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# Potential and Economics of Wetland Restoration as Climate Change Mitigation Activity in Iceland

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# Foreword

This paper discusses Wetland restoration as a climate change mitigation activity and possible climate mitigation potential for Iceland by including wetland restoration as a new climate mitigation activity at the request of the Ministry of the Environment. The report was prepared by Dr. Daði Már Kristófersson.

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## 1. Introduction

This paper discusses Wetland restoration (WR) as a climate change mitigation activity.

The focus of the paper is the case of Iceland, an Annex I Party that has proposed wetland restoration as a new elective activity in the LULUCF sector under Article 3.4. of the Kyoto Protocol. The paper describes how WR could be part of the Post-Kyoto climate regime, discusses realistic implementation consideration, highlights synergies with other environmental objectives and further, discusses socio/economic aspects of WR as an alternative land use regime.

Finally, the paper concludes on the possible climate mitigation potential for Iceland by including wetland restoration as a new climate mitigation activity.

## 2. Wetlands and their degradation in Iceland

The Icelandic government subsidized wetland drainage from the fifties until the early eighties as an effort to increase agricultural production. During this period as much as 32 thousand km of drainage ditches were dug (Hlynur Óskarsson 2008). This number does not reflect the total length of ditches since some ditches had to be dug over and over again in difficult areas.

The current estimates of the extent of drained wetlands are based on the analysis of satellite images. Drainage ditches are easily visible on such images since open grasslands are the dominant land type in Iceland. The estimated total length of the ditches based on this method is about 28 thousand km. The estimate for the area of irrigated wetlands based on the length of ditches, with approximately 7,3 km of ditches per $km^2$ of irrigated land. The total area of irrigated wetlands, based on these estimates, is about 3900 $km^2$. The total extent of wetlands in Iceland is however 10.025 $km^2$. The estimate indicates that about 40% of the wetlands has been drained. However this percentage may be misleading since it includes wetlands in uninhabited areas. Estimates for western Iceland suggest that as much as 82% of all lowland wetlands was drained (Hlynur Óskarsson 1998).

## 3. Wetlands and climate mitigation in Iceland

Wetlands are significant part of the Icelandic physical landscape, covering around 10% of its land area. Thereof around 4/5 are classified as "myres and swamps" and around 1/5 as lakes and rivers.

In Iceland, about 1.500 Gg $CO_2$ eq were reported as GHG emissions from wetlands, according to the Icelandic inventory reports to the UNFCCC under the Convention (Umhverfisstofnun 2008).

These emissions are significant in relation to Iceland's overall GHG emissions and can be compared to about 5.000 Gg $CO_2$ eq as total emission reported from Iceland, excluding LULUCF.

However, the greater portion of drained wetlands in Iceland have not been altered in other ways than the excavation of draining ditches, i.e. the soil surface has not been plowed or sown with non-wetland species.

Small-scale trials indicate that restoring drained wetlands in Iceland is both relatively technically easy and inexpensive. Expanding the scale of restoration activities depend largely on complex socio/economic factors that need to be properly analyzed and discussed among relevant stakeholders.

Therefore, wetland restoration (WR) is an activity with suggested high technical potential for reducing GHG emissions in Iceland.

## 4. Wetland restoration – a possible win-win synergy

Wetlands provide a number of ecosystem services. Restoring degraded wetlands can provide considerable environmental benefits beyond the climate mitigation gains, especially on biodiversity and hydrology (Arnþór Garðarsson et al. 2006). Although wetlands are among the most important habitats for biodiversity in Iceland, incentives for wetland restoration have been lacking. Including wetland restoration as a new climate mitigation activity might however provide the incentive structures for such initiatives and in purposely planned, generate important co-benefits to biodiversity conservation and water regulation.

## 5. Interactions of different GHG

Wetland emission includes interactions of several GHG gases, mainly $CH_4$, $N_2O$ and $CO_2$ gases. Wetland GHG fluxes are site specific and complex, depending on the physical properties of the respective wetlands. The seminal factor on the GHG balance is the degree of water saturation, as well as climate and nutrient availability.

Therefore, wetland degradation in the form of drainage, e.g. lowering the water table in myres and swamps, immediately impacts the GHG fluxes, additional to the impacts on hydrology and biodiversity.

Recent research in Iceland indicates significant emissions of $CO_2$ from decaying drained wetlands. The studies further, indicate similarity in $CO_2$ eq for $N_2O$ from drained soils and $CH_4$ from restored sites (Hlynur Óskadsson 2008).

The outcome of WR in Iceland suggests therefore that $N_2O$ decreased emissions balance the $CH_4$ increase and the net gain is the decrease on $CO_2$ emissions. Further, although slow process, carbon accumulation starts after the wetlands have been restored. This is in line with other studies, that in the mid- and long-term restoring wetland by rewetting leads to a net reduction of GHG emissions.

## 6. A realistic estimate of land availability for WR

No accurate estimate of the actual use of the drained wetlands exists. A rough estimate was obtained from Ólafur Dýrmundsson, an expert at the Farmers Association of Iceland. According to it, about 1200 $km^2$ of wetlands are fields for hay production, about 1800 $km^2$ are used for grazing while the remaining 900 $km^2$ are in limited direct use. The possibilities for wetland restoration are largely limited to the last category. Assuming that the size of this category is accurate, significant wetland restoration is possible without jeopardizing agricultural production.

The Icelandic Road Administration runs a program of wetland restoration in connection with road projects that involve drainage. This has been a type of "land for land" scheme. The experience from this project indicates that farmers are not interested in supplying land for restoration without compensation. In their mind, restoration only reduces the quality of the land for agriculture. Even if they have no immediate plans to use the land they feel the option to be able to use it, e.g. for grazing, is worth something and are not willing to give this option up without compensation. It is therefore likely that some financial incentive would have to be created to get farmers interested in large-scale wetland restoration.

Another source of land suitable for wetland restoration is state owned land. The state is by far the largest single owner of farms in Iceland with about 500 farm of a total of 6500 registered farms. However, the farmers that lease farms from the government have extensive rights regarding the management of the farms. The state cannot require them to participate in restoration projects. Of the 500 farms about 170 are in active production and another 130 are in some use, although not in agricultural production. The remaining 200 state-owned farms might be eligible for restoration (Erna Bjarnadóttir et al. 2007). Many of these farms are small. Assuming that these farms have a land composition that is similar to the average farm these farms might contain as much as 100 $km^2$ of restorable land. This figure is just a rough estimate and the actual number may be significantly smaller if state owned farms are generally smaller than the average Icelandic farm or situated in areas where wetland drainage was limited.

**7. WR economics**

Several difficulties arise when assessing the cost of $CO_2$ sequestration trough wetland restoration. It is fairly straightforward to assess the cost of filling in the drainage ditches. However, a monetary incentive would most likely have to be offered to the farmers that supply the land in addition to covering costs. It is difficult to determine what the size of this incentive would have to be. Without an incentive the supply of land will most probably be very limited. On the other extreme, paying full price for the land to the farmer may result in a supply that might even exceed the 900 $km^2$ of drained wetlands that is currently in limited agricultural use. Coming up with a good estimate is difficult. One way is to measure land rents from the opportunity cost of land in terms of lost productivity for grazing. This would be a measure of possible lost income. A different approach is to estimate the cost of a commitment to re-dig the drainage ditches at the end of the agreement period. Lastly, the necessary incentive should not exceed the price of land.

The unit price of carbon sequestration will depend heavily on the duration of the restoration project. The longer the project the cheaper the sequestration per unit $CO_2$ becomes. It seems natural to assume that contracts regarding restoration have a duration that is at least as long as the commitment period with respect to climate agreements. However, wetland restoration is a permanent way of reducing $CO_2$ emissions and one project may give results on a geological timescale. It is therefore natural to assume long project duration of e.g. 50 years or more.

First, let us look at the cost of filling drainage ditches. This is fairly cheap. According to estimates it costs about 60 ISK per $m^3$ to fill a ditch and you need 3 $m^3$ per meter of ditch it will cost about 180 ISK to fill each meter of ditch. There are on average 7,25 km of dishes per $km^2$ of drained wetlands (Hlynur Óskarsson 2008). Direct cost is therefore around 1,3 million ISK per $km^2$. It is assumed that drained wetlands emit 0,4 Gg $CO_2$ eq per $km^2$ (Brynhildur Davíðsdóttir et al. 2009. Umhverfisstofnun 2008). Assuming that the projects last for at least 12 years, the direct cost of wetland restoration is around 370 ISK per tonn $CO_2$ eq. A 50 year project would spread the cost on a larger emission reduction and would result in average costs of around 180 ISK per tonn $CO_2$ eq. The average cost for a perpetual project is about 160 ISK per tonn $CO_2$ eq.

Secondly we have the cost of the necessary incentive to convince farmers to supply land for restoration; based on the cost of re-drainage at the end of the restoration project; based on the opportunity cost of land measured by the loss in grazing productivity; based on land prices in a recent study.

According to Borgar Bragason an expert at the Farmers Association of Iceland, the cost of draining wetlands is about roughly the same as filling ditches, about 60 kr per $m^3$. However, it takes on average 25 km of ditches to drain one $km^2$ assuming the standard 40 m between ditches. This will therefore clearly overcompensate farmers for the lost drainage compared to the estimates of current drainage of 7,25 km/$km^2$ of ditches. The cost of draining one $km^2$ of wetlands given these assumptions is about 4.5 million ISK per $km^2$. The present value of 4.5 million ISK in 12 year at a 5% discount rate is 2.5 million ISK. In 50 years it is only 400 thousand ISK. According to this the average cost on a 12-year contract is 710 and 54 ISK per tonn $CO_2$ eq. on a 50 year contracts respectively (Table 2, assumption I).

Assessing the average opportunity cost of lost grazing due to wetland restoration is no exact science. Based on estimates from the Farmers Association of Iceland, we assume that the loss in productivity is about 50% and that grazing on low quality land is worth 800 thousand ISK per $km^2$ per year. This is based on the assumption that the land is used for horse grazing with

0,5 horses per ha and a grazing period of four months. The opportunity cost is therefore 400 thousand ISK per $km^2$ per year (or 40 thousand ISK per ha). This would result in the same increase of average cost, by 1000 ISK per tonn $CO_2$ eq, for all contract lengths, since both the cost and the carbon are flow variables (Table 2, assumption II).

Land prices have increased quite dramatically during the last few years. In a recent masters thesis Kolfinna Jóhannesdóttir (2008) estimates land price developments and the how land properties affect land price. According to her results the average land price is between 30-50 million ISK per $km^2$ (300-500 thousand ISK per ha), up from around 10 million ISK per $km^2$ just four to five years ago. Her results also indicate that land quality also affects land price and that land price falls with increasing share of wetlands in the total area of a farm. Based on her results we assume that the average price is around 30 million ISK per $km^2$ but reduces by 11,3 million ISK per $km^2$ if the land is solely un-drained wetland. This results in an increase in the average cost by 5500 ISK per tonn $CO_2$ eq on a 12 year contract, 4000 ISK per tonn $CO_2$ eq on a 50 year contract and 3750 ISK per tonn $CO_2$ eq. for a perpetual project (Table 2, assumption III).

The estimated costs are summarized in table 2.

Table 2. Cost of reducing carbon emissions with wetland restoration under three different assumptions regarding opportunity cost of land, in ISK per tonn $CO_2$ eq.

| Assumptions | Cost items | *Alternartive project duration* | | |
|---|---|---|---|---|
| | | *12 year contract* | *50 year contract* | *Perpetual* |
| **I.** | Direct refilling cost | 368 | 179 | 163 |
| | Redrainage cost | 707 | 54 | 0 |
| | **Total 1** | **1075** | **232** | **163** |
| **II.** | Lost grazing | 1000 | 1000 | 1000 |
| | **Total 2** | **1368** | **1179** | **1163** |
| **III.** | Full land price | 5525 | 3885 | 3750 |
| | **Total 3** | **5893** | **4064** | **3913** |

It is clear from the results in table 2 that if no compensation is needed wetland restoration is a very inexpensive way to reduce carbon emissions regardless of the length of the farmers commitment. Further if farmers do not require more than fair compensation for lost drainage or grazing this is still a competitive method for longer time horizons. However, buying land at full price for wetland restoration is not viable if no other benefits occur other than reduced carbon emissions.

It should be noted that wetland restoration has important positive external effects. The flora and fauna return to their original state. Bird habitats are restored and natural environments provide, once more, pleasure to nature enthusiasts. Wetlands further provide hydrological services such as filtering and evening out of water flow. These benefits are not taken into account here, only reduced carbon emissions. Where these benefits taken into account the costs that are born by the reduced carbon emissions would be reduced compared to the numbers in table 2.

**8. Institutional framework**

Iceland has run two projects on farmland during the last years that have a similar nature of being aimed at land restoration and requiring some form of legal restrictions on land use. Firstly there is a general land restoration program called Farmers Heal the Land - "Bændur græða landið". It is run by the Soil Conservation Service of Iceland and aimed at farmers. The second is a forestry program called Regional Forest Projects "Landshlutaverkefni í skógrækt" that is aimed at encouraging farmers to go into forestry. In both cases the Government subsidizes the projects but places restriction on the type of land use possible on project land. A similar institutional setting could be applied to wetland restoration.

Farmers viewed wetland drainage as very beneficial. It is likely that they will find wetland restoration damaging. However, farmers have through other land restoration projects become comfortable in the role of land managers. Wetland restoration has multiple benefits other than carbon sequestration. If farmers where approached with sound arguments for the benefits of wetland restoration and some financial incentives they will undoubtedly respond in a similarly positive manner as they have to other land restoration schemes.

Several different approaches to achieving emission reductions through wetland restoration are possible. The state could set up a scheme similar to the existing land and forest restoration schemes. These schemes would be responsible for securing contracts with farmers, overseeing restoration and monitoring land use. The funding of such a scheme would have to be addressed. Reduced emissions would benefit industries where emissions are increasing and it might be argued that the benefiting polluters should fund the scheme. One way to facilitate this is to set up a carbon-trading scheme, where polluters could trade permissions to pollute. The firms that need to increase their emissions could buy emission under such a scheme from farmers that engage in wetland restoration projects or carbon sequestration projects. Such schemes require a monitoring industry to work properly. This service should be provided by the government, and funded either by the polluters or fully by government.

## 9. Wetland restoration: overall mitigation potential

The extent of drained wetlands is estimated at 3900 km$^2$. The estimates put forth in this paper suggest that about 900 km$^2$ of drained wetlands are in limited use today. A rough estimate indicates that 100 km$^2$ of the 3900 km$^2$ total is on state owned farms and might be restored at minimum cost. Some compensation is however necessary to encourage farmers to supply land for restoration, judging from e.g. the experience of the Icelandic Road Administration and their project on wetland restoration. Table 3 sums up the approximate potential at different cost in terms of ISK per tonn $CO_2$ eq.

Table 3. Rough estimates of the potential for emission reductions through wetland restoration.

| Cost ISK/tonn $CO_2$ eq | Land Km$^2$ | Reduced emissions Gg $CO_2$ eq. | Total reduced emissions Gg $CO_2$ eq. |
|---|---|---|---|
| <200 | 100 | 40 | 40 |
| 200-1200 | 400 | 160 | 200 |
| 1200-2500 | 400 | 160 | 360 |
| >2500 | 1000 | 400 | 760 |

## 9. Conclusions

Wetland restoration involves land use change. Such change can generate great win-win synergies with biodiversity conservation and other ecosystem services that healthy wetlands deliver, especially related to water regulation. However, such change can involve completive use with other sectors, mainly agriculture. It is therefore of the utmost importance to design wetland restoration strategies concurrently with other land use strategies

This paper has identified significant potential in wetland restoration as a climate mitigation activity in Iceland, without compromising the agricultural potential. A realistic estimate of the climate mitigation potential is between 40 and 360 Gg $CO_2$ eq. per year.

The current estimates of drained wetlands are based on satellite images. Although this provides a good estimate of the length of drainage ditches some important factors remain unknown. As mentioned earlier the level of GHG emissions from drained wetlands depends on the water saturation. Water saturation depends on several factors such as the depth of the ditches, the distance from ditch, soil type, land topography and so forth. Many of these factors are interlinked and subject to change over time. For example, ditches in flat areas have a tendency to fill with vegetation over time leading to higher water saturation and eventually they stop working altogether. It is would be greatly beneficial to examine the actual condition of the current drainage in Iceland. This can e.g. be done conducting on site measurements of drainage projects of a sample from the database of drainage projects held by the Farmers Association. This would provide estimates of current use of drained areas, the condition of drainage projects, the speed of natural wetland restoration, and need for maintenance of drainage in different areas of Iceland. Such knowledge would greatly increase the accuracy of the estimated potential of wetland restoration as a mitigation activity.

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