EGU21-16111
https://doi.org/10.5194/egusphere-egu21-16111
EGU General Assembly 2021
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Bioenergy potentials from recently abandoned cropland under the land-energy-water nexus

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Bioenergy plays a key role in scenarios limiting global warming below 2°C in 2100 relative to pre-industrial times. Land availability for bioenergy production is constrained due to competition with agriculture, nature conservation and other land uses. Utilizing recently abandoned cropland to produce bioenergy is a promising option for gradual bioenergy deployment with lower risks of potential trade-offs on food security and the environment. Up until now, the global extent of abandoned cropland has been unclear. Furthermore, there is a need to better map bioenergy potentials, taking into account site-specific conditions such as local climate, soil characteristics, agricultural management and water use.

Our study spatially quantify global bioenergy potentials from recently abandoned cropland under the land-energy-water nexus. We integrate a recently developed high-resolution satellite-derived land cover product (European Space Agency Climate Change Initiative Land Cover) with an agro-ecological crop yield model (Global Agro-Ecological Zones 3.0). Abandoned cropland is mapped as pixels transitioning from cropland to non-urban classes. We further identify candidate areas for nature conservation and areas with increased pressure on water resources. Based on climatic conditions, soil characteristics and agricultural management levels, we spatially model bioenergy yields and irrigation water use on abandoned cropland for three perennial grasses. We compute and analyze bioenergy potentials for 296 different variants of management factors and land and water use constraints. By assessing key energy, water and land indicators, we identify optimal bioenergy production strategies and site-specific trade-offs.

We found 83 million hectares of abandoned cropland between 1992 and 2015, equivalent of 5% of today's cropland area. Bioenergy potentials range between 6-39 exajoules per year (EJ yr^{-1}) (11-68% of today's bioenergy demand), depending on agricultural management, land availability and irrigation water use. We further show and extensively discuss site-specific trade-offs between increased bioenergy production, land-use and water-use. Our high-end estimate (39 EJ yr^{-1}) relies on complete irrigation and land availability. When acknowledging site-specific trade-offs on water resources and nature conservation, a potential of 20 EJ yr^{-1} is achievable without production in biodiversity hotspots or irrigation in water scarce areas. This is equal to 8-23% of median projected bioenergy demand in 2050 for 1.5°C scenarios across different Shared Socio-economic Pathways. The associated land and water requirements are equal to 3% of current global cropland extent

and 8% of today's global agricultural water use, respectively.