GCP/MaGNET Workshop Report
IIASA, March 2-3, 2017

Land use related negative emission technologies (LUNETs) & their implications on food security and relevant SDGs

Contents

Background

Agriculture, forestry and other land use (AFOLU) is responsible for about 25% of global anthropogenic GHG emissions. Part of them, mostly related to land use change, can be eliminated at relatively low cost. However, substantially reducing direct, non-CO_2, emissions from agriculture would require a large re-organization of the whole food system. Still, reaching ambitious stabilization targets such as those stipulated by the *Paris Agreement* will - according to the large majority of currently quantified scenarios - require large deployment of negative emissions technologies (NETs) among which afforestation and bioenergy with carbon capture and storage (BECCS) are privileged by the Integrated Assessment Modeling (IAM) community. Another promising NET is carbon sequestration in agricultural soils, with a potential of 0.7 GtC-eq/yr in 2100 according to Smith et al. (2016), but it has been not considered by IAMs in AR5.

Afforestation and BECCS will require hundreds of million hectares of land already by mid of century. Depending on the location of the production, this may lead to competition for land and water with food production and hence presenting a threat to food availability. On the other hand, these NETs will represent new revenue opportunities for rural areas where still the large majority of food insecure people live and hence together with increased agricultural income could lead to improved access to food. Afforestation in the particular form of agroforestry is complementary with food and feed production but the feasibility of its upscaling remains to be investigated. Finally, soil organic carbon sequestration in agriculture may also benefit food production through increasing soil productivity, providing better resilience to extreme weather events and hence contributing to adaptation to climate change. However, in some cases, increasing the carbon content may require extensification of agricultural production and hence lead to reduced food availability. All these aspects are critical in particular because most of the projections expect large scale development in LUNETs in developing countries.

Besides their strong link to food security (SDG2) and climate change mitigation (SDG13), LUNETs may play an important role in achieving or not of many others SDGs such as, ending poverty (SDG1), ensuring inclusive education (SDG4), clean water (SDG6), access to energy (SDG7), sustainable economic growth and employment (SDG8), reduce inequality (SDG10), sustainable consumption patterns (SDG12), and sustainable terrestrial ecosystems (SDG15). Therefore, considering food security alone, could result in misleading conclusions.

Finally, the cost of LUNETs in terms of food security and potentially other SDGs needs to be weighed against the cost of alternative options, e.g. stricter mitigation in the agricultural sector itself or more severe climate change impacts because of the lack of mitigation.

Workshop objectives

1. Review the role and the land use implications of LUNETs deployment in deep decarbonization scenarios
2. Review the way how IAMs currently represent the link between land use and food security and the implications for conclusions on LUNETs
3. A roadmap for LUNETs deployment promoting food security and other relevant SDGs

Minutes

Day 1, Thursday 2nd March

Session 1: Setting the scene

Session chairs: Yoshiki Yamagata, Florian Kraxner

Net-Negative Emissions: Challenges and Opportunities – Nebosja Nakicenovic

- Paris Agreement:

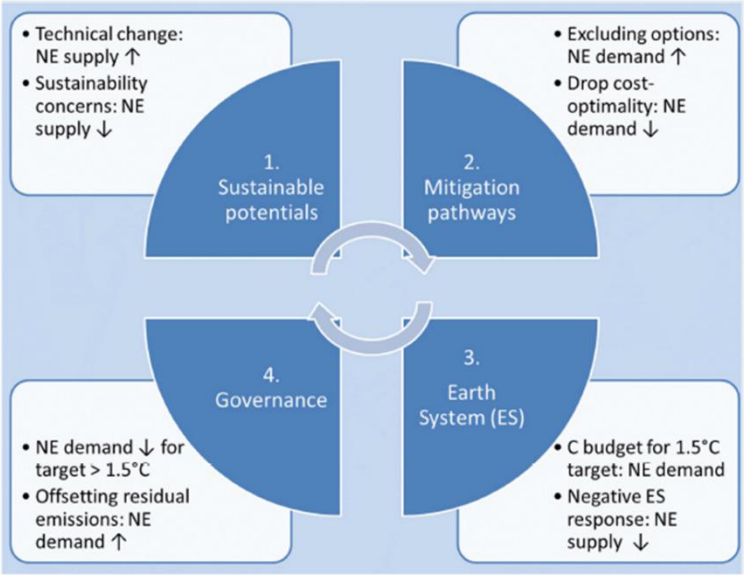
Limiting global warming to "well below" 2 degrees celsius	Achieving net-zero GHG emissions by mid of the 21st century	Regular review and improvement of nationally determined contributions	Mobilizing $100 billion a year in support by 2020 through 2025

- The formidable challenge of climate change (Holocene temperature profile, tipping elements and Paris)
- At the same time: development agenda and ongoing poverty
- Cumulative emissions already close to the budget for ambitious temperature targets → need for negative emissions
- Possible transformational technologies: ZEP in La Porte ,Texas (see slides)
- Carbon Capture and Usage (EOR)
- Technological change: Lumpy (large unit size, expensive, indivisible) versus granular technologies
- SDGs and the World in 2050
- Examples of disruptive change

What we know (and don't know) about negative emissions – Sabine Fuss

- Introduction to the Global Carbon Project and MaGNET
- ERL Focus on Negative Emissions Scenarios and Technologies
- Limits to LUNETS (land footprint, water needs, energy → Smith et al. 2016)
- Fast growth in literature on negative emissions (Minx et al. 2016)

- Key questions:
    - Role of negative emissions in 1.5°C scenarios
    - BECCS potentials (bioenergy and CCS)
    - Interactions with other land-based NETs (e.g. afforestation) and mitigation (e.g. avoided deforestation)
    - Side effects of deployment/Interactions with SDGs (food security)
    - Regional differences (Europe vs. different tropical basins) and implications
    - Possibilities in other sectors, state of technology (DAC)



- Expert survey

Negative emissions and pressure on land in 1.5°C scenarios– Joeri Rogelj

- Preview to the new pathways for 1.9 W/m^2:
    - Accelerated and steeper emissions reductions
    - Compared to 2°C
        - no room for further delay
        - Land-use expansion from NETs varies
            - No clear signal from energy crops expansion
            - Mixed signals for forest expansion
        - Pressure on cereal and pasture land increases due to strong emissions constraint
- Current NETs in scenarios are all LUNETs:
    - BECCS
    - Afforestation
    - cf. CEMICS project
    - NETs in 1.5°C scenarios induce important land-use shifts
    - Following a 1.5°C pathway puts a much stronger constraint on land-use change emissions.
- Overshoot and exceedance probability: increased dependence on negative emissions
- SSPs, SDGs

Potential implications of a 1.5°C target on food security – Petr Havlík

- Compare unabated climate change scenarios with ambitious mitigation scenarios: potentially large impact of stringent mitigation on food availability and food prices
- Geographically heterogeneous effect of carbon prices on food prices
- However: bioenergy not necessarily bad for food security (lower calorie loss)
- How to reconcile mitigation and food and nutrition security (FNS):
    - Technological development
    - Regionally sensitive policies
    - Subsidies rather than taxes?
- Co-benefits of food emissions pricing: significant health improvements (Springmann et al. 2016)
- Key questions for meeting:
    - Depending on implementation, mitigation can be worse than climate change impacts
      → What are the implications for relative costs?
    - Bioenergy, BECCS, SOC,… will reduce the need for mitigation in other sectors
      → Potential benefits for the food system?
    - On the ground, double to triple wins exist
      → How to reconcile global modeling with local opportuinities?

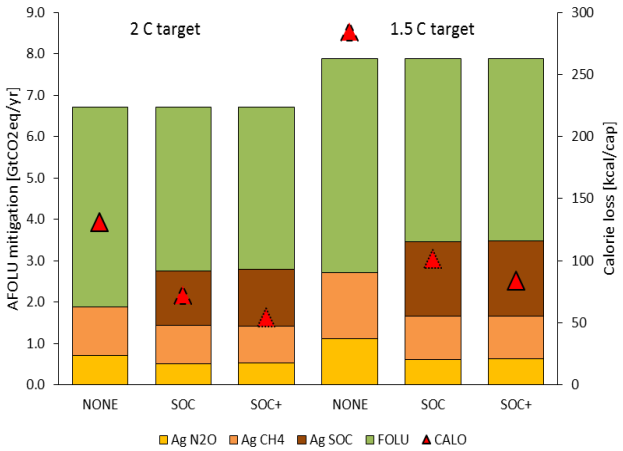
Session 2, part I: LUNETS and Food Security - Individual IAM presentations

Session chair: Hugo Valin

Deep mitigation scenarios and negative emissions in the GLOBIOM/MESSAGE modeling framework – Stefan Frank

- Recent GLOBIOM updates to include also SOC sequestration options and latest set of technical non-CO_2 options.
- Comprehensive representation of different mitigation wedges: SOC mitigation options (Smith et al, 2008), technical non-CO2 options (EPA, 2015), structural adjustments (Havlik et al, 2014) and consumers' response to prices.
- Around 8 $GtCO_2eq/yr$ expected from AFOLU applying uniform carbon price across sectors (including AFOLU) based on MESSAGE-GLOBIOM. But potential trade-offs with food security due to carbon price as food prices increase.
- Land rich countries with LUC emissions offer significant GHG mitigation potential with limited trade-offs with food security.
- Highly populated countries with intensive agriculture show limited GHG mitigation potential with large trade-offs.

- If SOC sequestration is considered in the mitigation portfolio, impacts on food security can be drastically reduced (-65%). Farmers get compensated for the carbon sink they provide and hence remain competitive even under stringent mitigation targets.



- Higher non-CO2 GHG emissions mitigation potential than previously estimated through integrated representation of structural and technical options, and consumers' response to prices and recent updates in EPA database i.e. comprehensive set of improved rice management options.
- Around 2.5 GtCO2eq of non-CO2 mitigation could be provided at 100 $/tCO2eq in 2050 by agriculture. 40% coming from technical options, 40% from structural options and 20% from the demand side.
- This could alleviate the need for negative emissions if this potential can be realized.

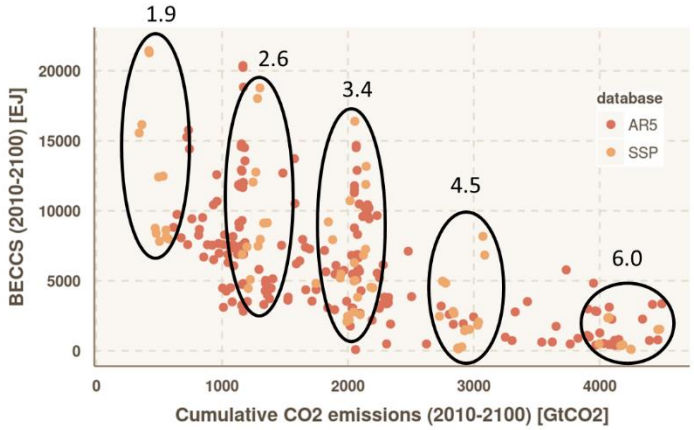
MAgPIE – land-based CDR options, potentials and tradeoffs – Alexander Popp

- MAgPIE has both BECCS and afforestation (and is working on terrestrial Enhanced Weathering through crushed olivine).
- It is not only land, but also the impact on water withdrawals and nutrients that need to be taken into account in the analysis of LUNETs. Need an integrated approach for assessment.
- Impact of afforestation on food security:
    - Large-scale afforestation can lead to substantial carbon sequestration.
    - But also associated with an increases in food prices due to competition for land.
    - Afforestation restricted to the tropics reduces food price response substantially while still high cumulative carbon sequestration is achieved.
- What can we learn from the different model types:
    - EMSs: albedo effects–decreasing afforestation potential
    - DGVMs1: lower potentials due to different crops(yields)
    - DGVMs2: different ag. Intensification pathways (bioenergy, food & feed crops; pasture intensification, LPSs)
    - DGVMs3: different representation of forest growth dynamics (afforestation, reforestation)

- Discussion: Food security is mostly analyzed in terms of availability of calories per capita and in terms of food prices, though these are acknowledged to be less good indicators. The income share would be much better. → Need to come up with consistent set of indicators for all SDGs across models to enable comparison.

Modelling LUNETs in an IAM, recent developments from the WITCH model – Laurent Drouet

- Recent update of renewables modelling in IAMs
    - Cost adjustment
    - System integration
    - Coordinated effort, FP7 ADVANCE project
    - No similar effort for BECCS
    - Is there an impact on BECCS penetration?
- BECCS versus carbon budget:
    - Spreads between IAMs from AR5 and SSP databases look very similar/consistent.
    - Spread becomes smaller for shrinking carbon budget.
    - BUT: for ADVANCE database (new model developments) spreads are smaller → to be investigated.



- WITCH:
    - at the lower end of BECCS spectrum
    - also includes afforestation now: 3-6 Gt CO_2 per year in 2100
    - Food price impacts: Higher CO_2 price leads to less calorie production in both crop and meat, small impact from the level of biomass production.

Session 2, part II: LUNETS and Food Security - Individual IAM presentations

Session chair: Joeri Rogelj

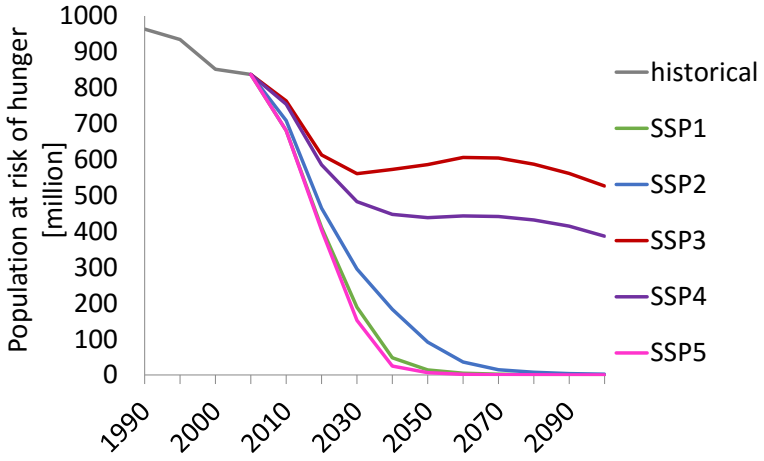
Deep mitigation scenarios and negative emissions in the IMAGE model framework – Detlef van Vuuren

- Preliminary BECCS results EMF33:
    - BECCS use typically around 10 GtCO2/yr
    - Bio-energy total typically around 200 EJ (2050)
- A wider framing in terms of SDGs needed

- Literature research on iLUC:
  - **ILUC factors**
    - Biodiesel has the highest ILUC factors (mean = 77 gCO_2-eq/MJ) and variation
    - Among 1st generation (mean = 28 gCO_2-eq/MJ), sugar crops have lowest factors
    - Advanced ethanol have lowest factors (mean = 11 gCO_2-eq/MJ) and variation…and limited studies
  - **Ranges within methods**
    - LCA + Empirical methods: Different allocation methods; technological choices
    - Economic methods: uncertainty of (marginal) crop yields; constraints on land conversions
    - Causal-Descriptive: Economic feedbacks → reduced food consumption
  - **Ranges across methods**
    - Generally, but not necessarily, equilibrium models agree with each other
    - LCAs + empirical studies have vastly different results
    - more uncertainties and sensitivities
    - Ranges are well outside those of equilibrium models
- IMAGE:
  - Like other assessment models, IMAGE relies heavily on negative emissions for reaching deep mitigation goals
  - Land-use for bioenergy starts to increase more than linearly at low targets, also with BECCS, bioenergy remains an issue (then for transport)
  - GHG emissions of bio-energy still very uncertain – depending especially on assumed location
  - Depending on location, afforestation might be attractive as alternative (but will similarly impact agriculture)
  - Lifestyle change could be way to reduce tensions, also carbon prices can cause diet shifts
  - Direct air capture provides negative emissions without land-use – but still has storage issues (but maybe preferable to BECCS?)

Trade-off between climate mitigation and food security: the experience of AIM - Tomoko Hasegawa

- Develop a multi-model hunger risk analysis tool on the basis of FAO approach
- Apply to SSPs to investigate risk of hunger in different worlds (see figure)
- Regional differences: e.g. high risk of hunger in South Asia and Africa depends greatly on high population growth.



- Use AIM/CGE model to investigate impact of climate change mitigation: population share at risk of hunger increases
- Proposal:
    - Transfers totaling $58 billion in the world (0.04% of world GDP) could decrease the damage in food consumption.
    - USA and Europe provide $47 billion (81% of the total).
    - South Asia receives most of the fund.

Potential food security implications of biomass electricity expansion in the US - Justin Baker

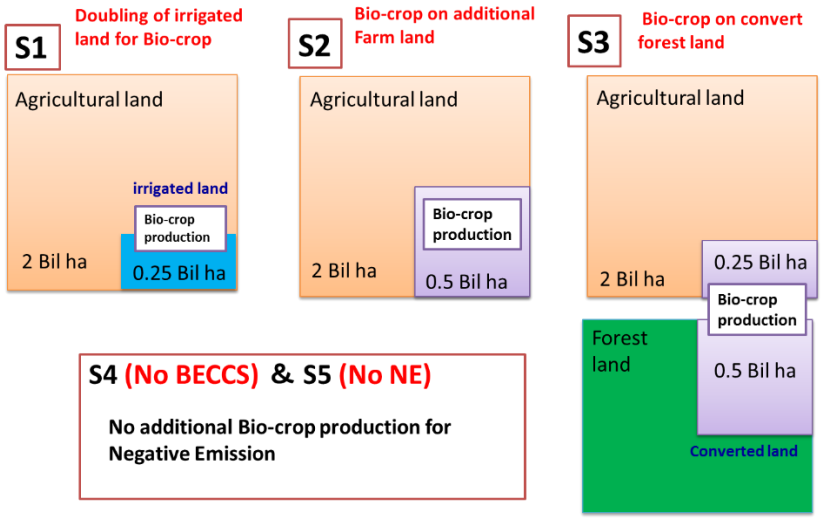
- Biomass is a renewable energy resource currently used by electricity and industrial sector facilities for energy generation – Less than 2% of total electricity generation, pulp and paper
- State and regional renewable energy policies could increase the demand for biomass energy
    - No national policy directing biopower, unlike biofuels
    - Energy security
    - Potential environmental benefits
- Many questions pertaining to potential positive and negative impacts, due to linked land and commodity markets, wide range of sources, different time scales for resource production, use and overall impacts – Use FASOM-GHG to find out whether electricity generation from biomass affects food supply.
- Findings:
    - Short run trade adjustments buffer domestic market – Potential global ramifications
    - Large shocks in restricted environments cause trouble in an optimization framework – e.g., forestry residue scenarios
    - Using an optimal biomass portfolio reduced food security concerns relative to only allowing specific sources – impacts from forest only scenarios are greater than agriculture only
    - Location of existing/planned infrastructure is an important determinant of feedstock choice and land management changes – policies can be designed to incentivize more GHG and calorie beneficial biomass pathways

Session 3: Complementary Modeling Approaches

Session chair: Yoshiki Yamagata

Spatial explicit BECCS land use scenarios (RCP2.6) and their implication for ecosystem services – Yoshiki Yamagata

- Use an array of indicators for the different SDGs to examine impact of land use scenarios on sustainable development.



- Application/Demonstration: Used water resource and ecosystem models to estimate implications to land use ecosystem services for ambitious temperature targets: tradeoffs exist between climate change mitigation and food security depending on the BECCS implementation strategies. Suggestion for workshop follow-up:
    - We are developing models to assess sustainability of BECCS Land use scenarios (RCP 2.6 + SSP2)
    - We need to further develop a framework to optimize land use allocation considering the synergies and tradeoffs
    - We can discuss about the collaborations with SGDs integrative assessments such as The World in 2050
    - Hope we can standardize common land use scenarios for proposing LUNET model inter-comparisons under MaGNET.
    - We need to develop spatially explicit Socio-Economic/land use modeling for the 5 SSPs and go beyond.
- Downscaling procedure for SSPs' population and GDP:
    - Compared to Brian/NCAR: Use auxiliary data (distance to ocean/airport/road, local/ global interaction); greater difference between urban and non-urban areas (e.g., no populations are distributed in desert in Saudi Arabia)
    - Download SSP1-3 at Http://www.cger.nies.go.jp/gcp/population-and-gdp.html

Feedstock and conversion process of bioenergy system for the anticipated sustainable BECCS – Etsushi Kato

- Possible cost-effective BECCS deployment pathways in the stringent climate target are assessed with the IAM GRAPE with detailed bioenergy processes
- In the case of full biomass supply, both power generation and production of fuels would contribute for the required BECCS significantly

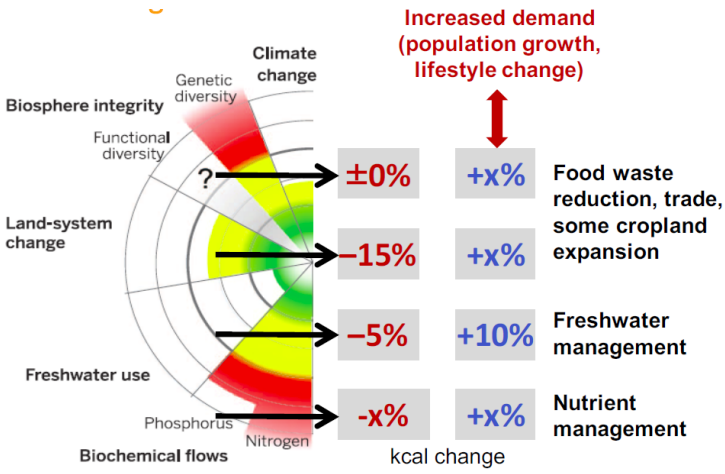
- If biomass supply level is low, available biomass are mainly used for the power generation with CCS, and early reduction of net CO_2 emissions required
- RD&D for scaling up of use of wood residues and MSW for BECCS is key to achieve sustainable BECCS

Assessing the biophysical impacts of land based mitigation in HadGEM2-ES - Andy Wiltshire

- Introduction to biophysical effects under the different RCPs. Under RCP4.5 strong local effects.
- Biophysical effects should be taken on board of IAM modeling – here a collaboration of an ESM (HadGEM2-ES) with MaGPIE.
- Normally, one would expect higher an offsetting temperature effect of afforestation in the boreal region due to the change in albedo.
- However, first results here show that the same target can be achieved with much lower levels of afforestation.

Terrestrial carbon dioxide removal and food production: planetary boundaries and opportunities - Vera Heck

- Introduction to planetary boundaries (PBs) à la Rockström
- Extension to social dimensions
- Negative emissions through BECCS within PBs?
    - Use LPJmL for analysis
- Results → → →



Climate risk management revisited - Michael Obersteiner

- Lower carbon budget does not matter: BECCS should only be deployed in the face of unexpected temperature spikes, i.e. a "fall-back climate risk reserve"
- Use alternative BECCS feedstocks: algae, etc. (could be opportunity for rural development)
- NETs to be excluded from cap-and-trade

Soil organic carbon/4 per 1000 initiative - Jean-Francois Soussana

- Soil organic carbon mitigation potential not negligible:
    - 2-3 times more carbon in soil organic matter than in atmospheric CO_2 [IPCC, 2013]
    - 1.4 Gt C/yr could be stored annually in agricultural soils, equivalent to a storage rate of 0.58%/year in top soil [after IPCC, 2007, 2014]

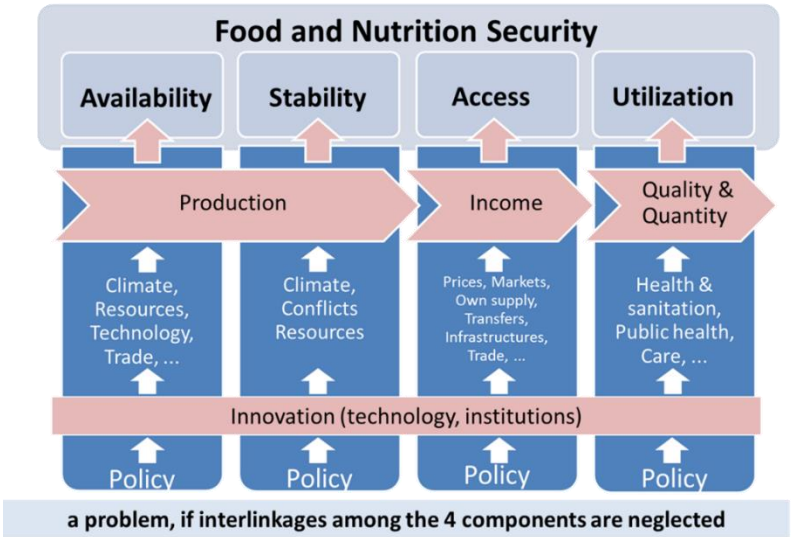
    - There are technical uncertainties about the potential, but 3.4 GtC/yr in total soils ('4/1000' target) is technically achievable
    - Achieving that potential would double by 2030 the total mitigation encompassed by the currently published INDCs
    - Economic potential is estimated at 1 Gt C/yr in agriculture (IIASA)
    - For a price of $120 per metric ton of CO_2 (compatible with the 2°C warming target)
    - In addition, local studies in Asia, Latin America and Africa show that best practices providing a 4/1000 increase in soil carbon have a large co-benefit: on average, a 1.3% increase in crop yields
- The 4 per 1000 target of 3.4 GtC/ yr is the sum of:
    - Agricultural soils (1.4 Gt C/yr)
    - Desertified/salinized soils (0.9 GtC/yr)
    - Forest soils (1.1 GtC/yr)
    - Forest management combines regrowth of secondary forests, plantations and agroforestry (extending Bonn declaration) and bring an above-ground sink of 2.2 GtC/yr
- Co-benefits of tapping into SOC:
    - Half of the agricultural soils are estimated to be degraded (FAO, 2006)
    - The annual cost of fertilizer to replace nutrients lost to erosion is US $ 110 – US $ 200 billion.
    - Emissions of 0.3–1.0 Gt C/yr through erosion of agricultural land
    - 24-40 million metric tons additional grains per ton C stored in soils OM in developing countries
    - Reduced yield variability after soil restoration leading to increased soil organic matter
- Limitations:
    - Adoption of SOC sequestration measures will take time,
    - SOC will increase only **over a finite period (30-50 yrs locally)**, up to the point when a new SOC equilibrium is approached,
    - The **additional SOC stock will need to be monitored** and preserved by adapting land management practices to climate change,
    - Soil phosphorus (P) and nitrogen (N) should be available (root symbioses could help)
    - Soil and water management need to be combined, especially in dry regions

Day 2, Friday 3rd March

Session 4, part I: Improving model relevance: Focus on food security (and other SDGs)

Chair: Petr Havlik

Modeling the various dimensions of food security: applications and lessons from the FOODSECURE project - Hans van Meijl



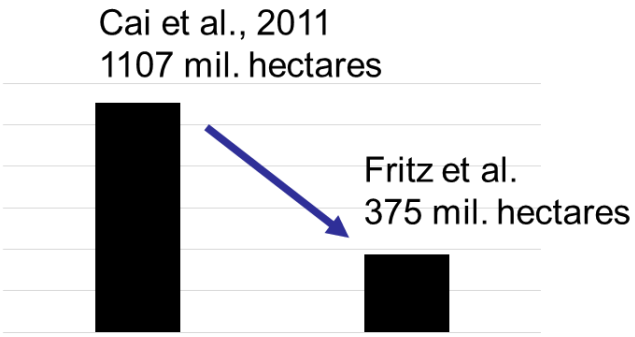
- FNS concept (not only calories!)
- Economic cost of malnutrition: $2.8- 3.5 trillion (4-5% global GDP)
- High food prices are bad for consumers but good for farmers. Food security impact is different and complex.
- SSPs mostly focus on food supply.
- MAGNET model (linked to IMAGE): can also examine food purchasing power indicator of low-income agricultural households and food purchasing power of farmers in cereals sector across scenarios, for example: much more differentiated picture.
- FoodSecure project: also considers inequality, e.g. food Lorenz curves of developing countries.

Bioenergy, land use and food security – lessons from recent policy assessments – Hugo Valin

- First generation biofuels offer an interesting first case study of how policies towards large scale deployment of biomass can lead to unexpected issues: indirect land use change, food versus fuel debate, land grabbing.
- Lessons learned so far:
    - Make the full consequential assessment
        - What feedstocks, what regions, what policy
    - Wrong policy design can lead to unintended effects and ruin the policy efficiency
        - Policy design will determine the impact of further deployment of bioenergy on food security
    - Effectiveness of land use control policies and economic instruments?
        - How fast agents shaping the land use patterns will react still to be determined
- Revisiting the slides is highly recommended for an in-depth review of both the debate at international level and within academia, and a history of the iLUC debate in the EU.

Land availability for biofuels – data improvement through citizen science - Ian McCallum

- Actually, we do not even know where all the land is that we would need for the additional biomass for BECCS in the 2°C scenarios: the uncertainty/disagreement across products is larger than the amount of land needed indicated by Joeri and others yesterday.
- Solutions: data sharing, crowd sourcing, validation, hybrid products.
- Geo-Wiki is an open platform that provides citizens with the means to engage in environmental monitoring by providing feedback on existing spatial information overlaid on satellite imagery or by contributing entirely new data.
- Example: Crowdsourcing could be used to downgrade land availability for additional biomass previously assessed by Cai et al. (2011).



Session 4, part II: Improving model relevance: Focus on technology

Session chair: Piera Patrizio

Comparative assessment of BECCS and Direct Air Capture (DAC) - Niall MacDowell, Mathilde Fajardy

- Main research questions:
  - Is BECCS carbon negative?
  - If at all, how long does it take for BECCS to be carbon negative?
  - Is BECCS a sustainable and resource efficient technology?
- BECCS versus DACS
- Use modular approach with:
  - regionally resolved climate data, yields and transport data
  - steady state supply chain model, power plant model and dynamic GHG accounting
  - arrive at BECCS GHG break-even time
- New methodology – included both direct and indirect land use.
- Result summary:

	BECCS	DACS
Strengths	1) Relatively resource efficient technology when deployed on marginal land, 2) Can be an energy net producer, 3) Partly uses existing infrastructures,	1) Land and water requirements negligible compared to those of BECCS, **2) Removes CO_2 right away,**
Weaknesses	4) High uncertainties around the LUC effects associated with the conversion of certain land types, 5) Can be an energy net consumer, 6) High land and water requirements compared to those of DACS. **7) Can take 1 to 50 years to be negative.**	2) High energy requirement, 3) Need carbon neutral power to be carbon efficient, 4) Geographical deployment constrained by renewable and storage (or utilisation) availability.

The sugar cane industry and BECCS in Brazil – José Moreira

- BECCS from sugar fermentation
- Technological and economical assessment: feasible for a CO2 tax of US$ 50, on 1st generation ethanol facilities. However, it is technically unfeasible on 2nd generation ethanol facilities
- BECCS with post-combustion – technically feasible but requires:
    - Significant financial support for demonstration projects
    - Large investment on CO_2 stripping equipment and in increasing heat generation and heat use optimization
    - Significant cut to saleable electricity revenue
    - Cost will be around US$100/t$CO_2$ stored, mainly due larger amount of CO_2 stored by unit of deliverable energy when compared with fossil fuel based CCS
- BECCS from sugar fermentation is no silver bullet (modest negative emissions potential), but deserves to be implemented.

Bridging technical and economic aspects of BECCS - Florian Kraxner

- It is important to complement the "top-down" analysis of IAMs and the "need" for negative emissions as represented by deployment in the ambitious stabilization pathways by detailed, spatially explicit bottom-up analysis to see what works locally.
- Techno-economic models like BEWHERE can help with this type of analysis
- Examples: South Korea, Japan, EU, Indonesia → Spatial optimization of bioenergy AND CO_2 infrastructure and storage sites.
- Can be complemented as well with environmental constraints, e.g. on locally known biodiversity hotspots.

- Similar for social conflicts (e.g. about land tenure).
- Extensions and stakeholder support: Visualization and Decision Support Tools
- However, also this approach is contingent on the availability of high-quality (geographical) data.

Session 5: Final discussion on the way forward

Session chair: Florian Kraxner

Three breakout groups (BOGs) were decided upon who then met in separate rooms and presented the results of their discussion back in plenary.

1) Compatibility LUNETs and FNS (chaired by Petr Havlik)
   a) Reconciliating scales (how much land really is available etc.)
   b) Reality check (policy constraints, inertia, other development objectives)
   c) Etc.

2) Necessary model/scenario development (keeping in mind what's already going on; chaired by Alexander Popp and Hugo Valin)
   a) to provide robust LUNETs assessment (also considering NET potentials in other sectors)?
   b) to comprehensively address also FNS (and possibly other SDGs)?

3) Governance issues around the large-scale application of LUNETs (chaired by Yoshiki Yamagata and José Moreira)

Our sincere thanks to all participants for their contributions and the inspiring discussions throughout the workshop!

Annex

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