# Scientific summary (abstract)

The land area of the Earth greatly influences climate dynamics through biogeophysical and biogeochemical processes. These processes concern, respectively, the exchange of energy and water, and the exchange of greenhouse gasses (GHGs) such as CO2, CH4 and N2O, between land systems and the atmosphere. By using the Earth’s land surface, humans have greatly altered it – leading to significant environmental impacts. Historically, climate change has mostly been caused by fossil fuel combustion. Land use, land-use change and forestry (LULUCF) have caused an estimated 34% of cumulative anthropogenic CO¬2 emissions since 1750. At the same time, agriculture is responsible for about 13% of global GHG emissions in the form of non-CO2 GHG emissions. The importance of land and land use in climate dynamics means that land has a role in preventing dangerous climate change. First, it is essential to significantly reduce the 23% of annual GHG emissions from the agriculture, forestry and other land use (AFOLU) sector to make ambitious climate targets feasible. Second, land is key to various techniques to remove carbon from the atmosphere (so-called negative emissions or carbon dioxide removal (CDR)). In this thesis, a large portfolio of land-based mitigation measures is assessed in the context of different land-use futures. In addition, detailed analysis are provided on two key land-based mitigation measures: afforestation, and peatland protection and restoration. In addition to climate, land is central to many other sustainable development issues and environmental challenges. For example, it is essential for the provision of resources such as food, energy and water, as well as to sustain terrestrial biodiversity, as also recognized in the Sustainable Development Goals and the planetary boundaries. A useful approach to study different dimensions of sustainable development and environmental change is the nexus concept which recognizes that components of a system are inherently interconnected and must be investigated and managed in an integrated, holistic manner. In this thesis, the water-land-energy-food-climate (WLEFC) nexus is addressed, taking into account trade-offs and synergies between these different systems in achieving multiple goals. Scenario analysis can be used to explore the role of land use in climate change and climate change mitigation, and for other societal goals related to the WLEFC nexus. An important ambition of the scientific community is to develop scenarios that achieve both climate and other environmental and sustainability goals such as the PBs and the SDGs. In this thesis, we use exploratory scenarios that investigate how the future might develop under pre-defined assumptions, as well as normative scenarios that aim for pre-defined targets and describe pathways that could achieve these goals. Examples of targets are stabilizing global warming, nature protection or limits to water extraction. These scenarios are developed using the IMAGE integrated assessment model framework

# Laymans summary (nl)

Landgebruik en klimaatverandering zijn nauw met elkaar verbonden. Bijvoorbeeld, door uitstoot van broeikasgassen uit de landbouw of ontbossing, door bio-energie, of door het planten van bomen om klimaatverandering tegen te gaan. Daarnaast is landgebruik van groot belang in andere milieuproblemen, bijvoorbeeld droogte, teveel stikstof, en natuurverlies. Ook voor de levens van mensen is land essentieel, denk aan de beschikbaarheid van voedsel en water.

In dit proefschrift beschrijf ik mijn onderzoek naar de toekomst van landgebruik op de wereldwijde schaal. Het onderzoek is gedaan met behulp van computermodellen. In de eerste plaats in de context van klimaatverandering: hoe zal landgebruik in de verre toekomst eruit zien (t/m het eind van de 21e eeuw) in verschillende scenario’s, en wat is het effect hiervan op het klimaat. Ik heb ook bekeken wat maatregelen kunnen doen om klimaatverandering tegen te gaan: bijvoorbeeld herbebossing, het beschermen en herstellen van veengebied, het gebruik van bio-energie en minder vlees eten. Als laatste heb ik de interactie tussen klimaatbeleid, milieuproblemen en de levens van mensen geanalyseerd.

De conclusie is dat landgebruik een essentiële rol speelt in zowel de oorzaak als de oplossing voor klimaatverandering. Herbebossing, veengebieden, bio-energie en minder vlees kunnen een flinke bijdrage leveren in het beperken van klimaatverandering. Echter, niet zo groot als het stoppen van het gebruik van fossiele brandstoffen. Herbebossing en bio-energie kunnen ook negatieve effecten hebben, zoals voedseltekorten of teveel watergebruik. Minder vleesconsumptie is echter goed op alle fronten, zoals het tegengaan van klimaatverandering, het beperken van natuurverlies, minder watergebruik en vervuiling.

# Laymans summary (eng)

Land use and climate change are closely related. For example, through greenhouse gas emissions from agriculture or deforestation, through bioenergy, or through planting of forest to combat climate change. In addition, land use is also of great importance for other environmental problems such as drought, too much nitrogen, and loss of nature. Also for people’s livelihoods land is essential, such as for food production and the provision of water.

In this thesis, I describe the research that I did on future land use at the global scale. The work has been done using computer models. First, in the context of climate change: what will land use in the long-term future look like (i.e. up to the end of the 21st century) in different scenarios, and what is the effect of land use on climate change. In addition, I looked into measures that can counteract climate change: for example afforestation, protection and restoration of peatlands, using bioenergy and less meat consumption. Finally, I studied the interactions between climate policy, environmental problems and people’s livelihoods.

I conclude that land use plays an essential role in both the cause and the solution of climate change. Reforestation, peatlands, bioenergy and less meat can substantially help to limit climate change. However, stopping fossil fuel use is the largest measure that is needed. Reforestation and bioenergy can also have negative effects, such as food shortages or too much water use. Less meat consumption is a win-win strategy, as it combats climate change, reduces nature loss and limits water consumption and pollution.