　　主　　論　　文　　の　　要　　旨

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論文題目：Tracking atmospheric chemical components in accordance with the Sustainable Development Goals (SDGs)

In this study, my initial emphasis was on researching air pollution at the local level. I examined the effects of extreme events on regional air pollution changes and drew lessons that could inform future policies. Subsequently, my focus shifted to greenhouse gas monitoring research. Specifically, I concentrated on estimating global terrestrial carbon fluxes and the development of a platform to monitor emissions of greenhouse gases from fossil fuels, along with examining carbon sequestration in forests and considering other pertinent factors at the local level. In this study, I answer these five research questions that are raised as follows:

*1. How did the COVID-19 lockdown and the armed conflict impact air quality in Ukraine, and what lessons can be derived for future policies?*

I analyzed NO2 levels in Ukraine during two significant periods and determined that meteorological factors were the primary contributors to the reduction in NO2 in populous cities during the lockdown period in 2020. After normalizing for meteorological effects, we observed a moderation in the increase of NO2 levels during the lockdown compared to pre-lockdown levels. Examining the same months during the conflict in 2022, I identified even more substantial reductions in NO2 levels in these cities. Additionally, beyond our investigation of major urban areas, we noticed decreases in NO2 levels in areas surrounding coal power plants that were damaged or destroyed during the conflict. Regarding major urban areas in Ukraine, we conclude that changes in daily anthropogenic activities due to conflict-related events had a more significant impact on NO2 levels than the COVID-19 lockdown. I recommend adopting a more stringent approach in future policies to reduce NO2 levels in Ukraine's urban areas.

*2. In what ways did the COVID-19 lockdown influence air quality in Japan, and what lessons can be learned for future policy considerations?*

I investigated the impact of NO2 reduction on O3 and CH4 in 14 metropolitan areas of Japan in 2020 by employing business-as-usual air quality time series generated by machine learning models. Additionally, I use satellite observations and biogeochemical model simulations to analyze air quality changes. I found that during the lockdown period from April 7 to May 25 in 2020, I observed a NO2 reduction that equated to a decrease equivalent to 3.4 years and 5 years of the corresponding trends in roadside and ambient air quality recorded from 2010 to 2019. After meteorological normalization, NO2 decreased by 14.5% at ambient air stations and 19.1% at roadside stations. Surprisingly, the NO2 reduction did not immediately lead to increased O3. Instead, O3 levels rose after the lockdown, specifically in August due to favorable sunny conditions. This finding is important for Japan and has not been reported in previous studies. We found that changes in NO2 and CO marginally contributed to variations in CH4 levels across the study areas. To effectively mitigate the adverse effects on O3 and Ch4, it is recommended to simultaneously reduce air pollutants as well as anthropogenic and biogenic volatile organic compounds in future policies.

*3. What methodology can be employed to map Plant Functional Types (PFTs) in data-sparse regions?*

I proposed a combined machine learning approach with a deep convolutional neural network (CNN) which improves the accuracy of plant functional types (PFTs) mapping and tree age estimation in Ena city, Japan. First, I employed the Random Forest (RF) classifier using Google Earth Engine (GEE) for forest mapping. Then, I designed a deep CNN architecture that works for PFTs and forest age mapping from coarse and polygonal ground-truth data. The proposed network has U-shape and comprises 3D Atrous Convolutions. The model was optimized by a weighted cross-entropy loss function. I trained the model with times-series Sentinel 1, 2, and Digital Elevation Model (DEM) data with sparse annotations. The proposed models achieved 94.5% overall accuracy (OA) for forest mapping, 77.80% (OA) for PFTs, and 81.74% (OA) for forest age classification, respectively which outperformed the 2D and 3D UNET performance.

*4. Can the utilization of updated PFT maps and models based on Transformer architecture enhance the accuracy of global carbon flux estimates?*

Yes, by utilizing the new PFTs dataset in combination with multivariate timeseries Transformer-based model we provided a monthly global gross primary production (GPP) and ecosystem respiration (RECO) dataset from 1990 to 2019 at 0.25° × 0.25° spatial resolution which outperforms FLUXCOM, NIES, and MetaFlux datasets when comparing the correlation at site-level and seasonal pattern with FLUXNET 2015, especially in tropical regions. Additionally, our dataset reveals the highest positive trend in GPP from 2001 to 2019, aligning with the widely recognized positive GPP trend due to the CO2 fertilization effect. Notably, it captures long-term trends that FLUXCOM and MetaFlux fail to replicate, contradicting the observed significant greening reported by other studies. Lastly, I compare our dataset's interannual variations with other datasets, finding lower variations in extreme-low-GPP regions than NIES data when considering the same utilized remote sensing resources.

*5. How can we efficiently monitor emissions of greenhouse gases derived from fossil fuels and the carbon sequestration from forests, in addition to addressing other relevant factors at the local level?*

I have developed a digital earth platform for monitoring greenhouse gas emissions from fossil fuels, offering a roadmap for achieving carbon neutrality at the municipality level in Japan. The platform integrates energy-related data, including information on energy consumption and electricity statistics from major domestic power companies. This encompasses data on electricity usage, forecasts, and supply, along with an assessment of the capacity of forest sinks. This integrated information provides a comprehensive overview of the status towards achieving zero-carbon at the municipality level in Japan. The platform is accessible at the following URL: http://de14.digitalasia.chubu.ac.jp/