Agrofuels threaten to accelerate global warming

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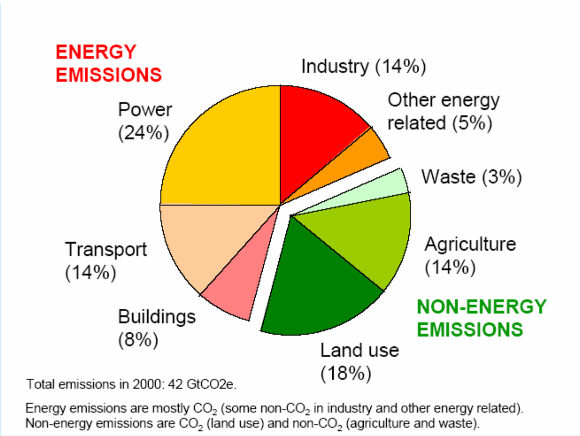
Background: Contribution of agriculture and land-use change to anthropogenic climate change.

This report looks at the impact which large-scale agrofuel production is likely to have on the global climate through agriculture and ecosystem destruction. It discusses the different sources of greenhouse gas emissions linked to the cultivation and refining of agrofuel feedstocks as well as the impact on overall fossil fuel consumption.

Particular emphasis is put on the direct and secondary impacts of agrofuel expansion on the world's terrestrial carbon sinks, particularly those in the tropics and subtropics. Crops grown for agrofuels can lead to the destruction of carbon sinks such as rainforests either because forests are directly converted to 'energy crops', or because other types of agricultural activities are displaced and pushed into forests and other important ecosystems.

Global warming is primarily a severe disturbance of the carbon cycle: On the one hand, humans are putting about 8 billion tones of carbon into the atmosphere every year. On the other hand, ecosystems are rapidly being destroyed and degraded. Ecosystems, including healthy soils, play an essential role in regulating the climate, by sequestering and storing carbon, by regulating the nitrogen cycle, by contributing to cloud formation, convection and thus regulating rainfall, and by maintaining the hydrological cycle. Ecosystem destruction is linked to 1-3 billion tonnes of carbon emissions per year, and it also causes significant regional warming as well as destabilizing the climate system in a highly unpredictable way.



(from the Stern Review – note that this omits emissions from peat degradation, and that the figure for agriculture relates to non-CO2 greenhouse gases only)

The Stern Review stresses that total emissions from land use will be greater, because there is no global estimate for soil carbon emissions as a result of agriculture and land-use change. Furthermore, neither the Stern Review, nor any of the IPCC Assessment Reports published to date, estimates global emissions from peat oxidation and fires. Different types and sources of greenhouse gas emissions linked to agriculture and land-use change, and the impact of large-scale agrofuel expansion will be examined below.

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Glossary

Agrofuels: Agrofuels are biofuels from agriculture and forestry. Biofuels from true waste products, such as waste vegetable oil, biogas from landfill or manure would not be classed as agrofuels. Nor would biofuels from algeae be classed as agrofuels.

Positive feedbacks: Positive feedbacks occur when a change in one component of a system leads to other changes which eventually 'feed back' on the original change to amplify it. It is widely believed that positive feedback mechanisms exist within the climate system which could amplify the global warming caused by anthropogenic greenhouse gas emissions.

Non-linear systems: Climate or ecosystems are widely believed to be non-linear systems, where a small push away from one state often has a small effect at first but beyond a certain point, they can rapidly flip into another state.

Intensive agriculture: We use this term to describe large-scale monoculture production which relies on high external inputs, including fertilisers and pesticides

Fossil fuel use set to keep expanding

There is increasing doubt that large-scale agrofuel expansion could even reduce fossil fuel emissions by a small proportion. Even if there were any such gains, they would be more than wiped out if the global transport sector continues to grow at present and forecast rates. The International Energy Authority states that, at present, agrofuels account for 1% of global transport fuel. They forecast that they could account for 8% by 2030, but that, even so, the use of fossil fuel oil in global transport will still increase in absolute terms[2], because of overall growth in transport fuel use.

As long as energy use keeps rising, agrofuels will not even be able to reduce fossil fuel use in absolute terms. Those IEA figures, however, refer only to the replacement of mineral petrol and diesel. They do not account for the fossil fuel use linked to agrofuel production, i.e. the fossil fuels used in agricultural machinery and equipment, the manufacture of fertilizers, production of pesticides, transport, and during the distillery and refinery process. A 2006 review of life-cycle energy and greenhouse gas assessments[38] found that 74-95% of the energy in corn ethanol comes from fossil fuel inputs, and even that study has been criticized as over-optimistic by Professor Tadeus Patzek[39]. Even those marginal fossil fuel savings can result in greater carbon emissions, as many refineries now rely on coal rather than gas or oil for energy. Coal has the highest carbon content (25.4 tonnes of carbon per terajoule compared to 19.9 tonnes per TJ for mineral oil). Fossil fuel use varies between different feedstocks – it is almost certainly highest for corn ethanol and substantially lower for sugar cane ethanol and palm oil biodiesel.

Carbon Storage in the Terrestrial Biosphere		
Soil and Vegetation	WBGU	ICBP
Tropical Forests	428 Gt	553 Gt
Temperate Forests	159 Gt	292 Gt
Boreal Forests	559 Gt	395 Gt
Tropical Grasslands	330 Gt	326 Gt
Temperate Grasslands	304 Gt	199 Gt
Deserts/Semi-Deserts	199 Gt	169 Gt
Tundra	127 Gt	117 Gt
Croplands	128 Gt	169 Gt
Wetlands	225 Gt	n/a

WBGU (1988): forest data from Dixon et al. (1994); other data from Atjay et al. (1979) IGBP-DIS (International Geosphere-Biosphere Programme – Data Information Service) soil carbon layer (Carter and Scholes, 2000) overlaid with De Fries et al. (1999) current vegetation map to give average ecosystem soil carbon. From: IPCC Third Assessment Report: http://www.grida.no/climate/ipcc_tar/wg1/099.htm

Our concern is that any small reduction in greenhouse gas emissions from fossil fuel use due to agrofuel expansion will be at the expense of large increases in greenhouse gas emissions from deforestation, from other land-use change, nitrous oxide emissions, carbon emissions from the loss of soil organic carbon, peat fires and oxidation, and potentially the loss of major carbon sinks. Our ability to stabilize greenhouse gas concentrations in the atmosphere and avoid the worst impacts of global warming depends on the ability of our ecosystems to continue functioning as carbon sinks, i.e. to continue absorbing large quantities of carbon from the atmosphere, including a considerable proportion of anthropogenic emissions. If ecosystems are destroyed or degraded so that they can no longer function as carbon sinks, then the ability of the earth system to stabilise the climate will be lost.

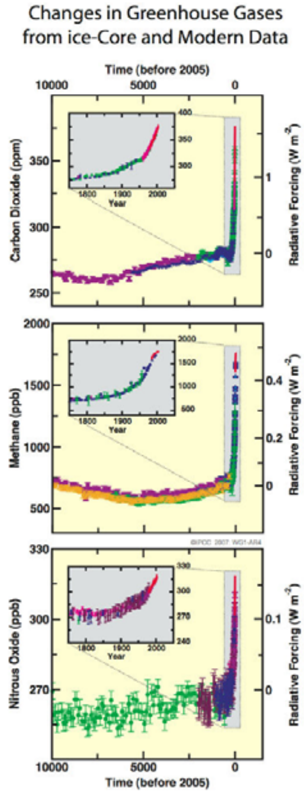
There is strong evidence that the results of deforestation and ecosystem degradation can be non-linear, i.e. that both agricultural intensification (based on large-scale monocultures and high fertiliser and pesticide inputs) and expansion could trigger large-scale, irreversible ecosystem changes and possible collapse which could then trigger equally irreversible climate feedbacks. This is dealt with in detail below.

Any assessment of the climate impact of agrofuels must consider the possibility of deforestation for monoculture expansion triggering a collapse in the rainfall system on which the Amazon forest depends, thus tipping all or part of that forest into an irreversible cycle of megafires and desertification. A recent scientific symposium on the Amazon puts the probability of continued deforestation together with rising temperatures triggering large-scale Amazon rainforest dieback within the next few decades at 10-40%[41]- a very high risk for an event which would have catastrophic impacts on the global climate, biodiversity and human populations.

The evidence that agrofuels mitigate climate change is scarce and controversial, particularly when examined beyond the micro-level (see discussion of life-cycle greenhouse gas assessments below). On the contrary there is growing evidence that a shift to agrofuels could greatly accelerate global warming.

Nitrous oxide emissions from agriculture

Nitrous oxide (N2O) is the third most important greenhouse gas responsible for anthropogenic global warming. Its global warming potential is around 296 times as great as that of carbon dioxide, and it has a long atmospheric life-time, of around 120 years. Atmospheric concentrations of N2O have increased by 17% since the industrial revolution. According to a 2006 report by the United States Environmental Protection Agency[3], annual global anthropogenic emissions of N2O are the equivalent of 3.114 billion tonnes of carbon dioxide emissions (which is equivalent to 849.55 million tonnes of carbon). Out of this total, agricultural nitrous oxide emissions account for the equivalent of 2.616 billion tonnes of carbon dioxide.



Historic radiative forcings since pre-industrial times for the three main greenhouse gases. IPCC 4th Assessment Report, 2007

According to the Stern Review, total agricultural emissions (not including deforestation) increased by 10% in the 1990s and are expected to increase by a further 30% between now and 2020 – not taking account of an increase in agrofuel production. Most of this increase is due to the greater use of fertilizers, particularly in the tropics, i.e. to practices mainly associated with intensive monoculture production. In Asia alone, nitrous oxide emissions have grown by 250%[4]. Adding the same amount of fertilizer to a hectare of tropical soils is linked to 10-100 times the amount of N2O emissions as doing the same in temperate soils.[5] Increasing intensive monoculture production, even without deforestation, will push those emissions up yet higher, particularly if it happens in the tropics. Yet it is expected by the United Nations Food and Agriculture Organisation (FAO) that intensive monocultures will provide the bulk of the growing agrofuel production globally. The FAO has clearly stated that rising crop yields are linked directly to both irrigation and greater fertilizer use[6]. Indeed, all the optimistic scenarios for increasing global biomass production for bioenergy hinge on a rise in yields, which inevitably means higher N2O emissions. Apart from fertiliser use, conversion of forests to cropland, large-scale planting of legumes (such as soybean), and decomposition of organic residue have been identified as important sources of agricultural N2O emissions[7]. Rising N2O emissions from agriculture due to the planned expansion of agrofuel production have not been factored into any emissions scenarios, but are clearly likely to be of global significance.

Climate impacts from nitrous oxide have been highlighted recently in a paper by Nobel prize winner Paul Crutzen and others who suggest that nitrous oxide emissions from nitrate fertilisers have been underestimated in biofuel greenhouse gas emissions calculations[42]. Crutzen challenges the IPCC estimate that just 2% of nitrogen which is applied to soils in the form of nitrate fertilisers is transformed by soil microbes into nitrous oxide arguing that after comparing the increase in nitrous oxide in the atmosphere to the known inputs by humans, and accounting for changes due to deforestation, that 3-5% of nitrate fertilisers must be converted to N2O. However, most life-cycle studies for biofuels also wrongly ignore part of the IPCC figure - they consider the approximately 1% of direct emissions from the field where the fertilisers are applied but ignore c.1% indirect emission from the much wider area which will be 'fertilised' through rainfall and runoffs from fields. They therefore significantly underestimate life-cycle greenhouse gas emissions from all agrofuel feedstocks which are grown with nitrate fertilisers.

In the case of oilseed rape, which accounts for 80% of EU home-grown biodiesel, Crutzen writes that biodiesel produced from it can generate up to 70% more greenhouse gas (GHG) emissions than fossil fuel diesel. Similarly, corn ethanol, which makes up most of the US biofuels market, can produce up to 50% more GHGs than petrol.

The findings of the Crutzen paper have been used to calculate that US greenhouse gas emissions could rise by 6% from nitrogen pollution alone if the US Senate's plans to increase maize ethanol production sevenfold by 2022 are adopted.[43]

US and European policy makers have not taken on board yet that agrofuels grown in the North, such as oil-seed rape and corn ethanol, have the potential to damage the climate through nitrogen fertilizer use[44]. Agrofuels grown in either the South or the North are likely to damage the climate, potentially catastrophically.

Biodiversity and secondary climate impacts from increased use of nitrate fertilizers

The full consequences of increased nitrate fertilization are not yet known. Humans have doubled the amount of biologically available nitrogen worldwide, and there is growing evidence that this is having disastrous impacts on biodiversity: Terrestrial ecosystems suffer as rain carries nitrogen-compounds over large areas and adding more nitrogen to soils leads to declines in plant species adapted to low-nitrogen environments. Freshwater ecosystems suffer from eutrophication, and UNEP have warned that hypoxic 'dead zones' in oceans are increasing rapidly in size and number and are to a large extent linked to agricultural nitrate run-offs and the use of nitrate fertilizers.[8]

Because scientists do not know the full impact of nitrogen overloading on ecosystems, it is impossible to predict how this will impact on ecosystems' ability to absorb and sequester carbon from the atmosphere. One recent study, published in the Proceedings of the National Academy of Sciences, suggests that higher levels of nitrogenous compounds in rain is causing peat bogs to emit more carbon dioxide, thus adding to global warming.[9] The author warns: "Now there are signs that indicate that nitrogenous compounds in the air make peat bogs start to give off more carbon dioxide than they bind, and that they may tip over from being a carbon trap to being a carbon source, thereby aggravating the greenhouse effect instead." Also, whilst soil nitrous oxide emissions linked to fertilizer input can be measured, less is known about similar soil emissions over larger areas fertilized not directly but indirectly, through rainfall.

Optimistic scenarios for global bioenergy production rely on agricultural intensification based on fossil fuel based external inputs.[10] The consequences for the global nitrogen cycle could have major impacts both on biodiversity and on the global climate. Many of these impacts are not yet fully understood. What is known, however, is that large-scale agrofuels will increase the amount of nitrogen available to the biosphere. This will have serious consequences for biodiversity, for global nitrous oxide emissions and, increase carbon dioxide emissions from peat bogs[9].

Nobody can predict the full scale of those impacts, but enough is known to merit extreme caution about adopting large-scale monocultures for agrofuels as a way of mitigating climate change.

Soil carbon emissions from agriculture

The Intergovernmental Panel on Climate Change estimate that soil carbon emissions have historically accounted for 55 billion tonnes of carbon. Soil carbon emissions vary according to soil type, climate and agricultural methods. One study estimates that, when land in temperate zones is converted from natural vegetation to crop land, emissions from the loss of soil organic carbon are around 3 tonnes per hectare, but far higher on peaty soils.[11]

A 2006 Wells-to-Wheels study by the Joint Research Council of the European Union, together with the European for Automotive R&D and the European oil companies' association Conservation of Clean Air and Water in Europe12 states: "We already warned that increase of arable area would cause loss of soil organic carbon from grassland or forest: we assume it will not be allowed." The United Nations Food and Agriculture Organisation (FAO), however, say that agrofuel expansion may well lead to crop expansion, particularly in North America and Western Europe.[13]

Some current claims being made about a large potential for agrofuel crops worldwide actually involve large-scale ploughing up of pasture land, For example the 2006 'Quickscan of global bio-energy potentials to 2050' study[14] says: "A key factor was the area of land suitable for crop production, but that is presently used for permanent grazing." As the Well-to-Wheels study, warns, ploughing up of longstanding pasture can result in a large carbon emissions.

Although no-till agriculture has been suggested as a way of increasing soil organic carbon content on land, different studies done in Argentina's Pampa region shows that rates of soil carbon emissions vary between different places and that there is no guaranteed net carbon storage gain, irrespective of external inputs. One recent study, which found some soil carbon storage gains, nonetheless suggested that the additional nitrous oxide emissions linked to no-till farming methods could outweigh any such benefits and lead to overall increased greenhouse gas emissions[15]. The same study also found that benefits in terms of soil organic carbon storage were considerably smaller than suggested by the IPCC. This study is very relevant in this context, because most of the soya grown in Argentina, Brazil, Chile and other countries is cultivated with no-till methods, and large-scale soya expansion for agrofuels is expected and, in some countries, like Argentina and Paraguay, has already begun.

No-till methods are linked to greater use of nitrate fertilisers for grain production (including maize, which is increasingly used for bioethanol), and to greater water retention and to greater soil compaction and soil water retention which also increase nitrous oxide emissions, including from soybean monocultures. Furthermore, several studies link soybean monocultures to high N2O emissions, even if little or no nitrate fertilisers are used. This may be because of the high rate of biological nitrate fixation in legumes[16]. Furthermore, glyphosate, the main herbicide used in no-till soya production degrades mainly to carbon dioxide and phosphate, according to one of its leading manufacturers, Monsanto.

Finally, using land for agrofuel production should be compared with the alternative, which is allowing natural vegetation to regenerate. Professor Renton Righelato, microbiologist and consultant on food chain issues to the European Commission, suggests that taking plantation land in Brazil out of production and allowing for natural forest regeneration (where possible), would sequester 20 tonnes of carbon dioxide per hectare over the next 50-100 years[17]. In a more recent paper, Renton Righelato with Dominick Spracklen from Leeds University show that current production methods of agrofuels will release between two and nine times more carbon gases over the next 30 years than if land was forested[49].

A study by Macedo et al[18], which does not take account of emissions from land use change, finds that sugar cane ethanol produced from one hectare of land reduces fossil fuel CO2 emissions by 13 tonnes. This figure ignores all emissions linked to deforestation, grassland conversion and soil organic carbon losses, but it is still substantially lower than the carbon savings which would be gained by allowing natural vegetation to re-grow.

Carbon emissions from peat degradation

Around 550 billion tonnes of carbon - 30% of all terrestrial carbon – are stored in global peatlands[19]. Draining the peat leads to oxidation, whereby the carbon in the peat, which was previous water-logged and thus not exposed to the atmosphere, reacts with oxygen in the air to form atmospheric carbon dioxide. Drained peat is often susceptible to fires, which can greatly speed up those carbon emissions, as is happening annually on Borneo and Sumatra. Peat cutting, drainage and 'conversion' is a problem all over the world, partly due to agricultural expansion. According to figures contained in the most recent IPCC Assessment Report Four, emissions from degraded peatlands have exceeded those from deforestation in the period since 1990. Peat destruction is most rapid and extensive in south-East Asia, with Indonesia alone holding 60% of all tropical peatlands in the world. Palm oil expansion is particularly rapid in the peatland areas of both Indonesia and Malaysia, and scientists expect that nearly all of the peat will be drained, mostly for plantations, in coming years or decades. This will eventually lead to the emission of virtually all the carbon held in South-east Asia's peat – 42-50 billion tonnes, which is the equivalent of around six years of global fossil fuel emissions. The Indonesian government is planning a 43-fold increase in palm oil production, largely in response to the growing global demand for agrofuels, with around 20 million hectares more land to be converted to oil palm plantations, as well as further concessions for sugar cane and jatropha for agrofuels.

A recent study by Wetlands International, Delft Hydraulics and Alterra[21] estimates that one tonne of biodiesel made from palm oil from South-east Asia's peatlands is linked to the emission of 10-30 tonnes of carbon dioxide. Once emissions from peat fires and the loss of carbon sink capacity are taken into account, we estimate that one tonne of palm oil biodiesel from South-east Asia would therefore have 2-8 times more life-cycle carbon emissions than the amount of mineral diesel it replaces.

South-east Asia's peatlands are one of the largest single carbon sinks worldwide, and their destruction is one of the largest single sources of carbon emissions worldwide – with the emission of up to 2.57 billion tonnes of carbon having been released in the worst fire season so far (1997/98)[22].

> The planned expansion of agrofuel production from Southeast Asian peatlands is widely expected to result in the destruction of this large carbon sink. The accumulated evidence from South-east Asia, where palm oil production has been undertaken for some time, illustrates that agrofuel expansion can significantly accelerate GHG emissions and exacerbate global warming.

Agrofuels, deforestation and global warming

FAO figures confirm that agricultural expansion is happening at the expense of natural habitats such as forests, particularly in Latin America, sub-Saharan Africa and south-East Asia[23]. Monoculture expansion, much of it for soya, palm oil and sugar cane, is currently accelerating at the expense of forests and other vital ecosystems. Further monoculture expansion in the global South will speed up deforestation and ecosystem destruction -as well as the destruction of biodiverse traditional farming systems, on which millions of people rely for their livelihoods and food security.

In September 2006, NASA published a study which showed that the rate of Amazon deforestation correlates with the price of soya[24]. Agrofuel expansion is likely to push up the price of soya, both by creating additional demand for soya biodiesel and by US farmers switching from soya production to corn for ethanol. The Amazon forest holds an estimate 100-120 billion tonnes of carbon, equivalent to 13-15 years of global fossil fuel emissions, and if it was destroyed or died back, it would dramatically increase global warming. There is strong evidence that old growth forests sequester significant amounts of carbon from the atmosphere[25]. Our ability to stabilize greenhouse gas concentrations in the atmosphere depends on ecosystems remaining capable of sequestering carbon: If ecosystems collapse or are destroyed on a large scale, then there would be no way of stopping greenhouse warming from running out of our control. In this context, recent evidence about the vulnerability of the Amazon forest, and its crucial role in regulating rainfall patterns over large parts of the Northern Hemisphere, is particularly worrying. The Amazon forest 'recycles' 50-80% of its annual rainfall via evapo-transpiration, i.e. it sustains its own hydrological cycle. Deforestation, and in particular conversion to cropland, are proven to have a significant regional warming and drying effect, worse even than conversion to pasture[26]. The Woods Hole Research Institute has been at the forefront of studying the Amazon carbon cycle, hydrological cycle, and vulnerability to logging and climate change:

"The risk of fire and drought is enhanced by logging, which opens the forests, and by farmers and ranchers who use fire to replace rainforests with crops and pastures. A brutal downward spiral of drought, forest fire, and further drought could expand across much of the Amazon, replacing the species-rich rainforest with savanna like vegetation."[27]

Feedback mechanisms have already been demonstrated by NASA: Aerosols from forest fires suppress precipitation completely from some clouds, causing further drought and larger fires. Several studies suggest that the ratio between evapo-transpiration and rainfall is key to determining tropical vegetation, and that "vegetation change can be unannounced, catastrophic and persistent", with the possibility of large parts of the Amazon rapidly drying up, burning, and turning into savannah.[28]

It is particularly concerning that extreme drought conditions have been reported in large parts of the Amazon rainforest for three consecutive years, with 3005 and 2007 having seen the largest number of fires. As Dr Philip Fearnside of Brazil's National Institute of Amazonian Research has said: "With every tree that falls we increase the probability that the tipping point will arrive." [29]

There is evidence that Amazon deforestation causes drying over a large region, as far as northern Mexico and Texas, and a forest die-back, it is widely feared, could devastate agriculture over much of Latin America and the southern US. Deforestation in Central Africa, on the other hand, has been linked to reduced rainfall in much of the US Midwest, whilst forest loss in South-east Asia appears to alter rainfall in China and the Balkan peninsula[30], with drastic consequences for agriculture over very large areas.

We have focused on the Amazon forest, because of the strong evidence that further conversion to cropland risks triggering disastrous and irreversible climate feedback mechanisms. The expansion of soya, palm oil and sugar cane, however, is also linked to deforestation in many parts of Asia, Latin America and Africa, with disastrous consequences in terms of carbon emissions, loss of carbon sinks, and regional drying and warming trends. Soya expansion is linked to deforestation in the Brazilian Cerrado, the Pantanal, South America's Atlantic Forest and a portion of the Paranaense forest in Paraguay and North of Argentina. In Argentina, more than 500 thousand hectares of forest land were converted to soya plantations between 1998 to 2002[31]. Sugar cane expansion is impacting on many forests, including the Amazon, the Pantanal, South America's Atlantic Forest, rainforests in Uganda, and in the Philippines. Palm oil is linked to large-scale deforestation in South-east Asia, Colombia, Ecuador, Brazil, Central America, Uganda, Cameroon and elsewhere.

There is a historic precedent for rapid desertification linked to vegetation loss: Around 6,000 years ago, the southern part of the Sahara was covered in savannah and lakes. It appears that the ecosystem had withstood an initial shift towards a drier climate, caused by changes in the North Atlantic heat transfer, but later rapidly collapsed and turned into desert, after extreme weather events had reduced the vegetation below a certain threshold.[51] This strongly suggests that the vegetation played a major role in attracting regular rainfall over the region and that the biosphere and the atmosphere are closely coupled. This evidence raises concerns not only over the direct destruction of the Amazon forest, but also over the conversion of the Cerrado, the Pantanal and other South American ecosystems to monoculture plantations, since those ecosystems could be crucial for drawing in rain clouds from the tropical Atlantic and feeding them into the Amazon basin by evapotranspiration. Ecosystems therefore maintain the climate not just by storing and sequestering carbon, but also by regulating convection, cloud formation and rainfall patterns.

The above-soil carbon held in a mature oil palm plantation is only a small fraction of what old growth forests store: Primary forests in Indonesia have been found to hold 306 tonnes of carbon per hectare, whereas mature oil palm plantations hold 63 tonnes per hectare, but are not expected to survive more than 25 years at the most.[32]

As long as there are no proven safeguards that agrofuel expansion will not trigger further deforestation or ecosystem destruction, the risks involved are far too high. Small-scale 'greenhouse gas savings' which can be measured in micro-studies do not outweigh the very real risk of triggering catastrophic forest die-back in the Amazon and elsewhere, which could cause massive carbon releases, trigger other irreversible climate feedbacks, and potentially disrupt rainfall patterns and thus agriculture over very large areas. Governments, including those in the Europe, are instead allowing biofuels derived from this land to enter the UK fuel supply chain masquerading as benign, 'clean', 'green' fuels, and such biofuel policy could unleash a huge humanitarian and ecological disaster[54].

Predictions for Agrofuel Supplies and Climate Change

It is of concern that many of the studies which suggest that agrofuel production can be increased significantly, particularly in Latin America, Asia, and Africa, without impacting on ecosystems or food supplies take no account of climate change projections.[33] Those studies project current climate conditions and crop trends for the past twenty years, well into the middle of this century. Policy decisions should take into account of IPCC climate change predictions and must not be based on studies which fail to take these into account.

The 2007 IPCC Summary for Policymakers[34] predicts significant drying over large parts of northern and southern Africa, most of Brazil and parts of neighbouring countries, Chile and Argentina, Central America, large parts of Australia, the Middle East, Europe and Central Asia, with seasonal drying over much of South and South-east Asia. Together with temperature rises, those drying trends will inevitably reduce agricultural production in the very countries where monoculture expansion for agrofuels is being promoted most strongly. Recent results from a climate modeling study for Brazil suggest that climate change will make cultivation of soya, corn and coffee impossible in large parts of Brazil, particularly in the north[35]. Predictions made for continuing yield increases in those countries clearly conflict with the results of climate change models.

In Europe, per hectare yields of oilseed rape have been falling for three years running because of 'extreme weather impacts'[36]. Climate change is expected to intensify those extreme weather trends. Falling per hectare yields will either lead to the expansion of cropland into land under natural vegetation, or to reduced output, or both.

Life-cycle greenhouse gas assessments: What can they tell us?

Much of the 'evidence' presented for agrofuels reducing greenhouse gas emissions is based on life-cycle greenhouse gas assessments, which look at emissions linked to agrofuel production within very close parameters, generally ignoring the larger picture of 'land use change', and often ignoring soil organic carbon emissions and, in some cases, nitrous oxide emissions. Only a limited number of life-cycle assessments have been peer-reviewed, and there is a complete lack of peer-reviewed evidence for some feedstocks such as palm oil or jatropha.

Many life-cycle assessments point to significant uncertainties, particularly with regard to the attribution of by-products, and soil nitrous oxide emissions[37]. Corn ethanol is one of the agrofuels for which most research evidence is available. An evaluation of six different analyses by Alexander Farrell et al, published in Science in January 2006[38] reveals a wide range of methods used and different results reached. The authors conclude that corn ethanol brings small greenhouse gas savings of 13% compared to petrol, but only if soil erosion and land conversion are ignored. This study, in turn has been criticized some scientists[39]. Alexander Farrell and his colleagues said in response to this criticism: "Including incommensurable quantities such as soil erosion and climate change into a single metric requires an arbitrary determination of their relative value." Yet soil erosion implies the loss of soil organic carbon and a need to use further energy and fertilizer input (with more nitrous oxide emissions) to be able to farm the land. Studies which ignore climate change impacts and soil erosion should be the basis for policy making.

Life-cycle assessments (LCAs) generally take no account of land-use change, which accounts for the greatest carbon emissions linked to agrofuel production. LCAs cannot take account of the indirect effects on deforestation and ecosystem destruction. One can measure emissions linked to the production of corn ethanol, but that corn may be grown at the expense of soya and, as a result, soya plantations in South America might be expanding and might cause more deforestation, resulting in very large carbon emissions.[40] Alternatively, one can measure emissions from soya plantations which displace traditional farmland, without then measuring emissions from deforestation which may result from the displacement of local communities. Given that LCAs do not measure those wider impacts, policymakers cannot rely on them to provide the full climate change impact of agrofuel production. Nor can LCAs account for the uncertainties over secondary climate impacts from nitrogen fertilization, or feedback mechanisms from deforestation[50]. And finally, they ignore the crucial role which ecosystems play in sustaining the hydrological cycle and the convection and cloud formation which are essential for climate regulation.

Can standards or certification avoid the risks of agrofuels accelerating global warming?

There is a proven link between monoculture expansion and deforestation, and further deforestation can result in non-linear feedbacks which would be impossible to stop and which could, in the worst case, push global warming beyond human control and devastate agriculture and the lives of hundreds of millions of people. These are not risks that policymakers can afford to take.

Those are not simply 'negative impacts' which can be reduced – they are not comparable to limited pollution over a small area, for example, which could be mitigated.

The emerging awareness of negative impacts from biofuel production has led for calls from governments and industry for sustainability criteria[47]. The industry wants such a mechanism to provide the appearance of 'clean' fuels and to gain the public support needed for the market to develop. Governments want to support industry and to be seen as moral by their electorate. However, the sustainability criteria being proposed lack credibility and create more questions than they answer[47,48]. For example, how can the huge EU demand for agrofuels be sourced 'sustainably', when the EU is already an importer of large amounts of unsustainable commodity products for other uses?

The impacts of deforestation will be the same whether agrofuels are grown directly at the expense of primary forests, or whether they displace other types of agriculture into those forests. There is an established link between commodity prices and deforestation rates, and there are no credible proposals as to how this link can be broken. Nor can certification make monoculture expansion sustainable or 'climate friendly'.

Previous attempt at certification of much simpler industries have largely failed, for example, the Forest Stewardship Certification that has not prevented precious wood sources from being devastated in the global South. None of the proposals for standards or certification has been developed with the support of the local communities whose livelihoods are being directly affected by agrofuel production and who are not being consulted as to whether they wish to see their land turned into monoculture plantations for agroenergy.

Intrinsic limits on 'sustainable' agrofuels

Humans already appropriate about 24% of the net productivity of the biosphere, according to a recent paper by Helmut Haberl et al [52]. Most of the world's arable land is already used for agriculture. Any attempt to replace a significant proportion of fossil fuels with agrofuels will greatly increase human pressure on the biosphere at a time when the extent of habitable and arable land is already shrinking due to global warming and fresh water depletion. The 2005 Millennium Ecosystem Assessment warned that 60% of global ecosystem services have been degraded or destroyed. According to G Huppes and E van der Voet of the University of Leiden, large-scale bioenergy expansion will inevitably reduce and eventually eliminate the space available for ecosystems and biodiversity. As we have discussed, there can be no stable and probably no tolerable climate without large intact ecosystems.

Conclusion:

Agrofuel expansion is accelerating climate change through deforestation, ecosystem destruction, peat drainage, soil organic carbon losses, and the wider effects of increased nitrate fertilization. Life-cycle greenhouse gas assessments, which only look at the micro-level, can capture those wider impacts. Even at the micro-level, there is little scientific consensus, and there are large uncertainties.

Agrofuel policies are being developed without any proper risk analysis having been done. The impacts from the 'worst case scenarios' such as the complete destruction of South-east Asia's peatlands, or the irreversible die-back of the Amazon forest are of such magnitude that they clearly are not risks worth taking. Policies are being developed based on micro-studies, and ignore important secondary impacts which have far-reaching consequences. The wider impacts on loss of natural ecosystems and the global climate have been under-estimated or ignored. Assessment of the evidence demonstrates that when macro secondary impacts are considered, the net impact of increased global agrofuels production is likely to be a reduction of natural carbon sinks and an overall increase in greenhouse gas emissions. Finally, there is strong evidence that the amount of agroenergy which would be required to replace a significant proportion of fossil fuels would greatly increase human pressures on an already vulnerable biosphere, thus further threatening widespread ecological and climate collapse.

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