# Carbon Sequestration–A Powerful Incentive in Combating Land Degradation and Desertification

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**Abstract**: Carbon sequestration within the context of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (FCCC) has great potential as an incentive for combating land degradation and desertification and restoring fertility to degraded land. Such conversion of greenhouse gas $CO_2$ to organic matter offers a powerful tool with which to combat climate change. The enlargement of carbon sinks stored in soil and biota is an essential tool in buying time while mankind seeks means to reduce emissions of greenhouse gases and to reduce the elevated levels of atmospheric $CO_2$.

In Iceland, carbon sequestration – a by-product of combating soil erosion, revegetating of eroded land and reforestation – has an important role in meeting national commitments to FCCC. Linking carbon sequestration with soil conservation activities has resulted in greatly increased funds for soil conservation and restoration in areas that have become severely degraded since settlement of the island 874 on.

Decisions regarding carbon sinks during finalization of the operational details of the Kyoto Protocol in 2001 fit well the needs of countries facing land degradation and desertification. However, incentives for such mitigation through the Clean Development Mechanism of the protocol are limited to forestry issues.

**Keywords**: carbon sequestration, incentives, land degradation, mitigating desertification, reforestation, revegetation, Kyoto protocol

## 1 Climate change and land degradation issues

In the Framework Convention on Climate Change (FCCC), *climate change* is defined as a "change of climate which is attributed … to human activity that alters the composition of the global atmosphere…" (Article 1). The FCCC's objective is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

Carbon has a pivotal role in the health of the global climatic system. Carbon – usually in the form of carbon dioxide ($CO_2$) – from fossil fuels and land degradation is the main factor in climate change. In addition to reducing emissions, a major tactic should be to return the carbon to the soil and store it in long-term or permanent reservoirs – i.e., carbon sequestration.

From 1850 to 1998, approximately 270 (±30) Pg of carbon has been emitted as $CO_2$ into the atmosphere from fossil fuel burning and cement production. About 136 (±55) Pg C has been emitted as a result of land use change (IPCC, 2000). Land-use change and degradation of soil and vegetation have played an important role in atmospheric enrichment of $CO_2$. Land degradation and desertification is a severe problem in many parts of the world, especially in the drylands where food insecurity is a major problem (Lal, 2001). Reversing the degradative trends by sequestering some of the lost carbon can play a major role as a tool in mitigating climate change and enhancing food security.

The FCCC defines *sink* as "… any process, activity or mechanism which removes a greenhouse gas … from the atmosphere" (FCCC, Article 1). In this way, *reservoirs* are generated or maintained, "… where a greenhouse gas … is stored," (FCCC, Article 1). Vegetation acts as a carbon sink because plants convert the naturally occurring atmospheric greenhouse gas, $CO_2$, into organic material – the tissues forming trunks, shoots, roots, leaves, etc., forming a carbon reservoir comprising all live and dead organic material. Most is stored in the ground and has a direct relation to soil fertility.

## 2 Land degradation and desertification in Iceland

Vast amounts of stored carbon have been released to the atmosphere due to degradation of Icelandic woods and rangelands throughout the second millennium. Restoring these degraded lands to sustainable woodlands and fertile grazing lands would ensure the ongoing presence of significant carbon sinks.

The settlers who came to Iceland 1100 years ago (about AD 874—930, The Age of Settlement) saw a fertile land. Vegetation may have covered more than 60% of the country, and woodlands, mainly birch (*Betula pubescens*), covered at least 25% of the land area. The vegetative cover provided good protection for the fragile volcanic soils. With the settlement, the delicate balance between a hostile climatic environment and vulnerable vegetation was disrupted (Thorsteinsson, 1986; Arnalds, A., 1987). The woodlands were grazed, cut for fuel or timber, or burnt to clear pasture. The initial causes of soil erosion in Iceland varied from place to place, but, clearly, the interaction of livestock grazing, and weak soil structure, harsh climate and volcanic eruptions is the main reason for the great ecosystem disturbance. Climatic fluctuations have also exacerbated this process, reducing further the ability of the vegetation to resist the unyielding pressure of man and livestock. Subsequent soil erosion devastated large parts of the ecosystem, reducing vegetative cover by about half. Trees now cover only 1% of the land area.

Arnalds, A. (1987) summarizes some of the various sources that can be used to reconstruct the vegetation of the past, and trace some of the major changes in cover and composition through the centuries. These include historical records, site names, pollen studies, remnants of former vegetation, and land-use indicators. The potential woodland distribution has also been assessed by meteorological data. Such information could also be used to map the potential for carbon sequestration in the degraded parts of the country.

Desertification continues to be a major threat to Iceland's natural resources, despite ample precipitation in most parts of the country. A national assessment of soil erosion indicates that 40% of Iceland is experiencing severe soil erosion (Arnalds, O., 1999; Arnalds, O. *et al*., 2001). Surfaces that become denuded are usually almost devoid of below-ground plant tissue and subsequent vegetation succession can be considered primary.

In addition to the loss of the woodlands, the vegetation composition in many parts of the country has been adversely altered by grazing and reduced soil fertility. Poor land health and continued soil erosion are considered the most severe environmental problems in Iceland. There is an urgent need to improve land quality over vast areas, which combines well with political efforts toward carbon sequestration and permanent storage of carbon in the form of organic matter in both soil and biota.

## 3 Carbon Sequestration in ICELAND

Carbon sequestration has an important role in the Icelandic climate change action programme that is evolving. A special sequestration programme conducted 1997—2000, emphasising revegetation and reforestation, lays the foundation.

### 3.1 Carbon dioxide – A resource OUT OF PLACE

In the April/May 1999 issue of *Conservation Voices*, the Soil and Water Conservation Society of U.S.A. presents the view that $CO_2$, despite being a dangerous greenhouse gas, is also a valuable resource. $CO_2$ is vilified as a principal culprit in the global warming debate, but that same carbon atom located in soil becomes organic matter, the key to soil fertility and increased food production for the world's ever-growing population.

In Iceland, a country of 103,000 $km^2$, at least 1,600 million tons of $CO_2$ equivalent has been lost from the ecosystem through land degradation and desertification. As a consequence, there is both a high potential and a great need for carbon sequestration for recovering land health. Experience from soil conservation projects demonstrates that restoring ecosystems and reducing atmospheric carbon can be combined to give multiple benefits. Halting soil erosion also has a major role in preventing release of stored carbon to the atmosphere.

### 3.2 Repaying the soil-carbon debt

From Iceland, emissions of greenhouse gases in $CO_2$ equivalents were about 3.2 million t in 1990. The government aims to restrict emissions to these levels. However, prior to 1990, greenhouse gas emissions had already been reduced substantially by replacing fossil fuels for house heating with geothermal and hydropower energy. Reducing emissions still further will be difficult without considerable impact on Iceland's economy.

Worldwide, Iceland's Soil Conservation Service (SCS) and Forestry Service (FS) are among the oldest (established 1907) and have a long history of successful soil conservation work. Based on this experience, and the great need for improved land quality, the Icelandic government decided to include carbon sequestration as a significant element in the national Climate Change Action Programme. To reach the goal of increasing 1990 annual carbon sequestration levels by 100,000 t $CO_2$ by 2000 the government provided 30% additional funds for reclamation and reforestation for 1997—2000. This goal was exceeded. In the soil conservation sector, additional carbon sequestration programmes focused on selected sites where results can easily be documented and demonstrated. Funds are still increasing, and carbon sequestration as a tool in meeting targets in greenhouse gas emissions thus has become a major financial incentive for soil conservation and forestry.

### 3.3 Community involvement in carbon sequestration

Based on this new incentive of using carbon sequestration to meet greenhouse gas emission targets, many projects have been started or expanded to combat desertification and heal eroded land. Projects to reforest damaged land were also expanded, including a grass-roots-oriented programme termed "reclamation forestry."

Land degradation has multidimensional consequences to society. These include reduced biological diversity, agricultural productivity and food security; loss of shelter against winds and snowdrifts; and degraded watershed hydrology. To build a strong relationship between conservation and society, SCS has been developing new approaches in its operation (Arnalds, A., 1999). Carbon sequestration adds a new dimension to strategy development, giving both projects and participants an additional role.

In general, mitigating land degradation is becoming more participatory, involving a wide cross-section of Icelandic society in ecosystem understanding and solution development. This also means widening the focus, from localized problems of soil erosion to the more complex issues of ecosystem management for multiple use (Arnalds, A., 2000). SCS currently works with a wide range of community groups, including municipal and rural authorities, a wide range of clubs and associations, and many individual volunteers.

### 3.4 Farmers heal the land

The Icelandic farm community is by far the most active group in reclaiming eroded land, and thus the most efficient in carbon sequestration. Programmes that motivate and provide livestock owners with voluntary incentives to adopt sound conservation practices have been evolving in Iceland since 1990 (Arnalds, A., 1999). The most extensive is *Farmers heal the land*, a partly locally-led programme centred on assisting landowners to reach their reclamation goals. The long-term goal is to increase conservation awareness and make the land users the true custodians of the land.

The farmers conduct the reclamation work, but receive 85% of fertilizer cost (which can be half of overall project cost), and grass seed as needed. Cost sharing is considered important, creating a feeling of ownership in the results. More than 30% of the sheep farmers are now actively participating, plus a number of other land users.

### 3.5 Carbon sequestration rates

Monitoring of carbon sequestration rates reveals high rates and a large potential for carbon sequestration in Iceland (Aradottir *et al*., 2000; Arnalds, O. *et al*., 2000). Although results are preliminary,

carbon sequestration through re-vegetation of desertified land using grasses and fertilizers may average 2.9 t/ha/yr $CO_2$, with about 65% stored in the soil (Ministry of Agriculture, 2000). Average rates from afforestation, partly of severely degraded and desertified lands, were 6.1 t/ha/yr. The Andosols and Histosols in Iceland can accumulate large quantities of carbon due to andic soil properties and cold climate. The carbon levels of the deserts before re-vegetation are also very low, with room for large increases and permanent storage (Aradottir *et al.*, 2000; Arnalds, O.,1999; Arnalds *et al.*, 2000).

### 3.6 Options for funding carbon sequestration in Iceland

It may be feasible for the Icelandic government to greatly increase funds for carbon sequestration projects. Ecosystem degradation, making soil carbon sequestration so essential, is centuries old. Restoration could therefore be regarded as a communal duty of the current generation, especially for future food security. Partial funding by the government as seed money would also attract funds from other sources.

Carbon sequestration adds a new dimension to agricultural and rural support. Some projects would offer direct income to farmers and other rural people, but the main benefit to agriculture would come from the carbon sequestration itself, through increased soil fertility and better plant growth. Stakeholder cost sharing may be important in projects where land utilization might reduce carbon sequestration rates.

### 3.7 Pollution fees

Utility fees are common in many countries, such as for waste disposal and recycling. Pollution fees are being discussed in Iceland, especially for $CO_2$. Part of such fee, for instance on fossil fuel, could be used to fund carbon sequestration. Annual carbon sequestration through the revegetation of about 1.1 ha of degraded land with low soil carbon, or establishing 0.6 ha of new woodlands, could balance $CO_2$ pollution from the average family car for the next 30 to 60 years.

About one third of Icelandic greenhouse gas emissions derive from the fishing fleet. Part of these emissions could also be met by carbon sequestration. The cost of meeting $CO_2$ emissions from gasoline and diesel fuel by sequestration is variable, but may require 2%—4% increase in fuel price.

### 3.8 Links with industry

Overall, there is an evolving interest in many sectors for balancing emissions against carbon sequestration. Taking the synergic effect of land improvements into account, it could be argued that a part of this cost should be met from non-polluting sources, such as government funding. However, using carbon sequestration is likely to be considerably cheaper than buying or renting emission quotas.

### 3.9 Funding and carbon credits

Nationally, there is wide interest in “healing the land,” and a large number of individuals, companies and societies are active in reclamation and forestry. As an example of the diverse private sponsorship, the Retailers Association of Iceland operates an environmental fund based on the sales of plastic shopping bags in shops. The fund supports a wide range of soil conservation and forestry activities.

Carbon sequestration has hitherto not been an issue in the work or funding of reclamation and forestry projects by various sectors of society. However, laws on carbon sequestration rights may have to be set if sequestered carbon becomes tradable like emissions quotas.

## 4 Carbon sequestration and the kyoto protocol

Carbon sequestration is one of the tools available in mitigating the potential risk of climate change. The operational details of the Kyoto Protocol to the Convention on Climate Change were finalized in 2001, despite considerable controversy. It was decided that countries included in Annex I to the Protocol may choose to use carbon sinks created after 1990 by revegetation, forest management, cropland

management, and grazing land management, in addition to afforestaton and deforestation, to meet country commitments.

### 4.1 Revegetation

"Revegetation" is defined as a direct human induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 ha but does not meet the FCCC definitions of afforestation and reforestation.

For countries that have suffered much erosion, like Iceland, the acceptance of re-vegetation was particularly important, enabling carbon sequestration as an incentive to combat desertification and restore eroded land. This decision encourages the use of low growing, non-forest, species as carbon sinks, where appropriate. Limitations to "forestry", especially under "tall tree" definitions, might in many projects have encouraged the use of introduced trees and monoculture at the cost of native species, threatening local biodiversity and thereby contradicting the goals of fundamental international conventions, such as the Convention on Biological Diversity (CBD), Convention on Desertification, and FCCC itself.

### 4.2 Forestry definitions

Each Party included in Annex I shall, for the purposes of applying the definition of "forest", select a single minimum tree crown cover value between 10 and 30 per cent, a single minimum land area value between 0.05 and 1 ha and a single minimum tree height value between 2 and 5 m. This selection shall be fixed during the first commitment period.

Care has to be taken that forest definitions, and thus the distinctions between forestry and revegetation as related to the Kyoto Protocol, meet the goals of landcare and biodiversity conservation. Degraded land in some parts of the world, especially the arid lands most prone to severe degradation or desertification, is often characterised low growing species that would not fall under common "forest" definitions, derived from tall timber uses. Iceland illustrates this well. Birch is the main native tree, but about 80% of the birch woodlands are below 2 m in height. Thus, if for instance the *State of the World's Forests* definition (FAO, 1977: 173-174) is used, only introduced species would meet "forestry" definitions. Such definition could encourage the use of non-native trees for carbon sequestration in Iceland, contravening CBD goals. It is important to encourage the use of native, naturally adapted species in areas prone to land degradation, including Iceland. The danger of exclusion of sinks because wooded areas do not meet classical forest definitions must be avoided.

From a carbon accounting perspective, soil carbon in forestry is important, as a large proportion of the carbon pool is below ground, and is often a more permanent storage form than the wood. Thus, planting trees in relatively fertile land may, at least initially, release carbon from the soil to the atmosphere. Using native trees or shrubs as reclamation species in unfertile land, in contrast, may yield large overall carbon sequestration rates in soil and biota, as indicated by preliminary research figures from Iceland (Aradottir *et al*., 2000; Arnalds, O. *et al*., 2000).

### 4.3 Land use change

The inclusion of "cropland management" provides great potential as an incentive for more sustainable crop production. This will encourage both improved practices for growing agricultural crops and temporary rest or non-use of land that may be damaged or too sensitive for cultivation.

The approval of "grazing land management" may also provide an incentive for more sustainable use of pastoral lands, although the additional carbon sequestration may be difficult to monitor in the context of lightly vegetated extensive grazing areas. As an example of the importance of this category in degraded environments, about 40% of Iceland's land area is affected by severe soil erosion. In many cases, protecting the most damaged land from grazing may be the most economic route to recovery. Annual carbon sequestration rates per unit area resulting from improved management or protection from grazing may be low, but the potential areas are large. The inclusion of such land use changes, i.e. as a tool in meeting national greenhouse gas targets, would be very beneficial to sustainable land use in Iceland.

From the community point of view, it would be economic for the government and other funding sources to assist in the development of options for improved management or protection of the most damaged rangelands from grazing, such as by improving through re-vegetation less sensitive land as an alternative grazing resource.

Re-vegetation of degraded land with grasses, legumes, native willows or birch are common tools in improving or restoring damaged land in Iceland. Such action increases carbon stocks in soil with low organic matter content, and provides multiple ecosystem and land use benefits. Measurement problems associated with the fate of existing soil carbon are negligible in these soils, as initial soil carbon levels are low.

The same would apply in many other countries where there is an urgent need to retire land from grazing or crop production in some areas, decrease the intensity of land use in other areas by management changes, and halt soil erosion or improve land by reclamation activities. Carbon sequestration, especially in the soil, is an additional incentive in the attack on soil degradation.

### 4.4 Carbon sequestraton – quality considerations

Land-use, land-use change and forestry activities must adhere to several principles. They should be based on sound science, with consistent methodologies used for accounting and reporting. Their implementation should also contribute to the conservation of biological diversity and sustainable use of natural resources.

Many nations have a large potential for carbon sequestration through additional activities incorporated in the Kyoto Protocol. This in particular applies to some agricultural countries, especially through improved management of agricultural land. Although carbon sequestration and reducing emissions are two different routes to the same goal, this is seen by many environmental groups as an escape route for such countries to avoid reducing emissions. Therefore the overall quality and benefits of such projects must be considered.

Carefully designed projects that aim to mitigate land degradation and desertification link well the goals of the conventions on climate, on biodiversity and on desertification. These, and other projects that are used to meet part of national commitments on reducing greenhouse gases, should be based on multiple objectives and be mutually supportive to the overall goals of the conventions.

## 5 Win-win option for the environment and the world's growing population

Synergy – "a combined effect … that exceeds the sum of individual effects" – is a characteristic of carefully selected and well designed carbon sequestration projects. Many types of carbon sinks are clearly synergic.

$CO_2$ levels in the atmosphere are already too high, and it is neither technologically nor economically possible to halt the rapid increase of the carbon dioxide curve at the rate probably required to reduce the risk of climate changes. Carbon sequestration could be seen as a tool to "buy time" for reducing greenhouse gas emissions and also as a means to return part of a displaced resource back into organic matter.

The "greenhouse" links may provide the additional source of funding needed for many projects combating desertification and improving land quality. In some countries, such as Iceland, this could augment both government and private sector funding for soil conservation projects. It could also encourage development of much-needed alternatives for land use changes in degraded areas. In Iceland projects are not selected on the basis of carbon sequestration rates, but on their overall values for society, and evaluating their effect on biological diversity. The carbon sequestration comes as an added bonus to such projects.

Article 12 of the Kyoto Protocol includes provisions for the establishment of a "clean development mechanism" (CDM). Its basic premise is that projects undertaken in developing countries can be counted towards meeting the emission targets of developed countries. In the finalised Kyoto Protocol to the Convention on Climate Change carbon sinks in the CDM were limited to forestry issues only. If forestry is defined in tall timber terms this may limit the "win-win" opportunity where developed countries would

invest in actions for mitigating desertification and improve land fertility that help them meet their commitments under the Protocol. The developed and developing countries need to find means to enable more such mutually beneficial co-operative efforts to meet the climate-change challenge. Such projects should be used where possible to reinforce sustainable land use and food security. The "big winners" would be the countries most affected by severe land degradation and desertification, especially the poorer countries.

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