AGROFORESTRY TRADE-OFFS BETWEEN BIOMASS PROVISION AND ABOVE-GROUND CARBON SEQUESTRATION

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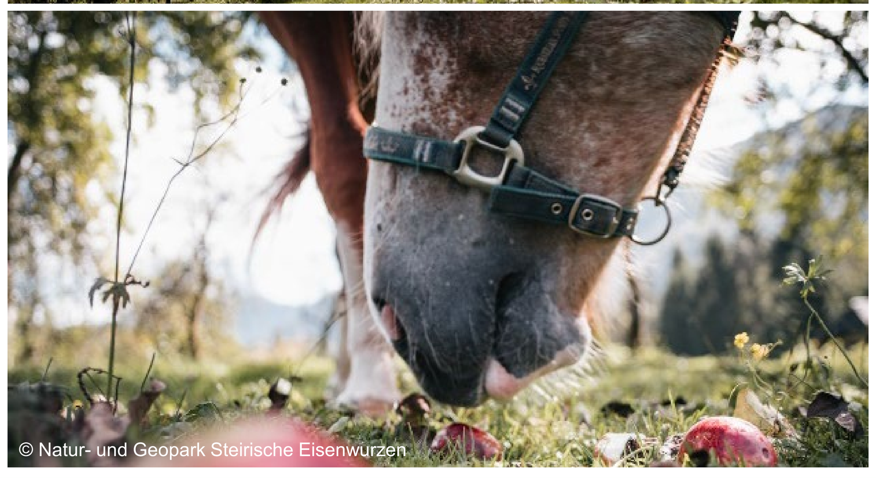
BACKGROUND

- **Traditional meadow orchards (“Streuobstwiesen”) were abundant in the Eisenwurzen region**, providing food, feed and fibre as well as biodiversity-rich habitats. Socio-economic drivers led to the quasi-disappearance of this land-use system during industrialization of agriculture in the 20th century.
- **Meadow orchards are typical agroforestry systems: a combination of woody vegetation with crops and/or livestock on the same unit of land.** They are integrated, multi-functional land-use systems, with large potentials for mitigating and adapting to climate change, combating biodiversity loss, erosion and eutrophication.
- **Recent activities in the region aim at maintenance, rejuvenation and replanting of meadow orchards**, preserving old and rare fruit tree varieties, supporting harvesting, processing and marketing of “Streuobst” products, and promoting its cultural heritage for tourism.

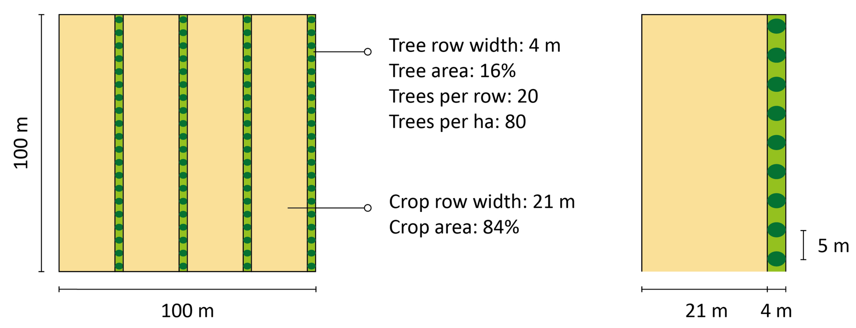
SCIENTIFIC OBJECTIVES

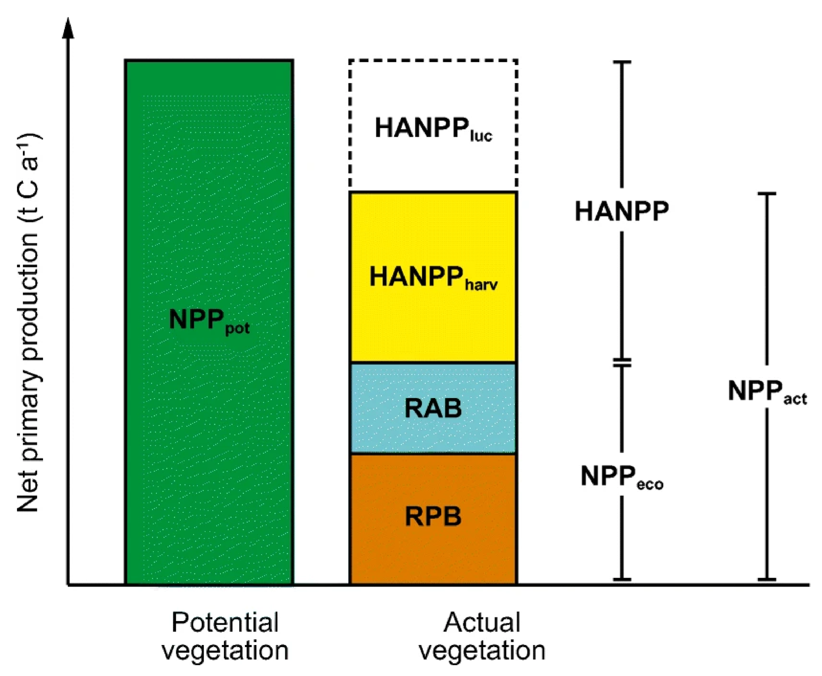
- Explore the **biophysical option-space** for a landscape-scale implementation of agroforestry in the region.
- **Quantify the above-ground carbon dynamics** of a business-as-usual and two agroforestry scenarios between 2020-2050 (resp. 2020-2080).
- **Focus on the trade-offs between “biomass provision” and “carbon sequestration”** to highlight a potential conflict between climate change mitigation and the provision of food, feed and fibre.



METHODOLOGY

- **Definition of a prototypical agroforestry system** assuming the integration of 80 wild cherry trees (Prunus Avium L.) per hectare, applied to all available crop- and grasslands in the study region.
- **Simulation of plot-scale growth dynamics in arable and agroforestry systems** (2020-2080) using Yield-SAFE model [1], parameterized with local soil data (eBOD) and climate projections (RCP4.5).
- **Upscaling of plot-scale growth dynamics to the landscape-scale** using simulations of future land-use change from SECLAND model (2020-2050) [2], based on the decision-making of agricultural actors under the SSP1 pathway.
- **Quantifying the carbon dynamics using an extended version of the HANPP framework,** representing fluxes of net primary production (NPP-pot) to account for the amount of carbon appropriated by humans [3].
- **Comparison of land-use scenarios** using conventional agriculture as a baseline scenario (AGR), differentiating between a gradual agroforestry implementation between 2020–2045 (AFS-GRAD), and an immediate agroforestry implementation in the year 2020 (AFS-IMM).

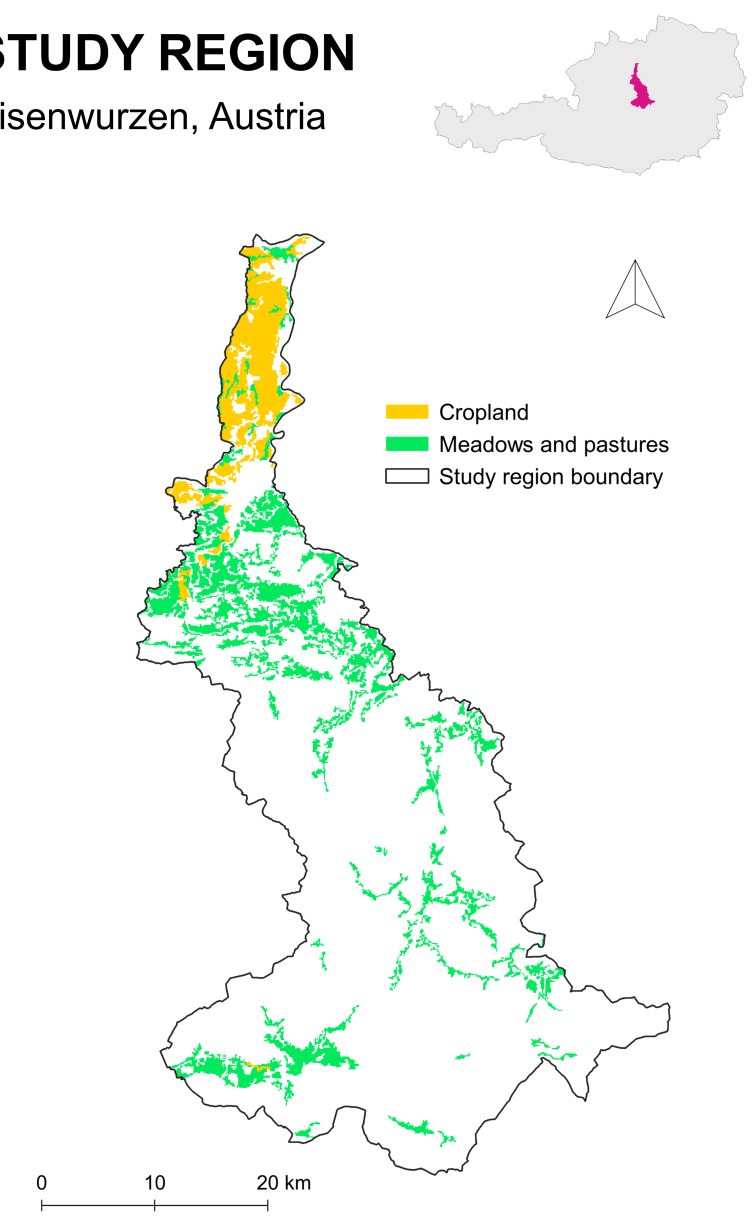




Human Appropriation of Net Primary Production (HANPP) representing the amount of C appropriated by humans (HANPP) through land-use change (HANPP-luc) and harvest (HANPP-harv), as well as the amount of C remaining in the ecosystem (NPP-eco) in the form of annual and perennial biomass (RAB, RPB). Adapted from Haberl et al. (2014).

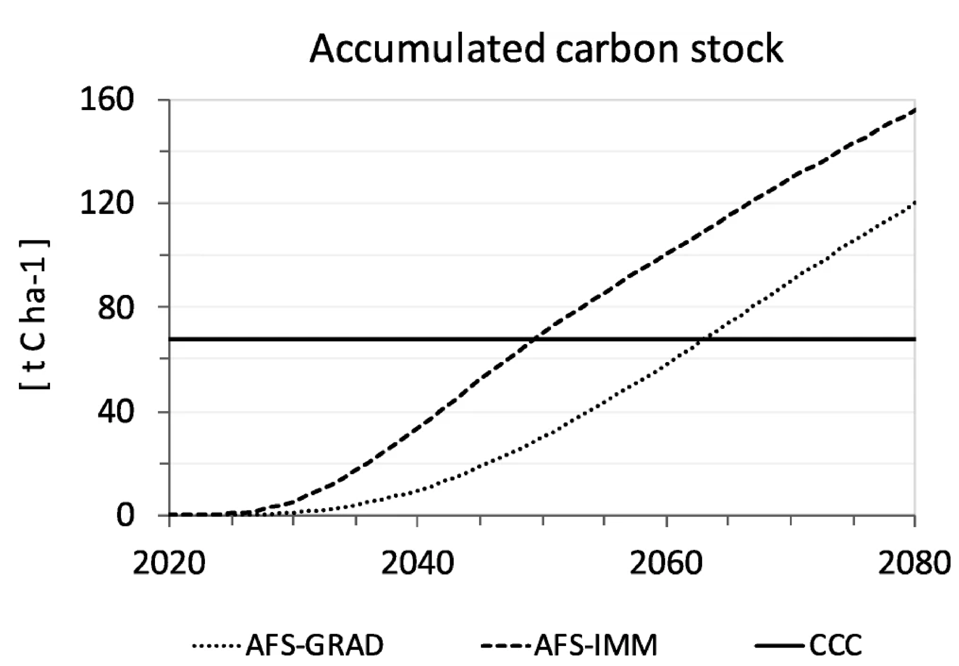
STUDY REGION

Eisenwurzen, Austria

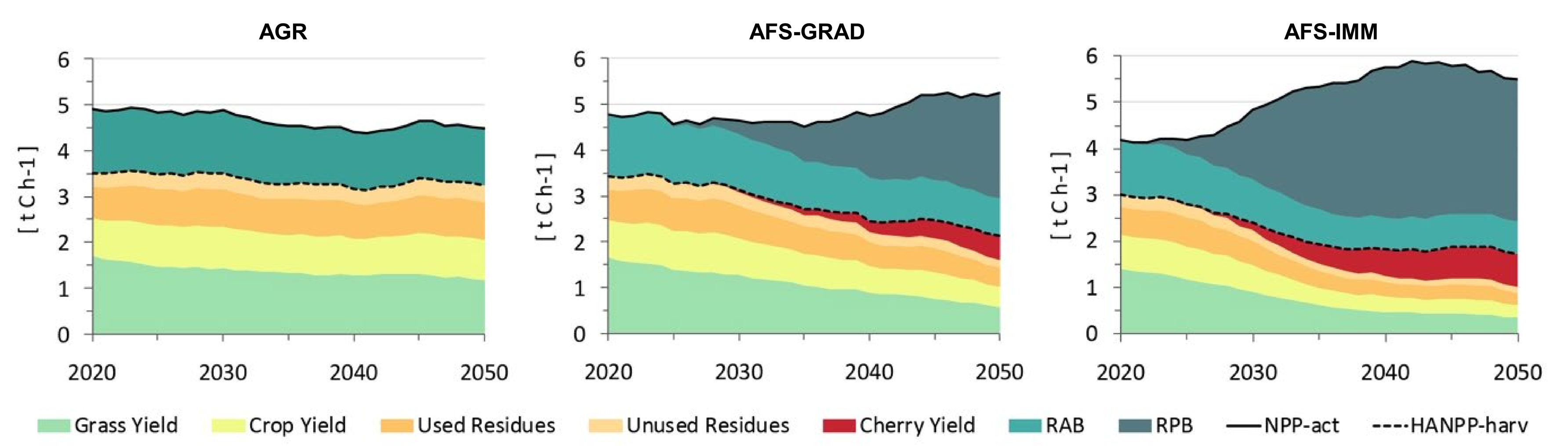


RESULTS

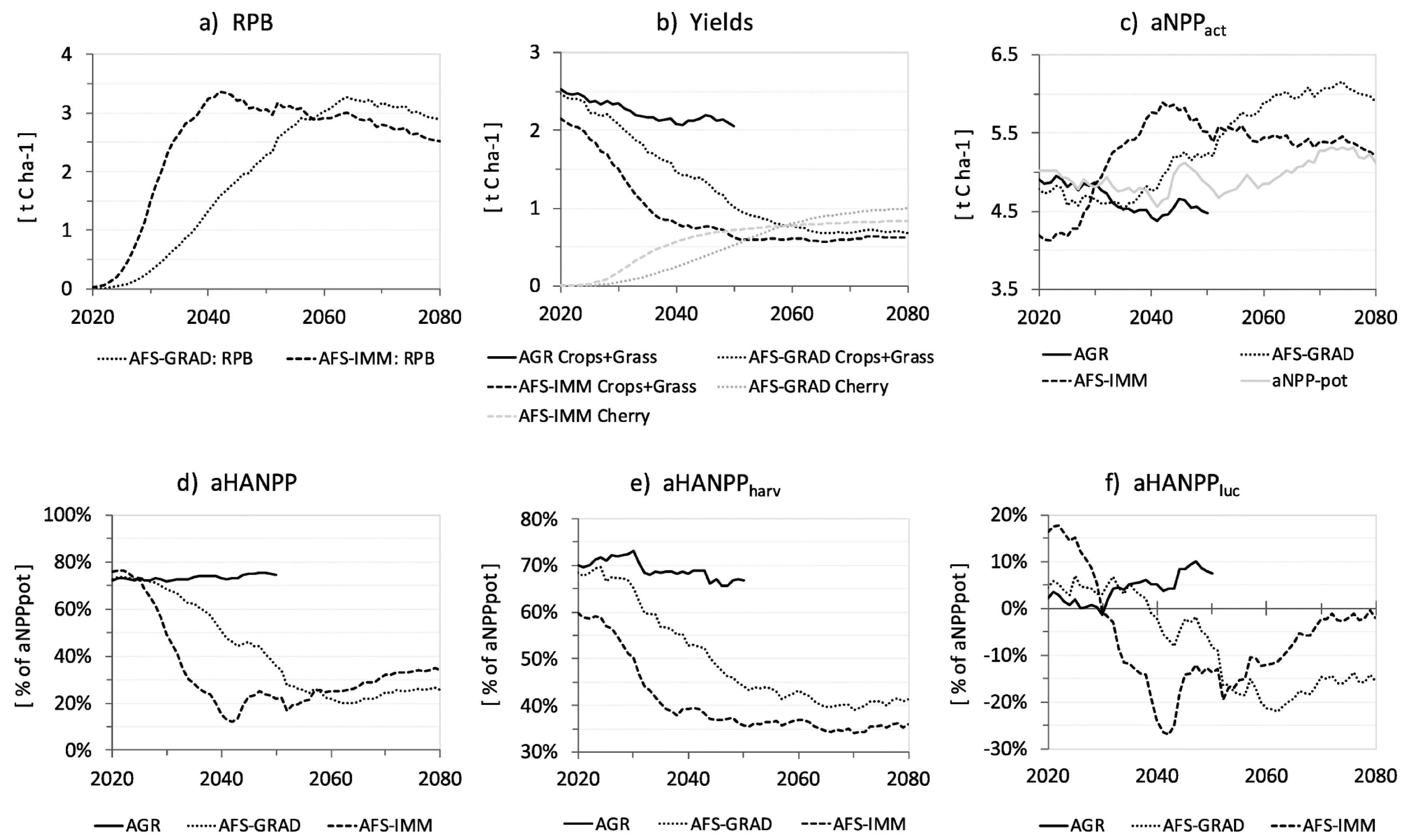
- A hypothetical transition to agroforestry in the Eisenwurzen **significantly decreases human-induced pressure on the agroecosystem, but results in significant trade-offs** between biomass provision and carbon sequestration.
- **The carbon sequestration potential is comparably high** but monetary remuneration for non-provisioning ecosystem services is required to counteract socio-economic burden of implementation.
- **Yield loss for crops and grass is attenuated by cherry fruit production but may inhibit large-scale implementation on intensive agricultural plots**, but trade-offs are less severe on extensive grasslands.



Development of the accumulated carbon stock and the carbon carrying capacity (CCC) in the study region: *CCC corresponds to the amount of carbon which can be stored in the system if tree age were distributed evenly throughout a harvest cycle (in this study 61 years). Intersections with the solid line depict the year in which the region’s carbon carrying capacity is reached in the respective scenario. Carbon carrying capacity thus corresponds to the net carbon sink in AFS. Carbon carrying capacity reaches 67.5 t C ha^{-1} at a mean tree age of 30.5 years, corresponding to roughly two thirds of the actual carbon stock per hectare in an Austrian mixed forest [4]. This is a substantial amount which leads to a total potential long-term carbon pool of 1.46 Mt C in the study area. Carbon carrying capacity is reached in 2063 in AFS-GRAD and in 2049 in AFS-IMM.*



Development of the three modelling scenarios (above: composition of NPP-act between 2020–2050; below: comparison of indicators for the extended period of 2020-2080). *Both AFS scenarios result in strong land use extensification, i.e. crop and grass yields decline significantly in both AFS scenarios. Simultaneously, from a productivity perspective, tree growth and cherry production overcompensate for losses in yields, as NPP-act increases significantly, resulting in negative HANPP-luc values by 2030 and 2040, respectively. Wild cherry trees feature a strong growth rate during the first 20 years, after which they sustain a considerably high but slightly decreasing annual increment until 2080. RPB peaks in 2042 in AFS-IMM and in 2064 in AFS-GRAD. Crop and grass yields in AFS-IMM and AFS-GRAD do not decrease any further beyond 2050 and 2065, respectively, and cherry yields stabilize likewise.*



References: [0] Bertsch-Hoermann et al. Agroforestry trade-offs between biomass provision and aboveground carbon sequestration in the alpine Eisenwurzen region, Austria. Reg Environ Change 21, 77 (2021). [1] van der Werf et al. „Yield-SAFE: A Parameter-Sparse, Process-Based Dynamic Model for Predicting Resource Capture, Growth, and Production in Agroforestry Systems“. Ecological Engineering 29, Nr. 4 (April 2007): 419–33. [2] Egger, C. et al. „Using the SECLAND Model to Project Future Land-Use until 2050 under Climate and Socioeconomic Change in the LTSER Region Eisenwurzen (Austria)“. Ecological Economics 201 (November 2022): 107559. [3] Haberl, H. et al. „Human Appropriation of Net Primary Production: Patterns, Trends, and Planetary Boundaries“. Annual Review of Environment and Resources 39, Nr. 1 (17. Oktober 2014): 363–91. [4] Erb, K.-H. „Land Use Related Changes in Aboveground Carbon Stocks of Austria’s Terrestrial Ecosystems“. Ecosystems 7, Nr. 5 (2004).