Focus on land use cover changes and environmental impacts in South/Southeast Asia

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Abstract
Understanding the impacts of land use cover changes (LUCC) on the environment is one of the most important scientific challenges in global change research. LUCC is one of the critical drivers of environmental change in South/Southeast Asia. Several studies suggest that LUCC in these countries is driven by population growth and economic development. In the region, LUCC is manifested in a variety of phenomena such as urban expansion, agricultural land loss, land abandonment, deforestation, logging, reforestation, etc. Documenting the LUCC and associated impacts gain significance as the results can aid improved land management. This editorial provides a summary and discussion of the nine different articles of the Focus issue, focusing on ground-based measurements, remote sensing, and modeling to quantify LUCC impacts. The results will be useful to academics, practitioners, government, and policymakers to quantify and address sustainable LUCC issues in South/Southeast Asian countries. The published papers add significant new science to the existing literature.

1. Introduction
Land use cover changes (LUCC) are the most common phenomenon in different regions of the world, including South/Southeast Asia. The drivers of LUCC vary widely, such as due to land tenure issues, economic development, government policies, inappropriate land management, etc. Besides, variability in the weather, climate, and socioeconomic factors are other drivers of LUCC. Some of the LUCC impacts include disruption of biogeochemical cycles, changes in atmospheric radiation, and surface energy balance. For documenting the LUCC, spatially explicit data are essential. Other forest-related changes include logging for conversion to rubber and oil palm plantations. Fires are mostly used in the region as a land clearing tool. Also, urbanization is most common. Remote sensing due to its multi-temporal, multi-spectral, repetitive, and synoptic coverage capabilities can be used to document LUCC and associated impacts. Further, in South/Southeast Asia countries, there is an increasing need to develop consistent regional LUCC products useful for environmental impact assessment and policymaking. The current focus issue highlights some of the region’s LUCC and their impacts, integrating remote sensing data, ground-based measurements and modeling. A summary of the published articles in the Focus issue is provided.

Terrestrial ecosystems play an important role in carbon (C) fluxes. Understanding the carbon budget in different ecosystems can reduce the uncertainties resulting from the climate and LUCC feedback. There is considerable disagreement on the role of terrestrial carbon uptake from diverse ecosystems and regions of the world. Several factors, such as CO2 fertilization, N deposition, forest regrowth, high latitude warming, and an increase in growing season length, can contribute to an increased terrestrial C sink. In contrast, drought, conversion of forests to agriculture, vegetation fires and N and phosphorus limitations can constrain the C uptake (Huntzinger et al 2017). Thus, quantifying carbon budgets and flux estimates are essential and needed for designing robust climate change policies. In a study ‘The terrestrial carbon budget of South and Southeast Asia,’ Cervarich et al (2016) integrate both top-down and bottom-up estimates to synthesize the carbon source/sink due to
net ecosystem productivity (NEP), Net Biome Production (NBP), land cover land-use change (LCLUC), fires and fossil burning in South Asia (SA), Southeast Asia (SEA) and South and Southeast Asia including each country. The results highlight that the SEA has relatively higher Net NEP per year, whereas SA has more NBP per year. Further, SEA countries are a relatively more top net source of carbon from LCLUC and fires than SA countries, whereas the latter countries contribute more carbon from fossil fuels every year. Authors also highlight the importance of addressing uncertainties resulting from the carbon sink quantification related to post-disturbance recovery and climate anomalies. In the paper, authors also stress the need for higher resolution input datasets for quantifying carbon fluxes useful for decision-making.

In several Southeast Asian countries, one of the leading commodities of estate crops is Rubber (Hevea brasiliensis). The rubber plantations have been expanding across Southeast Asia in response to the global demand for rubber products. Since the climate conditions impact land suitability, studies on identifying agro-climatological characteristics that suit rubber production in different regions of the world are important. A better understanding is needed on the efficiency, costs, and benefits, and trade-offs specific to rubber plantations and climate variability. In a paper titled 'Climate change impact assessment on the potential rubber cultivating area in the Greater Mekong Subregion,' Golbon et al. (2018) apply rule-based geographical classification scheme based on the downscaled IPCC AR5 climatic projections to map the potential geographical zones projected to be climatically suitable for rubber cultivation in Mainland South East Asia for 2030, 2050 and 2070. The results suggest significant expansion associated with the temperature where the total area conducive to rubber cultivation in the Greater Mekong Subregion is projected to exceed 50% by 2030. Authors also identify the largest detected cluster with 41% of the total shifting area, which is the most ecologically degraded, corresponding to northern Vietnam and Guangxi autonomous region of China (Golbon et al. 2018). The study’s importance lies in highlighting the uncertainties, which are highly relevant to policymakers. Overall, the results can be used by the local and regional decision-makers to develop policy guidelines and decision support mechanisms relating to rubber plantations and land use management in the study area.

Biomass burning is an important source of greenhouse gas emissions and aerosols. Of the different countries in Southeast Asia, biomass burning events in Indonesia are rampant impacting not only the country but also its neighboring countries such as Singapore, Malaysia, and Thailand. Most of the biomass burning events in Indonesia are attributed to the clearing of forests for planting oil palm. The dry climate also triggers the biomass burning events. Of the different regions, Riau province in Indonesia has the most fires per square kilometer. In the study 'Impact of the June 2013 Riau province Sumatera smoke haze event on regional air pollution,' Kusumaringtyas and Aldrian (2016), use ground-based AERONET measurements in conjunction with the HYSPLIT wind trajectory model to quantify the air pollution in the study area. The results highlight the detection of fires from the MODIS satellite observations during June 2013 with more than 3000 hotspots coinciding with the very high Pollution Standards Index (PSI), reaching more than 1000 in some regions. The aerosol optical depth (AOD), Ångstrom parameter and particle size distribution indicated the presence of fine aerosols in a great number in Singapore ground stations, which is characteristic of biomass burning aerosols. Also, the highest concentration of PM2.5 was recorded with 244.89 µg m⁻³ far exceeding the ambient air quality standards based on the World Health Organization (2006), which is 25.89 µg m⁻³ in Singapore. Results from the HYSPLIT model confirm the origin of fire pollutants from the Riau province, Indonesia.

In the same study area, Sze and Lee (2019) in a study 'Evaluating the social and environmental factors behind the 2015 extreme fire event in Sumatra, Indonesia,' develop 18 different proxy variables grouped into five categories, i.e. conflict, economic, population, forest degradation and biophysical conditions as plausible drivers of fire and evaluate how these influenced fire count at an administrative regime-level using 1 km MODIS satellite fire occurrence data. Authors identify rainfall, slope and population density as the most critical variables as predictors of fires. Overall, the authors identify biophysical and population variables as having a strong influence on fire count and occurrence at the regimen and pixel-level, respectively. The results also suggest economic variables such as small scale and medium-scale plantation landholdings and the use of fires to clear agricultural lands in villages as important drivers explaining fire count at the regimen-level (Sze et al., 2019). The results specific to low population densities associated with higher fire likelihoods observed in some remote areas can help identify and prioritize these areas for fire prevention, management, and mitigation efforts.

In another paper, ‘Impact of the 2015 wildfires on Malaysian air quality and exposure: a comparative study of observed and modeled data,’ Mead et al. (2018) highlight the impacts of wildfires on population. Most of the previous studies relating to population exposure to wildfires in Asia are limited due to a lack of robust air pollution datasets. Thus, the paper by Mead et al. (2018) is an excellent addition to scientific literature as they present a new data set consisting of hourly observations of PM10 and CO concentrations measured at 49 monitoring stations across peninsular Malaysia and Malaysian Borneo during the 2015 wildfires. Authors use the ground-based
datasets to parameterize the WRF model simulations and to estimate the impact of the 2015 wildfires on population exposure. Results suggest that 10 million people were exposed to PM$_{10}$ mean concentrations double the daily World Health Organization (WHO) limit during September and October 2015. Based on the simulation study, authors identify 64% of the population living in the Greater Klang Valley as hotspot areas systematically exposed to unhealthy air quality conditions. The study also emphasizes the role of long-range transport of pollutants from biomass burning, affecting air quality and population exposure across Malaysia. Authors also stress the need for robust mitigation strategies to address wildfires’ impacts at local and regional scales.

In addition to the forest fires, agricultural fires are rampant in South/Southeast Asian countries. Most of the farmers use fire as an inexpensive means to clear the crop residues after harvest. The advantages of using fires as a management tool include saving labor costs, controlling of insects, disease, and the emergence of invasive weed species. However, there are several disadvantages, such as loss of carbon through residues, the release of pollutants, and greenhouse gas emissions (GHG’s). In particular, our knowledge about the spatial extent of agricultural fires and their contribution to global climate change studies, including human health, are highly uncertain. Thus, it is essential to monitor agricultural fires through various methods. In a study, ‘Satellites may underestimate rice residue and associated burning emissions in Vietnam’ Lasko et al (2017), compare both ground-based measurements and satellite-based approach to quantify emissions from rice residue burning in Vietnam. Since Vietnam is mostly impacted by clouds that can hinder the use of optical remote sensing, authors use Synthetic Aperture Radar (SAR) as inputs for rice mapping. They then use the maps for post-harvest rice residue sampling, including straw and stubble left in the field for burning. Authors integrate data on dry rice straw left in the field, moisture content, the number of straw rows in the field, and separate fuel-loading factors such as straw, stubble, and total post-harvest biomass factors and emission factors to estimate potential rice residue emissions. The authors report total rice residue burning emissions as 2.24 Gg PM$_{2.5}$, 36.54 Gg CO and 567.79 Gg CO$_2$ for Hanoi Province, which is significantly higher than earlier studies. Authors attribute the higher emission estimates to improved fuel-loading factors. Also, the authors estimated rice residue PM$_{2.5}$ emissions for the entirety of Vietnam, compared them with existing satellite-based emission inventories, and concluded that the latter significantly underestimated emissions. The study is highly significant as it provides improved residue and emission estimates for Vietnam and highlights the need for robust integration of ground-based data for quantifying and refining emissions at various spatial scales.

In a unique study titled, ‘Biomass burning drives atmospheric nutrient redistribution within forested peatlands in Borneo,’ Ponette-González et al (2016) identify biomass burning from agriculture and peat fires as a significant source of N, P, and S in through-fall and bulk rainfall. Results suggest that the within 12 ha forested Bornean peatland receives some of the highest P (7.9 kg PO$_4^{3-}$ -P ha$^{-1}$ yr$^{-1}$) and S (42 kg SO$_4^{2-}$ -S ha$^{-1}$ yr$^{-1}$) deposition and that N deposition (8.7 kg inorganic N ha$^{-1}$ yr$^{-1}$) exceeds critical load limits suggested for tropical forests. Authors attribute most of the deposition rates resulting due to the biomass burning from oil palm plantations located in the peatland areas. They highlight how fire events can drive the redistribution of nutrients through land-atmospheric interactions and how biomass burning events can have fertilizing or polluting effects on various ecosystems. The study is highly novel and adds significant new datasets and science to the literature.

Aerosols contain a variety of liquids and solids and exist as dispersed phases in the air, resulting from both the natural and anthropogenic sources. Aerosols impact climate as they absorb as well as scatter the solar and infrared radiation in the atmosphere. They also impact the cloud formation processes by increasing the droplet number concentrations and ice particle concentrations. Also, aerosols can affect the health of biota through nutrient cycling. In addition to the ground-based measurement studies, satellite remote sensing can be used to study aerosol characteristics. One of the challenges of satellite remote sensing of aerosols relates to retrieving the optical properties, mostly influenced by the mixing of dust and soot aggregates. The mixing effect of aerosols on the top of the atmosphere reflectance is nonlinear, leading to retrieval errors from the satellite (Chang et al. 2016). In the study ‘Mixing weight determination for retrieving optical properties of polluted dust with MODIS and AERONET data,’ Chang et al (2016) developed a novel retrieval algorithm to determine the spatial distribution of mixing weights between dust and soot aerosols. Specifically, the authors use the triaxial-ellipsoidal dust model and the generalized multi-particle Mie-solution model to determine the mixing weights of dust–soot aerosols. Authors successfully apply the model in Egypt and Israel, and the results suggest more accurate aerosol retrievals using the MODIS satellite datasets.

Soils represent one of the largest global carbon pools. Specifically, soil organic matter (SOM) comprises several carbon fractions such as particulate organic matter, microbial biomass, water-stable organic matter, and humus, representing a stabilized organic matter. Thus, SOM as a whole represents soil quality and health as it affects water retention, aggregate formation, bulk density, mineralization, infiltration, aeration, microbial activity in the soils, etc. Recent literature suggests that addressing sustainable
land use management should include SOM dynamics as a critical variable (Magdoff and Weill, 2004, Oldfield et al 2019). Addressing soil organic carbon (SOC) changes due to the conversion of natural forests to plantations is a complex issue as various management practices can affect the soil quality parameters differently. In a study "Changes in soil organic carbon stocks after conversion from forest to oil palm plantations in Malaysian Borneo," Rahman et al (2018), show a significant decline in SOC stocks of about 42%, 24% and 18% after 29, 39 and 49 years after conversion respectively. The authors also highlight the most significant loss and differences in SOC in the topsoil (0–15 cm depth) in addition to the subsoil (>30 cm). The study also highlights SOC stocks in different management zones of oil palm plantation areas. Authors emphasize that although there was a decline in SOC levels from forests to plantations, during the second rotation of plantations, the SOC levels started recovering, as the time since conversion increased. Thus, improved management practices in the oil palm plantations can help in restoring SOC loss. The study suggests that appropriate land use and management practices can reverse soil degradation, improve soil quality and resilience in palm oil plantations.

Overall, the focus issue highlights the LUCC issues, specifically forest conversion to oil palm plantations and the resulting impacts on nutrient dynamics, biomass burning pollution, aerosol effects on climate, including carbon fluxes and budgets in various countries in South/Southeast Asia. The published papers add new science to the LUCC literature and guide scientists to some new datasets, algorithms, and research areas.

Data availability statement

No new data were created or analysed in this study.

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