Section 3

The influence of land use change from and to forestry on the emissions of nitrous oxide and methane

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3. The influence of land use change from and to forestry on the emissions of nitrous oxide and methane

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3.1. Introduction and background

Compared to the data available on nitrous oxide (N_2O) and methane (CH_4) emissions from agricultural or forest soils, there are only little information on the effect of land use change from and to forestry on the emissions of N_2O and CH_4. Predictions of N_2O and CH_4 release due to land use change are therefore calculated from existing general knowledge (mainly from agricultural soils) of the production and emission of these gases in relation to different soil types and climatic conditions.

Nitrous oxide and CH_4 are products of microbial processes in the soil. In general N_2O production increases with increasing concentrations of ammonium and nitrate, available organic C (carbon) content and with increasing soil wetness and soil density (Skiba & Smith, 2000). However, when the soil becomes too wet, N_2O is further reduced to N_2, therefore N_2O emissions decrease (Davidson, 1991).

The net CH_4 emission from a soil is influenced by the activity of two microbial communities, the methanogens and CH_4 oxidisers. Methane production requires strict anaerobic conditions and in the UK the wettest parts of moorlands are the largest source of $CH_{4,}$ but even the contribution of these to the total national emission is less than 5%. Occasionally grassland soils can be a temporary and small source of CH_4. Most of the CH_4 produced in the deeper anaerobic layers of a soil by the methanogens are oxidised by the methane oxidisers in the aerated upper parts of the same soil. Methane oxidisers are very sensitive to soil disturbance by physical means, for example ploughing and compaction, or chemical disturbance, mainly N fertilisation (MacDonald *et al.*, 1997).

Because of the lack of data on N_2O and CH_4 emissions caused by land use change, only the IPCC default methodology was applied.

3.2. Nitrous oxide emissions

3.2.1. Forest land remaining forests

The direct emissions of N_2O from forests remaining forest (IPCC good practice guidance for LULUCF equation 3.2.17) are calculated from the sum of organic and inorganic N fertiliser induced N_2O and the N_2O emitted due to drainage. *(from now on the IPCC good practice guidance for LULUCF will be referred to as: IPCC)*

N fertiliser: For the N fertiliser induced N_2O emission the standard EF1 (1.25% of N applied is emitted as N_2O) is applied. Normally only newly planted forests are fertilised at a rate of 150 kg N h^{-1}, the resulting N_2O emissions are shown in Table 3-1. The uncertainty range of emission factor EF_1 (0.25 to 6%) suggests that newly planted forests in the UK emit 0.06 to 117 t N_2O-N y^{-1}.

Drainage: The effect of drainage is dealt with by default emission rates based on very few data from Scandinavian countries (Appendix 3.a.2 Table 3a.2.1).

The influence of drainage on N_2O emissions is based on many assumptions, as data on drainage and fertility status of the UK forest soils are not readily available. Drainage induced N_2O

emissions were therefore calculated based on the assumption that 50 % of the organic soils are nutrient rich and 50% are nutrient poor and that in Britain 25% of forest grown on mineral soils and 50% of forests grown on organic soils are drained. For Northern Ireland it was assumed that 50% of all forests are drained. The default emissions of 0.1 and 0.6 kg N_2O-N ha^{-1} y^{-1} for nutrient poor and nutrient rich organic soils, and of 0.06 kg N_2O-N ha^{-1} y^{-1} for mineral soils were applied (IPCC Appendix 3.a.2 Table 3a.2.1) (Table 3-2). The drainage related emission rates carry large uncertainties, both in forest areas subjected to this practice and in the actual emission rates. This management practice 'drainage' influences N_2O emissions more than N application to newly planted forests.

Table 3-1 Direct N_2O emissions from newly planted forests

	Established forest	New Forest*	N fertiliser applied to new forest	N_2O emission from new forests+
	*1000ha	*1000ha	Kg N y^{-1}	t N y^{-1}
England	1104.69	5.31	796500	9.96
Wales	285.67	0.33	49500	0.62
Scotland	1320.27	6.73	1009500	12.62
N Ireland	80.4	0.59	88500	1.11
UK	2791.03	12.96	1944000	24.30

* planted 2002 – 2003, + EF_1

Table 3-2 The influence of drainage on N_2O emissions from existing forests

	Soil type		N_2O emission		
	Organic	Mineral	Organic	Mineral	All soils
	*1000 ha		t N_2O-N y^{-1}		
England	200.7	177.4	60.2	10.6	70.8
Wales	43.3	49.9	13.0	3.0	16.0
Scotland	286.5	188.5	86.0	11.3	97.3
N Ireland	20.1	20.1	6.0	1.2	7.2
UK	550.5	435.9	165.2	26.2	191.3

Indirect emissions due to atmospheric N deposition: Atmospheric depositions of N to forests soils are a much larger source of N_2O from established forests than mineral N fertiliser application and drainage induced emissions. The IPCC default emission factor for N deposition induced N_2O emissions is 1 and here was applied to soils with an organic matter content of >25.5%. For mineral soils (OM < 25.5%) the IPCC default emission factor was replaced by a linear regression equation ($N_2O\text{-}N_{(kgN/ha/y)} = 0.0006 * Ndep^2_{(kgN/ha/y)} + 0.0032 * N\ dep_{(kgN/ha/y)}$) based on CEH's data from forest and moorland soils in Britain. The atmospheric N deposition induced N_2O emission for UK forests was calculated at 0.9 kt N_2O-N y^{-1}, which is not included in the current inventory.

3.2.2. Land converted to forest

Agricultural land or moorland converted to forests may require some N_2O releasing activities, such as ploughing of grassland, drainage of wetlands, fertilisation and irrigation of the freshly planted trees. Drainage and ploughing will increase N_2O emission; unfortunately real data are very limited. If we assume that all trees on land converted to forests are fertilised at a rate of 150 kg N ha^{-1} d^{-1}, then this activity will not alter previous emission rates. However, if the land was converted from moorland or unmanaged wasteland then emissions will increase.

None of these activities are likely to increase N_2O emissions significantly. For example, if the existing forest area is increased by 50 %, and is fertilised at a rate of 150 kg N ha^{-1} y^{-1} and 50% is drained (as shown in section 3.2.1), then this activity will increase N_2O emissions by 2.7 kt N_2O-N y^{-1}, (2.6 kt are fertiliser induced emissions and 0.1 kt are drainage induced emissions). This exaggerated increase remains to be a small fraction of the total agricultural N_2O emissions of 86 kt N_2O-N (Skiba et al, 2005).

3.2.3. Land (forests) converted to cropland

Forest land converted to cropland requires clear felling, ploughing and perhaps drainage. All these activities will stimulate nitrogen mineralization of the organic matter.

In the first instance there will be no competition for this available nitrogen between plants and microbes, thereby maximising substrate availability for microbial nitrification and denitrification to occur and release N_2O. This initial surge in mineralisation rate and increase in N_2O emissions is a short-term effect (max 1 year). Unfortunately most of deforestation related greenhouse gas studies have concentrated on tropical forests; data from northern Europe are restricted to a few studies (eg. Emmett & Quarmby, 1991), therefore it is not possible to change the default methodology. It is assumed that the same emission factor EF1 (1.25%) used for N fertilised soils applies to nitrogen released by organic mineralization, which is calculated from the annual change in C stock (equation 3.3.12) divided by the C/N ratio (equation 3.3.15). Based on these equations and assuming a C/N ratio of 15 it was calculated that forest land converted to crops was responsible for an annual N_2O emission of 2.8 kt N_2O-N in 2002, which is 2.3% of the total UK N_2O emission budget. This emission rate did not change by more than 0.1 kt N_2O-N y^{-1} when applied to data of forest conversion to cropland over a 50-year period. (Figure 3-1).

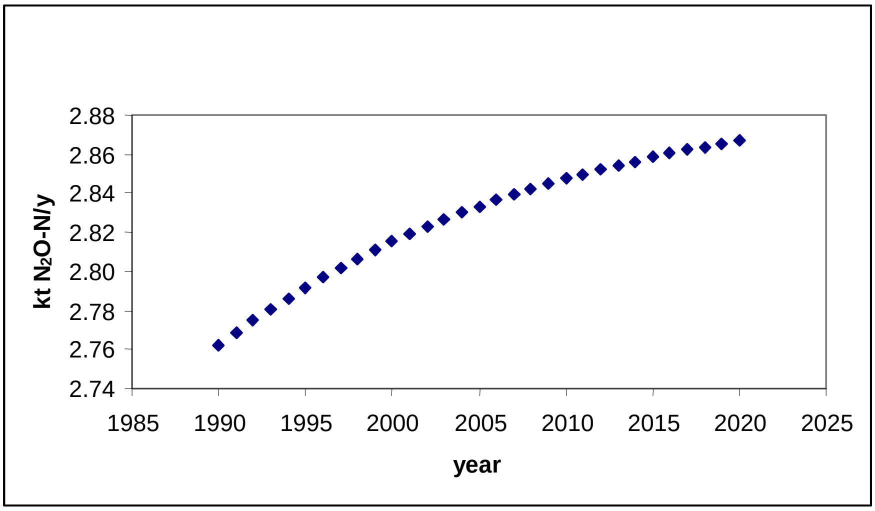

Figure 3-1 Nitrous oxide emissions from the mineralization of organic matter during land conversion from forests to crops in the UK (equation 3.3.15).

Land converted to grassland:

This activity will require N fertilisation and ploughing and in some circumstances drainage. Therefore N_2O emissions are likely to increase. The drainage, ploughing and fertiliser emission factors to be used remain the IPCC default emission factors, as there is not enough UK data or data from similar temperate climates. Generally grasslands tend to be larger sources of N_2O than arable soils or forests, due to larger mineralization rates and prevalence of grasslands in the wetter parts of the country. At present one can assume zero conversion from forest to grassland and hence zero source of N_2O and CH_4.

Land converted to wetlands:

The total area in the UK converted to wetlands is restricted to small insignificant areas of newly created riparian zones, along rivers in nitrogen vulnerable zones (NVZ). This activity has a potential to decrease N_2O emissions, if the soil water filled pore space (WFPS) can be maintained above 90% (Skiba & Smith, 2000). Under such conditions anaerobic conditions and accumulation of soil organic matter content will favour denitrification to proceed to N_2 rather than stop at N_2O production which is generally the case in more aerobic soils.

3.3. Methane emissions

In the UK soils contribute only 120 kt CH_4 y^{-1}, which is less than 6% of the total UK CH_4 budget. Therefore any landuse change will not significantly influence this budget.

3.3.1. Forest land remaining forests

Undisturbed forest soils are an important source of CH_4 oxidation. For European forests it was estimated that CH_4 is oxidised at a rate of 2.4 or 4.5 kg CH $ha^{-1}y^{-1}$ (Smith *et al.*, 2000 and van Cleemput *et al.*, 2000). Based on these oxidation rate established UK forests oxidise 9 kt CH_4 y^{-1}, which accounts for a small fraction of the total UK CH_4 emission (2228 kt CH_4 y^{-1}in 2002). Methane oxidation rates are affected by disturbance, such as land use change, drainage, ploughing and N fertiliser application (Prieme *et al.*, 1997, MacDonald *et al.*, 1997). Therefore any landuse change will reduce the CH_4 oxidising capacity of the forests.

Only very occasionally during wet soil conditions does the forest soil temporarily turns into a very small net source of CH_4.

3.3.2. Land converted to forest

Increasing the land area of forests will eventually increase the CH_4 oxidation capacity of the soil. If the previous landuse was undrained moorland the effect will be largest, and will slowly turn a net CH_4 source into a CH_4 sink (Prieme *et al.*, 1997). Again the influence on the UK CH_4 budget will be insignificant.

3.3.3. Land (forests) converted to cropland or grassland

These activities will reduce the CH_4 sink activity of forests, by disturbance and N fertilisation.

Land converted to wetlands:

Methane emissions will increase when land is converted to wetland. However, soils contribute to only a small fraction of the UK CH_4 budget, and an increase in this activity is unlikely to change this.

3.4. Conclusions

Landuse change to and from forestry will not provide a significant source of the greenhouse gases N_2O or CH_4 as shown in Table 3-3.

Table 3-3 The influence of landuse change on N_2O and CH_4 emissions. Emissions are expressed as a percentage of the UK agricultural N_2O emissions (86 kt N_2O- N y^{-1}) and wetland CH_4 flux (120 kt CH_4 y^{-1}).

	Forest- forest	Forest - crop	Forest - grass	Forest - moorland	Other land to forests
Nitrous oxide (kt N_2O-N y^{-1})	0.23 %	3.3 %	3.3 %	0 & uptake	3.1 %
Methane (kt CH_4 $y^{-1-)}$	-7.5% oxidation	0	0	7.5 emission	-7.5 % (after 2 0+ years) oxidation

3.5. References

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