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Land use, Climate Change and Biodiversity

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Land Use, Climate Change and Biodiversity

A report from the Nordic Genetic Resource Center
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Introduction

All living organisms, both wild and domesticated, are adapted to a certain climate. Some species have a larger tolerance range than others but all have limits. A changing climate will therefore affect the living world in different ways and to different degrees. This in turn will affect the systems the organisms are parts of.

For our future supply of food and other resources we are depending on both agriculture and forestry. They in turn depend on both biodiversity and the climate, directly as well as indirectly via the ecosystems they are parts of and interact with. Land can be used in many different ways. In this discussion 'land use' is the name for the sector that uses land for growing plants or trees, i.e. agriculture and forestry. 'Land use change' denotes an activity where land is converted from a particular type of land use (in the meaning above) to another type of land use, or where land is converted to or from land use in the sense above to or from something completely different. Land use change thus includes for instance converting forestland to agricultural land, converting one kind of forest to a significantly different kind of forest, or converting agricultural land to a residential area.

Both agriculture and forestry are among the activities that are hardest hit by the effects of climate change. At the same time, they are significant contributors to climate change, but have also the capacity to play significant parts in the solutions.

In both cases biodiversity is the key. Unfortunately, some activities used for mitigation of or adaptation to climate change might have negative effects on biodiversity. The trick is to get out of the frying pan without landing in the fire.

Climate change – a threat to biodiversity

Changes in the climate will, as is commonly known, have many different effects. One class of effects that are particularly worrying is effects on biodiversity. We already face a severe human-induced decline in biodiversity, and the pace of the decline will probably speed up even more with a rapidly changing climate.

The changing climate is expected to affect biodiversity in different ways. The rapidly increasing average temperature will in itself have a negative effect on some temperature sensitive life forms. Many of the accompanying effects such as sea level rise, changing precipitation, etc. might have even more serious repercussions for biodiversity than the temperature increase itself. Access to the right amount of water at the right time of year is essential for all life forms. For species in arid environments changing precipitation can be lethal.

When one life form is affected, that in turn will affect other life forms. Even in cases where one life form is affected in a positive way, it can in the next step have negative effects on others. In some cases, especially in areas that today are relatively cold and therefore hostile to many life forms, a milder climate will lead to increased competition from other species. In other cases species will be threatened for the opposite reason. Some species are important for other species as for example food, pollinators, etc. If they disappear other species will be negatively affected. Different species that depend on each other can also be affected differently by climate change. Species in a co-dependent system will have difficulties coping with a situation where one species has to move in one direction in a certain pace while another has to stay or move in a different direction or in a different pace because of differences in climate tolerance that did not matter before. In some cases these relationships are quite complicated and it is not always possible to foresee the effects beforehand.

It is also not just a matter of the mean temperature increase. The variations from the mean are also important limiting factors. It is not enough to be well adapted to a particular temperature or amount of rain. In reality organisms have to be adapted to a certain temperature range and to conditions that change during the day and the year. When both amplitude and frequency of the variations increase it will probably disfavor specialists and favor generalists. This means the diversity will decrease.

Biodiversity is not just important *among species*. We also have diversity *within species* as well as *between ecosystems*. Significant changes on the ecosystem level can have very serious effects for all life forms, including our own. We depend to a large extent on so called ecosystem services. The ecosystem services provide oxygen, pollination, protection against erosion, protection against flooding, improved soil fertility, nutrient cycling, “pest” control, etc. It is very likely that the changes in the climate will affect the ecosystem services. The effects of climate change on the ecosystem services have not received the same attention in media or in political negotiations as some of the other expected effects, possibly because these effects are a bit more difficult to understand both for the general public, and in fact also for the scientists. Even so, it is important not to neglect these effects that might in fact be the most serious of all effects from climate change.

Diversity within species (intraspecies diversity) is important for many different reasons. One is that the resilience of a species depends to a large degree on its genetic diversity. When things change in its environment, be it in the form of diseases, new predators or other changes, it is vital that the species contains a variety of properties for evolution to "choose" from. If the species contains enough diversity, some individuals will have the right properties to survive the disease, the new predator, the new climatic conditions etc. If the change in the environment is not happening too fast, the species will evolve based on its internal diversity. If a rapid change such as the changing climate causes many populations or varieties of a species to disappear, the species might not be able to respond to the next outbreak of a new disease. This means that a disturbance that does not on its own causes a species to go extinct, but severely affects its internal diversity, may still contribute to the extinction of the species in a later phase.

Different populations of the same species possessing different properties can also play important roles in different ecosystems. If a population that plays an important role in a particular ecosystem disappears, it will not help the system, or us, that other populations of the same species but with somewhat different properties survive in other areas.

Diminishing biodiversity is thus a very serious problem for us and maybe the most serious of all effects from climate change. As we will see soon, the diminishing biodiversity on different levels will also affect our ability to adapt to and mitigate climate change.

Apart from the effects a diminishing biodiversity has on us humans, it obviously also has severe effects on other sentient beings. So far, other species have played a very limited role in climate negotiations, and they have only been considered to the extent that they have some kind of value for us humans. This does however not reflect the development in ethics during the last decades. According to this development there is an increasing acceptance that all sentient beings are entitled to ethical consideration.

Climate change – a threat to agriculture and forestry

Both agriculture and forestry are very climate sensitive. The changing climate will lead to many new challenges for both agriculture and forestry. For instance:

- The increasing temperature and changes in precipitation and salinity will mean that some crops in some areas will grow bigger and faster and ripen earlier, while the same crop in other areas, and other crops in the same area will be stressed and not ripen at all. In some cases the growing season will be shorter. In other cases it will be longer.
- We will see some of the best lands become covered by water, while others will be affected by drought. Some lands will be degraded due for instance to salinization or erosion, while some will turn into deserts. Degradation of grasslands is expected to lead to productivity losses of between 40 and 90 % if the temperature increases by 2-3ºC.
- There is a risk for an increased number of wildfires and storms, and also for more violent storms. Both wildfires and storms are expected to cause severe damage on the forests, especially in combination with a drier climate that affects the trees' resistance to wind and fire.
- A changing climate will lead to an increase in diseases and so called pests that are detrimental to both agriculture and forestry. It will also let them spread into new areas and become a threat to agriculture and forestry in these areas. Here too reduced resistance in trees and crops will worsen the problem.
- Even worse than the mean changes in temperature, sea level, precipitation, winds, etc, are the extremes and the expected increase in variations from the mean values. The climate models warn that the climate will change faster and may even take sudden leaps, and that the weather will be more varying and more extreme. This will further complicate the lives for the farmer and the forester.
- Some things change in different directions while some things do not change at all or too slowly to have any discernible effect. The time when the sun rises and sets depends on the latitude and time of year and is not affected by climate change. Plants and animals whose life cycle is controlled by the sun will therefore not easily adapt to a changing climate, and might not be better off by moving to another climatic zone. Some organisms that are depending on each other may be affected differently by climate change. This means that just moving species and varieties between climatic zones will not always be a solution for agriculture and forestry when the climate changes.

These challenges will affect not only farmers and forest owners. They will in fact affect everyone in the form of a declining production rate for some important resources. The probably most serious result will be in the form of an unsecure food production. This in turn may cause health problems most notably in the form of undernourishment and starvation for vulnerable groups. In addition to this, we may also see economic and political problems in the form of high food prices and food riots.

Some of the changes in some areas have the potential to be for the better. It is expected that a warmer climate in some parts of northern Europe will lead to a higher productivity. This too implies some challenges however. We will need to adapt management, technology and crops to make optimal use of the new circumstances. There will also be a pressure to convert other types of land to agricultural land, and to protect land that is currently dedicated to agriculture against other uses such as building houses, roads, etc.

The role of biodiversity in adapting to climate change

In this section I will say a few words about how a sustainable use of biodiversity can play an important role in taking on the challenges listed in the previous section. Let us take a look at the challenges above one by one.

How can we deal efficiently with a situation where climate change is affecting the growing conditions in such a way that "some crops in some areas will grow bigger and faster and ripen earlier, while the same crop in other areas, and other crops in the same area will be stressed and not ripen at all", and where "[i]n some cases the growing season will be shorter [and i]n other cases it will be longer"? We need to find ways to both alleviate the effects of the negative changes, and to make optimal use of the positive changes. One important step is to use different crops. In order to adapt to the negative changes, we need to find crops that are less prone to heat stress and crops that can make the most of a limited water supply. In order make optimal use of the positive changes we will need crops that can make use of longer growing seasons. To utilize the longer season we need plants that can be productive also in periods with less daylight since the seasonal changes in day length will not change. Considering that the changing climate will have different and sometimes opposite effects in different areas (some areas will be drier, some wetter, some will have longer growing seasons, other will have shorter, etc) we will probably need to grow different crops in different areas. This is of course done already today but it will be even more important to use locally adapted crops in the future.

How do we find plants that are suitable for these new conditions? We have three options: (1) Find wild plants that have the desired properties. (2) Find and make better use of local varieties of crops that have the desired properties. They may for instance presently be or previously have been grown in areas with a local climate and other circumstances that are close to those we expect more of in our part of the world in the future. (3) Breed new plant varieties that have the desired properties.

All three options have one thing in common: They are heavily dependent on biodiversity. Option (1) presupposes a large selection of wild species and varieties where we can find what we need. Option (2) presupposes a large selection of cultivated species and varieties. Option (3) presupposes a large selection of both wild and cultivated plants. Breeding means crossing of individuals with attractive properties in order to promote certain properties and suppress others. In order to find individuals with the right heritable properties it is important to have a large diversity of genetic make ups to choose from. This includes both cultivated varieties and wild relatives.

If we are prepared to use modern biotechnology we can move genes across species boundaries, which means that all genetically heritable properties in nature can be of interest. If we talk only about traditional breeding it is in general necessary to stay within the species boundaries. The interspecies diversity is then particularly important. Biodiversity protection in nature aims in general at protecting the diversity on the species level. It is however important not to neglect interspecies diversity. Climate change makes this extra important both because climate change poses a threat to interspecies diversity (see above) and because interspecies diversity is of the greatest importance for adapting to climate change.

Conserving the biodiversity within cultivated species is a challenge in its own right since it is difficult for niche breeds to compete economically with big commercial brands. Many countries and also international organizations try to preserve such crop varieties both ex situ and in situ, but more needs to be done.

Protecting interspecies diversity in wild species poses a different kind of challenge. The threats to interspecies diversity are in general the same as the threats to species diversity. The difference is that it takes less to drive a sub-species to extinction than to cause an entire species to go extinct. If a disturbance is sufficient to drive a variety with certain properties to go extinct, other varieties with different properties might not be affected. If a population disappears in one area the species might still thrive in other areas. In order to protect diversity within and not just among species we cannot be content that a small number of populations of the species live on. We need to protect the different populations and varieties. In order to do that we need to go further in our protection both regarding what types of disturbances we can tolerate, and regarding how large population declines we can tolerate. When our aim is to conserve wild plants as genetic resources we have to use both in situ and ex situ conservation. Protecting the diversity on site in the form of living, reproducing plants is important for several reasons. Firstly, a selection of seeds preserved in a freezer is just that: A selection. For most species we cannot capture the whole diversity in this way, especially since knowledge of within species diversity is often lacking. Secondly, in nature the plants are subject to natural selection, and also exert selective pressure on other species. This means that as long as they are alive in nature and the populations are sufficiently large and diverse, new adaptations have a chance to evolve. Seeds in the freezer cannot evolve or exert selection pressure on other species. They can on the other hand capture a slice of the genetic diversity existing at a certain place at a certain time, and preserve it from both anthropogenic disturbance and further evolution, which means it is important to complement the in situ conservation with ex situ conservation. Genebank seeds are also important as they render the material accessible at any time. Plants in nature bear seeds only for limited periods of the year, while genebank material is accessible all through the year. The ideal solution when it comes to conserving genetic resources is to have ongoing evolution and functioning ecosystems in nature and, conserved germplasm in the form of seeds, in the genebank.

To preserve biodiversity on site in nature is of course also important for other reasons. That is for instance the only way the organisms and their properties can play their roles in the ecosystems and thereby contribute to the ecosystem services. It is also the only way biodiversity can be useful for other life forms, i.e. from a non-anthropocentric perspective.

The next challenge in the list in the previous section was about disappearing land and land degradation. In order to adapt to that, we need to have more tolerant crops and also be more productive on the remaining lands, and possibly also cultivate new lands. We can deal with this in different ways. We can for instance clear more forestland and use more intensive farming with a larger input of fertilizers and fossil fuels. To do that is not very sustainable however. It will also worsen the problem we are trying to adapt to, i.e. climate change. Another way of compensating land loss and land degradation is by using different crops that are either more productive or more tolerant to the changed circumstances. This can be achieved by any or all of the three methods (1), (2) and (3) above, which again means that biodiversity is a key to the solution.

The third challenge was about storm and fire. Wildfires are already becoming more frequent, and there is also a suspicion that both the number and the severity of storms may increase as a result of climate change. These problems can to a degree also be counteracted by the help of more storm resistant crops and trees. Methods (1)-(3) mentioned above will therefore be relevant also here. In the case of storms and wildfires, management will also play a large role. Management also includes a sustainable use of biodiversity in the form of resilience promotion and risk spreading. One way of preventing fire and storm damages is for example to use screens of more stable tree species and in general to use the right combination of trees.

The next challenge was about diseases and pests. These problems can also be handled in two diametrically different ways. They can at least in a short perspective be handled by an increased use of chemicals. This is however probably not a sustainable way of approaching the problem. This method might also create new and very serious problems by upsetting important ecosystem services. The other method is through a sustainable use of biodiversity. This can be done by using more resistant varieties found through methods (1)-(3) above, and by using ecosystem services. As we have already seen, both options are totally depending on biodiversity. There are also indications that a larger biodiversity in an area helps fight of pests.

The challenge posed to agriculture and forestry by extreme weather and by large and sudden variations in the weather will make it more difficult for both farmers and foresters to plan both annual and long term activities. This challenge can to some extent be alleviated by using species and varieties with a larger tolerance range, but it is also important to spread the risks. Risk spreading has to be done by both the society and the individual farmer or forest owner. The society has to see to that people will have access to food and other resources while the individual farmer needs to avoid a situation where she loses everything due to a particularly bad year.

Redistribution of resources within the country and import of resources from other countries are important ways for the society to limit the bad effects from extreme weather and increased variability in the weather. If these situations occur often or the entire production of a crop in the area is hit simultaneously this will be both expensive and politically strenuous. An increased mobility of food and other resources can also contribute to worsen the climate change if fossil fuels play a large role in the transportation systems.

Insurance is an important means for the individual to share risks with others. This too will be expensive if the situations that are insured against occur more often.

One way of dealing with the challenge of extreme variations that can be used on both the individual and the societal level is to spread the risks by growing a wider variety of plants and trees. In a world with a relatively stable climate where surprises are few and small, it might be most rational to grow a few high yielding crops that give best outcome on average, and therefore the best total outcome over time. In a future where the variations will be more extreme, more frequent, and harder to predict, this will no longer hold true. It is not possible to find one crop that can give maximum yield under an extremely wide range of different circumstances. Different species and varieties have different degrees of resistance to drought, insects, etc. This means that both the farmer and the society need to spread the risks by growing different species and varieties. It is not possible to predict whether a particular growing season will be extremely dry or wet or maybe hit by a hurricane, or an invading swarm of locust. Biodiversity is therefore not just a basis for new species and varieties, but also an insurance policy for both the individual farmer and the society against the increased inter- and intra-seasonal variability.

The last of the challenges listed in the previous section (though certainly not the last possible challenge to agriculture and forestry posed by climate change) was about the fact that some things change in different ways, and some things do not change at all or at least very slowly. This makes it difficult to adapt agriculture and forestry to climate change by simply moving species between areas. One could imagine that if a certain part of the world is expected to get a type of climate that used to be prevalent in another part of the world we could simply move plant and tree species from one area to the other. Unfortunately however things are not always as "simple" as that. This means that the biodiversity we need for methods (1) and (2) above has to be even larger than it would otherwise have to be in order to find crops that are adapted not only to the new climate but also to other circumstances such as day length and relations to other organisms. In cases where it will not be possible to find any suitable plant or tree among either wild or cultivated varieties, method (3), i.e. breeding, will play a more important role. As we have seen this method depends heavily on the existence of both wild and cultivated varieties with suitable properties that can be enhanced and combined in a way that suite our needs. Even here we are therefore absolutely dependant on biodiversity in wild as well as cultivated species.

Land use and land use change – a part of the problem

Agriculture and forestry contribute about 15 Gt of CO2-equivalents/year to the atmosphere. Deforestation is the largest contributor from this sector with 8 500 million tons of CO_2-equivalents/year, which is about 17% of the anthropogenic greenhouse gases. Agriculture contributes 6 500 million tons of CO_2-equivalents/year, which is about 13% of the anthropogenic GHG-emissions. Land use and land use change is thereby behind almost one third of the anthropogenic GHG-emissions measured as CO_2-equivalents. CO_2 makes up the largest part of both the total amount of anthropogenic GHG-emissions, and the emissions from land use and land use change. Most of the anthropogenic emissions of CH_4 and N_2O originate from agriculture that contributes about 60% of the N_2O-emissions and 50% of the CH_4-emissions. The emissions from land use change are mostly caused by conversion of forestland to agricultural land. Since forests in general store more carbon than agricultural land, this leads to a net emission of carbon. Grassland is also a relatively large carbon sink that has regularly been converted into agricultural land. It is estimated that over the past 140 years land use in the form of conversion of forests and grasslands into agricultural lands has led to a net release of 121 Gt C. In addition to that, carbon is released when wetlands are drained to make more agricultural land and the soil thereby becomes exposed to oxygen. Both forests and grasslands can also be degraded in their role as carbon sinks even if they are not converted into another type of land. Many grassland areas are for instance overgrazed which leads to a net loss of stored carbon. Forests can also be managed in many different ways that might be suitable for other purposes but make them less suitable as carbon sinks.

The net loss of carbon when forests and grasslands are converted to agricultural land does not only come from the trees. Much carbon is stored in the soil, and in case of forests also in the litter. The carbon stored in the soil and in the litter is exposed to oxygen and emitted as CO_2 when the land in converted.

Agriculture releases greenhouse gases in the form of CO_2, CH_4 and N_2O primarily as a result of plowing, planting, harvesting, rice cultivation, cattle breeding, burning, fertilization, and use of fossil fuels.

The role of land use and biodiversity in mitigation of climate change

The releases of greenhouse gases from both land use and land use change can be mitigated however. In fact, both agriculture and forestry have the potential to store large amounts of carbon and thus help us deal with some of the emissions caused by other sectors.

IPCC divides the methods for achieving this change into 4 categories:

- Activities that increase or maintain forested areas.
- Activities that manage forests to store more carbon.
- Activities that manage non-forested lands to store more carbon.
- Activities that reduce dependence on fossil fuels through product substitution (including both production of biofuel that can substitute fossil fuels, and production of wood products that it takes

less energy to produce compared to products from other materials, and that also stores carbon at least for a while).

Each of these four categories is made up by several more specific activities. The first category is relatively straight forward. Deforestation is as we saw above one of the major contributors to climate change and has to be stopped or at least limited. In addition to stopping or limiting deforestation we can increase the forested area. This can be done by reforestation or afforestation, i.e. by planting forest on areas that have recently been covered by forest, or by planting forest on areas that have not recently been covered by forest. The difference between the two is a matter of how we define 'recent' and the distinction is not sharp.

All activities in this category (afforestation, reforestation and protecting forests from deforestation) depend in different ways on biodiversity. In order to cover a previously non-forested area with forest in a way that is sustainable in the long run we need the forest to be a functioning ecosystem. In order to achieve that it is necessary to have access to trees adapted to the local climate and local environment. Trees are not the only organisms that make up a forest however. Also other organisms are necessary to build a sustainable self-regenerating ecosystem. In many cases an ecosystem will establish itself if there is a flora and fauna of suitable organisms that can move into the reforested/afforested area, and if the soil is suitable for sustaining a suitable flora and fauna. In some cases especially in tropical areas the soil will quickly be eroded and re-establishment may be virtually impossible or take a very long time.

Also in order to protect a forest from disappearing or even from being degraded, biodiversity is essential. Even though trees are the most salient organisms in a forest they are in fact dependant on other organisms. Mycorhizza where the roots of a tree work in symbiosis with fungi is a good example. Another example is birds and other animals who help the trees to spread their seeds. In order to protect the forest it is therefore important to protect the entire ecosystem. Even if a forest is not clear cut, its ability to sequester and store carbon can be degraded. It might be the case that biodiversity in general makes the forest more resilient though this is a controversial question.

Activities that manage forests to store more carbon are generally aiming at longer turnover times, and/or more biomass. To achieve this it is necessary to have access to the right tree species. This in turn calls for essentially the same methods mentioned in the section on adaptation, viz. (1) Find wild species or varieties with the desired properties. (2) Find cultivated local varieties with the desired properties. (3) Breed varieties with the desired properties. We can therefore conclude that even here biodiversity is the key.

Managing non-forested lands to store more carbon include a wide variety of activities of which several are more or less depending on biodiversity. These are for instance:

Improved rice cultivation techniques. Rice fields emit large amounts of NH_4. It is important to change the cultivation methods in a way that leads to a decrease in the NH_4-emissions without reducing the production of rice. Preferably the rice production should increase at the same time as the climate impact of the rice production should decrease. Finding new techniques that fulfill this dual goal is one of the big challenges for humanity. Different rice varieties will probably play an important part in the solution. To find or develop these varieties we will need access to a large array of genetic variation.

Reduced tilling. Tilling exposes the soil carbon to oxygen that reacts with the carbon, and as a result CO_2 is emitted into the atmosphere. By reducing tilling it is possible to decrease the leakage and even turn the soil into a net carbon sink. To do that without impairing the food production is a great challenge. It will be necessary to improve farming techniques, technology and crops. To find or develop crops that are better adapted to low tillage farming we will need the three methods (1)-(3) described above. Subsequently we will need a large diversity of both wild and cultivated plants where we can find either the plants we need or suitable properties that we can use to breed new varieties.

Reduced fertilization. Manufacturing and spreading of fertilization produces large amounts of CO_2. Nitrogen fertilization is also the largest source of anthropogenic N_2O. To be able to reduce the emissions caused by fertilization without jeopardizing food production the key is the same as for reducing tilling, i.e. improved farming techniques, new technologies and crops that can better utilize the nourishment and therefore need less fertilization. Depending on what techniques and technologies are chosen, technique and technology development will probably also need or at least benefit from finding or developing new crops. To find or develop these crops we need a great array of biodiversity to choose from.

Crop rotation. Improved and increased use of crop rotation is one of the techniques that can help us reduce the need for fertilization. It can also be used for sequestering carbon and transfer it to the soil where it can be stored. To improve this technique and make it more economic and user friendly we need to find or develop suitable crops by using the methods (1)-(3) above.

Cover crops. One way of decreasing the leakage of carbon from the soil is to keep it covered during a larger part of the year. To find or develop the best cover crops we again need a variety of both cultivated and wild species and varieties to choose from, or to use for breeding of new more suitable varieties.

Lower input of fossil fuel. Modern agriculture is uses a large input of fossil fuels. There are essentially two ways of reducing the use of fossil fuel in agriculture, viz. by fuel substitution and by becoming more energy efficient. In order to decrease the need for energy in agriculture we need exactly the same approach as we have seen earlier, i.e. new techniques, new technology and more well adapted crops, which means that we need biodiversity among both wild and cultivated plant species and varieties. When it comes to reducing the energy input it is particularly important to look at the possibility of using local varieties that are better adapted to the local environment and therefore need less caretaking. This in turn means that we will not be able to use the same species and varieties everywhere, which further emphasizes our dependence on biodiversity.

Substituting fossil fuels with other fuels will be important not just in agriculture but also in the society at large. Both agriculture and forestry can here play a role as producers of biofuel, which brings us to the last point of IPCC's list presented above of ways for agriculture and forestry to help mitigate climate change: Fuel substitution. In order for fuel substitution to have the desired effect, we need to take care that the production of biofuel will not in turn use large inputs of fossil fuel, call for farming methods that increase carbon leakage from the soil, result in deforestation etc. Just as with management of non-forested land we will also have to take care not to jeopardize food production, in this case by not supplanting land and other resources (such as water) needed for food production. In order to accomplish this balancing act we will need access to suitable energy crops or trees, and just as in the previous cases we depend on biodiversity to find or develop plants or trees with the desired properties.

If we want to substitute products with wood products (and other organic products) that take less energy to produce and store carbon we again need to use well suited species and varieties. This in turn means that we also in this case are depending on biodiversity.

On how not to solve one problem by worsening another

The battles against climate change and against the loss of biodiversity often go hand in hand. One of the largest causes of both climate change and loss of biodiversity is deforestation, especially in tropical areas. Protecting forests in general and tropical forests in particular will in general be a good way of promoting both climate mitigation and biodiversity conservation. In some cases however the two aims compete with each other. Planting forest on land that has not recently been forested (afforestation) will typically increase biodiversity but there are exceptions. If a species rich meadow is converted into a spruce plantation it will in most cases lead to reduced biodiversity.

Managing forests with the aim of optimizing carbon sequestration and storage can also have negative effects on biodiversity. One type of intervention that is used to increase the amount of biomass in the forest is fertilization, which has a negative effect on many forest organisms. Increased forest density also means that less light will find its way to the ground which in many cases has a negative impact on the ground flora and other ground living organisms. Some species, populations, etc, that are less competitive live in areas with low biodiversity. If the habitat is changed in order to store more carbon, that particular species, population, etc, will be negatively affected even if the change increases the total biodiversity in that particular area. This means that the global diversity decreases even though the local diversity increases. Some agricultural lands are for instance homes for rare species or special varieties that will be threatened if the land is converted to forest or grassland.

Biofuel production often competes with both food production and biodiversity. Land that is converted to biofuel production often loses biodiversity.

In several places I have mentioned breeding as a way of improving our odds to mitigate or adapt to climate change. Breeding is heavily dependent on biodiversity but in many cases the new varieties that result from the breeding compete with both the old land races and with wild species. They can ironically be a threat to the biodiversity that future breeding depends on. It is therefore important to take care not to destroy the source of genetic resources for further breeding as well as the source for many other goods such as ecosystem services.

We noted above that in some parts of the world the conditions for agriculture will probably improve as a result of climate change. This means there will be a need and an economic incentive to convert other types of land to agricultural land. This in turn may result in an increased pressure on nature reserves and other areas that are important refuges for threatened species.

Considering the immense importance of biodiversity for a number of goods and services including its importance for mitigation of, and adaptation to, climate change, it is immensely important not to fall victim of the temptation to meet the challenges from climate change by sacrificing biodiversity.

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