groups, such as women, pastoralists, landless poor, or ethnic minorities. Given the latter's reliance on common property resources for fuel, fiber, food, and other

necessities, this could have severe impacts on their livelihood security (Gundimeda, 2004).

In situations where land resources are subject to multiple uses and claims by diverse stakeholders, such as those described by Roncoli et al. (this issue) for north-central Mali, revenues from C trading payments may intensify tension among resource users. As in the mentioned case, the need for monitoring and enforcing compliance with agreed-upon management plans may further exacerbate conflicts, particularly when various institutional actors and project participants are motivated by different goals (Roncoli et al., this issue; Diagana et al., this issue). The case study of a sustainable pastureland management experiment examined by Roncoli et al. (this issue) shows that these tensions and conflicts occur within as well as across group boundaries and are closely linked to the uncertainties created by the political, administrative, and legislative systems in which these groups interact.

In sum, as is the case with other natural resource management and environmental services initiatives (Pagiola et al., 2005), community-based C sequestration and trading projects cannot operate and, particularly, be sustained in a vacuum. In order to achieve their environmental targets, economic goals, and social benefits, such activities must be backed by strong rural organizations, legitimate and representative leadership, client-driven extension, local capacity building, and informed and enabling policies. Coordinated interventions to strengthen this institutional scaffolding and to advance favorable policy reforms will need to complement efforts to stimulate widespread adoption of technical solutions.

7. Conclusion: How to move forward?

The previous sections and the papers in this special issue indicate that there is potential for C sequestration in African drylands, such as the Sudan-Sahel region. Realizing such potential, however, will be contingent on adequately addressing significant operational and institutional challenges. Both these potentials and challenges are unevenly distributed countries and regions. The diversity of agroecological systems in Africa and the adaptive capacity of African resource users offer opportunities that must be identified and capitalized upon (Raynaut, 1997; Scoones and Toulmin, 1999; Hilhorst and Toulmin, 2000; Hilhorst and Muchena, 2000; Scoones, 2001; Wiggins, 2002). Even within a limited area, multiple soil management or crop fertilization regimes may occur, some of which may be more promising than others (Ramish, 1999; Yusuf, 2001 in Mortimore et al., 2005; Warren, 2002; Place et al., 2003). For instance, in the Sudan-Sahel region, fields surrounding compounds are regularly fertilized while distant (bush) fields are managed by fallowing (Grégoire, 1980; Prudencio, 1993; Moussa, 2000; Mortimore et al., 2005). Compound fields may have maintained their fertility even though they have been cultivated for 30–40 years, to levels sometimes comparable to uncultivated land (Issaka, 2001).

While it is true that some areas experience soil degradation, elsewhere farmers are maintaining and reclaiming soil fertility and restoring vegetative cover through a variety of indigenous and introduced practices (Mortimore, 1989, 1998; Fairhead and Leach, 1996; Swift, 1996; Fairhead and Scoones, 2005; Leach and Mearns, 1996; McCann, 1999; Kull, 2000; Mortimore and Adams, 1999, 2001; Brockington, 2002; Gillson et al., 2003; Bradley and Grainger, 2004; Mortimore and Harris, 2005; Reij et al., 2005). These include soil and water conservation technologies, replacement of free grazing with crop and livestock systems, protection of trees in cultivated fields, and community-based management of forest resources (Issaka, 2001; Moussa, 2000; Joet et al., 1996; Mortimore et al., 2005; Reij et al., 2005). Particularly where population density and land pressure are increasing and where market incentives exist, crop and livestock production are becoming more intensified (Bourn and Wint, 1994; Hiernaux et al., 1998; Mortimore, 2001; Sissoko et al., 1998; Tappan and McGahuey, this issue). In short, maintaining and increasing soil C pools, and soil fertility in general, is already occurring, not only in regions of high agricultural potential but also in low productivity areas such as the Sahel. C sequestration projects should capitalize on these existing local initiatives, as C markets are more likely to spread where land management conditions are already better than average.

It is critical to promote policies and institutions that enable and encourage such initiatives. These include measures that stimulate market demand, increase access to market, and increase prices for agricultural goods, and make external inputs and conservation practices more affordable, particularly for resource-limited farmers. For C trading to work, farmer organizations and C-brokering firms will need to be strengthened and/or created to facilitate agreements that provide economic benefit to both groups. Brokering firms may need to provide, directly or through a subsidiary group, input supplies (seeds and fertilizers, etc.) and technical support in order to meet the standards of quality and quantity required by the C market. Resource users, for their part, will need to commit to follow agreed upon standards for management. The arrangement must also include a commitment from the brokers to purchase C stored by resource users, thus reducing market risks.

Given its reliance on complex global agreements, contractual commitments, and, possibly, subsidy programs, C trading will not be able to function without governments' firm backing. Governments' support will be instrumental in funding technology development and transfer, providing extension services, offering subsidies and incentives, regulating certification processes, and, in some cases, mobilizing resource users' participation (Richards, 2004). In addition, governments may need to intervene in order to help reduce transaction costs for C brokers and producers engaged in C trading, while ensuring that fair trading conditions exist for both brokers and producers. Governments may also have to adapt macroeconomic policies and

national strategies that directly or indirectly affect natural resource management and agricultural development in order to ensure that they do not undermine C trading efforts.

In their supporting role, however, governments will have to maintain a delicate balance between individual and national interests. Even though C trading can yield considerable gains for the country and be enthusiastically embraced by governments, the latter should refrain from forcing resource users to participate in C markets against their will and best interests. This is a relevant concern particularly in some African countries where the relationship between rural society and the state (and associated organs, such as cooperatives, parastatals, national organizations, etc.) remains problematic after decades of efforts by colonial and post-colonial regimes to extract revenues from farmers or to coerce them to produce at a loss. Such legacy is likely to dampen the enthusiasm of rural communities to participate in initiatives to organize them into broader units and connect them to global markets, unless such initiatives are mediated by institutions trusted and controlled by rural producers themselves.

This history, coupled with the dearth of resources and uneven continuity of several African governments, means that successful C sequestration and trading in semi-arid Africa is likely to be predicated upon an organic alliance of multiple stakeholders, such as community-based organizations, producers associations, NGOs, research institutions, and the private sector, in addition to government agencies. Ultimately, it will be the synergy of land management practices, measuring and monitoring methods, scaling up procedures, and institutional mechanisms that will generate and deliver a "marketable product." More applied research and practical experience are needed to better understand the uncertainties entailed in C sequestration and trading and to devise approaches that minimize risks and costs, create efficiencies, and promote participation.

Because technical, economic, and institutional conditions are not yet in place to make C sequestration profitable for resource-limited crop and livestock producers in African drylands, it is more practical to pursue C sequestration as "long-term pilot projects" (Ringius, 2002), which combine technological improvements, capacity building, and institutional support. Targeting pilot efforts to take advantage of existing synergies among intensification of resource use, elastic market demand, organizational capacity, and enabling policies will be critical to success. Fortunately, these conditions already exist in many communities in Africa.

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