Negative emissions - interactions with other mitigation options: a bottom-up methodology for Indonesia

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Abstract

BECCS (here the combination of forest-based bioenergy with carbon capture and storage) is seen as a promising tool to deliver large quantities of negative emissions needed to comply with ambitious climate stabilization targets. However, a land-based mitigation option such as large-scale bioenergy production (w/o CCS) might interfere with other land-based mitigation options popular for their large co-benefits such as reduced emissions from deforestation and degradation (REDD+). We develop a systems approach to identify and quantify possible tradeoffs between REDD+ and BECCS with the help of remote sensing and engineering modeling and apply this for illustration to Indonesia. First results indicate that prioritizing REDD+ does imply that there the BECCS potential remains limited. Further research is needed to take into account opportunities where the two options could be deployed synergetically, e.g. capitalizing on co-benefits. Definitely, BECCS and REDD+ have to be evaluated from a portfolio perspective, as estimating their potentials independently will not take such opportunities into account.

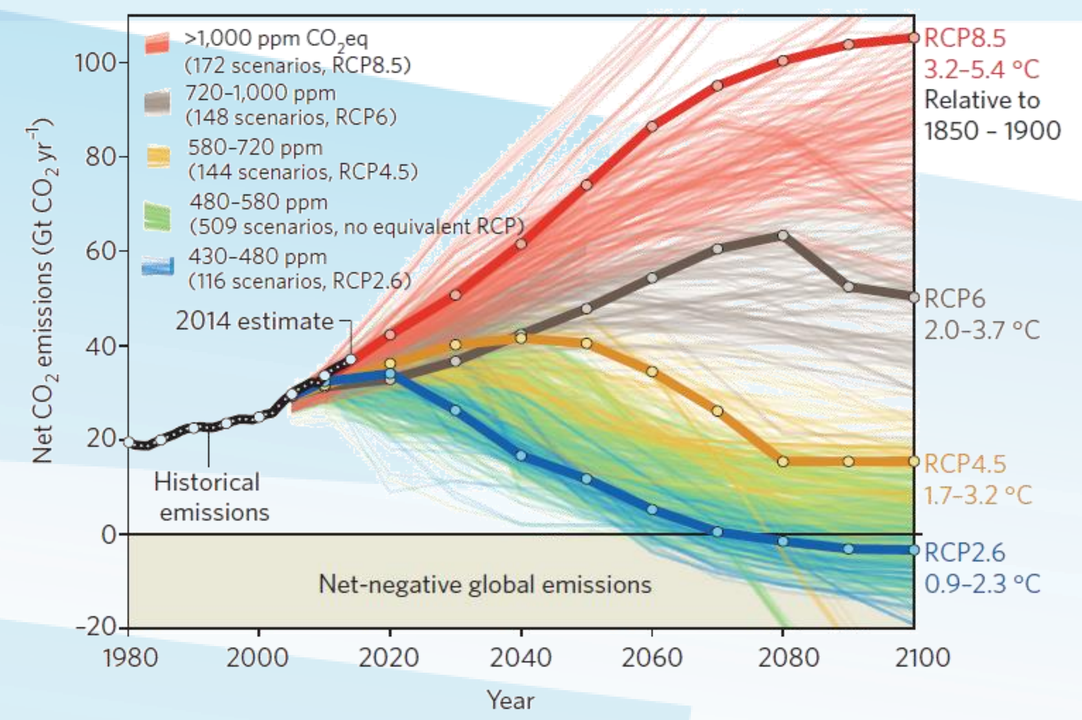

Figure 1: Carbon dioxide emission pathways until 2100 (Fuss et al. 2014 [3]).

Background

For complying with ambitious climate targets, land-based mitigation, i.e. through agriculture, forestry, and fossil fuel substitution by bioenergy, is an indispensable and significant part of the portfolio of mitigation strategies [1]. In addition, many scenarios and models featured in the IPCC's recent Assessment Report (AR5, [2]) rely on a substantial contribution of negative emissions to stabilize GHG concentration at levels consistent with 2°C above pre-industrial levels (see *Figure 1* [3]). Model projections for 21st century's energy portfolio indicate a major contribution from the bioenergy sector, i.e. 200-300 EJ, in 2100 [4], often in combination with CCS (BECCS [4-6]). One major concern is that high feedstock potentials are supposed to be located in the tropics, which is where at the same time forests are most vulnerable to deforestation [7,8]. Furthermore, the deployment of large-scale bioenergy production (w/o) CCS might also have crucial impact on green growth in developing countries where energy supply is still projected to strongly increase [9]. Yet, many uncertainties remain with respect to BECCS [3]. Inter-alia, the immense amount of bioenergy would need to be generated from sustainably managed agriculture and forests in order to avoid additional deforestation. Clearly, an interference of BECCS needs with options that are popular for their large co-benefits such as reduced emissions from deforestation and degradation (REDD+ [10]) has to be avoided. Moreover, downstream considerations, e.g. distribution and types of energy demand, are also important to ensure economic competitiveness with fossil fuel, particularly with limited presence of carbon price. At the end of the pipe, geological storage consideration and with it geographical optimization is important in ensuring negative emission results as well as economic feasibility of the BECCS technology.

Thus, based on a simplified multi-scale bottom-up modeling approach, this study aims to introduce the first steps to developing a systems approach to identify and quantify possible tradeoffs (i.e. land use-based mitigation options competing for the same land) and synergies (i.e. both options provide incentives to keep an intact and sustainably managed forest) between REDD+ and BECCS.

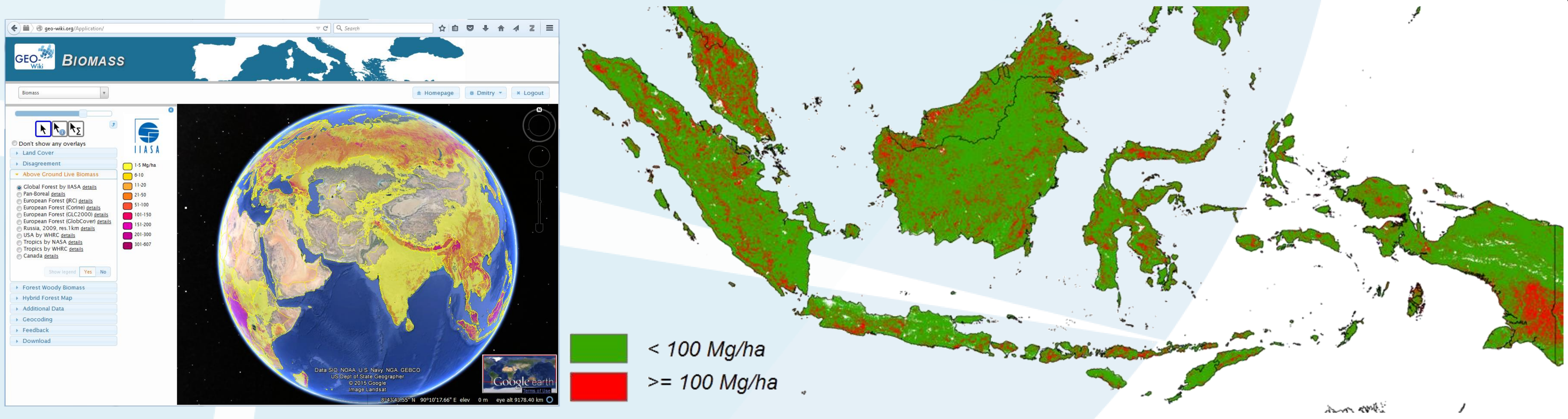

Figure 2: Left, www.geo-wiki.org, visualization and validation platform for biomass datasets. Right, disagreement map for biomass estimates between WHRC and NASA datasets for Indonesia [14,15].

Indonesia as case study

Calculations for global potentials of bioenergy or negative emissions demand, which focus on the system interactions at an aggregate level, typically cannot shed much light on the situation on the ground. Thus, local- level analyses need to be carried out as shown by [11]. Indonesia is chosen as a case study due to its ambitious green growth target of 5-7% economic growth while at the same time reducing 26-41% GHG emissions from the BAU scenario [12]. A high rate of deforestation and monoculture-plantations with oil palm have been shadowing the country's rapid economic growth during the past decades. Moreover, recent policies show ambitious aspirations for further economic growth that is still highly dependent on land and natural resources as well as fossil energy. The country is still in the process of unfolding on-the-ground complexity in managing land and forest areas, while large-scale investments in REDD+ are being undertaken by the international community (e.g. by Norway, US, ADB). Adding BECCS to the mitigation portfolio would add to this complexity being subject to uncertainty about the actual land use situation, tenure rights, and governance, that results in high uncertainty of biomass availability [13] and sustainability of these resources (see Figure 2 [14]).

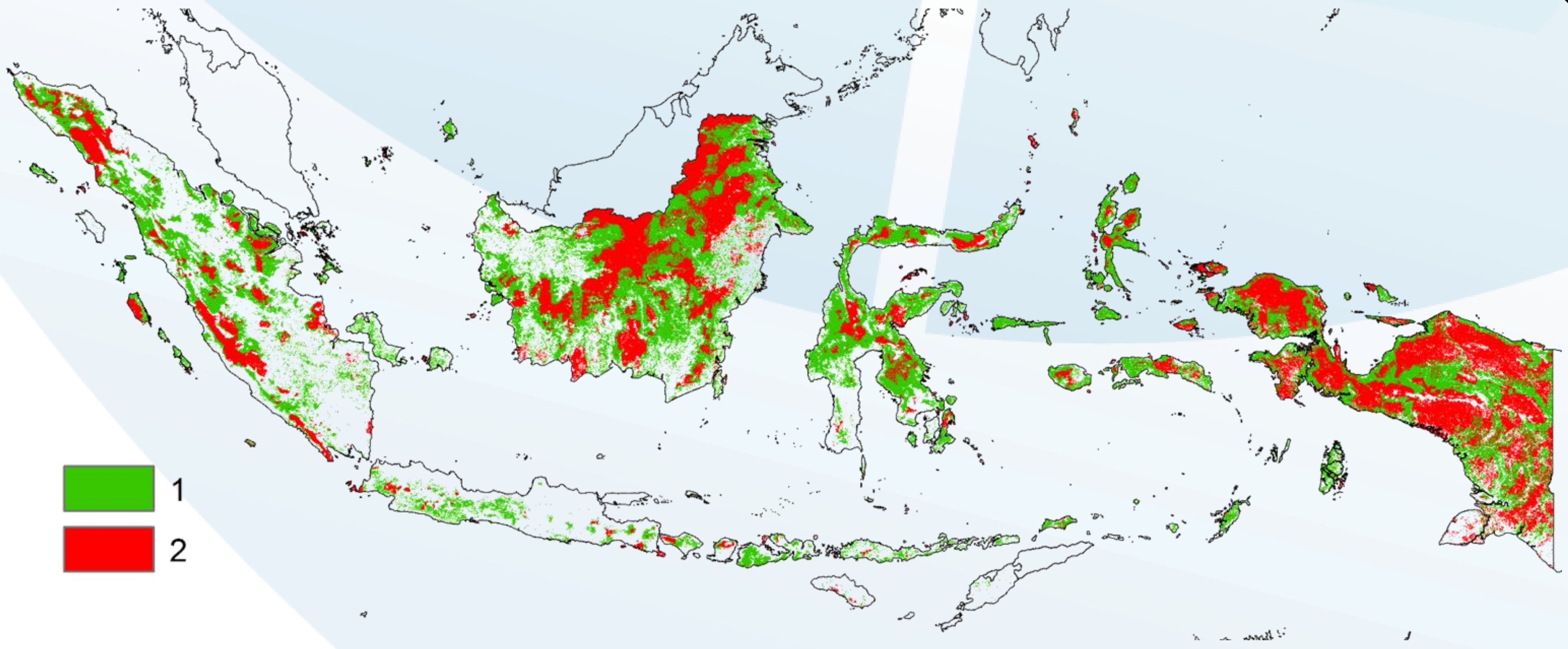

Figure 3: REDD map for Indonesia. 1, Biomass potential outside conservation and protected forest areas. 2, Biomass potential within conservation and protected forest areas which may be inaccessible under REDD+ policies [18].

Methodology

For the analysis of BECCS potentials, the entire process chain needs to be assessed, starting from identifying the biomass potential and availability, particularly considering "conventional" mitigation policies such as REDD+ (see *Figure 3*). The geographically explicit biomass availability is assessed using Geo-Wiki [15], a crowdsourcing validation platform, and G4M [16], a global forest management model, to complement satellite imagery-based biomass datasets.

In a first step, taking into account that avoided deforestation carries other than carbon benefits which are difficult to quantify and monetize (e.g. the conservation of certain ecosystems services), areas with high carbon stocks, e.g. protected and conserved forest areas [17] are excluded from the calculation. Under the assumed REDD+ policy, such areas are not being utilized for BECCS-feedstock production to ensure maximum amounts of negative emissions (REDD+BECCS, also for other considerations on various ecosystem services) [18]. The calibrated biomass potential is then linked with the techno-engineering renewable energy systems optimization model BeWhere [18,19] to optimize demand, supply, and transport for sustainable feedstock and bioenergy generation with in-situ CCS in Indonesia. Moreover, BeWhere also estimates the entire supply chain emissions for the BECCS system and superimposes a map of the geological suitability for CO2 storage ([20] see Figure 4). Note that we focus on woody biomass only to model the potential of sustainably managed forest in order to exclude biomass potentially sourced from disputed land resources with risk of recent (plantations) or future deforestation (REDD+ area).

Results and conclusions

The calculated REDD+ area amounts to 41.6 million ha of undisturbed forest. The remainder of 46.7 million ha is partially available for sustainably managed forestry to supply feedstock to the BECCS system. The modeling results from this very conservative approach (low plant capacities, highest feedstock sustainability, very limited area to source the feedstock etc.) present the optimal location of bioenergy production plants by capacity (see *Figure 4*). The total capacity would be equivalent to 1,200 MW_{bio}. It is assumed that only 20% of the increment from managed forest can be used for bioenergy purposes. Considering 80% capture efficiency, 2.5 $MtCO_2$ can be captured and stored on site, which corresponds to 12.5 million US$ of carbon benefit (from negative emissions and substitution effects) for a CO_2 price of 5US$.

Thus, prioritizing REDD+ indeed leaves only relatively small potentials for BECCS., On the other hand for a full comparison not only the emissions saved need to be compared, but also the co-benefits (e.g. ecosystems services protection through corridor function for species migration) need to be taken into account. While it is straightforward to calculate and price the co-benefit of BECCS in terms of energy produced, limited data availability has prevented us from also comparing the worth of preserved or enhanced ecosystems services in this first analysis.

Thus, being far from a complete analysis, the application to Indonesia still demonstrates very convincingly that BECCS and REDD+ have to be evaluated from a portfolio perspective, as estimating their potentials independently will not take such opportunities into account.

The presented methodology can furthermore be applied at the global scale to verify the "on the ground" feasibility of 2°C scenarios featuring BECCS. Future studies should factor in investment barriers and the techno-economic feasibility (i.e. achieving sufficient economies of scale over short time horizons) of BECCS applications within the existing and planned energy system. There is thus a need for further adaptation involving e.g. co-firing schemes, and the use of different feedstock types. In the context of Indonesia, this would mean assessing co-firing options from existing and planned coal-fired thermal power plants with existing biomass resources such as waste and residues.

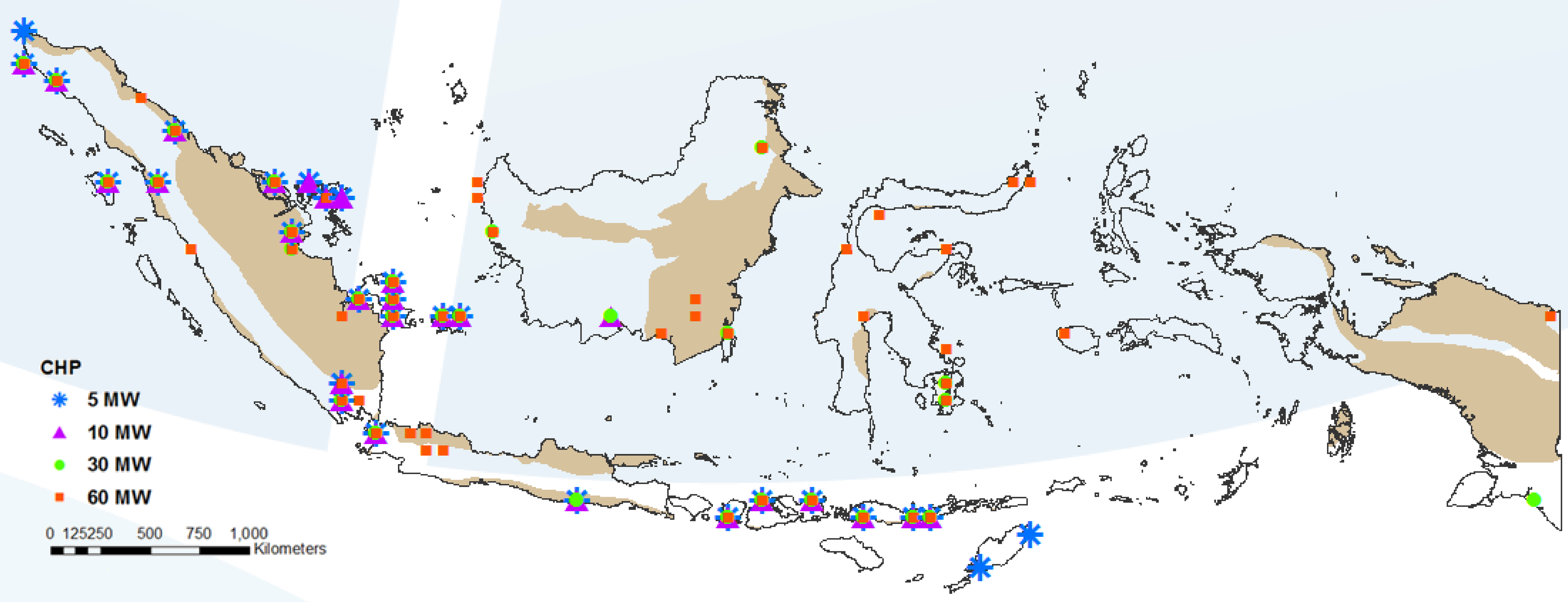

Figure 4: BeWhere – optimized green-field bioenergy plant locations and capacities combined with geological suitability for in-situ CCS (BECCS) [19,20].

Literature

[1] Rose S, Ahammad H, Eickhout B, Fisher B, Kurosawa A, Rao S, Riahi K, Van Vuuren DP (2011) Land-based mitigation in climate stabilization. Energy Economics. doi: 10.1016/j.eneco.2011.06.004; [2] IPCC, Intergovernmental Panel on Climate Change (2014) Summary for policymakers. In: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., et al. (eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.; [3] Fuss, S., Canadell, J.G., Peters, G.P., et al. (2014) Betting on negative emissions. Nature Climate Change, 850–853, doi:10.1038/nclimate2392.; [4] Azar,C. Lindgren,K. Obersteiner,M. Riahi,K. van Vuuren,D.P. den Elzen,K.M.G. Moellersten,K. Larson,E.D. (2010). The feasibility of low CO2 concentration targets and the role of bio-energy with carbon capture and storage (BECCS). Climatic Change, 100(1):195-202 (May 2010); [5] Obersteiner, M., Azar, C., Kauppi, P., et al. (2001) Managing climate risk. Science, 294 (5543), 786–787.; [6] Kraxner, F., Nilsson, S., and Obersteiner, M. (2003) Negative emissions from BioEnergy use, carbon capture and sequestration (BECS)—the case of biomass production by sustainable forest management from semi-natural temperate forests. Biomass and Bioenergy, 24, 285–296.; [7] Kraxner, F., Nordstrom, E.-M., Havlik, P., et al. (2013) Global bioenergy scenarios—future forest development, land-use implications, and trade-offs. Biomass and Bioenergy, 57, 86–96.; [8] Rokityanskiy, D., Benitez, P.C., Kraxner, F., et al. (2007) Geographically explicit global modeling of land-use change, carbon sequestration, and biomass supply. Technological Forecasting & Social Change (Special Issue: Greenhouse Gases—Integrated Assessment), 74 (7), 1057–1082.; [9] Kraxner F., Fuss S., Krey V., Best D., Leduc S., Kindermann G., Yamagata Y., Schepaschenko D., Shvidenko A., Aoki K., Yan J. The role of bioenergy with carbon capture and storage (BECCS) for climate policy. V. 3. P. 1466-1483. In: Yan J (Ed) 2015, The Handbook of Clean Energy Systems. John Wiley & Sons, Ltd.; [10] Obersteiner, M., Huettner, M., Kraxner, F., et al. (2009) On fair, effective and efficient REDD mechanism design. Carbon Balance and Management, 4, 11.; [11] Kraxner, F., Aoki, K., Leduc, S., et al. (2012a) BECCS in South Korea—analyzing the negative emissions potential of bioenergy as a mitigation tool. Renewable Energy, 61, 102–108.; [12] Masterplan for Acceleration and Expansion of Indonesia Economic Development 2011 – 2025, Jakarta, Coordinating Ministry for Economic Affairs (2011), 208p, ISBN 978-979-3754-14-7; [13] Fritz S, See L, van der Velde M, Nalepa R, Perger C, Schill C, McCallum I, Schepaschenko D, Kraxner F, et al. (2012). Downgrading Recent Estimates of Land Available for Biofuel Production. Environ. Sci. Technol. dx.doi.org/10.1021/es303141h; [14] Schepaschenko D, See L, Lesiv M, McCallum I, Fritz S, Salk C, Perger C, Shvidenko A, Albrecht F, Kraxner F, Duerauer M, Obersteiner M (2015) Development of a global hybrid forest mask through the synergy of remote sensing, crowdsourcing and FAO statistics. Remote Sensing of Environment, 162:208-220 (June 2015) ; [15] Fritz S, McCallum I, Schill C, Perger C, See L, Schepaschenko D, van der Velde M, Kraxner F, Obersteiner M (2012). Geo-Wiki: An online platform for improving global land cover. Environmental Modelling & Software 31 (2012), pages 110-123;. [16] Kindermann, G., Obersteiner, M., Sohngen, B., et al. (2008) Global cost estimates of reducing carbon emissions through avoided deforestation. PNAS, 105 (30), 10302–10307.; [17] IUCN and UNEP-WCMC (2015), The World Database on Protected Areas (WDPA) [On-line], [07/2015], Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net; [18] Kalkulasi Penutupan Lahan Indonesia tahum 2013, Jakarta, Ministry of Forestry (2014). Available at: http://webgis.dephut.go.id:8080/kemenhut/index.php/id/fitur/unduhan; [19] Leduc, S., Schmid, E., Obersteiner, M., and Riahi, K. (2009) Methanol production by gasification using a geographically explicit model. Biomass and Bioenergy, 33 (5), 745–751.; [20] Leduc S., Kindermann G., Forsell N., Kraxner F. (2015) Bioenergy potential from forest biomass. Vol. 1. P. 35-48. In: Yan J (Ed) 2015, The Handbook of Clean Energy Systems. John Wiley & Sons, Ltd.; [21] Bradshaw, J.B. and Dance, T. (2004) Mapping geological storage prospectivity of CO2 for the world sedimentary basins and regional source to sink matching. GHGT-7, 5–9 September 2004, Vancouver, Canada, v.I, 583–592.

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www.geo-wiki.org
www.iiasa.ac.at/bewhere
www.iiasa.ac.at/g4m
http://www.cger.nies.go.jp/gcp/magnet.html

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