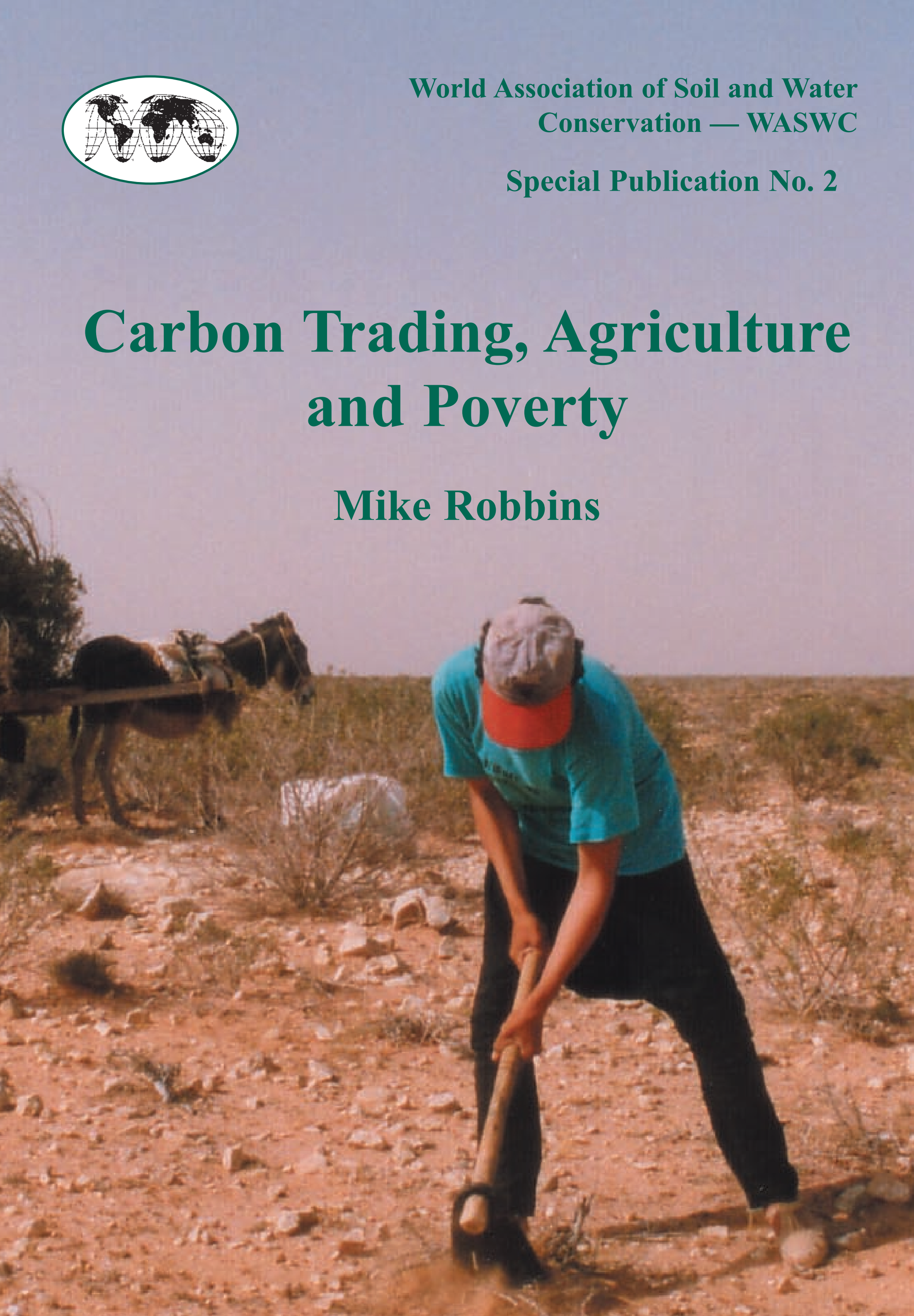
World Association of Soil and Water Conservation — WASWC

Special Publication No. 2

Carbon Trading, Agriculture and Poverty

Mike Robbins



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CARBON TRADING, AGRICULTURE AND POVERTY

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World Association of Soil and Water Conservation
Special Publication No. 2
Editor: Michael A. Zoebisch

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World Association of Soil and Water Conservation
Printed in Thailand
ISBN 974-92226-7-9

Cover photo (by Michael Zoebisch): Firewood gathering in Mersa Matruh, Egypt
Photos on pages 8, 16, 17, and 34: Michael Zoebisch
Page 19: Sabnam Aryal
Page 22: Le Thi Thu Huong
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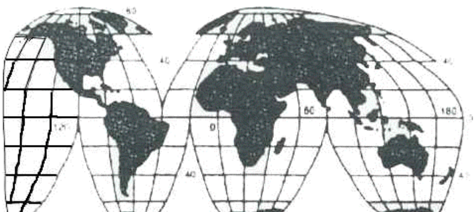

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This publication is sponsored in the memory of Mrs. Vishini K. Tejwani, wife of Dr. K.G. TEJWANI, Founder Member & Founder Vice President of WASWC

FOREWORD

Carbon is an essential building block of life. It has always been transported from one form or ecosystem to another as a basic part of natural processes. Examples include its transport, through soil erosion, into aquatic ecosystems, or the undersea formation of limestone, the chief component of which is carbon.

Much of the world's carbon is held in soils, including agricultural soils. Another significant carbon pool is in the atmosphere, as carbon dioxide. Ever since agriculture began, between 7,000 and 10,000 years ago, the balance between these two pools has been changing. The loss of soil carbon through soil disturbance has augmented the atmospheric carbon pool. Since about 1750, the burning of fossil fuels has accelerated the process. Carbon dioxide is the largest single agent of climate change. Of the increase in atmospheric C over the last 150 years, about a third is thought to have come from agriculture, and this has had adverse effects on sustainability and productivity as well as contributing to climate change.

Now we are trying to reverse the trend by putting more carbon into the ground. Processes that do this are known as carbon sequestration, and the deposits they create are called carbon sinks. Forestry is an important sink, but so, potentially, is agriculture. Burying that carbon back in the ground through better agricultural management practices could also partially reverse the soil degradation caused by millennia of ploughing.

As industrialized countries commit themselves to offsetting their carbon emissions, these sinks will acquire a cash value. Hence the emergence of global emissions trading. If developing countries can be paid to create these sinks, might this be a good way to finance agricultural development, soil conservation and poverty alleviation?

This model may have a big impact on agriculture in the developing world, and it is important that all those involved in agricultural development understand its implications. This includes WASWC members – especially our younger colleagues, who need to be kept abreast of recent trends in research and development that will affect them for many years to come. It is with this in mind that WASWC has published this, the second in its Special Publications series.

It will be clear to the reader that carbon sinks in agriculture present considerable technical problems. If they are to be traded, they will also raise questions of equity, ethics and international environmental governance. The author, Mike Robbins, has rightly not attempted to provide definitive answers to all of these. It will be a long time before anyone can, anyway.

What he has tried to do, is to outline the challenges that agricultural sinks could present for farmers, and for those of us who try to help them make best use of limited soil and water resources. In theory, there should be no such challenges; as I have explained, carbon sinks in agriculture should be a 'win-win' situation. But perhaps they will not always be. There are many different motors driving land conservation and degradation, and we as scientists must try to ensure that carbon sinks are not implemented on a large scale without understanding them.

I would like to finish by expressing my thanks to the author, editor and all those who have assisted with this publication. I would particularly like to thank Rattan Lal for his comments. He has played a significant role in recent years in enhancing our understanding of the relationship between agriculture and carbon emissions, and his input has been very valuable.

Samran Sombatpanit
WASWC President

PREFACE

This publication started life in the summer of 2003 in the School of Development Studies at the University of East Anglia (UEA) in the United Kingdom. But its origins lie in the mid-1990s, when I was a writer and editor at the International Center for Agricultural Research (ICARDA), in Syria.

The gravity of climate change was then becoming clear. At the same time, the region needed to produce more food while protecting a fragile natural-resource base. Yet funding for agricultural research and development in the developing world was declining. Linking agriculture to climate change might be a model that would address both challenges, helping to leverage the funding so badly needed for agricultural development.

Bodies such as FAO, the World Bank and the Global Environment Facility have now perceived this potential, and projects have started to appear. This publication takes a skeptical look at the model. This is not because the model is fatally flawed – I am far from sure of that. It is skeptical because fashions come and go in development, not always to good effect, and it seems wise to identify the pitfalls as soon as possible.

It was written under time and space constraints and is inevitably superficial. I also now feel I may have been too gloomy in places. Intensification is fine as a sequestration strategy if it is *good* intensification. And there is every reason to practise soil conservation, provided it does address farmers' concerns and is not implemented for its own sake. Soil organic matter is, perhaps, viewed too much as a good in itself. Moreover the paper does not set carbon sinks within the context of global environment policy and its origins; it needs a political ecology perspective. But I hope that this publication may still serve as a contribution to discussion of agriculture and climate change; and if it has shortcomings, I am happy to acknowledge them.

ACKNOWLEDGEMENTS

Many people have helped or encouraged me in preparing this publication – although they are in no way responsible for its quality, or the views expressed in it.

I am very grateful to Rattan Lal for taking the trouble to read the draft, and for his helpful comments. At UEA, I have had much help and advice from Katrina Brown, John McDonagh and Bruce Lankford. In Washington, Scott Christiansen and Andrea Pape-Christiansen gave advice, hospitality and support. Ian Noble and Sebastian Scholz of the Carbon Finance division at the World Bank were generous with their time, as were Paul Doraswaimy, Craig S.T. Daughtry and Greg Carty at the USDA-ARS Remote Sensing Laboratory. Further back, during my time as a writer at FAO, Theo Friedrich and Jose Benites originally briefed me on conservation agriculture, and Jacques Antoine on the link between agriculture and

climate change; while Gustavo Best helped revive my interest in it. John Ryan at ICARDA sparked that interest to begin with. Once again, it should be stressed that none of them are responsible for, or would necessarily endorse, the views in this publication.

Finally, Michael Zoebisch has been a long-standing source of advice and encouragement. I hope he will feel that this publication reflects his view that farmers, and their aspirations, are central to soil and water conservation.

Mike Robbins

Introduction

The economic consequences of climate change may be severe. But the cost of mitigation may also be high. Lomborg (2000: 310-311, 322) warns that the costs of implementing the Kyoto Protocol would be $150 billion annually, depending on the extent of emissions trading permitted. The cost of of stabilizing CO_2 concentrations at 450ppm has been estimated at $4-14 trillion (Azar and Schneider, 2002: 75). Several commentators have asked whether mitigation measures are worth the damage they might inflict on the world economy (op. cit.: 75-76). It has also been argued that these costs would easily be absorbed by global economic growth (op. cit.: 76-77), but either way climate change is going to be expensive.

There is therefore a need for 'win-win' strategies that either cut or reverse emissions of greenhouse gases (GHGs) without lowering living standards. To be acceptable to developing countries, they must reflect historic responsibility for climate change (Adams, 2001: 94). In other words, there must be transfer of resources from North to South.

The use of agricultural soils in the developing world to sequester soil organic carbon (SOC) appears to be such a strategy. Historically, agriculture is a source, not a sink; but better management practices could reverse this, while also improving the productivity and sustainability of farmland and grasslands. Such changes could be financed by a system of tradable emissions permits. Indeed, the Kyoto protocol includes provision in principle (Article 3.4) for Annex 1 countries to offset their own emissions by financing this type of development. This could also enhance food security for poorer farmers and pastoralists. It appears to be a win-win policy. Is it?

This publication attempts an answer. The writer first approached the subject while developing public-awareness articles, first for the International Center for Agricultural Research in the Dry Areas (ICARDA), and later for the United Nations Food and Agriculture Organization (FAO). The articles aimed to combat declining funding for agriculture in development by associating it with climate-change mitigation, with its higher public profile. They were therefore largely uncritical of the agricultural sinks model.

There are, however, problems. There is potential for perverse outcomes. Monitoring and verification will be difficult, and transaction costs may be highest for those who most need help with soil conservation – that is, those with the poorest soil. Also, farmers may be forced to 'grow' carbon without sharing the benefits. The aim of this work is not to discredit the model but to look at both its potential and the pitfalls, and to establish whether it is viable for farmers (and which farmers), and how best it might be done. Also examined is the relationship between sinks, agriculture, soil conservation and world trade.

Section one asks whether the model could have any real impact on atmospheric carbon, or would improve productivity and sustainability. This includes a review of some of the practices that are advocated for increasing SOC.

Section two looks at institutional design. Can a market exist for agricultural sinks, can SOC be measured accurately enough, and could the poorest farmers compete in it? Will development organizations need to act as intermediaries?

Section three asks whether farmers in developing countries would adopt carbon trading, and whether the developing world is the right place to pursue this model. It is argued that sinks and soil degradation need to be seen in the context of the global trade regime in agricultural products. It will be suggested that carbon sequestration in agriculture is a viable mitigation strategy, and can be used to alleviate poverty – but not in quite the way that the discourse on sinks has so far assumed.

Like any environmental discourse, that on sinks takes place within a social, political and ideological framework; and if the model has failings, the reasons may lie in that framework. This presents unlimited opportunities for discussion of sustainable development and the post-Rio discourse on climate change. Indeed the whole concept of market environmentalism is open to challenge (Adams, 2001: 104-110). But a review of these issues would require a section on its own.

1: A viable option?

Historically, agriculture has contributed to climate change (Adger and Brown, 1994: 22-23; De Pauw and Zoebisch, 2002: 308). Photosynthesis converts CO_2 into plant material, and some of this remains in the ground as soil organic matter (SOM). This is about 58 per cent soil organic carbon (SOC) (Follett, 2001: 88; Post et al., 2001: 73). This is the process of carbon sequestration. But SOC can revert into CO_2 through mineralization or decomposition when it is exposed to air. The extent to which this occurs is defined by a range of biophysical processes.

Thus some loss of SOC is anthropogenic, for example through tillage. Some is not; soil erosion is a major cause of the loss of SOC, but can be induced by natural processes and besides, it may simply move organic matter elsewhere, so that not all the SOC reverts to CO_2 (De Pauw and Zoebisch, 2002: 309). The relationship between agriculture and loss of SOC is therefore complex.

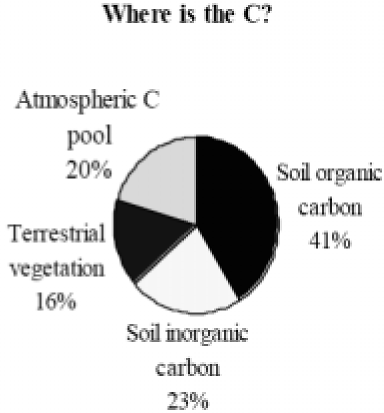
What is clear, is that there is a link between agriculture and climate change. The global area under crops expanded from 265 million ha in 1700 to 1,501 million ha in 1980 (Adger and Brown, 1994: 22-23), displacing different types of land use or vegetation in which SOC content was both higher and more stable. On the North American prairie, 60 per cent of the soil carbon has been lost since cultivation began around 1900 (Ryan and Robbins, 1997: 21). Intensive agricultural use without appropriate management practices causes SOC content to fall further.

However, management for sustainability can increase soil carbon. True, crop and grazing land will never hold as much carbon as some land uses; including above-ground biomass and depending on crop and soil type, about 60 t/ha at equilibrium compared to 450 t/ha for coniferous woodland or 350 t/ha for rough pasture, for example (Adger and Brown, 1994: 49). But the Intergovernmental Panel on Climate Change (IPCC) (2000: 184) has estimated that a selection of agronomic practices – reduced tillage, rotations, cover crops and others – could result in soil carbon increases of 0.32 t/ha a year in Annex 1 countries and 0.36 t/ha elsewhere, while for better management of grazing land the figures are 0.53 and 0.80 t/ha respectively. (As sequestration potential in industrialized as well as developing countries will be relevant to section three, they are included in this discussion.)

The amounts would tail off after 20-40 years as saturation point was reached (ibid.); Lal and Bruce (1999: 182) suggest 20-50 years. Besides, uncertainty on potential sequestration may be ±50 per cent (IPCC, 2000: 184). For example, there is clearly great variability in the potential of the lands in each category. The role of land-use change in the global C budget is far less precisely understood than that of emissions from fossil fuel (Lal, 2003: 3).

But it is significant. The global pool of SOC is about 1,550 Pg C (1 Pg = 1,000 million metric tons, or MMT). Taken together with soil inorganic carbon at about 750-950 Pg C, this is about three times the atmospheric C pool (Follett, 2001: 78-89). The net annual increase in the latter is thought to be about 3.3 Pg C (ibid.). Lal and Bruce (1999: 182) estimate the sequestration potential of global croplands in the region of 0.75-1.0 Pg C a year. Of this, about a third would be fossil fuel savings from reduced tillage. Total potential for soil carbon sequestration by agriculture may be as high as 1.4 Pg C a year, which would offset no less than 40 per cent of the estimated annual increase in atmospheric CO_2 concentration (Lal, 1997, quoted FAO, 2000: viii). The FAO (2000: 9-10) has argued that: "Soil carbon sequestration on agricultural land alone might offset the effects of fossil fuel emissions and land use change for one or two decades or even longer. Additional carbon sequestration is possible in… grassland soils."

But to be a win-win strategy, C sequestration in soils must present net benefits even if no mitigation takes place. It does this by improving productivity and sustainability.



How carbon is distributed. The soil C pool is more than double that of the atmosphere. (Adapted from Follett, 2001)

Caution is needed here; Follett (2001: 88-89) quotes a number of studies that link SOC and productivity but points out that the relationship is not properly understood. It is partially through water ingress; as stated earlier, SOC is the major constituent of soil organic matter (SOM). The higher the SOM content, the greater the aggregation of that soil. Soils that relatively lack organic matter are more likely to be compacted (livestock and machinery can also cause soil compaction). This reduces water ingress and thus productivity – and, in turn, further reduces the capacity of the soil to build up SOM, making it more vulnerable to wind and/or water erosion. The consequent disaggregation itself increases this.

There seems to be broad consensus that, besides reducing vulnerability to erosion, build-up of SOM/SOC assists productivity, through greater availability of nutrients as well as through improved infiltration. Better management practices:

> *…Can increase SOC content and soil productivity… Improving soil quality is a win-win strategy, while increasing productivity it also improves environment and partially mitigates the greenhouse effect* (Lal and Bruce, 1999: 177).

> *…Decrease in SOC content leads to decline in soil resilience, reduction in soil quality, biomass productivity and soil's environmental moderating capacity. In contrast, increase in SOC content improves aggregation, plant*

available water capacity, ion exchange capacities, soil biodiversity, and soil quality (op. cit: 178).

Altieri (2002: 6) states that:

Soils with high organic matter and active soil biological activity generally exhibit good soil fertility as well as complex food webs and beneficial organisms that prevent infection.

Again, this view should be qualified. SOM may contain the nutrients that a crop needs, but will only release them when it starts to decompose. As Zoebisch (2003: pers. comm.) comments:

An argument frequently used is that with carbon sequestration, soil organic matter will be improved. [But] *...There must also be nutrients that can benefit from the improved soil conditions to become effective.*

However, increasing SOM does increase the tendency of the succeeding crop to build up SOM in its turn. Zuhair Masri demonstrated this in Syria in the 1990s by incorporating legumes into rotations; the key factor in that case was improved water ingress (Ryan and Robbins, 1997: 22) – although, as Zoebisch (2003: pers. comm.) has pointed out, it helps if the moisture is there in the first place. Carbon sequestration thus becomes a continuous process unless either the improved practices are abandoned, or the soil reaches saturation point for SOC – as stated above, after about 20-50 years.

Soil carbon sequestration and increased productivity, then, are synergistic goals in theory; are they in practice? That depends on the methods used to sequester more carbon. An enormous variety of practices could be defined as 'carbon-friendly'. Indeed there is a need to decide what would be eligible for funding as part of an emissions trading system. As the IPCC (2000: 195) has noted, it will also be necessary to decide if simultaneous multiple activities can be eligible on the same plot, which would complicate carbon accounting. It gives three basic categories of activity: agricultural intensification, conservation tillage and erosion reduction (op. cit.: 201-204). These will be considered in turn.

Agricultural intensification

This is defined as anything that increases yields and thus biomass (op. cit.: 202). This could include improved cultivars or agronomy, use of green manure or cover crops, irrigation, organic or inorganic fertilization and other practices. However, many of these could cause perverse outcomes.

The IPCC report itself briefly mentions that intensification through irrigation can lead to erosion and salinization, which, it says, could 'reduce soil organic carbon levels and increase emissions' (ibid). In fact salinization, which may now affect up to 10 per cent of irrigated land worldwide (FAO, 2002c: 1), lowers productivity and in extreme cases can result in complete loss of land as a productive asset. This mostly occurs through poor irrigation management, and improved practices may halt and even reverse it (ibid). It might make a lot more sense to rehabilitate irrigated land than add to its stock. Indeed, a European working group rejected irrigation as a sequestration strategy as its environmental impact was just too great to be calculated (European Commission, 2000, Annex II: 3). There may be great potential for small-scale water-harvesting, especially in Africa (FAO, 2001c: 2). However, that is arguably more soil and water conservation than irrigation as such.

It would be unwise to completely reject intensification through irrigation as a sequestration strategy. Irrigated land already provides a disproportionate amount of the world's food and will have to go on doing so if future requirements are to be met. Besides, the problem arguably lies not in irrigation but in bad irrigation. Nonetheless, linking carbon funding to irrigation would seem to be a risky strategy.

Other forms of intensification mentioned by the IPCC also have pitfalls. This includes rotations. In the Middle East, rotations of cereals and feed legumes were brought from Australia in the 1980s and 1990s, in an attempt to reverse soil degradation and pest infestation due to cereals monocropping (Christiansen and Manners, 1995: 8-9). This also improves SOM and soil structure – in fact, it was found to increase SOC from 1 per cent to 1. 3 per cent over about 12 years (Ryan and Robbins, 1997: 22). Benefits included improved barley yields and better-nourished sheep (Bahhady and Robbins, 1998: 14-15).

However, machines were required for harvesting and seed sweeping (ibid.; Christiansen and Manners, 1995: 9-10; Haidar et al., 1998: 16-19), and farmer interest remained low. Moreover, greater emphasis on livestock could increase bread prices and CH_4 emissions. Rotations may raise as many questions as they answer.

Agricultural intensification could simply mean increased yields from existing cropping patterns, using improved cultivars and more fertilizer. But this would require inputs that poor farmers cannot afford, especially in the wake of structural adjustment programmes such as that in Zambia, where fertilizer use has fallen (Copestake, 1999: 8-10). Carbon payments might fund such inputs, but this would increase fossil fuel use (for their manufacture and transport); this is the other perverse outcome that the IPCC report briefly mentions. It could also mean increased N_20 output from fertilizer. It could even increase, not decrease, CO_2 emissions; in the Pakistan Punjab, average SOM, already below 1 per cent in the 1960s, fell by 2. 3 per cent per annum during the Green Revolution period (Ali and Byerlee, 2000: 15). Improved cultivars with insufficient fertilizer could be worse still.

This should not be taken as a blanket condemnation of intensification. As Lal (2004, pers. comm.) has pointed out, the problem lies not with Green Revolutions or intensive agriculture as such but with "exploitative practices including removal of crop residue (as is done in Punjab and elsewhere), plowing, excessive irrigation, imbalance in nutrient applications due to subsidy for nitrogen but not for P and K." Intensification should not be too readily dismissed when it will be needed anyway in the coming century to meet a growing demand for food. Nonetheless, great caution should be exercised in linking it to carbon funding. In the worst cases, it could lead to very perverse outcomes, with impacts on the soil carbon stock and on farming communities that were the very opposite of those intended.

Conservation tillage

This is the second strategy for SOC improvement highlighted by the IPCC report. Conservation tillage (CT) and conservation agriculture (CA) involve low, or no, tillage and use of crop residues as a soil cover.

Tillage prepares the seed bed, admits air and water, and starts the biological activity which allows the plants to absorb the nutrients around them (FAO, 2001d: 1; 2002b: 1). Tillage also controls pests and diseases by exposing them to the elements (FAO, 2001d: 1). However, this exposure also acts as a CO_2 source by allowing SOM to break down through mineralization or decomposition (USDA-ARS, 1997: 7).

Proponents of conservation tillage argue that the soil structure will be maintained by disturbing it as little as possible. Meanwhile, crop residues left on the surface start the biological activity, building up SOM (and therefore SOC); the resulting healthy soil structure permits water ingress (FAO, 2001d: 1). Seeds can be planted through the layer of residues, using a precision driller (ibid). Pests, meanwhile, can be controlled with rotations and Integrated Pest Management (IPM), using pests and diseases to balance each other.

The end result is a soil that is more productive, is better-protected against wind and water erosion and requires less fossil fuel for land preparation (FAO, 2001d: 1; 2002b: 1); in Brazil, the precision drillers have been adapted for animal traction, cutting fuel use even further (Calegari 2001: 344Not tilling also leads to higher SOC content, reducing carbon losses by four-fifths in experiments in the USA (USDA-ARS, 1997: 8).

Conservation agriculture has now been adopted on about 60 million ha worldwide (FAO, 2001d: 1). Much of this has been in the USA (ibid; IPCC, 2000: 202), where it seems to have the greatest potential for carbon sequestration (USDA-ARS, 1997: 8; 2001:1; 2002: 10). The 1980s saw widespread adoption in southern Brazil, as a reaction to erosion and declining soil quality brought about by mechanized agriculture (FAO, 2001d: 1; Evers and Agostini, 2001: 6).

Exact definitions of conservation agriculture vary from one organization to another. Some, such as FAO, believe that it should involve no tillage at all; the European Conservation Agriculture Federation allows reduced tillage.

However, the literature mostly refers to conservation tillage (CT) or zero tillage (ZT) rather than CA, and this can include several types of tillage while omitting some of the practices used in full CA (such as rotations). The IPCC (2002: 202) defines it as follows:

> *Conservation tillage is any tillage and planting system in which 30 per cent or more of the crop residue remains on the soil surface after planting to*

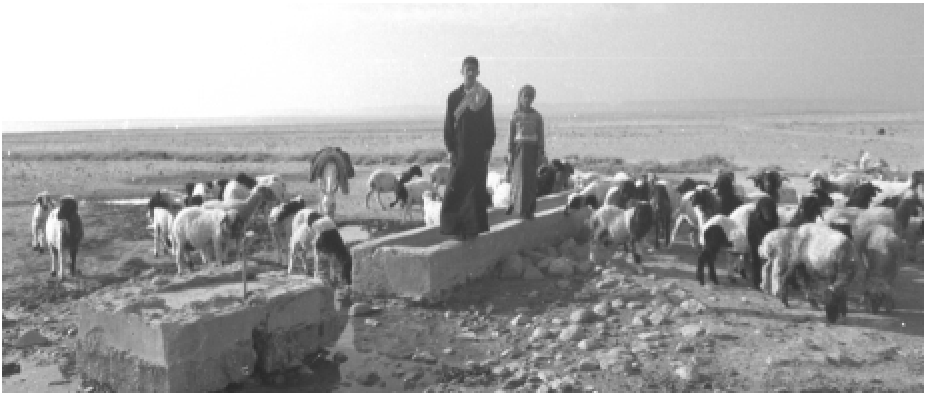
reduce soil erosion by water. Where soil erosion by wind is the primary concern, conservation tillage is any system that maintains at least 1,000 kg ha^{-1} of flat, small-grain residue on the surface throughout the critical wind erosion period…[citation deleted] *Conservation tillage can include specific tillage types such as no-till, ridge-till, mulch-till, zone-till, and strip-till systems that meet the residue requirements.*

Where large farms and strong conservation tillage federations exist, as in the USA or Australia, they can assess a farmer's compliance with this. In (say) southern Kyrgyzstan, where some holdings have plunged to under a hectare since 1991, and five hectares of irrigated land is now regarded as a large farm (Tacis-TDP, 1999: 1), such verification would greatly increase transaction costs. In arid zones in the Middle East and Africa, biomass production is subject to such year-on-year variations that farmers could not predict availability of 30 per cent of crop residues. This definition of CT would therefore be too restrictive for the developing world – yet it excludes rotations; CT does not sequester much extra carbon without them (FAO, 2001e: 22).

Implementing CT properly *does* sequester carbon (IPCC, 2000: 202-203; USDA-ARS, 1997: 7-8). An experiment in Rio Grande do Sul, Brazil found that a mucuna/maize rotation plot sequestered 15.5 Mg CO_2/ha^{-1} over 8 years, compared to a net emission of 4.32 Mg CO_2/ha^{-1} from the traditional maize/fallow plot. This was accompanied by fuel savings on some mechanized farms of up to 66 per cent (Evers and Agostini, 2001: 6).

But to be a true win-win strategy, CT would have to show other benefits. Pretty and Ball (2001: 17) cite reports of dramatic yield gains – as much as from three to five t/ha of maize in Brazil, while cereal yields in Argentina had nearly doubled. The 2000 study in Brazil reported by Evers and Agostini (2001: 4) did not confirm this; indeed, it reported large yield variations in the early years of adoption. Overall, however, these variations were reduced and yields – sometimes – improved. There were also other other benefits, incuding a reduction in run-off and erosion; this was substantial in some cases (ibid.). The study report also found a general increase in income, despite falling commodity prices; where incomes had fallen, they were found to

Better-aggregated soils permit more water to reach the root zone. This not only increases productivity; it may also reduce runoff, and thus erodibility.



Sheep in Syria's Khannasser valley, where arable farming meets the rangeland. Because of recent water problems, settled farmers as well as pastoralists now raise sheep on bought crop residues, and there is great interdependence between the two systems (Nielsen and Zoebisch, 2001: 144). Increasing value of crop residues could distort such relationships.

have done so less than on conventional farms. Moreover the reduction in labour requirement had enabled diversification into livestock and added-value processing (op. cit.: 5).

However, as the authors themselves make clear, the report's conclusions would not be applicable everywhere. It discussed farmers who observed three key principles: soil cover, no-, rather than low-, till, and rotations. As we have seen, the IPCC definition insists only on the first of these. Second, the report may reveal little about the utility of CT in areas where small farm sizes, land tenure, lack of marketing opportunities for legumes, poor education and the effect of HIV on labour supply would be constraints to adoption.

Third, the area studied had average annual rainfall of 1,000-2,000mm (op. cit.: 3), implying a high level of biomass production. In arid and semi-arid areas, however, crop residues are too valuable to be left on the surface. Indeed, in parts of the Middle East, the yield of a barley variety is secondary to the quality of its straw as feed (ICARDA, 1995: 6-7). Where the farmers do not themselves need crop residues as feed, they are sold off-farm to Bedou pastoralists on the desert margin, providing them with an important safety net and reducing grazing pressure on degraded rangeland (Gintzburger, 1996: 15). Carbon payments for CT, by tipping the balance in favour of their retention in the field, could upset the delicate balance of farming systems in fragile environments.

It should not be concluded that CT is therefore unsuitable for low-rainfall zones. CT does make better use of available moisture, and recent experiments suggest wheat yields rising from 0.5 to 1.5 t/ha and even annual, instead of biennial, cropping, in areas with just 200mm annual rainfall (FAO, 2002b: 1). But it will never produce as much extra biomass as it will in temperate zones. This is unfortunate; as De Pauw and Zoebisch (2002: 309) point out, soil carbon content is especially far below potential in the drier areas.

Fourth, even CT proponents accept that herbicide requirement may rise during the first years of adoption (FAO, 2001d: 1). Fifth, soils may become more anaerobic under no-till and it has been suggested that the resulting increase in N_20 emissions could reduce CT's net mitigation potential by as much as 50-60 per cent (European Commission, 2000, Annex I: 4).

CT may be good for sustainability in fragile environments, but that is a separate argument. For carbon sequestration purposes it may be better suited to industrialized countries, where it will also save more fossil fuels – a benefit that continues when SOC reaches equilibrium (West and Marland, 2002: 230).

Erosion control

Erosion control is the IPCC's third strategy for win-win carbon sequestration in croplands (IPCC, 2-000: 204). Erosion is a significant source of CO_2:

> *Being located in the vicinity of the soil surface and of low density, soil organic carbon (SOC) is drastically impacted by erosional processes. Thus, importance of soil degradation in general and that of soil erosion in particular on C dynamics and possible emissions of GHGs cannot be overemphasized…* (Lal, 2003:3).
>
> *…Of the 4. 0–6. 0 Pg C/year translocated by water erosion, ...0.8–1. 2 Pg C/year is emitted into the atmosphere* (op. cit. : 11).

So although only about a fifth of the displaced SOC is emitted as CO_2, it is equivalent to about a third of the net annual increase in emissions. And much of the remainder must end up where it is neither needed nor wanted (for example, silting up hydroelectric installations).

No-one really knows the extent of soil erosion worldwide; as Lal (2003: 2) puts it, "most available statistics on the extent and severity of soil erosion…[are] subjective, qualitative, obsolete, crude and unreliable. " The most widely used estimates – Oldeman's, from 1994 – put total land area affected by water erosion at 1,094 million ha, of which 751 million ha is severely affected, and that by wind erosion at 549 million ha, of which 296 million ha is severely affected (ibid.). A more recent estimate suggests an annual loss of 75 billion tons (Eswaran et al., 2001: 22).

But to be a win-win strategy, erosion control would have to provide benefits beyond retention and sequestration of carbon. And it is not just the extent of erosion that is unclear; as Piers Blaikie has pointed out, there are also conflicting views on whether (carbon apart) it matters. Indeed, he quotes Boserup's view that it actually stimulates innovation (Blaikie, 1985: 12-14). The Machakos district in Kenya is often quoted in this context (Adams, 2001: 194-197; Critchley et al., 2001: 332; Pandey, 2001: 71).

Ploughing in Nepal. Design of soil-conservation measures may fail to consider working practices – for example, the need to turn a plough at the end of a terrace. Farmer involvement in technology development is essential to avoid such errors, and demands a process- rather than target-based approach (McDonald and Brown, 2000). By linking soil conservation to specific targets, carbon funding could make this harder.

However, the fact that this one example is so widely quoted should perhaps engender caution. Blaikie does think erosion matters; he quotes estimates that in 1976 the equivalent of five gallons of fuel per acre were being used in fertilizer to offset the effects of erosion in North America (Blaikie, 1985: 18), a source of emissions in itself. Eswaran et al. (2001: 22) suggest that erosion costs $70 per person per year – about $400 billion in all. Stocking and Tengberg (1999: 93), focusing mainly on water erosion, identify "a significant impact…, making it inevitable that rural producers find it increasingly difficult to survive." Carbon sequestration through soil conservation, therefore, is in theory a win-win situation.

Soil conservation measures take two basic forms, agronomic and mechanical (Blaikie, 1985: 40-41). Agronomic techniques are generally crop rotations or changes in tillage regime, so they have in effect been discussed above. Mechanical works are physical structures to govern movements of soil and water (ibid.). They could include masonry walls to both protect soil from erosion, and conserve water. Terracing is another important, and ancient, technique. But terraces require such a high capital and labour input that they are only suitable where high-value crops are grown, or in areas of high population density (op. cit.: 41). No household will lightly undertake such works, even if it has the resources.

This can infuriate governments that perceive an urgent need. As Zoebisch et al. (1997: 14) put it: "The old answer to what is perceived as farmer apathy has been to devise soil conservation measures and enforce them. That does not work." Thus bunds constructed under official programmes in West Bengal have subsequently been neglected, and relations between staff and farmers at district level in India are often poor (Stocking, 1993: 295). Herweg (1993: 391-411) has reported similar failures in Ethiopia.

Moreover, it is not clear if there is a real 'win-win' outcome for farmers. If soil nutrients have been lost, soil conservation alone will not reverse loss of productivity – other inputs will also be needed (Drechsel and Penning de Vries, 2001: 58). Herweg (1993: 405) points out that terracing can store nutrients but also reduces cropping area and causes rodent infestation. As for the carbon funding, Zoebisch (2003, pers. comm.) has pointed out that much would end up in the pockets of officials.

It is possible to foresee two possible outcomes if carbon trading is used to fund soil conservation. The first is that farmer uptake would be at best patchy – a subject further discussed in section three. The second is that governments may seek certified emissions reductions (CERs) through compulsory conservation measures. At best, there would be tensions, rent-seeking and a general alienation; at worst, civil disorder.

It is hard to escape the conclusion that the real answers to soil erosion (and thus, by implication, carbon sequestration) lie pretty much where Blaikie said they did nearly 20 years ago – in the structure of economic relationships that govern land use. This discussion will also be taken further in section three.

Section one: Summary

This section sought to establish whether agriculture could be significant in climate-change mitigation, and whether this would have unrelated benefits – a 'win-win' strategy. It was suggested that:

- Building up organic matter in agricultural soils might significantly mitigate the increase in atmospheric CO_2, probably for 20-40 years, while bringing about worthwhile improvements in productivity and sustainability.
- It is however unclear how much carbon could be sequestered in this way, and for how long. Besides, the productivity benefits would not be automatic, being dependent on the presence of moisture and nutrients.

The technical measures for agricultural carbon sequestration were considered as three basic strategies, as defined by the IPCC (2000: 201-204):

- Agricultural intensification has so much potential for perverse outcomes that it should not be used for this purpose.
- Erosion control has potential, but labour requirement may be prohibitive and the benefits are uncertain. Compulsory measures would be disastrous.
- Conservation tillage offers the best prospects. But its potential may be least where it is needed most.

However, a carbon-trading system might provide the incentives for these hurdles to be overcome. After all, tradeable emissions encourage technical progress in emissions control (Adger and Brown, 1994: 215). Much depends on the funding model and institutional framework, and these will be discussed in the next section.

2: From theory to practice: ‘market’ structure

If farmers do sequester carbon, how will they be paid for this? Can such sequestration be verified?

All institutional models for carbon trading create a market value for carbon – a commodity that does not normally have one, but is a by-product of others that do. Where a transaction produces CO_2, the models induce parties to the transaction to internalize that value. So it makes no sense to talk about a ‘free market’ for carbon.

However, there is a ‘spontaneous’ or commercial approach, whereby parties simply trade carbon credits. The price is underpinned by current emissions reduction requirements, but is not linked to any other externality. This is a system that may emerge in countries that choose not to ratify Kyoto. Because it treats carbon as a simple commodity, it will demand fairly accurate payment per ton. This poses immediate problems of measurement and verification.

The other end of the spectrum is exemplified by the Clean Development Mechanism, which links the transaction to sustainable development. This approach may not require such precise measurement of carbon, as it sees the transaction as compensating the farmer for protecting the environment, rather than simply buying a commodity. But criteria for how that carbon had been sequestered would be stricter.

Both approaches create a cash value for carbon, but they do it very differently, and to the advantage of very different types of farmers. This section will discuss which is the most practical and equitable. Much depends on measuring and verification, which will therefore be discussed in detail, as will their relative efficiency in valuing and internalizing the real costs and benefits of CO_2 emissions and sequestration.

An emerging commodity market

A European carbon market will begin operation in 2005, but elsewhere informal trading has begun between energy producers and farmers, especially in North America (Pretty and Ball, 2001: 21). From 1996 to the middle of 2002, 157 million tons were traded (Lecocq and Kapoor, 2002: 8); during 2002, global trading in GHG credits tripled to 67 million tons (Newcombe, 2003: 1). This has been simply the speculative trading of credits as a commodity.

The case for such commodity-market trading is forcefully put by Antle and Mooney (1999). Subsidies based on land use, they say, have not worked. They cite the Conservation Reserve Program (CRP) in the USA; after the Dust Bowl of the 1930s, this paid farmers for ‘resting’ land. However, farmers selected land that was already degraded, and continued to use their best land intensively (Antle and Mooney, 1999: 5). Had they been expected to produce a measurable ‘carbon crop’, farmers might have used their best land for this.

It is also argued that the beneficial externalities of conservation are not reflected in a per-hectare subsidy (op. cit., 14). Neither are its real costs, because these too vary from farm to farm. Antle and Mooney concluded that the only efficient option

Can small-scale farmers become carbon traders? Or would transaction costs be prohibitive?

for carbon sequestration is to pay farmers per ton sequestered; they can then decide whether, on their farm, carbon is a profitable crop.

This model has a strength that Antle and Mooney do not mention: that a per-hectare payment may undervalue alternative land uses as yet unforeseen. Thus when failures in the Soviet harvest caused heavy grain purchases on the US market, the subsequent rise in grain prices was reflected in the ploughing of some 27 million ha (Blaikie, 1985: 45), wiping out gains from soil-conservation programmes (op. cit., 85). But in a carbon commodity market, the grain purchases would have also driven up the price of carbon, forcing emitters to pay more.

However, this model discriminates against smaller producers, whose transaction costs are higher. True, Antle and Mooney nowhere imply that the model is equitable; but, as Adger et al. (2002: 2-3) argue, equity is one of the keys to making an environmental policy workable. Another is efficiency (ibid.). Antle and Mooney state (1999: 12) that "An efficient policy would structure payments so that each producer is compensated for all benefits provided by management changes."

Indeed, CT in Brazil and Argentina has resulted at times in the reappearance of long-gone springs, and the reduction of silting in watercourses (Evers and Agostini, 2001: 6; FAO, 2001d: 1). But who is to assess and value this?

The externalities of GHGs may themselves not be reflected in the market price. They are the costs that emission of a GHG can impose upon the community, and include flood and storm damage, drought, loss of biodiversity, rises in parasitic diseases, rises in water levels and more (Pretty and Ball, 2001: 20). Calculating these externalities is difficult; estimates have ranged from \$20 to \$95 (ibid.). But market values are currently about \$2.50-\$5 a ton (FAO, 2001e: 35). To correct this, a 'real' value for CO_2 would have to be agreed, and it is hard to see how this could be done; the estimates above were weighted according to national levels of wealth and capacity for adaptation (ibid.), giving endless opportunities for argument at Conferences of the Parties (COPs) to the Climate Change Convention.

Finally, no company would buy a ton of grain without means to verify the amount delivered. So they will not buy carbon that way either.

Can soil carbon be verified?

Post et al. (2001: 93) report that current methods permit 'reasonably affordable' evaluation of SOC at low precision (20 to 50 per cent error) every 3 to 5 years. There will, they say, be considerable pressure to design improved protocols, but this can not be done without knowing the economic and policy rules under which they are to be used (op. cit.: 94). In effect, there is a chicken-and-egg problem. The technologies needed to monitor actual soil carbon (direct methods), and those needed to estimate sequestration by monitoring land use (indirect), would not be the same (op. cit.: 76).

Direct methods would include soil sampling, but Post et al. (op. cit.: 80) cite Wilding and Drees's (1983) conclusion that the number of variables is such that, although SOC (and other soil properties) can be estimated within ±10 per cent and a 95 per cent confidence level, this would be unrealistic because of the large number of samples involved. Infrared spectroscopy is an alternative; experience remains limited (op. cit.: 79), but the technology has been used successfully in other areas – for example, to predict the feed qualities of barley straw samples as part of crop-breeding programmes (Goodchild and Jaby El-Haramein, 1996: 5.) This could have potential, as near-infrared reflectance (NIR) data could be obtained by passing a spectrophotometer over the soil surface, eliminating the need to collect and analyze samples. But early experiments have been unsatisfactory, although progress is still being made (Barnes et al., 2003: 623).

Even the highest level of accuracy will not allow for the fact that SOM will be moved by erosion over time and one may not know whether it has moved only a few inches from the sampling point or has ended up jammed against a dam 100 miles away. In the first case, it still belongs to the farmer's net SOC stocks. In the second it clearly does not. There are technical solutions to this (carbon isotopes may reveal where soil has come from) but they are uneconomic.

A theoretical alternative is offered by eddy covariance – the measurement of vertical air movements over a vegetated surface (Post et al., 2001: 81). This is correlated with CO_2 concentrations and can thus measure sequestration as it happens. It is a proven technique (IPCC, 2000: 99), but the equipment costs anything from \$500 to \$50,000 (ibid.) and needs judgement and site-specific experience (Post et al., 2001: 81). It might however be economic in some circumstances – for example, on large areas of steppe, where experiments are underway (USGS, 2004: 1).

But direct measurement of carbon clearly presents challenges. An alternative is indirect measurement. This allows farmers to be compensated per acre for certain recommended practices, the carbon sequestration rate of which has been projected in advance. Information from soil samples, cropping history, topography and C measurements under different land uses are entered into a geographical information system (GIS) to establish C content across a given area under different cropping patterns. This is then collated with remote-sensing information on subsequent land use. The technique is called stratified accounting.

Remote sensing over wide areas can be done with light aircraft, and the Japanese cooperation agency JICA once startled Bedou pastoralists by using a large dirigible to photograph the Syrian rangeland (Fujita and Yamamoto, 1996: 17). However, satellite imagery is the focus of research into carbon accounting. Recent innovations have included the MODIS (*MOD*erate-resolution *I*maging *S*pectroradiometer) sensor on NASA's Earth Science Enterprise, in orbit since December 1999 (Post et al., 2001: 85).

There are thus improvements in not only spatial but spectral resolution. As stated above, infrared spectroscopy can reveal the characteristics of organic matter in soil samples; spectroscopy from remote-sensing data can only measure surface reflectance, but this would still reveal vegetative cover (ibid; Pinter et al., 2003: 648), detecting the presence or absence of crop residues on the surface, and verifying cropping patterns.

Are indirect methods practical? Post et al. (2001: 94) think so, but say that greater accuracy will be needed; moreover their discussion is based primarily on US evidence. And it will not be economic if a dataset is built up for every field. Barnes et al. (2003) discuss detailed soil mapping for a range of characteristics including SOM, and conclude that it is possible, but will require more research to integrate data sources and determine robust algorithms that would reduce the need for local calibration. The latter point must have implications for transaction costs in carbon trading. Researchers from USDA's Hydrology and Remote Sensing laboratory are currently collaborating with a number of other institutions on a project in Mali to design a system that would allow such scaling-up, specifically to enable a carbon-trading system in West Africa. But even with sufficient remotely-sensed data and the resources to process it, it will not always be possible to assess changes at plot level (Doraswaimy et al., 2003: pers. comm.).

However, the Ecomarkets project in Costa Rica is making carbon payments to farmers using a combination of remote sensing and GPS-referenced data (de Haan, 2003: pers. comm.), although in this case the relevant land uses are easier to verify. Ian Noble, one of the editors of the IPCC LULUCF report and now chair of the Technical Advisory Committee of the Bank's BioCarbon Fund, thinks that much is possible with stratified surveys. But he accepts that there are limitations (Noble, 2003: pers. comm.).

Stratified accounting may soon support commodity trading in soil carbon, but extrapolating rather than measuring it is bound to lead to disputed payments. Moreover the true costs of CO_2 are unlikely to be reflected in the market price of C. So although a C market in agriculture is developing in Northern countries, farmers are unlikely to be compensated for the full value to society of the carbon they have sequestered. This will restrict its mitigation potential.

With certain policy changes, this could change; that will be discussed in section three. But in the developing world, verification issues and other transaction costs will present serious difficulties. It would be wrong to say that they can never be overcome; that is far from clear. However, an alternative may be development intervention that assists farmers in providing environmental services that benefit others – Global Public Goods, or GPGs.

Global Public Goods

Under this approach, carbon trading is not a simple commodity exchange, but compensation for resource conservation. FAO (2002d: 186) lists a number of bodies as financing opportunities for global public goods (GPGs) in agriculture. GPGs are those by-products of good farming practices which benefit everyone, but are not reflected in market prices. Besides C sequestration, they include preservation of biodiversity, sustainable land use and flood protection (op. cit.: 178). Agriculture can therefore provide synergies between the three major international environmental treaties, or IETs – the UNFCCC, UNCCD and CBD – that permit three-way leveraging of funding.

Resource-poor farmers may not want to risk what little they have on carbon sequestration.

Some of the opportunities listed by FAO – Debt-for-Nature swaps, National Environment Funds, and the as-yet unfunded Climate Change Fund – offer theoretical possibilities for agricultural sinks, but there is no sign of them being used that way yet. Others, however, have more concrete possibilities, including the Global Environment Facility (GEF). Its mandate includes biodiversity, climate change, and desertification; in October 2002 this was specifically extended to land degradation (GEF, 2002: 1). It is funding a relevant project in Kazakhstan, described below.

The CDM may have a mandate for agricultural sinks after 2012 – again, this is discussed below. FAO also mentions 'improved mobilization of domestic resources'. It is vague as to what this means, but does mention the removal of perverse subsidies; this will be discussed in section three.

There are also opportunities not mentioned by FAO. The Global Mechanism of the UNCCD has no funds of its own but can leverage them, and is involved in the Kazakhstan project.

Joint Implementation (JI) will permit trading between developed countries. This will include transition economies, and might therefore cover what are effectively developing countries in Central Asia; Kazakhstan, for one, hopes to accede to Kyoto as an Annex 1 country (Climate Change Coordination Center, 2003: 1). However, an EBRD study (Fankhauser and Lavric, 2003: 2) sees those countries in the CDM rather than JI, and it is possible that no developing countries will be involved. In any case, the EBRD survey indicates similar issues to those raised by the CDM, which are dealt with below.

Also missing from FAO's list is the BioCarbon Fund, which was not yet launched – although the authors mention it briefly elsewhere (FAO, 2002d: 195). This is part of the World Bank's Prototype Carbon Fund and will leverage funding for Kyoto-compliant land-use projects. It includes a "second window" for projects that are not eligible for any form of Kyoto funding, but may become so in the CDM's second reporting period. The CDM, BioCarbon Fund and GEF are the most important for the development of traded, or compensated, carbon in agriculture.

The Clean Development Mechanism

Agricultural sinks will not be eligible for CDM funding before 2012. They may not be then (FAO, 2002d: 194). Besides, the CDM is capped, limiting its mitigation potential. But this could change; and before the cap was decided, the OECD suggested that that "between 31 per cent and 55 per cent… of the total abatement effort required by the Kyoto Protocol" could be met through the CDM; other estimates were even higher (Rowlands, 2001: 796). Besides, should the US propose an alternative to Kyoto, it would surely be based on market forces and participation of developing countries – the underlying principles of the CDM (op. cit.: 795). It therefore still makes sense to review its design in any discussion of agricultural sinks.

The CDM has an inherent flaw. The rationale behind the concept of carbon trading is that an emitter searches for the lowest abatement costs, and because CDM projects will have to meet sustainable development criteria, they will not be the cheapest. Investors may therefore not come forward unless CERs are *only* issued for activities that are Kyoto-compliant; but other options may appear in countries that do not ratify Kyoto. Indeed a global trading system may emerge, though it may well be a compromise between the rival designs (Sandor et al, 2003: 69).

There will also be alternatives within the CDM that are better value than others. China alone is likely to secure over half the CDM funding because it has a huge pollution problem with coal, and the abatement costs for this would be low (Austin et al, 1999: 11). This will leave little room for agricultural sinks even if the CDM is uncapped, as their abatement costs will be much higher.

This reflects the lower amounts of carbon involved, and the higher transaction costs per ton. Both factors will work against a pro-poor outcome in agricultural sinks even where they *are* used. As FAO (2002d: 203) points out, poorer farmers will not be the most competitive carbon suppliers. They will sequester less, because they have less productive soil. This link is not universally accepted, especially at regional level (ibid), but it may be indirect; for example Palmer-Jones and Sen (2003: 15) report a relationship between poverty reduction and physical potential for irrigation. On a micro level, a link has indeed been found between land degradation and poverty (FAO, 2002d: 203); Stocking and Tengberg (1999: 116) found that on most African soil types, the poor tended to face a greater risk of erosion.

Their capacity for investment in soil-erosion control will be limited, they will be less able to spare crop residues and they will be more risk-averse. They may be unable to bear the cost if they fail to deliver a set amount of carbon (FAO, 2002d: 206). They may therefore refuse to adopt altogether (for these reasons, but also for others that are discussed in section three). They will also face higher transaction costs because of their smaller holdings and diverse management levels (ibid.).

Imaginative institutional design may address much of this. Baumert et al. (2000: 3-7) describe three main models of CDM mechanism: bilateral, multilateral or unilateral. Under a bilateral arrangement, a concern wishing to obtain emissions credits simply finances a project in a non-Annex 1 country. But a multilateral design would allow investors to trade with a body administering a portfolio of projects, spreading risk (op. cit.: 5); moreover a multilateral fund might be run by the public sector, and absorb differences in transaction costs. Better still would be a unilateral CDM; a country or consortium mounts a project itself, and then simply sells the CERs earned from it at the market price afterwards. The buyer will be unconcerned by transaction costs because it did not bear them (op. cit.: 6-7).

The CDM is unlikely to secure much carbon investment for poor farmers, but, with the right institutional mechanisms, it could prove effective in some cases.

The BioCarbon Fund: a pilot programme

The BioCarbon Fund, a new component of the World Bank's Prototype Carbon Fund (PCF), will concentrate on sinks in forests and agro-ecosystems while alleviating poverty (World Bank, 2002: 1). The Fund has been presented as a chance to buy carbon at $3-4 a ton and sell it on the European carbon market after 2005 at perhaps four times that amount (*Environnement et Stratégie*, 2003: 8). Investors include household names such as Swiss Re and STMicroelectronics (BioCarbon Fund, 2002a: 2-3). Despite that, total investment is targeted at $100 million over a 10-year period, or $10 million a year (World Bank, 2002: 1), which is insufficient for significant mitigation.

But that is not the Fund's objective. Like its parent body, it is a pilot, developing project designs that will prove robust under the CDM or a similar mechanism. It therefore seeks to strengthen Kyoto. That has not prevented an NGO, the Climate Action Network, from accusing the Prototype Climate Fund of undermining the Kyoto Protocol (CAN, 2003: 1), although the opposite is the case.

The Fund is not seeking the maximum income per ton, and would not expect to be the sole funding source for a project; rather, its small inputs would leverage bank loans for those who could not otherwise obtain them. Or it could improve a project that was already going to happen. Noble (2003: pers. comm.) uses the example of an investor who puts in fast-growing eucalypts; with the Fund's help, they could instead use slower-growing species to rehabilitate degraded land while encouraging greater biodiversity. Indeed it is proposed to monitor other GPGs such as biodiversity, which the Fund says "might, in due course, be unbundled and traded as separate commodities" (BioCarbon Fund, 2002b: 5).

The Fund is thus an important experiment that may achieve more than its size suggests. But, like the CDM, it will have to compete with lower-cost abatement opportunities.

The GEF and Kazakhstan: A pilot project

The GEF is significant partly because of its size, but also because its mandate covers the three relevant IETs. Soil conservation is clearly relevant to desertification. But sustainable agriculture also encourages biodiversity in the form of native vegetation and soil biota. This synergy could help the GEF to fund carbon-friendly projects not initially tied to specific sequestration targets, so they will not have to compete with cheaper abatement strategies. This may also permit a holistic approach to carbon sequestration that does not exclude other concerns. Any CERs that do accrue could then be sold later to offset project costs.

This approach is exemplified by the recently-approved Kazakhstan Drylands Management Project. Total budget over five years will be $9.7 million; about half will be from the GEF. The bulk of the remainder will be from local sources, but will include inputs from IFAD and the Global Mechanism (World Bank, 2003: 18).

The project will address the consequences of the Virgin Land Scheme. In the 1950s and 1960s about 35 million ha of often unsuitable southern steppe were put under cereal cultivation. Where wheat is still being grown in the project area, yields are low: about 500-600 kg/ha (op. cit., 2003: 8, 98), compared with over 7 t/ha in North America (FAOSTAT). In any case, former collective members can now not afford the inputs needed to maintain cultivation on this unsuitable land, and much has been abandoned.

However, the abandoned land has not regenerated to rangeland, which could provide grazing, because the native species are gone – a process that has also taken place following unwise cultivation in the Middle East (Gintzburger, 1996: 15). Pasture too has often been abandoned, reflecting a reduction in livestock from 35 million to just 10 million head – fewer than at the start of the 20th century (World Bank, 2003: 6). In fact, since 1991, 37 per cent of arable land and 60 per cent of pasture and rangeland in Kazakhstan has been lost through degradation and abandonment (ibid.). Given that 44 per cent of the population is rural (ibid), there are severe implications for living standards. The strategy, therefore, is to assist reversion of 30,000 ha of abandoned land back to livestock production by reseeding it with perennial grasses, as well as improving management of degraded pastures and rangelands (op. cit.: 10).

This will also sequester a lot of carbon. Although improved cropland management can sequester 0.3 t/ha a year, conversion from arable to grassland can sequester 0.8 t/ha a year (IPCC, 2000: 14). There has been some internal debate on the tonnage that might be sequestered in the project area, but it is expected to be about 0.63 million tons, although it is not clear over what period. The World Bank (2003: 48) thinks that, based on a price of $2.50/ton for CO_2 equivalent, this should generate carbon worth about $5.7 million; "enough," it says, "to cover the whole external financing of the project."

In fact, the project will not trade this carbon, but it is anticipated that this could be done later to finance replication of the project (op. cit.: 11, 25, 41) – in effect, a unilateral CDM. Carbon sequestration is so crucial to the project that $1.3 million of the $9.7 million budget is being spent on carbon-related activities – mainly monitoring and the development of models for stratified accounting (op. cit.: 38-39).

There are of course unanswered questions. Expansion of livestock numbers is likely to increase CH_4 emissions, but the CO_2 figures were drawn up according to the 1996 IPCC guidelines, so the complicated assessment of net radiative forcing must have been carried out. A bigger concern might be the sheer size of what is basically an experiment. And although some project documents seem to suggest that the farmers will be able to trade the carbon, elsewhere it is implied, although not explicitly stated (op. cit.: 25), that the government will own it – a dangerous precedent if it leads to coercive projects in any country in the future.

This raises an issue for which there has been little space in this publication, but it is clearly significant. The model of land ownership found in most developed countries would confer ownership of carbon on the land owner, but usufruct or traditional land-use rights, common in many parts of Africa (Brown, 1999: 6), might or might not do so. Security of tenure is also critical; in the Kazakhstan case, at least one consultant raised security of tenure as part of the review of the project appraisal document, asking whether farmers might be forced off the land as its value rose. Further complications could arise in situations where land is rotated; that would not preclude a group carbon budget, but this would require agreement between all land-users in a given area, and this would be dependent on the level of social capital and the legal instruments available. Tenure issues are considered briefly in section three below, but ownership of SOC as such needs further study.

The fact remains that the Kazakhstan project is one of the first major ventures into agricultural sinks in development, and may offer a framework for integrating them with sustainable development and poverty alleviation. It is possible to speculate that developed countries seeking to meet emissions reductions commitments under Kyoto or similar mechanisms may one day do so by funding public-sector work of this sort in the South. This has great potential – provided funds are not diverted from other development interventions, for example in health or education.

Section 2: Summary

Section one reviewed the scientific and agronomic basis for agricultural sinks. Section two discussed the institutional options for them, and found that:

- A commercial commodity market would not be efficient, as it could never internalize all the costs and benefits involved.
- It would also require measurement and verification on a scale that is not yet possible. Stratified accounting may eventually work for some countries, but there is too much optimism about its use in the developing world.

- There are public-sector led approaches that are designed to compensate farmers for providing global public goods; these would have greater impact on poverty. But such mechanisms may struggle for a share of the carbon market.
- In any system, the poorest farmers are uncompetitive as carbon traders. Institutional design can deal with some but not all of this.
- An alternative is to incorporate carbon sequestration into development projects designed to alleviate poverty, especially those that create synergies between IETs. If the carbon sequestered can later be sold, so much the better. The GEF-funded project that has just begun in Kazakhstan may point the way, although it carries risks (for example, ownership of carbon).

The implications of section two are that a functional commodity market may appear – indeed, is already appearing – in the industrialized countries; but not in the developing world. It is not clear whether Kyoto-compliant projects could compete with it. So although some project outcomes might be negotiated into CERs, farmers in developing countries would never be carbon traders on any scale; but farmers in wealthier countries may well be.

But perhaps this is really the best outcome. To understand why, it is necessary to consider the real structures that underlie farmers' land-use, not just in the developing world but on a global scale. This will be done in section three.

Kazakh nomads on the Central Asian steppe in 1911. Areas of the steppe were ploughed during the Soviet era; the Kazakhstan project will address some of the consequences – including the loss of carbon. Library of Congress, Prints & Photographs Division, Prokudin-Gorskii Collection, (LC-DIG-ppmsc-03979) (6)

3: Who will adopt? Who should adopt?

So far, this discussion has assumed that agricultural sinks can alleviate poverty because poor farmers will be paid for creating them. But, as has been shown, this model faces serious constraints. What has not yet been discussed is whether resource-poor farmers would want to adopt it anyway.

The technical measures required for carbon sequestration are effectively those required for soil conservation. There is extensive literature on farmers' adoption or rejection of these, but it has had little impact on market environmentalism, as the latter's proponents tend to be from different disciplines and have not encountered the research on adoption. They therefore make far too many assumptions about farmer behaviour. The implications of this for soil carbon will become apparent in this section.

Conservation measures: adoption and destruction

Some farmers may regard carbon payments with deep suspicion. Herweg (1993: 407), in his discussion of failed Food-For-Work soil conservation in Ethiopia, comments that many farmers consider agricultural research stations to be magic places responsible for the absence of rain. This may be an extreme, but resource-poor farmers do have particular adoption constraints. Some were discussed in section one, in relation to specific technologies. But there are other factors. Security of land tenure, for example, is related to improvement or investment. True, it can be an ambiguous relationship; farmers who lack security of tenure may invest in the land in order to obtain it (Neef and Sangkapitux, 2001: 361). But Ståhl (1993: 381-382) found a correlation between security of tenure and conservation measures in Ethiopia, Kenya, Tanzania and Uganda, while Laing and Ashby (1993: 64) found that farmers with insecure occupancy rights were less likely to adopt rotations.

Moreover carbon trading is effectively an incentive to take conservation measures. Incentives can make farmers reluctant to adopt any innovation for which they are *not* being compensated (Stocking, 1993: 298; Sombatpanit et al, 1993: 333). This is less important in Europe, where farmers have been incentive-dependent for 50 years. Incentives may also be inequitable – Stocking (1993: 294-295) observes that successful farmers will be more able to take advantage of them.

Incentives may also induce farmers to make 'improvements' that they have no intention of maintaining (Herweg, 1993: 397; Kerr and Sanghi, 1993: 282). The Kazakhstan Drylands Management Project was to have required agreements from farmers not to plough the improved land (World Bank, 2003: 26), although this now seems to have been abandoned. The need to ensure permanence is a difficult part of the sinks discourse. Renwick et al. (2003: 189) suggest innovative payment schemes for farmers in the North that might work there. But experience in developing countries suggest that subsidised innovations are not maintained when no further payment is expected, and this is likely to apply to sinks.

However, farmers do adopt conservation measures, spontaneously – for their own reasons. The key to carbon sequestration may lie in understanding what those reasons are. Laing and Ashby (1993: 62-64) describe the *abonera* system brought by Guatemalan and Mexican immigrants to Honduras. The traditional maize-cropping cycle was replaced by a single planting a year, intercropped with mucuna beans – a velvet bean, the nitrogen-fixing qualities of which make it synergistic with maize. Considerable claims have been made for this plant; see for example Pettifer (2001: 1-2). The system is more sustainable (and would sequester plenty of carbon). However, farmers did not adopt it for that reason, but because it increased short-term returns (op. cit.: 63). Adoption occurs when farmers perceive an opportunity to increase production in the near future.

The technology associated with carbon sequestration does not offer the immediate returns associated with a crop; and the carbon payments may be diverted by corrupt officials, not such a problem in developed countries (Zoebisch, 2003: pers. comm.) So farmers are more impressed by the income from their produce. If this is reduced by resource degradation, they may implement conservation measures of their own accord (Laing and Ashby, 1993: 72-73).

That income must be sufficient both to finance conservation measures, and to make them worthwhile. This requires adequate farm-gate prices, and for these, farmers must have access to markets. For example Pandey (2001: 70) reports that in Thailand, improved access to markets through road construction provided upland farmers with the liquidity to fund soil-conservation measures. Such access may also slow resource degradation by encouraging better use of comparative advantage; thus regional self-sufficiency in Vietnam encouraged shifting cultivation and the degradation of fragile uplands, but when the policy was abandoned, food production switched to areas better suited to it (op. cit: 68). This argument can be challenged; for example, Napier and Sommers (1993: 22) argue that market access shifts emphasis from subsistence to cash crops and that this increases soil loss. However, as Stonehouse and Protz (1993: 42) point out, the real problem may be subsidies on cash crops. In any case, farmers can hardly take conservation measures without the resources to do so, so that soil loss would have happened anyway.

Better market access might also discourage rural-urban migration, which has disrupted hitherto effective indigenous measures for controlling soil erosion in the Middle East, Peru and Colombia (Blaikie, 1985: 25). As Boserup (1981, cited Pandey 2001: 70) argues, market access determines farming systems, and it does seem to encourage more permanent conservation measures than incentives such as carbon trading. But, as Stonehouse and Protz (1993: 37-38) point out:

> *Protective policies for developed countries' agriculture and food sectors … effectively exclude exports from developing countries… Such trade distortions… both impede the development of food production sectors and retard investments in resource conservation measures in many developing countries.*

The scale of subsidies to Northern farmers beggars belief. In 1999, the combined amounts paid to support farmers in 30 OECD countries exceeded the GDP of Sub-Saharan Africa (FAO, 2001a: 1). In 2000, total transfers to OECD farmers were $327 billion (ibid), dwarfing total aid flows from those countries, which were $47,580 million in 1997 (Thomas and Allen, 2000: 207). FAO's Director-General, Jacques Diouf, said in 2001 that:

> *While each OECD farmer received US$ 11 000 of support, an agricultural farm worker in a developing country received a mere US$ 4.3 of ODA* [in 1999]. (FAO, 2001a: 1.)

This has been a direct cause of resource degradation in both Europe and North Africa. As was stated earlier, outmigration can cause the decay of existing soil-conservation measures. Southern Tunisia is an example; it has only about 200mm annual rainfall, but it tends to come all at once, bringing soil with it. The traditional *jessour* system – a series of stone and earth walls across narrow valley watersheds – collects not only the water but the soil, and forms it into terraces (Aw-Hassan, 1996: 18). The traditional crops grown in this way are barley and olives (op. cit.: 18-19). In recent years, the system has broken down due to outmigration of skilled labour, and this is leading to serious loss of productive soil (ibid.) – and thus carbon.

Income from olives should prevent this. Tunisia produces 9 per cent of the world's olive oil (ALEB, 2002: 6) but only consumes 2 per cent (op. cit.: 7). It should therefore have done well from the rise in world olive-oil exports, from about 500,000 MT in 1980 to 2.3 million MT in 2000 (op. cit.: 10).

However, Spain, Italy and Greece account for nearly three-quarters of world production, and the EU spends about $2.3 billion on subsidies – over a third of the value of total world production (PPI, 2003: 1). In 1996, the World Trade Organization insisted that support be cut by 20 per cent by 2002 (ALEB, 2002: 15). But as the EU complied by removing price support while continuing production subsidies (ibid.), this may simply have driven down prices for non-EU exporters such as Tunisia.

Meanwhile European production has been intensified, to counteract falling prices by taking advantage of producer subsidies. As a result, Spain's Ministry of Agriculture estimates that 80 million MT of soil a year are lost from the 1 million hectares of olive plantations in Andalusia alone (Pohl, 2001: 3). There is an inherently high risk of erosion in many olive-farming areas (Beaufoy, 2001: 4). In fact, nearly 75 per cent of Southern European soils now have a low (3.4 per cent) or very low (1.4 per cent) SOM content (European Commission, 2000, Annex III: 2). Organic matter is also now low in Northern European soils, with much of the damage done since 1980 (ibid.)

Lines of olive trees march across a semi-arid landscape in the Middle East. Soil erosion is an issue here, but it is hard to persuade farmers it is worth dealing with when their olive oil is unable to compete with the huge production subsidies offered to producers in Southern Europe. It becomes uneconomic to maintain the groves, and carbon is lost.

A better place to farm carbon?

The potential for carbon sequestration is in fact higher in temperate countries. Niles et al. (2003: 78-79) estimated annual sequestration potential for the developing world for the period 2003-12. They assumed 20 per cent adoption of sustainable practices, which in view of the constraints discussed above may be high. They suggest that Latin American agriculture could sequester 93.1 mt/C, Africa 69.7 mt/C and Asia 227.3 mt/C, a total of 420.6 mt/C, which they value at $2,910.8 million. This is about $291 million a year, about three times the OECD aid budget. But relatively little would go to Africa. And the recipients would not be the poorest farmers, as explained in section two. So if this income were to displace current aid flows, the poor would end up rather worse off.

Moreover the total annual agricultural sequestration potential of the three continents, at about 42 mt/C, should be compared to the USA's, at 75-208 mt (Lal et al, 1998, quoted Renwick et al, 2003: 174) – enough to meet 24 per cent of the USA's Kyoto commitment. True, the latter figures are probably based on crop area, and adoption would not be 100 per cent, even in the USA. But it would be high, and the comparison is indicative.

Jotzo and Michaelowa (2002: 179-196) also find higher potential in developed countries. They estimated annual agricultural sinks potential at between 179 mt/C and 239.3 mt/C for the United States. For the EU the figures were 147.1 mt/C and 609.7 – 15.8 per cent of its Kyoto commitment. Comparisons of sequestration potential are problematic, as there is little consistency so far on many of the variables; and as Jotzo and Michaelowa accept (2002: 179-196), only a small percentage of the land is likely to be managed for carbon storage by the time of the commitment period. But they add:

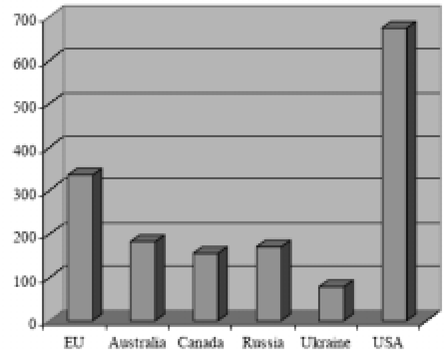
> *Still, the… amounts can be staggering. Even if only 10 per cent of available agricultural land are managed, about 1 per cent of total Annex B emissions would be covered under the medium variant* [three scenarios were presented]. *In the United States, currently 17.5 per cent of cropland is managed in this way compared to just around 6 per cent in 1990.*

This takes no account of the fuel use in Northern agriculture, mentioned briefly in section one. Pretty et al. (2003: 198) point out that low-input or organic rice production in Bangladesh, China and India is 15-25 times more energy-efficient than irrigated rice in the USA.

It also considers only carbon. Indeed this publication has not attempted to consider the net GHG flux from agriculture, except where management for carbon sequestration could cause perverse outcomes through higher N_20 and CH_4 emissions. But it is worth noting the further net emissions benefits from a review of subsidies. As Adger and Brown (1994: 187) point out: "The reduction of CH_4 emissions from livestock is an unpriced, and generally unaccounted for, benefit of agricultural policy reform in highly subsidised agricultural sectors."

The institutional structure for a carbon market is also easier to build in developed countries. Sandor et al. (2003: 60-61) cite the growth of the SO_2 (sulphur dioxide) market in the USA in the 1990s and the embryonic CO_2 markets under development – in the Netherlands and Germany (op. cit.: 65), and in the USA, where they have the support of political heavyweights such as Senators McCain and Lieberman (ibid.).

Moreover, as Renwick et al. (2003: 188) point out, governments already intervene heavily in agriculture in developed countries, and there may be scope for altering existing policies. Reducing subsidies could also cut the opportunity costs of sequestration measures (ibid.). Houghton (2002: 71-88) has suggested that woody encroachment in the USA, and agricultural abandonment worldwide in general, are significant.



Approximate annual agricultural sequestration potential(Mt/C) of the EU (before2004 accessions) and five Annex B countries under a medium scenario. Direct comparison with Niles et al.(see page 36) should be avoided as the assumptions (for example on adoption) are not the same*. (Adapted from Jotzo and Michaelowa, 2002)*

This indicates set-aside as an option. It would need modification; British farmers, for example, often move set-aside around the farm (Renwick et al., 2003: 188-189). But this is surely much easier than designing carbon trading for Niger or Zambia.

Thus the degraded olive groves of southern Europe could be rehabilitated, and enhanced as a sink, by replacing olive-oil producer payments with agro-environmental payments unrelated to production or yields (Beaufoy, 2001: 64-65). As the price of olive oil rises, farmers may start rehabilitating the Tunisian *jessour* system, enhancing both SOC and farming incomes. This is a true win-win situation.

Section three: Summary

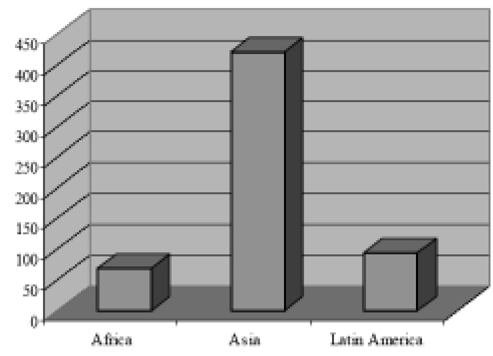
This section began a discussion of whether resource-poor farmers would adopt sequestration measures under a carbon model. It was stated that:

- External incentives achieve at best temporary adoption of conservation measures.
- Adoption decisions will be based on immediate productivity concerns.
- Adoption of conservation measures may be encouraged by market access, but this is constrained by high subsidies to agriculture in industrial countries.
- These subsidies cause environmental degradation in those countries.
- Their potential for C sequestration may be higher than that of the developing world.

Resources devoted to production support should be switched to encouraging carbon-friendly agronomic practices in industrialized countries.

This could improve market access for farmers in the developing world, and would not only alleviate poverty, but also give them the means and incentive to modify their agronomic practices.

In this way, C sequestration could be encouraged in both North and South.



Approximate annual agricultural sequestration potential(Mt/C) of the developing world. Latin America is distorted by Brazil and Mexico, which together have about two-thirds of the potential; in Asia, China, India, Indonesia and to a lesser extent Thailand account for virtually all, but in Africa the potential is spread across the continent. Adoption hectarages have been projected for each country. (Adapted from Niles et al., 2003)

Conclusions

The question asked in the introduction was whether carbon trading could be used to finance practices in the developing world that make agriculture more sustainable, and also sequester carbon – thus alleviating poverty. It does seem that there are severe constraints to such a model, although they may not be insuperable.

But if the words 'in the developing world' are removed, then the model is likely to work. It might also provide industrialized countries with a graceful exit from their current high-subsidy regime, which causes so much resentment in the developing world that it derailed the WTO Ministerial Meeting at Cancún in September 2003, having already nearly done so two years earlier in Doha (FAO, 2001a: 1). Indeed pressure for reform is urgent within the EU itself, and the sinks option may offer governments such as that of France a way to accept CAP reform without domestic loss of face.

It may seem that a 'win-win' strategy has been rejected only to be replaced by another, and there is indeed potential for perverse outcomes. Unleashing the vast sinks potential in Annex B countries might discourage more permanent abatement strategies in their other sectors; when agricultural sinks reach saturation point, those strategies will still be necessary, and will have become more expensive. But this may be counterbalanced by more stringent GHG commitments after 2012.

Reform may also mean more expensive food in industrialized countries. However, as Renwick et al. (2003: 191) have pointed out, this is now a small percentage of most people's living costs. It is safe to risk what would probably be a small, and incremental, rise in food prices in Europe. In low-income countries, however, experiments with sinks might generate opportunity costs that would be passed straight to poor urban consumers, for whom food represents the greater part of the household budget.

Last but not least, farmers in industrialized countries are likely to be a lot more enthusiastic about carbon trading than their counterparts in Africa or Asia; indeed, they may pursue options such as biofuels production. The economics of this are contested; indeed, Gielen et al. (2002: 319-333) argue that carbon storage and bioenergy production are conflicting strategies. But Pretty et al. (2003: 201-202) suggest that if 10 per cent of the EU's agricultural land were used for biofuel in combination with woodland regeneration, the reduction in overall emissions would equal the EU's Kyoto commitment. Britain is now investing _30 million in a seven-year biofuels pilot project (European Commission, 2000: 20). Meanwhile a carbon market is developing rapidly in North America and elsewhere, despite the USA's non-ratification of Kyoto (Sandor et al., 2003: 64-66). In Germany, farmers may already receive payments for no-till (European Commission, 2000: 8).

None of this means that agricultural sinks are completely without potential in the developing world. The unilateral sale of CERs following projects such as that in Kazakhstan seems to be the most practical framework. Such initiatives may have considerable local impacts on poverty. But they are unlikely to be significant as a mitigation strategy. The real link between carbon, agriculture and poverty must be found in wealthier countries, and it could happen.

Finally, it was stated at the outset that this publication would not attempt to address the broader ideologies underpinning the post-Rio process. But it is necessary to acknowledge them. Adams (2001: 171) refers to "the view of sustainable development as essentially a managerial process, where reform of procedures will ensure some 'optimal' outcome". This limited view may lead to attempts to introduce sinks in agriculture in the wrong countries, without either knowledge of how resource-poor farmers really function, or a deeper understanding of the links between land use, the broader economy, and international trade. In that case, agricultural sinks – a promising concept in many ways – will be bound to fail. The evidence in this publication suggests a need for a broader, multidisciplinary perspective.

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WASWC – World Association of Soil and Water Conservation

Established 1983

The conservation and enhancement of the quality of soil and water are a common concern of all humanity. We strive to promote policies, approaches and technologies that will improve the care of soil and water resources and eliminate unsustainable land use practices.

The Objectives of WASWC
The basic objective of WASWC is to promote the wise use of our soil and water resources. In doing so WASWC aims to:

- Facilitate interaction, cooperation and links among its members.
- Provide a forum for the discussion and dissemination of good soil and water conservation practices.
- Convene and hold conferences and meetings and conduct field studies connected with the development of better soil and water conservation.
- Assist in developing the objectives and themes for ISCO conferences and collaborate in their running.
- Produce, publish and distribute policies, guidelines, books, papers and other information that promote better soil and water conservation.
- Encourage and develop awareness, discussion and consideration of good conservation practices among associated organizations.
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The Author

Mike Robbins was born in England in 1957. His early career was not connected with agriculture; he studied History and Politics at the University of Warwick, graduating in 1979. He went on to do a number of jobs in journalism and communications, including periods as a financial journalist, a traffic broadcaster and a reporter on the fishing industry. In 1987 he began what would eventually be over four years as a development volunteer, initially with the Government of Sudan in Refugee Settlement Administration near the Eritrean border.

Robbins became directly involved in agriculture in 1992, when he joined the Department of Agriculture of the Royal Government of Bhutan. In 1995 became Science Writer/Editor at the International Center for Agricultural Research in the Dry Areas (ICARDA), in Aleppo, Syria. In 1998 he went to Brussels to join a project disseminating the experience of the European Commission's work in the former Soviet Union, including its technical assistance to agricultural systems that had been faced with rapid change. In 2001 he moved to the Food and Agriculture Organization (FAO) in Rome to work as a consultant on the preparations for the World Food Summit: Five Years Later; this was postponed, but he remained at FAO until it had taken place.

In September 2002, Robbins decided to strengthen his formal qualifications at the University of East Anglia in the United Kingdom. The University's School of Development Studies, with its multidisciplinary capacity, has proved the ideal place for him to look at agriculture within a wider development and environmental context; the campus is also home to a number of research centres on the environment, including two devoted to climate change. Robbins is now undertaking a PhD on the potential of carbon sequestration in agriculture, with the emphasis on its benefits and drawbacks for the developing world.

Printed by Funny Publishing
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