Review

Towards the Reduction of Greenhouse Gas Emissions and Protecting Surface Waters in the Province of North Savo, Finland

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Abstract: Ordinary people and political leaders must know the sources of greenhouse gas emissions and their effect on global climate change before they have ability to make decisions to reduce emissions and increase sinks of these gases. These people must, however, understand where greenhouse gas emissions are formed and how reductions can be made: they must understand where carbon dioxide sinks are and how to preserve or increase these sinks. North Savo is the example used in this work to describe the present emissions and sinks. There are proposals on what should and could be done to reduce greenhouse gas emissions caused by traffic, heating, forests and agriculture. There are possibilities of reducing emissions of greenhouse gases in traffic and heating in spite of the fact that the province has a low population density with long distances between homes and workplaces and schools, and a cold climate. We believe that research will also find solutions for reducing greenhouse gases and protecting waters, which are used for recreational purposes and for raw water of drinking water in many places. Luckily forests cover large areas of North Savo and their growth is an important carbon dioxide sink. In addition, forest soils serve as a valuable storage of carbon. Besides carbon dioxide emissions, emissions of nitrous oxide and methane must also be considered since they are more potent greenhouse gases than carbon dioxide and land use can thus influence these gas emissions.

Keywords: agricultural soils; carbon dioxide (CO_2), energy; forests; methane (CH_4), nitrous oxide (N_2O), nutrient leaching; peat; traffic

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1. Introduction

North Savo, with its almost 250,000 inhabitants, is situated in eastern Central Finland. The total area of this province is 20,367 km^2 and lakes cover 18% of the area. Its capital, Kuopio, has 119,000 inhabitants, and approximately half of them live in central or suburban areas, with the other half live in rural environments, some of whom work in agriculture and forestry.

The climate is boreal with long summer days and short winter days. There is thus snow and ice during winter. The climate is controlled by the Atlantic Ocean and the Eurasian Continent, causing high variation. In Kuopio, the monthly mean temperature can vary from +22^{o}C (in July) to -20^{o}C (usually in January) and the daily temperatures can be +30^{o}C in summer and under -30^{o}C in winter. The mean daily temperatures are usually under 0^{o}C from November to March according to climate data statistics since 1961 [1].

Climate change has already made the incidence of snow and ice shorter. The dates of ice freezing and melting in Lake Kallavesi at Kuopio harbour have been documented carefully since 1833 [2] because historically surface waters served as major transportation routes in winter on ice and in summer by boats. At the start of this documentation the freezing dates of Lake Kallavesi in November–December were 15 days earlier than today and the ice melting dates in May were 12 days later than today. The mean time of ice cover in this lake is thus 27 days shorter today than it was in 1833. Correspondingly the growth time of vegetation — when the temperature is higher than 5°C — in North Savo is more than three weeks longer than in 1833 but the annual variations in temperature and precipitation are still high. There can be night frosts in each month apart from July. In addition, the number of sunlight hours will be shorter after the autumnal equinox, limiting the growth of vegetation in spite of the fact that there may still be warm days.

We know today that human activity has an important role in climate change due to the increasing production of greenhouse gas emissions. The climate politics of the European Union [3] have been adopted by member states — including Finland — and carbon neutrality is one of its goals. Thus the Finnish state has decided to be carbon neutral by 2035 [4]. Some institutes, such as the University of Eastern Finland, have decided to adopt carbon neutrality by 2025 [5]. This North Savo project has not yet set any time to be carbon neutral but its target time should not be any later than that of the Finnish state.

In addition, methane (CH_4) and nitrous oxide (N_2O) are important greenhouse gases for global warming as the global warming potential of methane is counted to be 28–36 times that of carbon dioxide for 100 years, with that of nitrous oxide being even 265–298 times that of carbon dioxide for 100 years [6]. Warming of climate is very clear especially during recent winters in North Savo so that Christmas has often been black instead of being white with snow cover. Since mean precipitation as water and snow is higher than evaporation, different wetlands will be formed in North Savo. Therefore, forest and agricultural soils are often drained with ditches. Both wetlands and their ditches are considered in this article as emission sources for methane and nitrous oxide.

This project describes the major emissions and sinks of greenhouse gases present in North Savo. The main aim of this article is to give knowledge about sizes of greenhouse gas emissions and their sinks and how emissions can be reduced and sinks can be increased so that people know better how the carbon neutrality can be reached. Thus, sustainability can be increased while at the same time North Savo's rich surface waters can be protected and these waters will stay as raw water for drinking water and for fishing and other recreation activities. This higher sustainability may also mean a better adaptation to environmental changes in new climatical conditions.

2. Specific Sources of Greenhouse Gas Emissions

2.1. Industry

In North Savo there are four large industrial enterprises which are under the emission trading scheme. Two of them belong to the forest industry, one is a mine for the fertilization industry and one is a large dairy. Together their emissions are counted to correspond annually to 272.5 kton CO_2 equivalence. The emissions of all small industrial enterprises correspond together 112.4 kton CO_2 equivalence [7].

2.2. Energy for Electricity and Heating

An electrical network covers the whole of North Savo. Nuclear power, hydropower, and electricity imported from abroad are the major primary energy sources. Today windmills are rapidly growing as new sources for the production of electricity. Three modern windmills started to produce electricity in 2017 in North Savo, but most Finnish windmills are still situated along the Baltic Sea or in Lapland.

All dwelling houses must be heated during cold periods to keep room temperatures at approximately 20°C and to produce hot water for washing. Thus, the energy need is high in towns and in rural areas. In towns energy is often made in large combined production units which make heat, hot water and also some electricity. The energy sources used can vary, including wood, residual wood industrial products and many other raw materials [8]. These combined processes in North Savo utilize the burning process. In the city of Kuopio, almost 80,000 inhabitants utilize a centralized combined heat and hot water production unit [9]. In addition, many hospitals and schools, offices and shops use this heat and hot water. Peat is still one energy source in spite of its high greenhouse gas emissions [10]. In centralized heating systems there is a tendency for peat to be replaced with other energy sources as wood, forest by-products, biogas etc. The total replacement of peat with other fuels will need some additional work since the use of peat can control the corrosion of fire boxes. The Kuopio energy company uses oil only as a reserve energy source during very cold periods and the amount of oil is usually 0.1-0.2 % of total annual energy use [10]. Some deviances in oil consumption, however, are expected since cold periods can happen at any time between November and March and last from some hours to a few weeks. Thus, the oil consumption increased in 2019 to approximately 1.3 % of total annual energy use [11] due to a large-scale power failure on 2 Jan. 2019 in Central Finland caused by a strong windstorm which cut trees on electric lines and still very cold periods from late January to early February and again in late December [1].

In total, the centralized and combined production of heat and electricity saves energy partly due to the highly optimized burning process and controlled operations considering the actual air temperature, wind direction, and time of the week. It saves human labour and there are only a few chimneys in the whole city so the burning gases are easier to treat. In addition, heat and hot water are available for 24 hours every day. The exact and constant room temperature of 20°C has been utilized in some research works at the Department of Environmental and Biological Sciences, University of Eastern Finland in the Kuopio Campus. The exact temperature was verified by constant temperature measurements over many weeks.

Many rural houses, including farms, themselves produce the heat and hot water which is also needed in milk hygiene. The energy source is often wood or wood products and this wood can often originate from forests situated nearby. In addition, some rural private houses use direct electricity for heating both houses and hot water and in the rural area of Kuopio there are some such 7000 houses. Geothermal heating as well as air-source heat pumps are becoming more common. In these cases electrical energy is needed for the pumps, but this energy is much lower than the energy needed in the burning processes to produce electricity. In total, the heating of the whole province was calculated to cause emissions of 457.7 kton CO_2 equivalence in the year 2018, with half of this caused by the centralized heating units available in the Kuopio central area and in many other towns and villages [7].

Nowadays many houses have solar panels for electricity production and extra electricity (a maximal efficiency of some 3000 kW only in Kuopio central and rural areas) can be sold to energy companies if the system is connected to the electrical network. These panels are beginning to be common in farms, especially if they need more electricity in summer for cooling milk, berries etc. Such installations were encouraged by local associations of farmers and the work was often done in co-operation with the local electricity company. Solar panels are also used in private houses, shops and public buildings belonging, for instance, to the university hospital, energy companies, the city of Kuopio and the university. Solar radiation is, however, very limited in winter due to the area's Northern situation and to possible snow cover.

2.3. Traffic

Low population density does not favour good and frequent public transport, apart from transportation across the national main road which runs from south to north between three major cities. In addition, there is a railway, mainly serving long distance traffic. Despite this, private cars are often used. People are encouraged to travel between their homes and workplaces together with others to reduce traffic. Some employers provide bus transportation for their workers, especially if good public transport is not available. In some cases, there are extra bus connections to big university hospital or schools at specific times. Private cars can sometimes be replaced with bicycles or light electric bicycles, which can also be hired.

In 2018, road traffic consumed energy which was calculated to be as high as 562.1 kton CO_2 equivalence just from the traffic from inside the province. This traffic is caused mainly (60%) by personal traffic and the rest 40% caused by heavy traffic. Besides this more local traffic there is also an element of transit traffic (partly international) which is calculated to produce emissions of 432.2 kton CO_2 equivalence. This is mainly heavy traffic [7, 12].

2.4. Land Use

2.4.1. Forests

Forests cover 13,990 km^2,with the main tree species being Norway spruce, Scots pine and birch. Forest trees are used for timber and chemical forest products such as different cardboards, which are made either from virgin pulp or recycled kraft. Some trees are harvested for heating fuel, especially in rural areas.

Boreal coniferous forest soils, including North Savo soils, are very rich in humus because organic compounds originating from vegetation degrade slowly in cold climates – especially if the soil is saturated with water, which limits aerobic respiration. Clemmensen *et al*. [13] studied carbon dynamics in Swedish coniferous forest sites where climate was similar to that in North Savo. They found that the age of carbon was 2500 years in root areas at a depth of 90–100 cm if the soil was undisturbed. In this site stable isotopes of carbon (C-13) and nitrogen (N-15) had concentrated in the deepest soil layers through the activity of roots and mycorrhiza. The age of the present growing trees was approximately 100 years old, and their photosynthesis served continuously as a sink of atmospheric carbon dioxide, producing growth of both trees and their associated root fungi and other microorganisms. In contrast, in another soil site disturbed by fires the age of carbon was only some hundred years at a depth of 90–100 cm [13]. Thus, in the intact coniferous forest, soils with tree roots are an important carbon storage containing, for instance, 121–133 ton C/ha while the above tree mass of the living spruces was 48 ton C/ha [14].

A Finnish inventory work collected data over 82 years in many different forests counting the carbon changes. In this research work the annual mean net primary production was 0.375 kg C/m^2. The annual mean removals of timber and harvest residues were 0.060 and 0.063 kgC/m^2 and the litter took 0.213 kgC/m^2 while the annual increase to tree biomass was 0.028 kg/m^2 and the increase to soil with roots was 0.011 kg/m^2 during this time. There was, however, a high variation between different forests due to environmental, economic, and political factors in different areas causing especially changes of tree removal intensity [15].

Forest soils contain a seed bank of trees. New trees start to grow naturally without human labour after the old trees have been harvested or after they have been destroyed by wind or fire if there is light, water, and a suitable temperature range. It is possible that growth that is influenced by human work will be more rapid but then there is the need for seeds or seedlings and their seeding, or for plantations. In addition soil preparation, and fertilization require still additional natural resources and money. There is also often a need to make early thinning harvests where the work can be more expensive than the harvested trees.

Forest soil and tree roots, especially fine roots and mycorrhiza, typically form a higher carbon storage than tree trunks or the whole tree biomass [14, 15] and boreal soils are often seen globally as very important carbon storage having an influence on global climate as described above. This storage can well survive if the soil is not disturbed [13, 14]. In North Savo it is estimated that all growing forests and their soil could be a sink for carbon of 1379.6 kton CO_2 equivalence in the year 2018 [7]. Some forest-rich municipal areas in North Savo are already carbon sinks when considering land use and all other human activities.

2.4.2. Peatland Forests

Peatlands provide very rich carbon storage, and thus natural boreal forest soils and boreal peat soils serve as globally valuable carbon storage in spite of the fact that their total area is limited [14]. In natural undisturbed wetlands, photosynthesis reduces atmospheric carbon dioxide to organic compounds. Emissions of methane (CH_4) and nitrous oxide (N_2O) may be important greenhouse gases in wet peatlands as presented in the next paragraphs.

Methane is formed by methanogenic bacteria in deeper layers of wet humus-rich soils where oxygen is lacking. If the water table is a few centimetres under the soil surface, methane may be oxidized by methanotrophic bacteria into carbon dioxide, which will be emitted to the air but then the emissions of methane can be low [16]. The most important pathway for N_2O formation is the nitrification-denitrification process. Since the nitrification-denitrification process depends on the nitrogen concentration in soil, the variation can be very high. In some cases, afforestation of Finnish peat soils has led to very high nitrous oxide emissions, especially if the soil is rich with nitrate-nitrogen or total nitrogen [17]. Nitrogen fertilization is often done in the afforestation process and this nitrogen can mean that high emissions of nitrous oxide are still possible after some time.

General atmospheric nitrogen fallout originating from many sources is still rather high. In North Savo the annual mean nitrogen fallout is approximately 5–10 kg/ha and almost 90% of this is as nitric oxide (NO) and the other oxides of nitrogen (NO_x), which will be transformed into nitrate in the soil including the peatland, too [18]. The nitrate will also be easily denitrified to nitrous oxide in soil so that emissions of nitrous oxide can also be meaningful during cold seasons when the growth of vegetation is limited [17]. There can be also local atmospheric nitrogen fallout sources from farms with high animal numbers and manure treatment (in North Savo this is mainly from cows) and from heavy traffic with trucks or tractors or wastewater treatment plants etc. If peat is extracted and used for energy production in burning, the emissions are included as part energy politics (see 2.2. Energy for Electricity and Heating) and peat as an energy source can be compared to the emissions caused by burning of coal [19]. Transportation in the peat extraction process can also be rather important source for high emissions.

After the peat has been mined and burned, there will be some after-use of this former peatland. The emissions of greenhouse gases partly depend on the method of after-use. One possible approach is afforestation. If this afforestation is successful, the new forest growth can become a sink of greenhouse gases. The second possibility for after-use is turning it into agricultural soil, which usually means the emission of carbon dioxide (see 2.4.4. Agricultural Soils). A third alternative is restoration to wetland by increasing the water table. The restored wetlands can be sinks of greenhouse gases only in poor soils but in fertile soils there can be emissions of nitrous oxide and methane since nitrification-denitrification can add N_2O emissions and anaerobic processes can add CH_4 emissions [20]. Again the variation is high between years and soils and thus it is not easy to get trustworthy results.

2.4.3. Drainage of Soils

In many cases the disturbance of wet peatlands is caused by drainage activity, which in Finland and in North Savo has been very intensive. This disturbance will mean the soil becomes more aerobic so that more organic matter will be degraded into carbon dioxide and emissions will increase. Drainage can happen via natural brooks and rivers, but the drainage of wetlands often happens via man-made ditches.

From maps it is easy to see that ditches have been made in almost all places where the forest soil was wet in order to increase forest tree growth. The author of this paper and many other people have noticed this also when walking in forests. The Finnish State has supported this work financially from the 1920s to the 1970s. Nowadays in North Savo, wet forest soils with ditches cover some 3500 km^2, with less than 1000 km^2 wet forest having no ditches. Today very few new ditches are created, but some 20–30-year-old ditches are renovated as vegetation and soil particles can fill them little by little [21]. The drainage of soil can increase the emission of greenhouse gases and the leaching of nitrogen and phosphorus to surface waters [22]. This leaching means the loss of valuable natural resources.

The drainage of some wetlands has been unsuccessful, meaning that forest growth can be very low. Therefore, ditches in drained bogs have sometimes been blocked, aiming to re-create a natural bog. However, in some cases emissions of N_2O and CH_4 have been very high after blocking ditches in British bogs that correspond to Finnish bog soils [23, 24]. Often the emissions of CH_4 and N_2O are not simultaneous so that when there are lower emissions of CH_4, there tend to be more emissions of N_2O and *vice versa* [16]. In the articles referred to above the variation between parallel plots and sampling times is always very high. Thus, it is problematic to assume that blocking ditches could be a general method of inhibiting the formation of greenhouse gases such as methane and nitrous oxide. Often the mean values of greenhouse gas emissions are clearly higher in treated soils than in non-treated control soils but without any statistical significance due to high variations.

Thus, if there is a real aim to reduce emission of greenhouse gases with some land use management of wetlands, there should be careful, versatile, and long-lasting studies about the specific soils and their chemical and microbiological characters as well as the climate. There should be a possibility of following all greenhouse gas emissions of the study area first in a small area and measuring real emissions of greenhouse gases for many years afterwards.

2.4.4. Agricultural Soils

In Finland both fertile forest soils and the most fertile wetland soils have been drained and taken for agricultural use. In past times, slashing and burn-clearing was a typical way to create agricultural land. The area of agricultural soils increased with the increase in population, and the total agricultural area in North Savo today is some 1488 km^2. Agriculture is presently based mainly on milk production since the long summer daylight and relatively rich rains and low evaporation suit the growth of grass and grass-clover better than that of cereals especially if the summer is short, cold and/or rainy. Thus, approximately half of the agricultural area is used to cultivate grass and grass-clover for cattle, with some 30% of the area under cereal cultivation for animal feed and for human food. Besides milk, the cultivation of strawberries and other berries is economically important today.

Rye was the most common cereal in historic agriculture and many different types of rye breads are still popular in Finland. However, the old varieties of rye originated from warmer climates, meaning that yields were not always sure. The years 1866–1868 were a terrible example of uncertain agricultural yields. During these years occurred the last massive European deaths of starvation during peace time: some 7–8% of the Finnish population lost their lives.

After these years of famine, more new agricultural soils were opened up for cultivation. In addition, agriculture started to be based more on the production of milk than on rye cultivation. Farms also started to cultivate more garden plants such as berries, potatoes etc. Farmers started to understand the value of animal quality and began to use only good animals for breeding. Because rural people were able to read, different societies established short courses about agricultural works for young rural men and separate courses on garden and kitchen works and milk production for young rural women. The scientific agricultural development observed in other countries could also be followed. Butter from North Savo was sold to Sankt Petersburg soon after the years of famine (Finland was an autonomous part in Russia between 1809 and 1917) before the Russian Revolution, and cereal was purchased from Russia instead of being cultivated locally. The Saimaa Canal made transportation easier so that food availability could be better secured [25]. In independent Finland large areas of forests have been taken up for agriculture due to land reforms after both World Wars and the territorial concession to the Soviet Union in 1944. Today agricultural production is higher and Finland is basically able to produce its own food. Today a high percentage of North Savo milk is prepared in the form of a Swiss cheese which is exported to many countries. In addition, some former agricultural soils are again afforested – especially if the specific plot or the whole farm was unprofitable.

Agricultural production needs transportation, seeds, fertilizers, buildings and fuels which all cause greenhouse gas emissions. These emissions are especially high when fodder is an intermediate product, with milk as the final product and cattle meat as a by-product. The high emissions are partly caused by the fact that many soils are organic soils rich with humus which degrades to carbon dioxide and in addition, there are emissions of methane and nitrous oxide. Thus, agriculture produces emissions in North Savo corresponding to 445.4 kton CO_2 equivalence [7]. The risk of emissions of nitrous oxide are higher in fertile soils than in poor soils.

3. Proposals to Reduce Greenhouse Gases to Reach Carbon Neutrality and Discussion

3.1. Industrial Emissions in the Future

Industrial enterprises generally try to save raw materials and energy as much as possible. If there is excess heat, this energy can often be sold as heat for companies making combined heat or it can be used in other purposes. Enterprises work in order to find solutions for their by-products especially when landfill will be more restricted or more expensive. Circulation is a key factor according to the EU's circulation strategy [26]. This strategy should be followed when enterprises seek environmental permission and when authorities accept them. The emission trading scheme may help enterprises to reduce their emissions, particularly if the price of emissions increases. In some cases there is a need for research to develop new by-products and to find ways to make products with less energy and use already mined wastes instead of new mining. If former waste products become new resources, this will increase the sustainable use of natural resources as well as reducing contamination to air, soil and water. In North Savo this practice can protect surface waters better.

3.2. Possibilities for Saving Energy in the Production of Electricity and Heating

Savings and higher energy efficiency, improved by optimization and better control, are the most important issues in energy politics. There will be a reduction in energy needs and a reduction in emissions and costs. In this regard the present centralized heat system is good, as it can also use waste heat from different activities including industry. Thus, buildings in the centre of the Siilinjärvi district (a municipality near Kuopio) will soon get their heat energy from the waste heat of the local mining industry, with heat distributed via the heat network of the local energy company Savon Voima [27]. Heating energy can be saved by improving the production process and the network controls developed by experts. Heat from exhaust air is already often used for heating or drying. There are many such examples where waste heat is transferred to other uses.

Buildings intended for permanent housing are already now well heat-insulated with double or triple windows and heat-insulated walls and roofs so that the need for heating energy is moderate during winter. Insulation can, however, still often be improved. There can also be heat leakages causing heat losses and draughts. These leakages can cause a high risk since they can add moisture into building materials and thus allow growth of microorganisms and damage to the building. The possibility of heat leakages should be studied and leakages detected must be repaired. Often a feeling of cold can really be due to draughts, and it can be reduced by tightening the windows. Today room temperatures can sometimes be at 21–22°C. Reducing the room temperature to 19–20°C would save energy without compromising convenience and comfort.

The most effective way to reduce greenhouse gas emissions in heating is to reduce the burning of peat, even though other possible fuels might have a higher price. Instead of peat, energy production should be based on renewed resources such as solar radiation, windmills and geothermal energy. In addition, we should use more of those different energy sources that are currently being wasted. Thus, biogas should be used for energy and electricity where it forms.

Today illumination of building interiors and roads is often by LED lighting, since it saves energy and in roads cold temperatures do not affect them. In road illumination these lamps, with their better control with sensors, can detect a single car or pedestrian and switch on illumination before and off after the contact so that electricity can be saved and the whole road length is not illuminated if there is no traffic. Besides ordinary illumination, UV LEDs also offer the possibility of being used in hospitals or other places where UV-disinfection is needed [28].

3.3. Reductions of Greenhouse Gas Emissions from Traffic

Traffic produces surprisingly high emissions of carbon dioxide. There should be sustainable possibilities of reducing greenhouse gas emissions. Using newer cars may consume less energy and cause less air pollutants. These cars may often use electricity. Anyhow, still now power loading may be problematic if there are needs to drive at -25°C hundreds of kilometres without possibility for electricity loading. The loading possibilities should be improved and the prices of cars should be lower before electric cars can be a general solution.

Biogas has sometimes been presented as a solution but North Savo dairy farms are usually situated far from main roads and cattle manure is not the best source for biogas production. The production of biogas is not continuous if the raw materials on which it depends are variable and can contain inhibiting factors, as can be the case in farms (manure, residual or contaminated forage, milk containing antibiotics or other medicines, washing waters with detergents etc.). Therefore it would be difficult to set up safe biogas production, especially in a cold climate.

Heavy freight transportation should be moved much more onto railways, which in Finland use hydropower electricity, meaning that the carbon dioxide emissions from trains are low. North Savo should have more double-track railways to allow oncoming trains to pass. In many places the railway tracks should be renovated. Possibly, the price politics of railways should favour more trains rather than roads. In the European Union, taxation could perhaps be used to encourage more heavy freight to use railways. The safety in railways is also much better than in roads – especially in winters, since road traffic can have problems with skidding when the temperature is near 0^{o}C. Snow on roads and snowflakes on windscreen also often cause problems. In addition, traffic causes a deterioration of roads, as does the repeated freezing and thawing of water, meaning there is often a need to repair them.

Transportation via waterways may be a partial solution, but only when there is no ice. In practice it is difficult to know this time even some weeks before. Local short-distance passenger trains could also be an option to reduce car traffic. This service was available some 40 years ago but it is no longer. In some cases, a higher provincial production of food and other products could reduce transportation needs.

In addition, traffic causes noise and pollutes air due to evaporated fuel components and fine particles into the air from tyres and roads. The most serious health problems caused by traffic are cardiovascular morbidity cases among adult people and respiratory diseases, especially among children [29]. In extreme cases they can cause death.

In spring 2020 the corona (Covid-19) epidemic limited personal contacts. Most children and students from primary school to university, together with many working people, worked from homes using mobile telephones and internet connections. Car traffic was reduced in North Savo as could be seen in many Kuopio parking spaces. Still now in autumn 2020 many official meetings and meetings of non-governmental organizations are web meetings. It will be interesting to see if people will in future work more days from home, perhaps using internet connections so that there is the possibility of saving fuel, roads and time. In many cases it would be possible to work at home for some days in the week.

3.4. Forests as Sinks of Greenhouse Gases—What about Peatland Forests?

Boreal forests with variable ages of treed are an important greenhouse gas sink and oxygen source due to photosynthesis. Therefore, forest owners are encouraged to allow their forests to grow. As forest soil contains most carbon storage [14], it is highly recommended to select those forest management methods which do not cause disturbances in the soil. Tree stumps can be used as fuel but they should not be harvested if the soil is intended to stay as forest, since harvesting also stumps in peatland means loss of woody biomass as carbon sink and this practice can increase leaching of nutrients (nitrogen, potassium, boron etc.) and mercury to waters so that the next rotation of forest may suffer depletions of these nutrients [30, 31) and mercury in surface waters may contaminate predatory fishes. Forests with large trees are better sinks for carbon dioxide than forests with seedlings so an incentive scheme to allow forest owners to keep the forests in mature stage for some years should be discussed. In addition, old forests are important both for landscape and outdoor recreation purposes.

If a forest has been harvested by clear cutting and the soil is prepared and fertilized, nutrients will leach into waters during heavy rains. There are also high risks that the fertilization with nitrogen will degrade to nitrous oxide which will be emitted to the air [17]. In some cases the expensive fertilizers used will be lost and both air and water will be polluted. There should be more research work performed about biological and economic factors including:

1) how the harvesting of forests should be performed so that the forests and their soils remain as effective sinks of greenhouse gases,
2) how to ensure contamination to brooks and other surface water is minimal in forest harvesting, and

3) ensuring forest owners are able to get a moderate income and do not lose money on useless fertilization.

However, continuous cover management of forests means that forest trees are always growing, without land preparation and fertilization so that the soil is never disturbed and carbon storage and nutrients can be conserved. Continuous cover management in forests can give the same or even a higher income for the forest owner than management which ends in clear cutting and begins with land preparation and new planting of seedlings [32].

The present forestry industry should be developed so that instead of cheap bulk products such as cellulose (even if it is circulated as fibres many times), products in future should be those more expensive ones, such as timber for construction of buildings and furniture materials, timber product fibres, food, or medicine products etc. There should also be research work into finding these new products and developing present production methods.

If the Finnish state is no longer supporting the opening of new ditches and reopening of old ones, there might be an increase in the water table. It should be remembered that birches and other deciduous trees can evaporate high amounts of water making ditches partly unnecessary, and therefore forests with both deciduous and coniferous trees should be favoured. It should also be understood that higher temperatures will increase evaporation. In addition, it may be better to allow many different tree species to grow in the same forest site so that the forest becomes more resilient to climate change. If Norway spruces can no longer survive well in the new climate, it is possible that birches, linden trees, oaks or other deciduous trees will grow. Linden trees in North Savo are still a rare relic from times when temperatures were higher than today so the soil there does allow its growth.

The extraction of peat should be highly reduced before it is limited by regulation. Areas where peat has been extracted can be used for plant production either as new forests or agricultural land. They may also be suitable for other purposes such as for different sports or training. One possibility is to convert these areas into fish breeding ponds or areas of protection for birdlife, possibly including ponds as has been done by the North Savo Nature Protection District organization. When the peatland soil is afforested the fertilization amount — especially that of nitrogen — should be low.

Peatlands with peat should be allowed to continue as peatlands so that their natural species will begin to return. Some peatlands which still contain natural values have been protected and in this case the landowner can sell her/his land to the state. Some valuable berries and medical plants often grow on wetlands. Currently everybody is allowed to pick wild berries freely but to pick medicinal plants as *Drosera rotundifolia* there must be permission from the landowner.

In total, the different protected areas cover only some 3% of the forest area in North Savo and this area should be higher in order to increase biodiversity. In addition, there are many small protected areas which were the gifts of landowners to the 100-year-old fatherland (in 2017) and some which private landowners wanted to protect due to their beautiful landscapes. These protected areas often also have different natural and cultural historical values.

3.5. Development of Agricultural Soils

The experimental farm of the Natural Resources Institute Finland is situated in the Kuopio rural area and its main focus is research work into grass and grass-clover cultivation for dairy cows. Recently this farm has announced its aim to be carbon neutral. This aim is ambitious, but totally possible since some background work has already been done [33–39]. Fertilization and other agricultural works must be done with great care. All fertilization must be accurate in each separate square metre, since there are still nutrient losses to surface water during times of ice melting and also during heavy autumn rains after the growth season [33]. These nutrient losses were much higher from agricultural soils than from forests or areas including both forests and agricultural soils, in spite of the fact that amounts of fertilization had already been reduced to the recommended level. In addition, forest soils with higher humus could absorb water better than agricultural soils so that leaching of water was lower from forested areas compared to that from agricultural soils [33]. The farmer must have a detailed knowledge of the fertility of all agricultural soil plots in the whole farm.

In addition, the farmer must know the concentrations of nitrogen and phosphorus in all animal manures and manage this manure well so that ammonia is not evaporated and manure is used as a fertilizer at the correct time.

There are relatively new research works into losses of nutrients and emissions of greenhouse gases made in North Savo and partly in the fields of this experimental farm [34–36]. This experimental farm already has a bioreactor which makes biogas from cattle manure, which may increase its fertilization value of nitrogen and phosphorus so that the amount of fertilizers used can be reduced [37]. Less manure is formed in bioreactors in summer since cows graze grass daily for many hours and only young calves and calving cows are indoors. Biogas is used for heat and electricity, partly for heating water to guarantee milk hygiene and partly for cooling the milk.

If fertilization is very well balanced and all nutrients are taken up by vegetation there will be no (or less) leaching of nutrients to surface water. In this case the formation of greenhouse gases — especially formation of nitrous oxide — will be low and these emissions will be compensated for by photosynthesis of grass so that carbon dioxide is turned to grass mass. There must be protecting strips against surface waters in cultivated fields and fields should be grazed so that leaching from grazing area is minimal, and vegetation will utilize the nutrients from fertilizers as efficiently as possible [38, 39].

If carbon neutrality is reached by this experimental farm, it is expected that many North Savo farms will follow suit. They will benefit from these best practices since farmers want lower fertilization costs. Modern farmers often have university or applied university education so that they can follow developments. They know well that the highest yield is not the same as the most economic yield so they do not like to over-fertilize their soils. In addition, they and their family typically live on the farms and swim or fish in the closest surface waters and want to protect them. Sometimes it will take time since, if a farm either alone or together with its neighbours has recently acquired a machine system, it may not be reasonable to replace the old one with a new one in spite of the fact that the new one could be better.

Reductions in emissions must be accepted by all people. The amount of food waste should be reduced first. In addition, the consumption of all meat should be greatly reduced and diets should be more (but not totally) vegetarian since this diet would produce less greenhouse gas emissions [40]. Already many people prefer not to eat red meat or indeed any meat.

In North Savo, general eating less meat and milk will lead to a situation where less milk will be needed. In this case, agriculture should start to produce something else. Global climate change will cause an increase in temperature, so it may be that cultivation of cereals will be more profitable. Farms in North Savo already cultivate high-quality berries, potatoes, carrots, onions and many other vegetables. For example, a high percentage of Finnish onions and berries are cultivated in North Savo. High consumption of meat could easily be replaced with the many inland fish species originating from the North Savo lakes: fishing is a fairly common hobby and there is also some commercial fishing. Eating more inland lake fish would be a water protection action as it would reduce excess amounts of nutrient from surface waters and would thereby reduce the risk of eutrophication in waters.

4. Conclusions

A better and more accurate knowledge about greenhouse gas emissions and sinks in North Savo can give some tools to show people how they themselves can reduce emissions and increase sinks in their homes, work life, agriculture and forestry. Local people could co-work more with authorities and the authorities should co-work and supervise local people less [41].

This work may make many sectors of the economy more sustainable. Energy and material will be saved. Finnish State is working on order to reduce energy and material consumptions by giving information and following the development. Already now the total Finnish electricity consumption has reduced from over 1400 PJ still in 2011 to less than 1400 PJ and it was 1361 PJ in 2019 [42] while number of population has been almost constant. The waste formation and circulation in households has improved but mineral wastes from mining and construction are still high and the reductions have been modest [43]. In North Savo a part of gypsum waste from mining industry has been used to control phosphorus leaching from agricultural fields near Baltic Sea. Anyhow, better and more sustainable use of material and energy would reduce pollution of surface waters. Saving of material and energy will improve profitability at least if material waste can be utilized in another place. Society will be better adapted to climate change.

Forests soils can be a very effective sink for carbon and the photosynthesis of growing forest trees is able to fix carbon dioxide from the air into the tree biomass and the root area. In addition, leaching of nutrients and waters is much lower from forests than from agricultural soils. Most forested areas of the North Savo province are already carbon sinks. These are the reasons why those soils which are not needed for agriculture should be afforested. This higher sustainability may well mean a higher resilience in the changing climate.

This work is partly an example and a paper for reaching carbon neutrality. The ideas presented can be freely borrowed by any other area, since greenhouse gas emissions that are too high are a common problem for all people in all continents and in all climates. The best practices can be taken and improved or adapted as they fit in different areas.

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