Final Report of Information Gathering and Verification Survey on Sustainable Peatland Management and Conservation Cooperation

March 2023

Japan International Cooperation Agency (JICA)

Japan Forest Technology Association (JAFTA)
Nippon Koei Co.,Ltd.

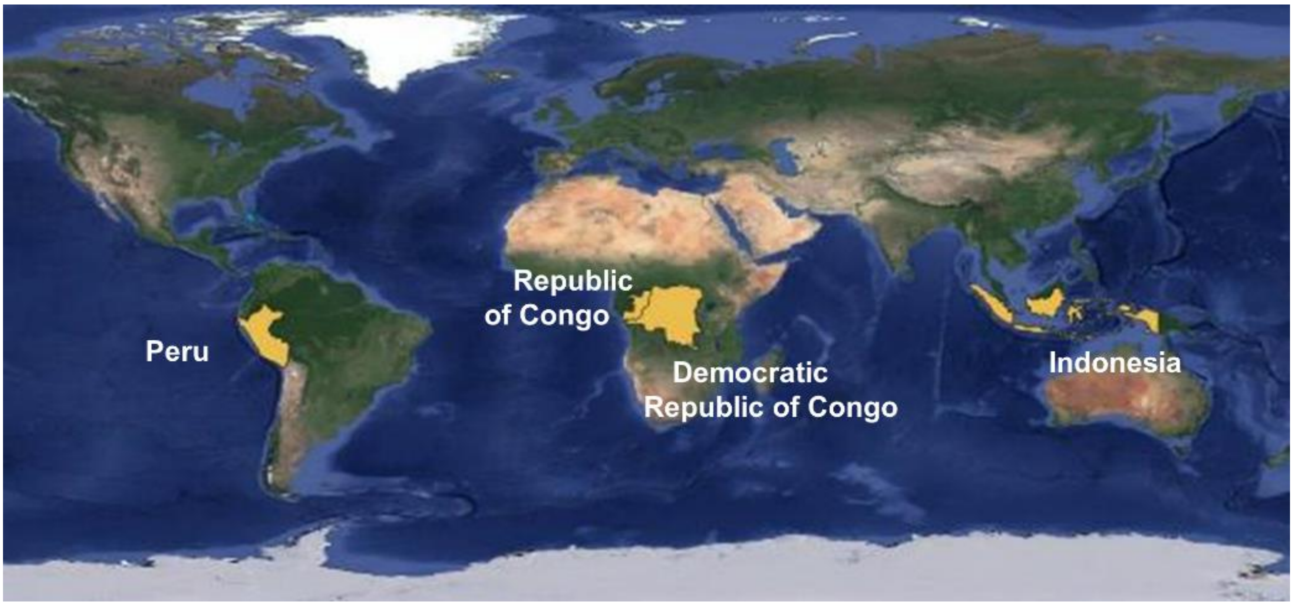
GE
JR
23-036

Table of Contents

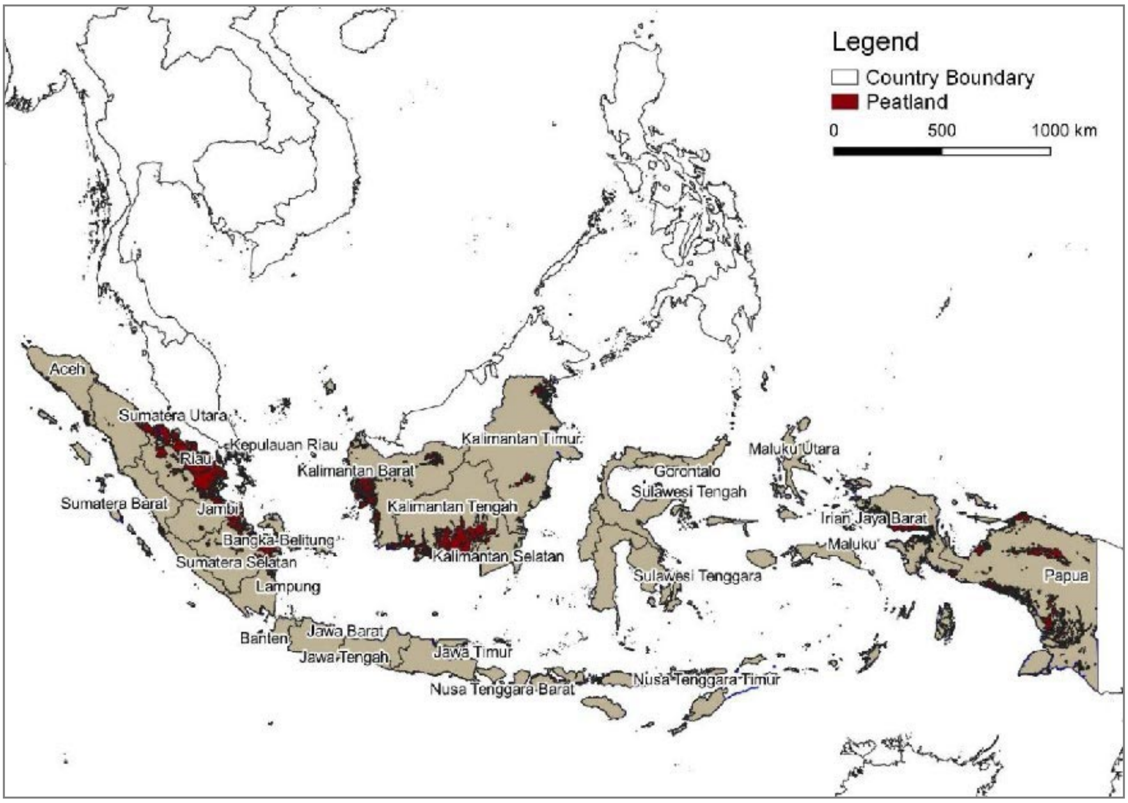
Figures

Tables

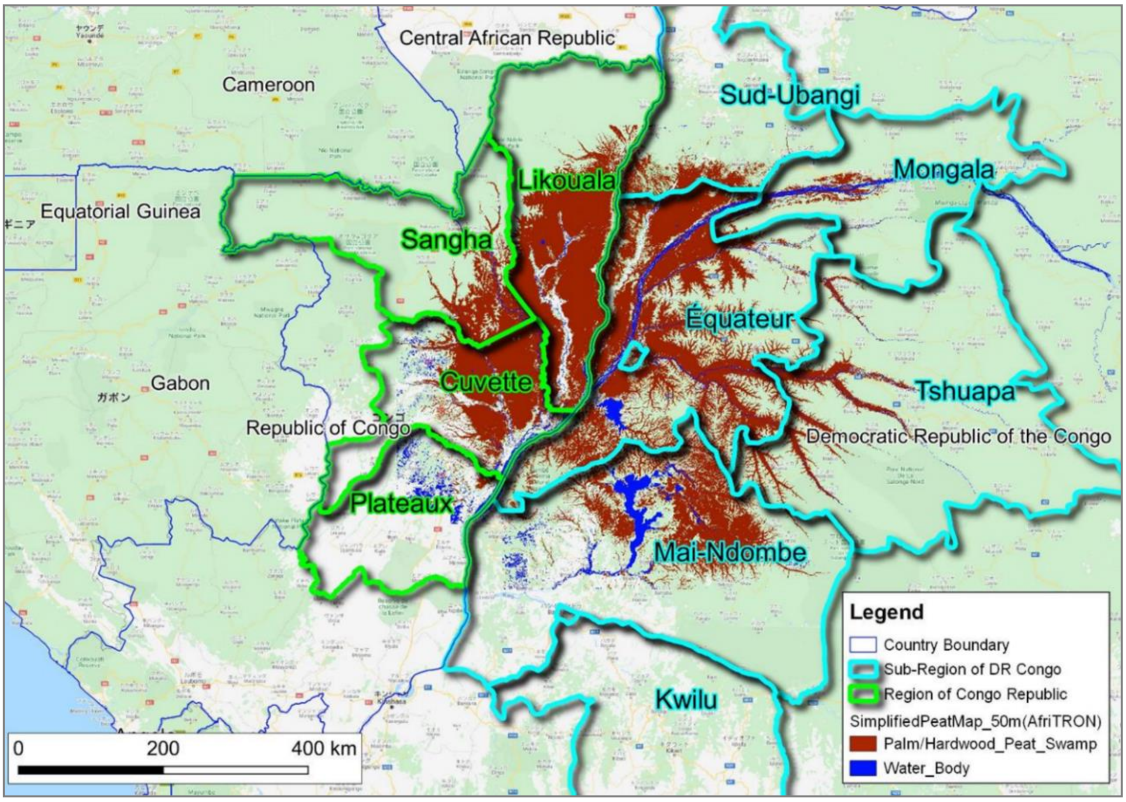
Location map of countries surveyed (Survey team,2023)



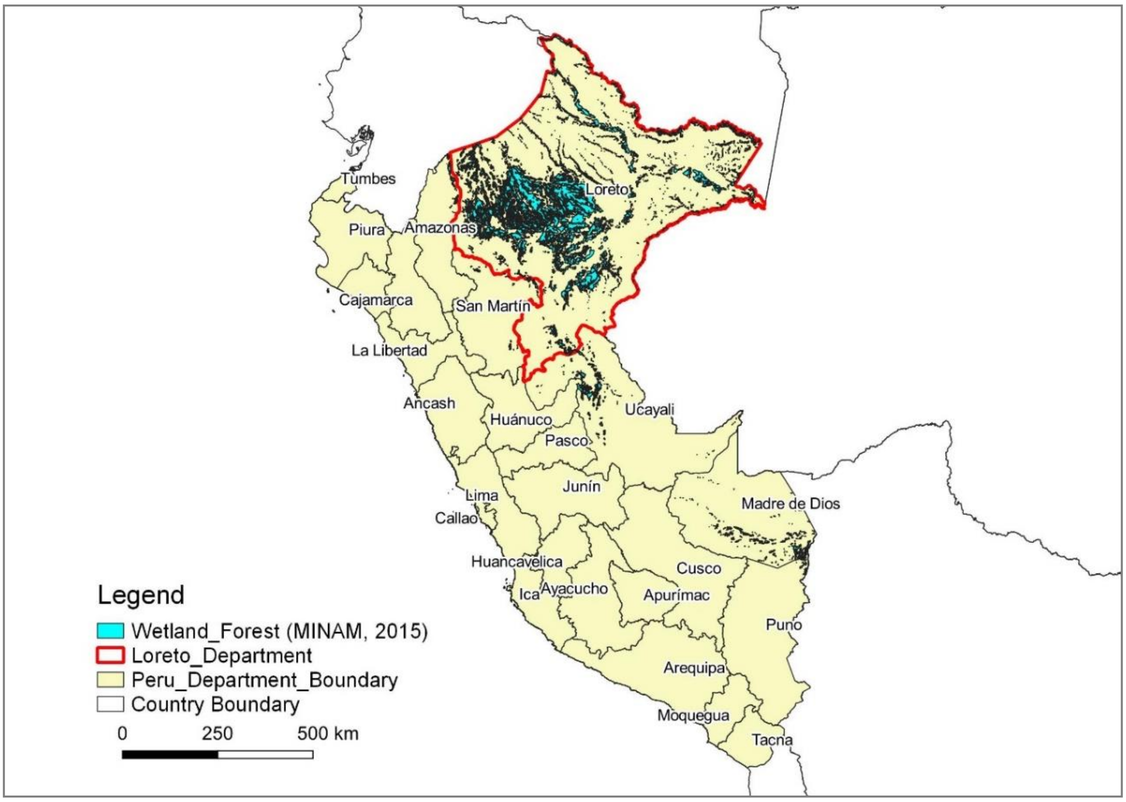
Peatland Location Map : Indonesia (Gathering and Verification Survey on Sustainable Peatland Management and Conservation Cooperation Survey team, 2023)



Peatland Location Map : Republic of Congo and Democratic Republic of the Congo (Gathering and Verification Survey on Sustainable Peatland Management and Conservation Cooperation Survey team, 2023)



Peatland Location Map: Peru(Gathering and Verification Survey on Sustainable Peatland Management and Conservation Cooperation Survey team, 2023)



Abbreviations

Abbreviation	English, French, Spanish, German, Indonesian
AD	Activity Data
AE	Accredited Entity
Bappenas	Kementerian Perencanaan Pembangunan Nasional (Ministry of National Development Planning)
BIG	Badan Informasi Geospasial (Geospatial Information Agency)
BBSDLP	Balai Besar Litbang Sumber Daya Lahan Pertanian (Center for Research and Development of Agricultural Land Resources)
BMKG	Badan Meteorologi, Klimatologi, dan Geofisika (Meteorology, Climatology and Geophysics Agency)
BPPT	Badan Pengkajian dan Penerapan Teknologi (Technology Assessment and Application Agency)
BRGM	Badan Restorasi Gambut dan Mangrove (Peat and Mangrove Restoration Agency)
BUR	Biennial Update Report
CAFI	Central Africa Forest Initiative
CBD	Convention on Biological Diversity
CIFOR	Center for International Forstry Research
COP	Conference of the Parties
DDD	Direction Développement Durable
DG	Division Géomatique
DIAF	Direction Inventaire, Aménagement Forestier
DIF	Division Inventaire Forestier
DRC	Democratic Republic of the Congo
DTM	Degital Terrain Model
EF	Emission Factor
ETD	Decentralized Territorial Entity
ESG	Environment, Social, Governance
F/R	Final Report
FAO	United Nations Food & Agriculture Organization
FONAREDD	Fonds National de REDD+
FREL	Forest Reference Emission Levels
GCF	Green Climate Fund
GEC	Global Environmental Center
GFW	Global Forest Watch

Abbreviation	English, French, Spanish, German, Indonesian
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	Deutsche GesellschaftfürInternationale Zusammenarbeit GmbH
GPI	Grobal Peatland Insitiative
GSMaP	Global Satelite Mapping of Precipitation
GT	Ground Truth
IP	Investment Plan of REDD+
IPCC	Intergovernmental Panel on Climate Change
ITPC	International Tropical Peatland Center
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JJ-FAST	JICA-JAXA Forest Early Warning System in the Tropics
KBDI	Keetch-Byram Drought Index
Kemendagri	Kementerian Dalam Negeri (Ministry of Interior)
KGE	Kling-Gupta Efficiency
KLHK	Kementerian Lingkungan Hidup dan Kehutanan (Ministry of Environment and Forests)
KATR	Kementerian Agraria dan Tata Ruang (Ministry of Agriculture and Spatial Planning)
LAPAN	Lembaga Penerbangan dan Antariksa Nasiona (National Institute of Aeronautics and Space)
LiDAR	light detection and ranging
LIPI	Lembaga Ilum Pengetahuan Indoneisa
MECNDD	Ministre de l'Environnement, Conservation de la Nature et Développement Durable
MEDD	Ministre de l'Environnement et Développement Durable
mKBDI	Modified Keetch-Byram Drought Index
MRV	Measurement, Reporting and Verification
NC	National Communication
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDA	National Designated Authorities
NDC	Nationally Determined Contributions
NDVI	Normalized Difference Vegetation Index
NFI	National Forest Inventory
NFMS	National Forest Monitoring Systems
NICFI	Norway's International Climate and Forest Initiative

Abbreviation	English, French, Spanish, German, Indonesian
PARSAR	Phased Array Type L-band Synthetic Aperture Radar
PF	Plate-Forme technique de coordination
PFVI	Peatland Fire Verification Index
PRIMS	Pranata Informasi Restorasi Ekosistem Gambut (Peatland Ecosystem Restoration Information Officer)
PUPR	Kementerian Pekerjaan Umum dan Perumahan Rakyat (Ministry of Public Works and Housing)
Ramsar	The Ramsar Convention
REDD	Reducing Emissions from Deforestation & Forest Degradation
ROC	Republic of Congo
RS	Remote Sensing
SERFOR	Servicio Nacional Forestal y de Fauna Silvestre (The National Forestry and Wildlife Service)
SAR	Synthetic Aperture Radar
SEPAL	System for Earth Observation Data Access, Processing & Analysis for Monitoring
SIPALAGA	Sistim Pemantauan Air Lahan Gambut
SISFO BRG	Sistim Informasi BRG (BRG Information System)
TOR	Terms of References
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRF	Weather Research and Forecasting Model

Executive Summary

Chapter 1 Introduction
Project Background

Mechanisms to reduce emissions from deforestation and forest degradation have been discussed in the United Nations Framework Convention on Climate Change (UNFCCC), along with the importance of strengthening the conservation of forests and other greenhouse gas (GHG) sinks. Although peatlands cover only 3% of the Earth's surface area[1], it is estimated that they fix at least nearly twice as much carbon as the aboveground biomass carbon storage of the world's forests. Conversely, about 15% of peat has been released into the atmosphere to date, due to the lowering of the water table caused by development, releasing stored carbon. These peatland-derived carbon dioxide emissions are said to be equivalent to 5% of emissions from human activities[2], emphasizing the urgent need to reduce peat-derived greenhouse gas emissions.[3] The Republic of Indonesia ("Indonesia"), the Democratic Republic of the Congo ("DRC"), The Republic of Congo (“ROC) and the Republic of Peru ("Peru"), which are estimated to have the most tropical peatlands, have vast areas threatened by anthropogenic exploitation and are therefore considered to be the most important sources of greenhouse gas emissions.

Conversely, no proper methodology for assessing peat-derived greenhouse gas emissions has yet been established and the global peat distribution area and its carbon content remain unclear. The international community has begun to promote peatland mapping to determine the global peat distribution area. With this and future technical cooperation in mind, we will focus on internationally important tropical peatlands, develop a program to estimate groundwater levels in peatlands in real time and map major tropical peatlands and collect basic information on the policies of major countries and trends in related actors involved in peatland conservation. Plans were also made to collect basic information on the policies of major countries involved in peatland conservation and the trends of related actors and examine the potential for future cooperation on peatland cooperation.

Contents of the study

This study will target four countries that are considered to have the largest amount of tropical peat: Indonesia, the Democratic Republic of the Congo, the Republic of the Congo, and Peru.

To consider cooperation strategies related to peat, the following survey will be conducted in the above four countries, which are considered to have potentially high peatland conservation and management effectiveness, but have not yet collected sufficient information on peatland evaluation models and appropriate conservation and management, in order to collect and analyze basic information for the formation of peat cooperation projects.:

- Peatland maps will be developed for the target countries. In Indonesia, a high-precision soil moisture map will be developed and a groundwater level estimation model, a greenhouse gas emission assessment model and a peat fire and intensity prediction map program based on this map will be developed (hereinafter referred to as "high-precision soil moisture mapping-based program development").

[1] Joosten, H. (2009): The Global Peatland CO_2 Picture. Peatland status and emissions in all countries of the World. Wetlands International, Ede. 10 p.
[2] IPCC.(2014) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
[3] FAO. 2020. Peatlands mapping and monitoring - Recommendations and technical overview.

■ The purpose of this project is to understand the current situation and identify issues related to peatland conservation and sustainable management in the target countries, examine effective business models for peatland conservation and study the possibility of Japan's future support for peatland cooperation.

Survey Area and Notes

The four countries included in this study are Indonesia, DRC, ROC and Peru, which are considered to have the largest tropical peatland area. The notes for each are as follows:

The work in each of the surveyed regions is summarized and shown in the table below.

Table i. Summary of operations by surveyed area

No.	Main Work	Indonesia	Congo Basin		Peru	Remarks
			DRC	RC		
1	Development of High-accuracy soil moisture mapping-based technology program (by involving the Japanese Service Provider)	●	-	-	-	Utilizing the findings by the Japanese researchers from JICA SATREP Cooperation in Indonesia
2	Peatland mapping (Based on the vegetation specific to peatland)	-	●	●	●	Utilizing the findings from JICA REDD+ Cooperation
3	Collection of information on peatland management and protection as well as analysis of cooperation potential	●	●	●	● (by Interim Report)	For the current cooperation in Peru and new cooperation in Indonesia as well as for framework of wide area projects
4	Transmission of information	●	●	●	●	COP(UK)

(1) Indonesia

Indonesia is the largest holder of tropical peatlands, which are called huge carbon stores and is said to hold 36% of the world's peatlands.[4] JICA implemented the Scientific and Technological Cooperation (SATREPS) "Fire and Carbon Management in Peat and Forest in Indonesia Project" for four years and four months from 2009 and accumulated basic data through on-site measurements, remote sensing, simulation models, etc., to establish a peatland management approach. Based on the basic data, a model to estimate groundwater level from soil moisture content (groundwater level estimation model) and a fire detection system and carbon assessment model based on the model were developed in collaboration with Hokkaido University and Kyoto University. In future, to ensure peat is managed and evaluated appropriately, it is necessary to establish a model for evaluating carbon emissions from peatlands using these models and develop a program to operate it, as well as standardize the model internationally for application elsewhere.

(2) DRC and ROC

The Congo Basin is estimated to contain about 30% of the world's tropical peatland carbon stocks and the peatlands that exist between the DRC and ROC across the Congo River are said to be the largest contiguous tropical peatlands in the world. This peatland includes three Ramsar wetlands, totaling 1,292 million hectares, making it one of the largest Ramsar wetlands worldwide. Although the peat strata are relatively shallow with a median thickness of 2 m, they cover an area of more than 1,400 million ha and are projected to store 30 billion t-CO_2eq of carbon.[5] Development pressure on peatlands is expected to increase in future, including

[4] Warren, M., Hergoualc'h, K., Kauffman, J.B., Murdiyarso, D. & Kolka, R. 2017. An appraisal of Indonesia's immense peat carbon stock using national peatland maps: uncertainties and potential losses from conversion. carbon balance and management,12(1): pp. 12 -12.

[5] Dargie, G. C., Lewis, S. L., Lawson, I. T. et al. (2017) Age, extent and carbon storage of the central Congo Basin peatland complex. nature, 542 (7639). pp. 86-90.

concession development plans. In this context, there is an urgent need to clarify the current status of peatlands in the Congo Basin and provide directions for their conservation.

In this study, we collected basic information on peatland mapping and conservation in the Congo Basin (DRC, ROC) and organized the information for subsequent identification of cooperation potentials.

(3) Peru

Peru's tropical forests belong to the Amazon River Basin, which has the world's largest tropical forests and is the second-largest area of Amazonian tropical forests after Brazil. Peru's tropical peat forests are said to be the third-largest worldwide after Indonesia and the Congo Basin. Although no large-scale peatland development projects are planned yet, the Peruvian government is becoming increasingly aware of the importance of peatland conservation in response to recently proliferating international discussions on climate change and peatlands. However, the distribution of peat forests as well as the storage and emission of greenhouse gases are still not accurately known.[6] JICA has been providing technical assistance in the forestry sector since 2016, using satellite remote sensing technology to support the development of a vegetation-based peatland mapping methodology. Based on the trial version of the peatland map, field surveys were conducted in parts of Ucayali and San Martín in 2018 and December 2019 to verify the applicability of our mapping methodology as well as to collect information on the distribution and partial depth of the peat itself by gathering peat samples.

In this study, we will also collect information on the vegetation-based peatland mapping method developed in the above project and analyze the differences from the high-precision soil moisture mapping-based peatland mapping method to be developed in this study, as well as the required operational framework. Information was also collected and organized for future potential studies in peatland cooperation.

Chapter 2 Identification of the current status and issues related to the field of peatland management and conservation in the countries under study

Indonesia

The international framework, related international conventions, relevant actors and national level policy systems regarding peatlands in Indonesia were summarized. Indonesia has ratified five international frameworks related to peatlands: i.e. Ramsar Convention, Convention on Biological Diversity, United Nations Framework Convention on Climate. It also participates in regional cooperation frameworks such as the ASOEN-HTTF and SRFA for Sumatra and Borneo, the ASEAN Regional Haze Action Plan, the ASEAN Agreement on Transboundary Haze Pollution and the ASEAN Peatland Management Initiative (APMI).

The Indonesian government has positioned the management and protection of peatlands as one of its important national strategies and main focal points are the Ministry of Environment and Forestry, the Mangrove and Peatland Restoration Agency (BRGM) and the Ministry of Agriculture. In addition, for peatland restoration activities, the governors of seven provinces with extensive peatlands are assigned some administrative duties in the environmental forestry sector. The seven priority provinces for peatland conservation include Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua. The total area of peatlands is estimated at 24 million ha and among them, 20.7 million ha are lightly degraded peatlands, 2.5 million ha are moderately degraded and 0.7 ha are severely degraded.

As peatlands are particularly widespread on Indonesia's three large islands, Sumatra, Kalimantan and Papua, efforts to manage and protect peatlands by the central government, including Indonesian ministries and

[6] Forest Conservation and REDD+ Mechanism Capacity Building Project

national institutions, have been implemented and also ongoing. Concessionaires may also be asked to implement in the concession areas, by restoring the peat ecosystem, installing rainfall monitoring stations, rehabilitating by planting indigenous plant species and so on.

The Indonesian government has developed a monitoring system called PRIMS (Pranata Informasi Restorasi), which compiles maps and information on peat.

Indonesia's enhanced NDC was submitted to the UNFCCC in September 2022 on reducing GHG emissions through peatland conservation. By 2030, GHG emissions will be reduced by 31.89% (unconditionally) through domestic efforts alone and by 43.20% (conditionally) if the necessary international assistance is received, compared to the BAU in 2010.

Regarding the methodology for estimating the reduction of GHG emissions from peatlands, the JICA-JST Science and Technology Research Partnership for Sustainable Development (SATREPS) Fire and Carbon Management Project in Peatlands and Forests (JICA-JST SATREPS Project) was implemented from 2009 to March 2014 in Kalimantan Province. JICA-JST SATREPS Project produced results in research and technology development related to carbon management of peatlands, which have particularly high carbon stocks.

Congo Basin

The Congo Basin, known as "one lung of the earth," has the second largest forested area worldwide after the Amazon in South America. The peat swamp vegetation in the basin has various appearances, including forested areas, swampy palm forests and herbaceous swamps. Approximately 10,000 species of tropical plants are found in the Congo Basin, 30% of which are endemic to the region. It is also a growth and habitat area for 425 species of regionally endemic mammals, including the marumimizo elephant, western lowland gorilla, bonobo and okapi. Because of its valuable ecosystems and biodiversity, 206 protected areas have been designated. More than two million people live in the Congo Basin, particularly around Lake Télle and Lake Tumba, which straddle both DRC and ROC. The population uses fish and other fishery resources, as well as farming and gathering forest products. The use of fisheries resources supports the livelihood of local communities and the surrounding population and also contributes to trade, playing an important role in supporting the economies of both countries. In addition, some of the forests around the peatlands have cultural significance, such as being the object of religious beliefs.

In peatland conservation, various threats exist due to the effects of human activities. Deforestation, of which there have not been many examples, has been identified as a risk leading to fragmentation, destruction and loss of terrestrial and aquatic habitats. Slash-and-burn agriculture has also been highlighted as one of the causes of deforestation and destruction and is considered a factor that attracts wildfires. Poaching is also practiced in the area and such illegal activities also exacerbate the loss of ecosystems and biodiversity in the peatlands.

Currently, international agreements and conventions related to the management and protection of peatlands that have been ratified by the DRC and ROC Communities include the Ramsar Convention, the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change. Others include the UNEA Resolution on Conservation and Sustainable Management of Peatlands, adopted as an outcome document at the UN Conference on Sustainable Development in March 2019 and the UNEA Resolution on Conservation and Sustainable Management of Peatlands, which was adopted as an outcome document of the UN Conference on Sustainable Development in March and which encourages enhanced regional and international cooperation to conserve and sustainably manage peatlands. The Global Peatland Initiative (GPI), the Brazzaville Declaration and the Congo Basin Forest Fund (CBFF) are examples of international frameworks related to peatlands. The peatlands of the Cuvette Central within the Congo Basin are known to have begun accumulating about 10,600 years ago, with a maximum depth of 5.9 m and an average depth of 2.0 m. The peatland area is estimated to be 145,500 km^2. The carbon content of the peatlands is estimated to be about 30 billion tons, which is equivalent to 20 years of CO_2 emissions from the United States.

GPI member countries recognize the importance of peatland development and therefore the need to map peatlands, assess carbon stocks and protect them from wildfires and forests. The Peatland Management Unit (PMU) in the DRC Ministère has been informed that the Centre de Recherche Géologique et Minière (CRGM) has the necessary equipment for peat analysis (quantification of the carbon content of peat samples) and that CRGM is already providing this analysis service for the FAO.

With reference to the status of the study of methodologies for estimating peatland-derived greenhouse gas emission reductions, the document "Carbon, Biodiversity and Land Use in the Peatlands of the Central Congo Basin (Carbon, biodiversity and land-use in theCentral Congo Basin Peatlands)[7] " is instructive. In terms of the current situation of the DRC, there is no evidence of large-scale degradation of peatlands and therefore no significant anthropogenic greenhouse gas emissions. The DRC are working on a project to comprehensively map the peatlands and estimate their carbon stocks by a clear definition in the context of the DRC. The process adopted by the DRC to arrive at this national definition of peatlands is 1. to allow time for national exchange of ideas and consultations to arrive at a commonly accepted definition, 2. collectively define the main objectives of the definition and 3. learn from the experience of other countries. Namely, statements like "a minimum depth of 15 cm and containing at least 5% organic matter" are under consideration with a common definition with neighboring countries in mind for the important parameter of "at least 15 cm depth".

The following is an overview of the DRC and ROC respectively.

DRC

Currently, there is no formal definition of peatlands in the DRC or specific national policies or regulations on peatland conservation, but a "National Peatland Strategy" is being developed. Legal documents dealing directly or indirectly with peatland management at the national level of the DRC include 1) Law No. 15/026 of December 31, 2015 on water, 2) Law No. 014/003 of February 11, 2014 on nature protection, 3) Law No. 011 of August 29, 2002 on forestry law /202, 4) Law No. 11/009 of July 9, 2011 on Basic Principles for Environmental Protection, 5) Decree of June 20, 1957 on Urban Planning and 6) National Strategy for Biodiversity Conservation in Protected Areas in the DRC. As a national peatlands strategy, the DRC's Government has started to develop a framework to coordinate and implement national strategies, initiatives, projects and programs on peatlands.In July 2019, the first national peatlands information workshop was held and a roadmap for the preparatory phase of peatlands management was initiated in August 2020.

As for the structure of the central government institutions, the Assembly is responsible for formulating and revising laws to guarantee the conservation and sustainable management of peatlands and the guarantee of management by legislators on government actions for the sustainable management of peatlands; the Ministry of Environment and Sustainable Development (MEDD) is responsible for managing the environment sustainably and conserving biodiversity and ecosystems and the Ministry of Environment and Sustainable Development (MEDD) is responsible for the The establishment of the MEDD was established by Regulation No. 20/017 of March 27, 2020 on the establishment of the Ministry of the DRC, to be responsible for the implementation of national policies related to the sustainable management of the environment, the preparation, study and evaluation of plans for the implementation of policies and the sustainable management of forests, water resources, fauna and environmental resources.

The State Council has the role of taking legal actions at the state level to enhance peatland conservation. It is also responsible for managing the actions of the state government with regard to peatland protection and the Governor prepares the State Development Plan and Governor's Decree, taking into account priorities with regard to the conservation and management of peatlands. The State Planning Department ensures that the State Development Plan includes peat conservation and sustainable management and the State Department of Land Use Development Planning initiates and coordinates the process of developing a State Development Plan that

7 https://www.unep.org/resources/publication/carbon-biodiversity-and-land-use-central-congo-basin-peatlands

integrates peatland conservation and sustainable management. In addition, the ACE Provincial Branch is responsible for reviewing and approving strategic environmental assessments of provincial and regional land use plans and impact assessments that may have an impact on peatlands.

A summary of other donor and private sector peatland conservation and management support projects shows that 1) The Global Peatland Initiative Project (Projet de l'Initiative Mondiale pour les Tourbières) has been holding national stakeholders' capacity-building sessions for peatland mapping. Congo Peat (Congo Peat) is also analyzing peat samples to reconstruct the historical climate record of the Congo Basin, including changes in peat over time; expanding and refining mapping, range and carbon content estimates, including field data collection in the DRC; modeling various development and disturbance scenarios and and estimating potential future impacts on these sensitive ecosystems, among others. In addition, the IKI project (Project for the Protection of Biodiversity, Carbon and Water Supply in Peatlands of the Congo Basin, Projet " Protéger la biodiversité, le carbone et les réserves d'eau dans les tourbières du Bassin du Congo") focuses on five axes: i) Enabling Environments; ii) Biodiversity, growth and habitats; iii) Water and climate; iv) Peatlands and ecosystems; v) Capacity-building and knowledge management iii) Biodiversity.

ROC

Regarding the laws and decrees related to peatland management and protection in the ROC, 1) Law No. 37-2008 of November 28, 2008 on basic policies and general conditions for the sustainable conservation and management of fauna, growth and habitats and ecosystems; 2) Forest Law (No.16-2000 of November 20, 2000); 3) Law No.003/91 of April 23, 1991; 4) Decree No. 2002/437 of December 31, 2002; 5) Law No.13-2003 of April 10, 2003 on water; and 6) Law No.3-2010 of June 14, 2010 on fishery operations.

The Ministry of Environment, Sustainable Development and the Congo Basin is in charge of combating climate change, biodiversity and peatland conservation in the Congo. The Ministry of Environment, Sustainable Development and the Congo Basin was renamed the Ministry of Environment and Sustainable Development (Ministère du Tourisme et de l'Environnement) in May 2021 to address more sustainable issues. The Ministry of Forestry and Economy (Ministère de l'Economie forestière) is also responsible for issues related to forest conservation and management in the ROC and REDD+.

Although no pertinent information is available on the state-level structure, as a state-level initiative, the French Agency for Development (AFD) is implementing projects in the areas of climate change and ecosystem conservation in the ROC. Projects in the field of climate change are taking place in Cameroon, the DRC and the ROC and are being implemented by AFD and the EU. The project aims to improve anti-corruption policies and practices in climate change initiatives such as REDD+ and the forest sector in Central Africa.

In the area of biodiversity, a project is being implemented in the northern province of Likouala starting in 2020. The project is co-financed by AFD and the Fonds français pour l'environnement mondial (FFEM). It aims to support development strategies at the local level while promoting the conservation of forests and biodiversity and the appropriate maintenance of land. In addition, readiness-like activities have been carried out since 2018 with small-scale funding through GPI and the same activities are working to strengthen the capacity of remote sensing technologies.

Peru

The international frameworks, related international treaties, relevant actors, national-level policy systems, etc. related to peatlands in Peru were summarized. Peru has ratified four international frameworks related to peatlands: i.e. the Ramsar Convention, the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change and the Paris Agreement. The three departments under Ministry of the Environment are the Peruvian government's focal points for them; i.e. Directorate General of Natural Resources and Strategic Development, Directorate General of Biodiversity and Directorate General of Climate Change and Desertification. Investigative research activities involving peat are being conducted by the Institute of Amazon Research (IIAP) under the Ministry of the Environment. In May 2021, SERFOR became the agency responsible for managing the conservation and sustainable use of carbon-rich ecosystems such as peatlands. However, since there is no definition of peatland in Peru so far, it is difficult to evaluate the area and carbon storage of peatland. Recently, the reduction of GHG emissions through peatland conservation is expected to contribute to climate change mitigation as a national GHG reduction target (NDC), therefore, basic information is being developed, such as the creation of policies and guidelines for management and conservation of the peatlands. In addition, there are the following issues, lessons learned and needs from ongoing cooperation projects: i.e. (1) Issues/Lessons: There are issues in the government regarding personnel, budget and frequent changes of personnel in charge of peatland-related work, therefore it is necessary to indicate the importance of operations related to peatlands and the vision and roadmap for peatland conservation and secure personnel and budget. Conversely, due to the growing debate on climate change, it is important to accurately understand the distribution of peatlands and the amount of carbon stocks, but the definition of peatlands and the methodology of mapping have not been sufficiently discussed. (2) Needs: there are high needs particularly in the areas such as peatland mapping, degradation restoration and inventory

Chapter 3 Peatland Mapping (Bordering)

In Chapter 3, the method for mapping peatlands were developed. Tropical peatlands spread in Indonesia/Malaysia, Peru (Amazon Basin) and Congo Basin and various peatland maps have been created, but most peatland maps in Indonesia/Malaysia are based on ground boring surveys and there are few mapping methods applied to peatland in Indonesia using satellite images that can be applied to other areas. A few papers on peatland mapping using satellite images have been reported in Peru and the Congo Basin, but none of them describe the detailed characteristics of the satellite images in peatlands and there are no mapping methods applicable to other regions. Therefore, in this survey, free satellite imagery (Sentinel-2, PALSAR and SRTM/DEM) and open source software were used to develop a simple and highly reproducible mapping method that anyone can utilize.

Congo Basin

To date, only Dargie et al. (2017) have published a peatland map of the Congo Basin, but because there is no detailed description of the characteristics of the satellite images of the peatlands and the date of observation, the reproducibility is low. In this survey, spectral analysis of Sentinel-2 in peatlands were first performed and peatland vegetation and non-peatland vegetation were discriminated. Next, peatland vegetation in the rainy season was extracted from the backscattering characteristics of PALSAR. In addition, the river floodplains were removed from the SRTM/DEM elevation values. In order to verify this method, potential peatland sites were extracted by this method in the vicinity of Nioki in the southern part of Mai Dombe province, which is easily accessible in the Democratic Republic of the Congo. As a result of a field survey conducted in September 2021, peatlands with a maximum thickness of 3.5 m were confirmed and the effectiveness of this method were demonstrated.

Peru

The method to extract “Aguaje” palm forest, which is a typical vegetation in peatland, using optical sensors (Sentinel-2 and Landsat-8), was developed through the technical cooperation project on “The Project on Capacity Development for Forest Conservation and REDD+ Mechanisms” implemented in the departments of San Martin and Ucayali, Peru from 2016 to 2021. In this survey, the method was determined for extracting peatland vegetation; i.e. Aguaje palm forest, with high accuracy using microwave images obtained by PALSAR. The following results were obtained using PALSAR/FBS-HH, FBD-HH and FBD-HV. (1) FBS-HH backscatter values of Aguaje are relatively lower than Mixed-Forest, (2) horizontal polarization (HH) has a wide range of backscatter values of Aguaje and (3) for horizontal polarization (HH) and cross polarization (HV), the range of backscatter values of Aguaje is narrow. Conversely, such characteristics could not be confirmed in all the target peatlands in the departments of San Martin and Ucayali. As a result, it was confirmed that the effectiveness of PALSAR images appeared in about 60% of the peatlands. The effectiveness of PALSAR depends on the factors such as the extent of the submerged area and the density of Aguaje in the peatland.

Chapter 4 Program Development and Validation of Groundwater Level Estimation Model Based on Highly Accurate Soil Moisture Map

In Chapter 4, the program development and verification of the groundwater level estimation model based on the high-precision soil moisture map were conducted. These programs consist of the following five. 1) high precision soil moisture mapping, 2) groundwater level distribution map (groundwater level estimation model), 3) Greenhouse Gas emission estimation model (carbon dioxide and methane) from the groundwater level estimation model, 4) peat fire frequency and intensity prediction model and 5) Peatland bordering estimation model. Program development was mainly carried out by subcontracting in Japan and partly by the Survey Team. The target provinces are Riau, Central Kalimantan and West Kalimantan. Program development was mainly conducted in Japan, but field surveys were conducted during the rainy season (May 2022) and the dry season (August 2022) in Riau province, one of the target provinces, for on-site measurement and verification.

In the high-precision soil moisture mapping, the soil moisture content was estimated using Weather Research and Forecasting (WRF) Model data for the target three provinces. The simulation of WRF was calculated in the following four areas. 1) 27km mesh area covering the whole of Indonesia, 2) 9km mesh for the main area, 3) 3km mesh, 4) 1km mesh for the main area for detailed examination. As a result of multiple regression analysis, when the optimum window area and the optimum number of calculation days are taken, the coefficient of determination exceeds 0.6 at 26 out of 32 points (81%) and 22 points exceed 0.7 (68%). Utilization of SAR data was examined and estimation of soil moisture content using SAR data was carried out in Riau region. A multiple regression analysis was performed using observation data from four locations in the Riau region where field surveys were conducted and five SAR images. At this time, two patterns of analysis were performed: (A) the case of combining all regions and images and (B) the case of each region. As a result, in the case of (A), the F value was 0.0505 and the multiple correlation coefficient was 0.72 and F values for case (B) was 0.49 and 0.12. The relationship between SAR and WRF suggested that the soil moisture content has a strong regional tendency, by verification of the SAR data based on WRF. When estimating soil moisture content from SAR over a wider range, it is necessary to grasp the tendency of soil moisture content for each region in advance and create a multiple regression equation for each region. In addition, as a result of verifying SAR data using drone images, it was confirmed that the difference in soil moisture content between the dry and rainy seasons was reflected in the SAR data to some extent.

Regarding the groundwater level distribution map, the regression equation obtained by multiple regression analysis was used for the three target provinces and the widening of the groundwater level (groundwater level mapping) was examined from the viewpoint of land use. As a result of estimating the groundwater level over a wide area, in contrast to the existing observation data, the groundwater level of some areas showed low along the coastal area. This was considered to be due to the fact that WRF did not consider the pushing up of the groundwater level by seawater. Therefore, based on the existing observation data (groundwater level and tide) in the low rain season, the WRF result was corrected. As a result, the formula showing the groundwater level distribution area was corrected.

Regarding the greenhouse gas (carbon dioxide/methane) emission distribution map, analysis on carbon dioxide and methane were conducted for the three target states. With respect to carbon dioxide, areas with fires tend to have higher emissions and higher sequestration of CO_2. Areas with anthropogenic alterations such as fires and deforestation had to be assessed separately for their CO2 emission budget. Using the results of the daily mean value of the 1km grid groundwater level estimated by WRF, the relational expression with the amount of Net Ecosystem Exchange (NEE) was developed. For methane, an equation between ecosystem-scale CH4 flux (emissions) and groundwater levels was developed. At this time, as well as carbon dioxide, the result of daily average groundwater level of 1km grid estimated by WRF was used.

A model for estimating the frequency and intensity of peatland fires was conducted for the target three provinces. After examining various fire indices, it was decided to use the modified KBDI (KBDIadj), which is conventional fire index, as the peat fire index method. As for adaptation to wide areas, calculation from GSMaP using KBDIadj, whose accuracy is relatively stable, was considered. Regarding the relationship between fire frequency and fire index, hotspots are also relatively easy to detect when KBDIadj falls into the 'highest class'. Furthermore, regarding fire monitoring by drones, it was found that fire monitoring by thermal infrared cameras is effective.

Regarding the peatland bordering (boundary) estimation model (peatland mapping), the existing peatland map was verified based on the results of the existing peatland map and the field survey. In the field survey, to grasp the situation of the peat during rainy season and dry season and to understand the soil characteristics, etc. for both rainy season (May) and dry season (August), hand augering, ground penetrating radar (GPR), LiDAR elevation map, hydrological surveys, vegetation surveys were carried out. As a result, it was found that the existing bordering data did not reflect local variations in peat thickness due to their low resolution. Also, peat boundaries and slopes tend not to be represented. Vegetation information can also be used to confirm the water holding capacity of peat soils.

Unlike the Congo Basin and Peru, there are not specific vegetation that is likely to reflect its characteristics on satellite images for the peatlands in Indonesia (e.g., Aguaje palm in Peru, Raphia palm in the Congo Basin, etc.). Conversely, in this survey, a groundwater level estimation model was developed from the soil moisture obtained from WRF model. Since the groundwater level of peatlands is characterized by being higher than that of the surrounding non-peatland, it is conceivable that there is a close relationship between the groundwater level estimated by WRF and the boundaries of peatlands. In this survey, the "peatland bordering" method, which estimates the boundaries of peatlands from groundwater level information estimated by WRF, was examined in the provinces of Central Kalimantan, West Kalimantan and Riau. The information used was: (1) WRF groundwater level data (August 16, 2019), (2) BBSDLP (2019) peat land map, (3) Land cover map (2019), (4) SRTM/DEM and (5) Boring data obtained in the project of “Environment Research and Technology Development Fund” by Ministry of the Environment, Japan, from 2016-2017. As a result of comparing the BBSDLP (2019) peatland map and various data, (1) the WRF groundwater level in the peatland of the BBSDLP (2019) peatland map is about -90 cm to -50 cm and (2) the SRTM/DEM elevation value is less than 80 m, (3) the type of peatland in the land cover map (2019) was “03_Primary Swamp Forest” or “04 Secondary Swamp Forest”. By setting the conditions (1) to (3), it is possible to evaluate the boundaries of peatlands around existing peatlands and in the areas in which peatlands have not been confirmed.

As part of social implementation, the developed program was tested for related institutions in Indonesia. Specifically, the data and programs were shared with the local related organizations (BRIN：Badan Riset dan Inovasi Nasional) via the cloud, etc. and installed to their computers through online and face-to-face explanations. In addition, the operation method was explained in an online seminar and the program was operated on a trial basis.

Chapter 5 Identification of candidate areas for peatland management and conservation project formation and project needs

Past JICA projects for tropical peatland management

From 2008 to 2013, JICA implemented the "Fire and Carbon Management in Indonesian Peat and Forest" under the International Science and Technology Cooperation Program for Global Issues (SATREPS) in Central Kalimantan, Indonesia, which covers more than half of the world's tropical peat area. The study proposed a world-first MRV system that accurately assesses carbon emissions from peatlands by fusing both ground and satellite data. The system was designed for comprehensive management of tropical peatlands, carbon emission control and carbon management. In this MRV system, eight monitoring targets were selected to comprehensively understand the carbon dynamics of peatlands and technology development related to the quantification of CO_2 emissions using ground-based measurements and satellite data was conducted.

Emissions from three ecosystems with different degrees of disturbance (undrained tropical peat swamp forests (UF), drained tropical peat swamp forests (DF) and forest sites burned after drainage (DB)), continuous observation data of CO_2 exchange (flux) and evapotranspiration between the ecosystems and the atmosphere and environmental data on meteorology, soil, groundwater level, etc., were accumulated. The accumulation of environmental data such as meteorological, soil and groundwater level data has been conducted and it emerged that 1) even undrained wetland forests (UF) are a net source of CO_2 emissions, 2) CO_2 emissions increase as environmental disturbance progresses (averaged over 4 years (2004-2008) DB (4.99 tC ha-1 y-1) > DF (3.28 tC ha-1 y-1)) and 3) the amount of CO_2 emitted from the UF exceeds that from the DB (4.99 tC ha-1 y-1). (4.99 tC ha-1 y-1) > DF (3.28 tC ha-1 y-1) > UF (1.72 tC ha-1 y-1)) and 3) CO_2 emissions are larger in El Niño years, as demonstrated for the first time worldwide.

A peat management system similar to the above remains in operation in peatlands in West Kalimantan by Sumitomo Forestry Co. In Sumitomo Forestry's monitoring system, CO_2 emissions are measured by the eddy correlation method as described above, but groundwater levels and meteorological data are obtained using sPOTELKA, which can be completely remote-controlled. Sumitomo Forestry Co., Ltd. manages 150,000 hectares of peatland, of which approximately 4,000 hectares are covered by sPOTEKA to monitor CO_2 flux, meteorological data and groundwater levels. The acquired data is transferred via satellite communication and the groundwater level is managed to keep it at a constant level. Conversely, such a peatland management system for Indonesia would be difficult to apply to the Congo Basin, where the peatland formation process is different and no model of CO_2 emissions has been established, utilizing flux towers and meteorological observation meters. However, as carbon neutrality is being discussed on a global scale, it will become increasingly important to clarify the CO_2 emission mechanism in the Congo Basin, where a huge amount of carbon (30.6 gigatons) is stored.

Potential study sites for peatland management and conservation projects in the Congo Basin

As far as the potential sites in the Équateur province of DRC are concerned, there has been little research in the Congo Basin, although peat surveys were conducted by British researchers in the ROC and there is little existing information (land cover maps, topographic maps, etc.) to determine the CO_2 emission mechanisms. However, a land cover map prepared by the Greifswald Mire Centre (GMC) exists for the Jardin Botanique d'EALA peat swamp near Mbandaka, Équateur Province which is located approximately 2 km east of Mbandaka and has very good access to peatlands. The availability of GMC land cover maps makes it easier than other sites to consider locations for meteorological and groundwater level measurement equipment. Furthermore, easy access to urban areas has the advantage of allowing for quick response in case of equipment failure. If a 10 km square peatland including the Jardin Botanique d'EALA peat bog is to be monitored, there are peatlands within a 10 km radius to the south where CO_2 measurement equipment and the sPOTEKA parent unit can be installed. Sentinel-2 images of the candidate peatlands show no evidence of disturbance and are therefore considered to be suitable as survey sites for future peatland management and conservation projects. Note that CO_2 fluxes have been measured since 2020 at Yangambi, about 600 km east of the peatlands in the Congo Basin. However, since it is not a peatland, CO_2 emissions are measured only from tropical forests.

Conversely, looking at candidate sites outside of the Équateur province of DRC, other than the Jardin Botanique d'EALA peat swamp near Mbandaka, the lack of existing information available and the poor accessibility to the study site make them carefull considaration as candidate sites for peatland management and conservation projects. The peat swamps are not considered suitable for peatland management and conservation projects due to lack of existing information and poor accessibility to the study sites. If other than Mbandaka, Equatorial Province is to be considered, the peatlands in MaiNdombe Province, considering the accessibility from Kinshasa and the distribution of peatlands. Basic surveys have identified peatlands in the southeastern part of Nioki, but their limited distribution renders them unsuitable for the construction of the flux towers.

In developing this project for the ROC, we took care to carefully explain and involve the government of the destination country to ensure that the maps and ground data that would be the outcome of the project would be utilized to a high degree. This was based on the experience of other donors in the past, where the use of the final results did not progress due to a lack of explanation to the government agencies.

In relation to the above conditions and candidate projects, a request letter dated August 3, 2021 from the Undersecretary of the Ministry of Environment to the Director of the JICA DRCs Office regarding future assistance in the peat field, preparation of a request for Japanese grant assistance (digital grant) including installation of a flux tower, weather and groundwater observation equipment in a pilot project on peat lands began. The JICA Congo Civil Affairs Office has also begun to study scope to conduct a request survey for technical cooperation on peatlands. Although the status of realization of this technical cooperation is still under consideration as of 2023, the necessary strategies include the mapping of peatlands in the Congo Basin, the establishment of a monitoring system for GHG emissions from peatlands and the development of a peatland management system, with the aim of creating environmental conditions that will allow private funds to be invested in peatland conservation and management in the Congo Basin in future. A possible concept is to support policy development in which the peatland component contributes to the achievement of NDCs in both countries.

Direction of peatland management and conservation projects using external funding

JICA has been entrusted by CAFI to implement the Integrated REDD+ (PIREDD) program in Kwilu Province under LOI1 and is currently seeking letter of interest for the program in the Congo under CAFI LOI2, which will be announced in May 2022. When considering the direction of peatland management and conservation projects utilizing CAFI funds with consideration of logistics supply zone to Kinshasa and other large cities. It is important to keep the movements of other donors related to LOI2 in mind.

Chapter 6 Recommendations on Future Cooperation Strategies for Peatland Management and Conservation

The Place of Peatlands on the Agenda of the International Community

In recommending a future cooperation strategy for peatland conservation and management, we reviewed the agendas being discussed by the international community and the status of peatlands.

Discussions in the United Nations Environment Program held the 4th United Nations Environment Assembly in Nairobi in March 2019, which adopted 16 resolutions, with "Conservation and sustainable management of peatlands" as the fourth. A notable paragraph in this resolution stated that the most accurate inventory data possible is essential for the international community to take any action (intervention) on peatland management and suggested the importance of efforts from the research field. Peatlands can be understood as co-beneficial landscapes that provide various ecosystem services, but they can also be understood as nature-based solutions (NbS) to social problems. In addition, at the 5th United Nations Environment Assembly held in Nairobi in 2022, the importance of NbS and the promotion of NbS activities by each country was reconfirmed and it was settled, beyond doubt, that ecosystem conservation, including peatland conservation, is indispensable. In addition, in the context of NbS, it was clearly stated that NbS including peatland management promotion plans can only be implemented efficiently and effectively if there is a scientific basis and methodology.

In addition, at the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow in November 2021, attention was focused on "methane emission reductions," which are highly effective in reducing greenhouse gas emissions. Against this background, a joint proposal by the US and EU European Commission for COP26 Global Methane Pledge (GMP) was expressed[8] . While no sectoral breakdown of the 30% reduction is given, it is clear that reducing methane emissions from peatlands is one of the key and land sector initiatives. Emissions from peatlands clearly represent the most important initiative in the land sector.

Furthermore, at the 15th Conference of the Parties to the Convention on Biological Diversity (CBD-COP15) held in Montreal, Canada in December 2022, the main agenda item was the formulation of a "Post-2020 Biodiversity Framework" to replace the "Aichi Targets," which were the global targets until 2020. Of the 23 specific targets, Target 11 "Maintain, restore and enhance ecosystem regulating functions and services through natural or ecosystem-based approaches" is the most relevant to peatlands. There, the goal is to work through NbS. Target 15 also specifies that the risks and impacts on natural resources must be taken into account when developing private sector activities.

As for other international organizations, FAO and GPI are developing activities related to peatlands. FAO's "Peatland mapping and monitoring- Recommendations and technical overview" published in 2020[9] and GPI's "Gobal peatland assessments" in November 2022[10], leading international discussions with specific results. Although there are other international organizations such as Wetland International and The International Peatland Society, FAO and GPI are the two organizations that are most easily linked to JICA's activities, especially peatland monitoring and management. Many of the researchers working at these organizations are involved in the preparation of IPCC guidelines, and they are considered to be important collaborators in communicating JICA's activities internationally.

Trends in Japan and the Position of Peatland Management

Japan has submitted the goal of reducing greenhouse gas emissions by 26% by 2030 to the United Nations. As a longer-term goal, the Fourth Basic Environment Plan calls for an 80% reduction by 2050. Alongside this, the private sector is accelerating its efforts to reduce emissions, particularly by launching initiatives like carbon pricing and the GX League, which aims to "formulate policies through dialogue among businesses that are leading pioneering initiatives" through (1) a forum for dialogue on the future society, (2) market rule formation and (3) voluntary emissions trading. The GX-League is to "formulate policies through dialogue among businesses that lead pioneering initiatives" through (1) a forum for dialogue on a vision for the future society, (2) a forum for market rule formation and (3) a forum for voluntary emissions trading. In particular, in (iii) the voluntary emissions trading forum, demand for emission reduction credits is expected to increase, since high emission reduction targets will be voluntarily set and efforts to achieve them will be promoted and disclosed and voluntary emissions trading will be conducted through the carbon credit market.

8 https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_21_5206
9 https://www.fao.org/3/CA8200EN/CA8200EN.pdf
10 https://globalpeatlands.org/resource-library/global-peatlands-assessment-state-worlds-peatlands-main-report

As mentioned earlier, greenhouse gas emission reductions resulting from peatland management are recognized by the international community as a crucial initiative and they are expected to play an important role in meeting the demand for emission reduction credits needed by the private sector.

Meanwhile, at the World Economic Forum Annual Meeting in Davos in January 2019, the Taskforce on Nature-related Financial Disclosures (TNFD) was conceived to direct the flow of funds toward nature conservation and restoration activities. The TNFD's Beta Framework v0.3, which provides guidance on disclosure and other matters, identifies how organizations can identify their nature-related dependencies, impacts, risks and opportunities and use this information to improve their sustainability performance. The TNFD requires organizations to disclose how they identify, assess and manage nature-related dependencies, impacts, risks and opportunities. Peatlands are used for economic activities by various companies, such as palm oil production and afforestation activities and are a landscape with extremely high dependency between corporate activities and natural resources. Therefore, companies engaged in such activities must identify and assess peatlands in accordance with the disclosure requirements of the TNFD and disclosure through the TNFD is expected to become an important prerequisite for obtaining ESG investment.

Points to keep in mind when considering future cooperation strategy on peatland management and conservation

Although the international community is strongly aware of the importance of peatland management, private funds cannot be mobilized for sustainable activities and private capital inflows into peatlands, encouraged by domestic trends, are expected.

Examining domestic trends from a private-company perspective, peatlands are seen as a place to create highly effective GHG emission reduction credits and promote ESG investment while utilizing the peatlands as a venue for their own economic activities.

Here are some points to keep in mind when private funds are introduced:

・ **Creation of GHG-emisstion reduction credits with high credibility**

It is important to focus closely on the reliability of GHG emission reduction credits, despite their high expectations, which may be subject to criticism due to so-called “greenwashing” in recent years. In the case of emission reduction credits, the uncertainty of non-standardized assessment methods and high uncertainty in quantification may fall under this category. This is why the basic data and assessment methods necessary for peatland management must be addressed in a robust manner using the latest available knowledge while ensuring transparency as much as possible. Therefore, the basic data and evaluation methods required for peatland management must be as transparent as possible. With this in mind, it would be preferable if IPCC guidelines to clearly specify the various methods and data were used.

・ **The speed of the private sector's consideration of the project.**

As discussed in the Trends in Japan, demand for GHG emission reduction credits from the private sector is growing at an ever-faster pace. Conversely, as mentioned above, international organizations must establish guidelines for methods of managing peatland so that environmental considerations do not become a sham. To fill the time gap required for this effort, it is important to adopt a stepwise approach in which results and findings obtained are published gradually, rather than waiting until all methodologies and basic data have been completed. Specific examples include registering project results in the emissions intensity database11 maintained by the IPCC. It should be noted that it is essential to publish the results in a paper or other work to achieve this.

[11] https://www.ipcc-nggip.iges.or.jp/EFDB/main.php

・ **The justification of addressing nature positive trends and peatlands**

The G7 2030 Nature Compact, agreed at the G7 Summit held in the UK in June 2021, set a goal of halting and reversing biodiversity loss by 2030. In response, CBD-COP15 adopted a goal of effectively conserving at least 30% of land and sea as healthy ecosystems by 2030 (30 by 30), with the goal of halting and reversing biodiversity loss by 2030 (Nature Positive). As mentioned earlier, peatlands are a unique landscape that provides a variety of ecosystem services, and at the same time, they are an area with high climate change mitigation function effectiveness, making them worth focusing on.

Future cooperation strategy on peatland management and conservation based on the results of basic information collection surveys

In this basic study, we estimated peatland distribution using satellite data, estimated greenhouse gas (CO_2, CH2) absorption emissions from peatlands using a meteorological model and developed technologies for refining basic information. These efforts have contributed significantly to the methodology and basic information required by the international community, as well as to the standardization of peat assessment to encourage private sector participation.

While taking this into consideration above, we have taken into account that tropical peatlands have regional characteristics, such as those that form peat domes and cases where there is a mineral supply from rivers, we recommend two pathways of policies for future peatland management and conservation using each seed technology.

Refinement and methodological internationalization of absorption emissions from peatlands using a combination of satellite data and Flux towers.

Around the Congo Basin, we have worked on the estimation of peatland distribution using satellite technology and clarified the peatland distribution in the DRC (Equatorial Province) and the ROC (around Gamboma). Following these results, the Japanese government has decided to implement the installation of Flux towers in the DRC from 2023 using a non-professional grant scheme. Through this activity, it is expected that the CO_2 and CH4 absorption emissions from peatlands will be determined by combining the peatland distribution map and detailed parameters obtained from the Flux Tower. In some cases, complementary data from the ISS onboard hyperspectral sensor (HISUI) may also be used as part of efforts to help improve accuracy.

To optimally exploit the results of these activities and contribute to the international community, it is important to collaborate with various stakeholders. Specifically, sharing information and methodologies with internationally active organizations such as the Global Peatland Initiative (GPI) is an efficient and effective approach to internationalize the technologies developed by JICA.

From the perspective of technology internationalization, the ideal path is for developed methodologies to be included in the IPCC guidelines and promoted for use in other countries, so collaboration with prominent international organizations such as those mentioned on the left is also important here.

Social implementation of the calculation of CO_2 and CH_4 absorption emissions in peatlands using the WRF model.

In Indonesia, efforts were made to estimate soil moisture and groundwater levels using the WRF model and the parameters were used to estimate CO_2 and CH_4 absorption and emissions from peatlands. As the next step, it is important to encourage Indonesian government officials to maintain the development model and estimate CO_2 and CH_4 absorption emissions from peatlands over time. In this process, further refinement of the WRF model is essential, while obtaining basic information from borehole surveys and Flux Tower for field verification.

In turn, it is expected to increase recognition and credibility within the Indonesian government, with the ultimate goal of inclusion in the GHG inventory and contribution in the revision of the NDC.

(20)

The Body of the report

Preface

This report presents the results of the "Information Collection and Verification Study on Global Sustainable Peatland Management and Conservation Cooperation" for the period January 2021 to February 2023.

CHAPTER 1. INTRODUCTION

1.1 Project Background

In the United Nations Framework Convention on Climate Change (UNFCCC), mechanisms to reduce emissions from deforestation and forest degradation have been discussed, along with the importance of strengthening the conservation of forests and other greenhouse gas (GHG) sinks. In addition, at the 13th Conference of the Parties to the Ramsar Convention held in 2018, it was recognized that reducing GHG emissions from peatlands and managing and conserving coastal ecosystems are crucial for climate change countermeasures (mitigation and adaptation), disaster prevention and mitigation and biodiversity conservation and require urgent action.

Peatlands cover only 3%[12] of the Earth's surface area, but are estimated to hold at least nearly twice as much carbon as the above-ground biomass carbon stores of the world's forests. Conversely, about 15% of peat to date has been exposed to the atmosphere due to the lowering of the water table caused by development, releasing stored carbon and these peatland-derived carbon dioxide emissions are said to be equivalent to 5% of emissions from human activities[13], underlining the urgency of measures to reduce peat-derived greenhouse gas emissions. The Republic of Indonesia ("Indonesia"), the Democratic Republic of the Congo(DRC), the Republic of Congo(ROC) and the Republic of Peru ("Peru"), which are estimated to have the most tropical peatlands[14] , have vast such areas threatened by anthropogenic development.

Conversely, a proper methodology for assessing peatland-derived greenhouse gas emissions has yet to be established and the global peat distribution area and its carbon content are still not accurately known. In the international community, the Global Peatlands Initiative (GPI) was launched in 2016 with the aim of reducing greenhouse gas emissions through peatland conservation and has begun promoting peatland mapping to determine the global peat distribution area. In this context and with a view to new technical cooperation in future, we will focus on internationally important tropical peatlands, develop programs such as models to estimate groundwater levels in peatlands in real time and map major tropical peatlands, while collecting basic information on policies of major countries related to peatland conservation and trends in related actors. A study to collect basic information on the policies of major countries involved in peatland conservation and trends of related actors was also planned as well as to examine the potential for future cooperation on peatland cooperation.

1.2 Scope of the study

1.2.1 Purpose of the study

This study will target four countries that are considered to have the largest amount of tropical peat: Indonesia, the Democratic Republic of the Congo, the Republic of the Congo, and Peru To consider cooperation strategies related to peat, the following survey will be conducted in the above four countries, which are considered to have potentially high peatland conservation and management effectiveness, but have not yet collected sufficient information on peatland evaluation models and appropriate conservation and management, in order to collect and analyze basic information for the formation of peat cooperation projects.::

[12] Joosten, H. (2009): The Global Peatland CO2 Picture. Peatland status and emissions in all countries of the World. Wetlands International, Ede. 10 p.
[13] IPCC.(2014) Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.
[14] FAO. 2020. Peatlands mapping and monitoring - Recommendations and technical overview.

1) Develop peatland maps for target countries. In Indonesia, a high-precision soil moisture map will be developed and a groundwater level estimation model (below figure), a greenhouse gas emission assessment model and a peat fire and intensity prediction map program based on the soil moisture map will be developed (hereinafter referred to as the "high-precision soil moisture mapping-based program development").

2) The purpose of this project is to clarify the current situation and identify issues related to peatland conservation and sustainable management in the target countries, to examine effective business models for peatland conservation and to study scope for Japan's future support for peatland cooperation.

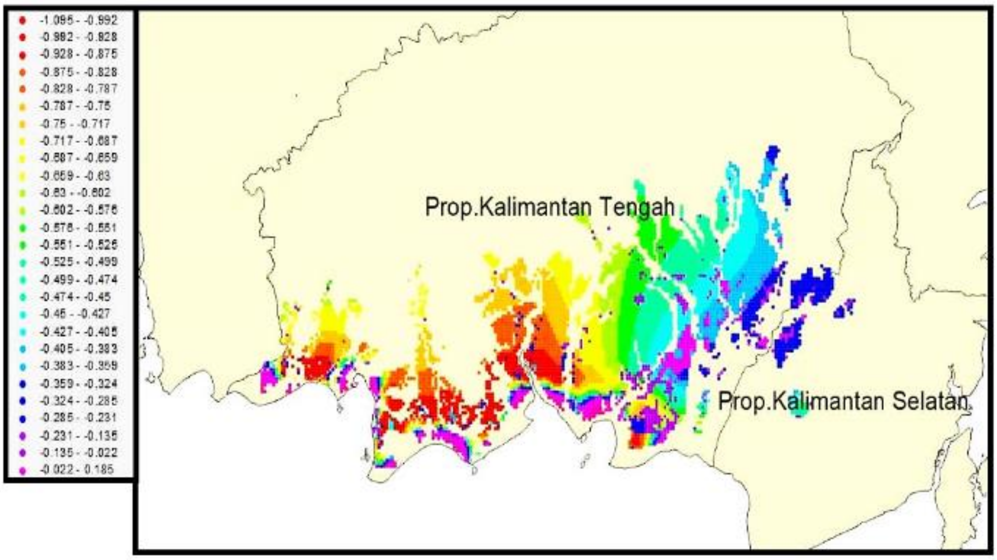


Figure1.2 1 Example of groundwater level map in Central Kalimantan, Indonesia

1.2.2 Study area and points to note

The four countries included in this study are Indonesia, DRC, ROC and Peru, which are considered to have the largest tropical peatland areas (see map at the beginning of this volume). The notes for each country are as follows:

The work in each of the studied regions is summarized in the following table:

Table1.2 1 Summary of operations by study area

No.	Main Work	Indonesia	Congo Basin		Peru	Remarks
			DRC	RC		
1	Development of High-accuracy soil moisture mapping-based technology program (by involving the Japanese Service Provider)	●	-	-	-	Utilizing the findings by the Japanese researchers from JICA SATREP Cooperation in Indonesia
2	Peatland mapping (Based on the vegetation specific to peatland)	-	●	●	●	Utilizing the findings from JICA REDD+ Cooperation
3	Collection of information on peatland management and protection as well as analysis of cooperation potential	●	●	●	● (by Interim Report)	For the current cooperation in Peru and new cooperation in Indonesia as well as for framework of wide area projects
4	Transmission of information	●	●	●	●	COP(UK)

(1) Indonesia

Indonesia is the largest holder of tropical peatlands, which are huge carbon stores and is said to hold 36% of global peatland.15 JICA implemented the Scientific and Technological Cooperation (SATREPS) "Fire and Carbon Management in Peat and Forest in Indonesia Project" for four years and four months from 2009 and accumulated basic data through on-site measurements, remote sensing, simulation models, etc., to establish a peatland management approach. Based on the basic data, a model to estimate the groundwater level from the soil moisture content (groundwater level estimation model) and a fire detection system and carbon assessment model based on the model were developed in collaboration with Hokkaido University and Kyoto University. In future, to manage and assess peat appropriately, it is necessary to establish a model for assessing carbon emissions from peatlands using these models and develop a program to operate the model, as well as standardize the model internationally for application elsewhere.

It is expected that the results of this study will be effectively utilized in two new technical cooperation projects[16] to be formed in FY2020 and beyond, creating a synergistic effect. Information will be collected from long-term experts in these two projects and an exchange of opinions will be coordinated with government officials in other countries.

(2) DRC and ROC

The Congo Basin is estimated to contain about 30% of the world's tropical peatland carbon stocks and the peatlands that exist between DRC and ROC across the Congo River are said to be the largest contiguous tropical peatland area in the world. This peatland includes three Ramsar wetlands, totaling 1,292 million hectares and is one of the largest Ramsar wetlands worldwide. Although the peat strata are relatively shallow, with median thickness of 2 m, they cover more than 1,400 million ha and are projected to store 30 billion t-CO_2eq of carbon[6]. Development pressure on peatlands is expected to increase in future, including concession development plans. In this context, the need to clarify the current status of peatlands in the Congo Basin and provide directions for their conservation is urgent. JICA began dispatching "Forest and Climate Change Policy Advisors" to the ROC in 2018 and as part of their activities, held the first peatland conservation workshop in the Congolese Republic. The ROC participated in the workshop in July 2019.

In this study, basic information on peatland mapping and peatland conservation in DRC and ROC will be collected and stakeholder analysis and issues identified through interviews with relevant actors to organize information for subsequent identification of the scope for cooperation.

(3) Peru

Peru's tropical forests belong to the Amazon River Basin, which has the world's largest tropical forests and is the second-largest area of Amazonian tropical forests after Brazil. Peru's tropical peat forests are said to be the third-largest worldwide, after Indonesia and the Congo Basin. Although no large-scale peatland development projects are planned yet, the Peruvian government is becoming increasingly aware of the importance of peatland conservation in response to recent intensified international discussions on climate change and peatlands. However, the distribution of peat forests and the storage and emission of greenhouse gases still remain unclear[7]. JICA has been providing technical assistance in the forestry sector since 2016,

---

[15] Warren, M., Hergoualc'h, K., Kauffman, J. B., Murdiyarso, D. & Kolka, R. 2017. An appraisal of Indonesia's immense peat carbon stock using national peatland maps: uncertainties and potential losses from conversion. carbon balance and management,12(1): pp. 12-12.

[16] Project to Strengthen the System for Implementing the Community Exercise Program for Forest Land Fire Prevention. Indonesia-JICA Climate Change LULUCF Sector Mitigation Project

using satellite remote sensing technology to support the development of vegetation-based peatland mapping methodology. Based on a trial version of the peatland map, field surveys were conducted in parts of Ucayali and San Martín in 2018 and December 2019 to verify the applicability of our mapping methodology as well as collect information on the distribution and partial depth of the peat itself by collecting peat samples.

In this study, we will also collect information on the vegetation-based peatland mapping method developed in the above project and analyze the differences from the high-precision soil moisture mapping-based peatland mapping method to be developed in this study, as well as the necessary operational framework. Information will also be collected and organized to examine the potential for future peatland cooperation. From the perspective of the formation of projects that will contribute to future peat in Peru and the potential for collaboration with current projects, it was decided to concentrate the collection of information on the Peruvian part of the project in the first half of the project as far as possible and include this information in the monthly reports and other documents.

1.3 Operation of the study

In accordance with the JICA Procurement Department document "JICA's response to the spread of COVID-19" updated on March 18, 2020, there will be no members of the delegation to Peru and Indonesia based on the current suspension of travel. Conversely, for the DRC, we began dispatching in August 2021 to prepare for the drilling survey and hold discussions with the government of the destination country. In addition, due to the impact of the spread of the Omicron strain of COVID-19 in December 2021, planned survey in Congo basin was cancelled.

Subsequently, starting in May 2022, field survey was conducted in Congo Basin, the results were presented at the National Peat Conference in DRC. Similarly, in May, field verification was conducted in Indonesia by a domestic subcontractor, followed in August by a supplementary survey during the dry season, conducted mainly by the Indonesian partner of the domestic subcontractor. Other domestic work was also conducted.

CHAPTER 2. REVIEW OF THE CURRENT SITUATION AND IDENTIFICATION OF ISSUES RELATED TO THE FIELD OF PEATLAND MANAGEMENT AND CONSERVATION IN THE COUNTRIES UNDER SURVEY

2.1 Indonesia

2.1.1 International Framework for Peatlands, Related International Treaties and Related Actors

2.1.1.1. Relate international agreements

Currently Indonesia has ratified international agreements and conventions related to peatland management and protection as shown in Table 2.1.1.1.

Table2.1 1 International Frameworks and Treaties Related to Peatlands Management and Conservation[17]

No	Treaties	Date signed	Date ratified	Laws	Approved by
1	Convention on Wetlands of International Importance Especially as Waterfowl Habitat (The Ramsar Convention)	February 2, 1971 in Ramsar, Iran	19-Oct-91	Presidential Decree No. 48/1991	Mr. Soeharto, President of Indonesia (1968-1998)
2	United Nations Convention on Biological Diversity	June 5, 1992 in Rio de Janeiro, Brazil	1-Aug-94	Law No. 5/1994	Mr. Soeharto, President of Indonesia (1968-1998)
3	United Nations Framework Convention on Climate Change (UNFCCC)	June 5, 1992 in Rio de Janeiro, Brazil	1-Aug-94	Law No. 6/1994	Mr. Soeharto, President of Indonesia (1968-1998)
4	Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC)	December 11, 1997 in Kyoto, Japan	16-Feb-05	Law No. 17/2004	Mrs. Megawati Soekarnoputri, President of Indonesia (2001-2004)
5	Paris Agreement in the United Nations Framework Convention on Climate Change (UNFCCC)	April 22, 2016 in New York, United States	24-Oct-16	Law No. 16/2016	Mr. Joko Widodo, President of Indonesia (2014-2024)

As Indonesia's commitment to control climate change and participation in the Conference of the Parties in the United Nations Framework Convention on Climate Change and as a follow-up to these participations, Indonesia ratified several agreements, the newest of which was the Paris Agreement through Law No. 16/2016. Indonesia added a Nationally Determined Contribution (NDC) document to the UNFCCC Secretariat as a commitment to the Paris Agreement, which is submitted to the UNFCCC secretariat every five years. In the first period of the Paris Agreement, Indonesia's NDC target involves reducing emissions by 29% to 41%,

17 Source: Hukum Online, 2021; UNFCCC, 2021

contingent on international support from business as usual by 2030. This effort will be achieved, among others, through the forestry sector, energy, waste, industry and agriculture. Indonesia's NDC commitments for the next period will be determined based on the next performance assessment.

2.1.1.2. Regional cooperations concerning peatland management and protection in Indonesia[18]

(1) ASEAN Institutional Framework

1) ASOEN-HTTF and SRFAs for Sumatra and Borneo

As a subsidiary body of the ASEAN Senior Officials on the Environment (ASOEN), the ASOEN-Haze Technical Task Force (ASOENHTTF) was established in 1995, comprising senior officials from the ten AMS. The ASOEN-HTTF was chaired by Indonesia and reported to the ASEAN Ministerial Meeting on Haze (AMMH). Realising the need to focus on fire management efforts in specific areas, in April 1998 the ASOEN-HTTF established two working groups for the sub-regions of Sumatra and Borneo, namely the Sub-regional Fire-fighting Arrangement for Sumatra (SRFA Sumatra) and Sub-regional Fire-fighting Arrangement for Borneo (SRFA-Borneo). Two other subsidiary bodies under the ASOENHTTF were the SRFA Legal Group and Law Enforcement, focusing on legal and law enforcement matters and the Sub-Regional Climate Review meeting, focusing on climate and meteorological conditions. An ad-hoc Simulation Organizing Committee for SRFA Fire and Haze Disaster Simulation Exercise was formed in 2002 to develop standard operating procedures for assessment, monitoring and joint emergency response for the SRFA and prepare details for SRFA simulation exercises. Following the entry into force of the ASEAN Agreement on Transboundary Haze Pollution (AATHP) in 2003, the AMMH and its subsidiary bodies were replaced by the Conference of the Parties to AATHP, which was established under the Agreement.

The Sub-Regional Ministerial Steering Committee (MSC) on Transboundary Haze Pollution was established in November 2006 to oversee the implementation of the Plan of Action (PoA) to effectively tackle regional haze problems in the short, medium and long term. Members include Brunei Darussalam, Indonesia, Malaysia, Singapore and Thailand. The MSC is supported by a Technical Working Group (TWG) to implement programs as directed by the MSC. Its programs and activities include, among others, enhancing haze control management, early warning/monitoring, fire prevention and fire suppression capabilities; bilateral collaboration and a Regional Haze Training Network.

2) ASEAN Regional Haze Action Plan

The Regional Haze Action Plan (RHAP) was endorsed by the ASEAN Environment Ministers in December 1997 during a period of intense fire and transboundary haze pollution. Under the overall framework of the RHAP, strategic measures and activities aim to strengthen the region’s capacity and capability to address transboundary haze pollution problems. There are three primary objectives of the RHAP, namely: (i) to prevent land and forest fires through better management policies and enforcement, (ii) to establish an operational mechanism to monitor land and forest fires and (iii) to strengthen regional land and forest firefighting capability with other mitigation measures.

3) ASEAN Agreement on Transboundary Haze Pollution

The ASEAN Agreement on Transboundary Haze Pollution was signed by 10 countries in Kuala Lumpur, Malaysia on June 10, 2002. The agreement includes mechanisms for monitoring, assessment and prevention,

[18] Source: SEA Peat, 2018

technical cooperation and scientific research, and coordination. It also provides for the establishment of an ASEAN Coordination Center for the Control of Transboundary Haze Pollution..

4) ASEAN Peatland Management Initiative (APMI)

APMI was adopted at the 20th ASOEN-HTTF meeting held in Manila, Philippines in February 2003, with a work plan for the period 2003-2005 The objective of APMI is to promote sustainable management of peatlands in the ASEAN region through collective action and enhanced cooperation, support and sustain local livelihoods, reduce the risk of fire and associated local haze, and contribute to global environmental management. .

2.1.2 National level policy system

2.1.2.1 Forest and Land Fire Management in Indonesia[19]

Due to the occurrence of devastating forest and land fires in 1982/1983 and 1997/1998, forest and land fires in Indonesia have attracted global attention. Significant forest and land fires are reiterated to occur in 2007, 2012 and 2015, causing transboundary haze pollution in the ASEAN region, and once again attracting global attention. Since the problem of forest and land fires has continued to intensify, a special institution to deal with fires was created at the Echelon 2 (Directorate) level starting in 1999. In 2002, the program, called "Daops Manggala Agni", was developed for further forest and land fire control. It is an institution tasked with controlling forest and land fires at the local level and an extension of the central government in the provinces for the purpose of controlling forest and land fires. Furthermore, as a commitment to mitigate transboundary haze pollution, the Government of Indonesia ratified the ASEAN Agreement on Transboundary Haze Pollution (AATHP) in 2014.

To manage forest and land fires, progams at national and local level have also been implemented. The intentions of these activities are as follows:

- to ensure peatland areas are managed effectively, while focusing on areas and regions particularly prone to forest and land fires;
- to mainstream forest and land fire control programs;
- to ensure the active participation of all stakeholders in these programs;
- to develop early warning systems that provide sufficient lead time to implement control measures and;
- to eliminate and prohibit the practice of burning to clear land in high-risk areas, particularly peatlands.

Indonesia has been monitoring forest and land fires since 1984. In the initial stages, those monitoring efforts were based on ground reports through nationwide government offices, including details of the occurrences of fires and estimations of burned areas. From 1997 to 2006, Indonesia cooperated with JICA to develop a satellite-based system to monitor hotspots using NOAA satellites. However, coverage for this monitoring only reached western and central Indonesia. Since 2007, under cooperation with Aus Aid, Indonesia has developed a fire watch system to monitor hotspots using Terra/Aqua (MODIS) satellites, which have thermal sensors for detecting fires and which cover the whole of Indonesia. In March 2015, the Ministry of Environment and Forestry launched the SIPONGI system, which is an integrated system with near-real-time hotspot information, by combining hotspot data from NOAA, Terra/Aqua, SNPP and field data from regional government offices.

[19] Source: The State of Indonesia's Forests 2020

Indonesia started serious efforts to calculate burnt areas from 2015. These efforts are used to support field activities to control and manage forest and land fires. Burnt areas are calculated using satellite imagery data, hotspot data, ground check reports and reports from forest and land fire suppression operations.

Since 2018, a monitoring system using thermal CCTV has been installed at 15 fire-prone areas. This program aims to make the monitoring system more reliable in particular areas, so that the ground-level checks can be implemented faster. The Ministry of Environment and Forestry issued regulation No P.8/MENLHK/SETJEN/KUM.1/3/2018 regarding Standard Operating Procedures (SOP) for hotspot ground-checks and all related information from the ground.

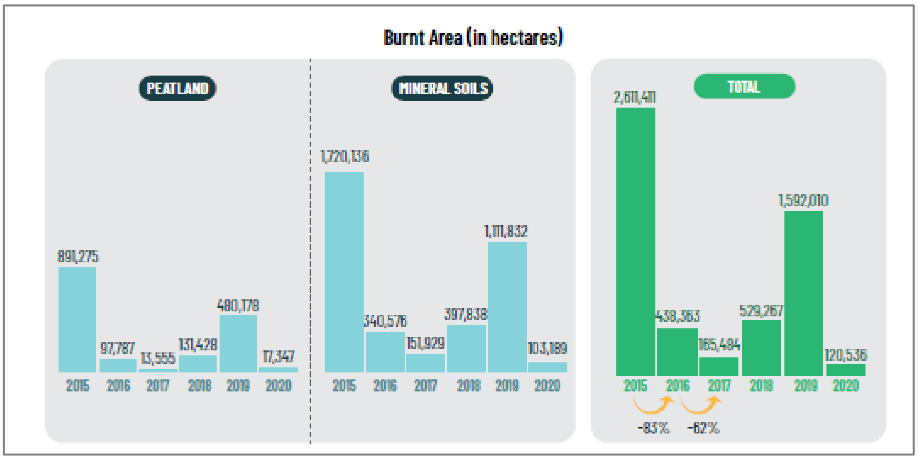


Figure2.1 1 Burnt areas of forest and land fires between 2015 and 2022

Forest and land fires in Indonesia are strongly influenced by the weather and climate. While forest fires typically occur in Indonesia annually from July through October, those in 2019 began in January 2019 and lasted until the end of the year. This was because of the higher average temperature compared to 2018, a rainy season that came later than usual, as many as 150 days without rain in various regions and the influence of changes in the global climate.

Since 2020, Indonesia has started to carry out “cloud seeding”[20] operations before the dry season peaks, particularly in fire-prone provinces like Riau, South Sumatra and Jambi. Various government agencies are also involved, such as the Ministry of Environment and Forestry, as well as the Meteorology, Climatology and Geophysics Agency (BMKG), the Agency for the Assessment and Application of Technology (BPPT), the Indonesian Military (TNI) and the National Agency for Disaster Management (BNPB). Weather modification with cloud seeding focuses on areas with peatlands or those predicted to experience severe drought.

Important areas to focus on for Indonesia in future on forest and land fire control activities are as follows:

- To prioritize the prevention of forest and land fires;
- To increase the active participation of business actors in the field of agriculture, industrial timber plantations and mining, taking their impact on forest and land fires into consideration;
- To strengthen independent and integrated patrols, particularly in fire-prone provinces in Indonesia;
- To increase community awareness of and participation in forest fire control, through campaigns and publications, online and social media and collaboration with educational institutions, religious groups and social groups;

[20] Cloud seeding is a type of weather modification aiming to change the amount or type of precipitation that falls from clouds by dispersing substances into the air that aid in cloud condensation and precipitation.

- To encourage Provincial/District/City Governments to allocate budgets for and optimize the use of DBH-DR (local reforestation fund shares) for faster forest and land fire alert systems, to further optimize forest and land fire control;
- To strengthen the capacity of Manggala Agni and enhance the role of MPA as forest and land firefighters;
- To increase the technological capacity for early warning and detection of forest and land fires and;
- To conduct community and civil society monitoring and online reporting at http://sipongi.menlhk.go.id on the activities of business actors in the forestry and plantation sector.

2.1.2.2 Policies related to peatland

Policies related to the regulation of utilization and cultivation on peatlands by the Government of Indonesia were drawn up more than half a century ago with initial discussions to meet national food needs. Since the end of the New Order era, policy discourse has begun to shift to the paradigm of managing and protecting peat ecosystems, influenced by rampant land and forest fires, damage to natural resources and climate change, as well as changes in government coalitions with civil society organizations (NGOs). It follows moves to consolidate the global environmental movement and open up structures of political opportunity (Situmorang 2013; Ardhian et al., 2016 in Baskoro et al., 2018).

Policies related to peat management and cultivation during the period 1990 – 2017 are divided into three periods, namely pre-2007, 2007–2014 and 2014–2017 respectively. The division of this period is mainly based on the government's response through policy products issued to the phenomenon of socio-politics in Indonesia. Policy discourse on peat management and cultivation in Indonesia can be seen in Table as follow (Baskoro et al., 2018)

Table2.1 2 National Policy Background[21]

Situation Background	National Policy
The high demand for food and agricultural products for domestic consumption and exports (Osaki et al. 2016 in Baskoro et al., 2018). Reduced agricultural land due to conversion become residential land, urban development, etc.	Presidential Decree No. 32/1990 Presidential Decree No. 82/1995 Presidential Decree No. 74/1998 Presidential Decree No. 133/1998 Presidential Decree No. 80/1999
The issue of climate change is intensifying after Indonesia hosted the UNFCCC COP13 in Bali and created the Bali Roadmap. Followed by results COP15 in Copenhagen and COP16 in Cancun and G8 Meeting in Pittsburgh in the 2009. Indonesia committed to reducing greenhouse gas emissions by 26% of its own accord and 41% with international assistance. The more open the regime is to foreign investment, the greater the motivation for the Government to handle environmental complaints more seriously following outside (international) pressure. Changes in political structure have seen the government open up in response to collective environmental complaints and protests, particularly in the context of stopping pollution and environmental damage.	Instruction of President No. 2/2007 Law No. 26/2007 Government Regulation No. 26/2008 Law No. 32/2009 Regulation of Agriculture Minister No. 14/2009 Regulation of Environment Minister No. 10/2010 Regulation of President No. 61/2011 Instruction of President 10/2011 (updated every two years and running

[21] Source: Analisis Kebijakan Pengelolaan and Budidaya Ekosistem Gambut di Indonesia - Penerapan Pendekatan Advocacy Coalition Framework, 2018.

Situation Background	National Policy
Forest and land fires in 2006 covered the largest area since 1997/98.	until now)
The more open the structure of political opportunity. Changes in the post-election political structure, the entry of elites as part of a civil movement for government structures and large-scale forest and land fires in 2015	Government Regulation No. 71/2014 Government Regulation No. 57/2016 Government Regulation No. 1/2016

The government has issued policy systems related to managing and protecting peatlands as shown in the following table.

Table2.1 3 National Policy System related to the Peatland Management and Protection[22]

Policy System	Overview
Law No. 5/1990	Concerning the Conservation of Biological Natural Resources and their Ecosystems, the aim is to strive to preserve living natural resources and the balance of their ecosystems so that they can better support efforts to improve community welfare and the quality of human life.
Presidential Decree No. 32/1990	Concerning the Management of Protected Areas to Prevent Damage to Environmental Functions, peatland areas are subject to protection. Protection of peatland areas is intended to control the hydrology of the area, which holds water and prevents flooding, as well as protecting the unique ecosystem in the area concerned. The criteria for peatland areas are peat soils with a thickness of 3m or more located in the upper reaches of rivers and swamps.
Presidential Decree No. 82/1995 changed to Presidential Decree No. 74/1998 changed to Presidential Decree No. 80/1999	Concerning the General Guidelines for Area Planning and Management Peatland Development in Central Kalimantan as the foundation of the one-million hectare Peatland Development Project (PLG) in Central Kalimantan
Law No. 41/1999	Concerning the Forestry, that forestry operations aim to ensure the existence of forests with a sufficient area and proportional distribution; optimizing various forest functions which include conservation functions, protection functions and production functions to achieve balanced and sustainable environmental, social, cultural and economic benefits; etc.
Government Regulation No. 150/2000	Concerning Soil Damage Control for Biomass Production, aims to control soil degradation for biomass production.
Decree of the People's Consultative Assembly No. IX/MPR/2001	Concerning the Agrarian Reform and Natural Resource Management, that the management of natural resources contained in land, sea and space is carried out in an optimal, fair, sustainable and environmentally friendly manner.
Government Regulation No. 4/2001	Concerning the Control of Damage and/or Pollution Environment Related to Forest and/or Land Fire, contains provisions for establishing standard general criteria for peat soil damage related to forest fires and/or land.

22 Source: BPK RI, 2021; Hukum Online, 2021

Policy System	Overview
Instructions of President No. 2/2007	Concerning the Accelerate Rehabilitation and Revitalization Peatland Development Area in Central Kalimantan to accelerate the rehabilitation and revitalization of the peatland area development in Central Kalimantan.
Law No. 26/2007	Concerning the Spatial Planning, that the peatland area is a protected area.
Law No. 32/2009	Concerning the Environmental Protection and Management, that peatland ecosystem is a conservation of natural resources which is sought to maintain the preservation of environmental functions and prevent environmental degradation or damage caused by human actions.
Law No. 41/2009	Concerning the Protection of Agricultural Land for Sustainable Food aims to protect the area and land for sustainable food agriculture; ensure the availability of sustainable food agricultural land; etc.
Government Regulation No. 37/2012	Concerning the Watershed Management, discusses the inventory of watersheds, the process of determining watershed boundaries, compiling watershed classifications, etc.
Instructions of President No. 6/2013	Concerning the Deposit of Granting of New Licenses and Improvements of Primary Natural Forest and Peatland Governance, to complete various efforts to improve the governance ongoing forest and peatland management in the context of efforts reducing emissions from deforestation and forest degradation
Government Regulation No. 73/2013	Concerning the Swamps, regulates the determination of swamps, swamp management, swamp information systems, licensing and supervision and community empowerment
Law No. 37/2014	Concerning the Water and Soil Conservation aims to optimize the function of land to realize economic, social and environmental benefits in a balanced and sustainable; and the peatland area is a protected area.
Law No. 39/2014	Concerning the Plantations, that every plantation business actor is obliged to maintain the preservation of environmental functions by analyzing environmental impacts or environmental management efforts and environmental monitoring efforts.
Instructions of President No. 8/2015	Concerning the Postponement of Granting New Permits and Improving the Governance of Primary Natural Forests and Peatlands in the context of efforts to reduce emissions from deforestation and forest degradation.
Government Regulation no. 28/11 changed to Government Regulation no. 108/2015	Concerning the Management of Natural Areas and Natural Conservation Area, that peatland is an essential ecosystem area that must be protected.
Government Regulation no. 71/2014 changed to Government Regulation no. 57/2016	Concerning the Protection and Management of Peatland Ecosystems contains: Definition of the peatland ecosystem protection and management; Utilization of the peatland ecosystem protection and management; Planning of the peatland ecosystem protection and management; Damage control of the peatland ecosystem; Maintenance of the peatland ecosystem; Supervision of the peatland ecosystem protection and management; Administrative sanctions; and the transitional provisions of the peatland ecosystem management.
Government Regulation no. 26/2008 changed to Government Regulation no. 13/2017	Concerning the National Spatial Plan that the peatland is an area that provides protection for the area below it, with the following criteria: in the form of a peat dome and a peat thickness of 3 meters or more located in upstream rivers or swamps. Zoning regulations for peat areas are drawn up with regard to: Use of space for nature tourism, research and

Policy System	Overview
	development, science knowledge and/or environmental services without changing landscapes; Provisions to prohibit all activities with the potential to change water systems and ecosystems unique; Control of sediment material entering the peat areas through water bodies; and measures to counter damage to the peat ecosystem.
Government Regulation No. 22/2021	Concerning the Implementation of Environment Protection and Management that the government and local government reporting information systems related to the status and condition of the environment, one of them concerns the quality of the peat ecosystem.
Government Regulation No. 44/2004 changed to Government Regulation no. 23/2021	Concerning the Implementation of Forestry that supports the rehabilitation of forests and land and the restoration of the peatland ecosystem.

Due to the significant damage caused by forest and land fires in 2015, Decree No. 57/2016 on the protection and management of peat ecosystems was issued, taking into account the need for intensive efforts to protect and manage peat ecosystems. .

Table2.1 4 Important points in the Government Regulation No. 57/2016

Article	Summary
Article 9: Determination of the Peatland Protection Function	The Minister is obliged to determine the protection function of the Peatland Ecosystem at least 30% and the entire area of the Peatland Hydrological Unit, which is located starting from one or more from the top of the peat dome that still exists: Peat with a thickness of 3 (three) meters or more; specific and/or endemic germplasm; protected species in accordance with statutory regulations; and/or the Peatland Ecosystems located in protected areas as stipulated in the regional spatial plan, protected forest areas and conservation forest areas. Accordingly, the minister shall determine asid areas as subject to the peatland ecosystem protection function.
Article 17: the Peatland Ecosystem Protection and Management Plan	Must focus on: diversity of physical and biophysical characteristics of ecological functions; distribution of natural resource potential; climate change; population distribution; local culture; community aspirations; spatial plans; and efforts to restore damage to the Peatland Ecosystem.
Article 26: Prohibition of Peatland use	Everyone is prohibited from: opening up new land (land clearing) until the zoning of protection functions and functions is determined, cultivation of certain plants in the Peatland Ecosystem area; creating drainage channels that cause the peat to dry out; burning peatland and/or allowing burning to occur; and/or carrying out any other activities that result in the standard criteria for damage being exceeded.

2.1.3 System and status of central government

The main national institutions that are vital in managing and protecting peatlands in Indonesia include the Ministry of Environment and Forestry, the Peatland Restoration Agency (BRG) /the Mangrove and Peatland Restoration Agency (BRGM) and Ministry of Agriculture, etc.

2.1.3.1 The Ministry of Environment and Forestry

The Ministry of Environment and Forestry comprises four previously separate organizations; i.e. The Ministry of the Environment, the Ministry of Forestry, the National Council on Climate Change (Dewan Nasional Perubahan Iklim: DNPI) and the Deforestation and Deforestation Emission Reduction Management Organization (Badan Pengelola Penurunan Emisi Gas Rumah Kaca dari Deforestasi, Degradasi, Hutan dan Lahan Gambut (BP REDD+).

According to the Presidential Regulation of the Republic of Indonesia No. 92/2020, the Ministry of Environment and Forestry is under and responsible to the President and performs the following functions:

1) Formulating, stipulating and implementing policies in the field of implementing forest area stabilization and environmental management sustainably, management of conservation of natural resources and their ecosystems, increasing the carrying capacity of watersheds and forest rehabilitation, sustainable forest management, making forest product primary industries more competitive, controlling pollution and environmental damage, management of waste, hazardous and toxic materials and hazardous and toxic waste, control of climate change, control of forest and land fires, social forestry and environmental partnerships and law enforcement in the field of environment and forestry;
2) Coordination and synchronization of policy implementation in the field of sustainable environmental management, increasing the carrying capacity of watersheds and forest rehabilitation, control of pollution and environmental damage, management of waste, hazardous and toxic materials and hazardous and toxic waste, climate change control, fire control forest and land, environmental partnerships, as well as law enforcement in the field of environment and forestry;
3) Coordinating the implementation of tasks, fostering and providing administrative support to all organizational elements within the Ministry of Environment and Forestry;
4) Management of state property/wealth which is the responsibility of the Ministry of Environment and Forestry;
5) Supervising the implementation of tasks within the Ministry of Environment and Forestry;
6) Implementation of technical guidance and supervision of the implementation of the affairs of the Ministry of Environment and Forestry in the regions; and
7) Implementation of substantive support to all organizational elements within the Ministry of Environment and Forestry

In peatland management and protection activities, the Ministry of Environment and Forestry issues several policy systems as shown in Table below.

Table2.1 5 the Ministry of Environment and Forestry Policy System related to the Peatland Management and Protection[23]

Policy System	Overview
Regulation of Minister of Forestry No. P.3/Menhut-II/2008	Concerning the Delineation of Business Permit Areas for the Utilization of Timber Forest Products in Plantation Forests, that the peat forest areas upstream of rivers and swamps with a thickness of more than three meters are included in the criteria for natural forest areas that must be maintained.
Regulation of Minister of Environment and Forestry No. 10/2010	Concerning Pollution and/or Damage Prevention Mechanism Environment Related to Forest and/or Land Fire that the person in charge of the business and/or activity utilizing peatlands must: Apply standard water management techniques; and Have an annual work plan.

[23] Source: Ministry of Environment and Forestry, 2021a.

Policy System	Overview
Regulation of Minister of Environment and Forestry No. P.12/Menlhk-Ii/2015	Concerning the Development of Industrial Plantation Forests, that optimizing production functions in peat forest areas upstream of rivers and swamps with a thickness of more than three meters while taking into account the environmental and social balance.
Regulation of Minister of Environment and Forestry No. P.15/Menhk/Setjen/Kum.1/2/2017	Concerning Procedures for Measuring Groundwater Levels at Peat Ecosystem Compliance Points, that Measurement of ground water level in Peat Ecosystem determined at the supervisory control point called compliance point, set at least 15% of the total number of crop plots principal or production block and is in the middle (centroid) main crop plots or production blocks
Regulation of Minister of Environment and Forestry No. P.16/Menhk/Setjen/Kum.1/2/2017	Concerning Technical Guidelines for the Restoration of Peat Ecosystem Functions
Regulation of Minister of Environment and Forestry No. P.97/Menhk/Setjen/Kum.1/11/2018	Concerning Exchange Forest Area in permanent forest and permanent production forest.
Regulation of Minister of Environment and Forestry No. P. 60/Menlhk/Setjen/Kum.1/10/2019	Concerning the Procedures for Preparation, Determination and Amendment of the Peat Ecosystem Protection and Management Plan regarding the preparation of the Peatland Ecosystem Protection and Management plan; determination of the plan to Protect and Manage the Peatland Ecosystem; changes to the plan to Protect and Manage Peat Ecosystems; monitoring and evaluation; and financing.
Regulation of Minister of Environment and Forestry No. SK.246/Menlhk/Setjen/Kum.1/6/2020	Concerning the National Peatland Ecosystem Protection and Management Plan to preserve the function of the Peat Ecosystem and prevent damage to the Peat Ecosystem which is carried out systematically and integrally, within a period of thirty years (2020-2049).
Regulation of Minister of Environment and Forestry No. 2/2021	Concerning the Assignment of Partial Government Affairs in the Environment and Forestry Sector to 7 (Seven) Governors for Peat Restoration Activities for Fiscal Year 2021 which regulates: assignment, coordination of programs, activities and Co-Administration budgets; implementation of Co-administered Tasks; Co-Administration Reporting; goods resulting from the implementation of Co-administered Tasks; and coaching and supervising Co-Administration.

2.1.3.2 Peatland Restoration Agency (BRG) /Mangrove and Peatland Restoration Agency (BRGM)

According to the Presidential Regulation of Republic of Indonesia No. 1/2016, Peatland Restoration Agency (BRG) is a non-structural institution which is under and responsible to the President. BRG has the following duties: facilitate the acceleration of peatland restoration implementation and efforts to improve welfare communities in the peat restoration work area in Riau Province, Jambi Province, South Sumatra Province, West Kalimantan Province, Central Province Kalimantan, South Kalimantan Province and Papua Province.

In 2020, the president changed the Peatland Restoration Agency (BRG) to the Peatland and Mangrove Restoration Agency (BRGM) as stated in the Presidential Regulation of Republic of Indonesia No. 120/2020 with the same duties as BRG and additional tasks for mangrove rehabilitation. The focus of BRGM's tasks for the period 2021-2024 is to rehabilitate 600,000 ha of degraded mangroves, as well as continuing to restore 1.2 million ha of peatland.

BRGM performs the following functions: implementation of peatland restoration; planning, control and evaluation implementation of peat restoration; implementation of construction, operation and maintenance wetting infrastructure (rewetting) of peatland and all accessories; implementation of community institutional strengthening in the context of peatland restoration; implementation of peatland restoration socialization and education; implementation of improving people's livelihoods in peatlands; providing administrative support; and execution of other functions given by the President.

In peatland management and protection activities, the Mangrove and Peatland Restoration Agency issues several policy systems as shown in following table.

Table2.1 6 Peatland Restoration Agency Policy System related to the Peatland Management and Protection[24]

Policy System	Overview
Regulation of the Head of the Peatland Restoration Agency No. P.1/BRG-KB/2017	Concerning the Technical Guidelines for Distribution of Government Assistance to Local Governments or Communities Scope of the Peatland Restoration Agency, which includes peatland rewetting infrastructure to local governments or communities
Decree of the Head of the Peatland Restoration Agency No. SK.15/BRG/KPTS/2018	Concerning the Determination of the Main Performance Indicators of the Peatland Restoration Agency which includes: Planning and cooperation; restoration of degraded peatlands; education, outreach, participation and partnerships; research and development; and support for peat restoration management and operations.
Decree of the Head of the Peatland Restoration Agency No. SK.17/BRG/KPTS/2018	Concerning the Establishment of a Peatland Ecosystem Restoration Monitoring System to monitor the implementation of planning, development of peatland clearance infrastructure, participation, partnership, research and development through the Peatland Restoration Information and Monitoring System and monitoring of peat soil water levels and other indicators through the Peatland Water Monitoring System

2.1.3.3 The Ministry of Agriculture

The following are agricultural ministerial decrees related to the management and protection of peatlands.

Table2.1 7 Ministry of Agriculture Policy System related to the Peatland Management and Protection[25]

Policy System	Overview
Regulation of Agriculture Minister No. 09/Permentan/OT.140/3/2006	Concerning the Organization and Working Procedures of the Swampland Agricultural Research Center, that the swampland agricultural research center has the task of carrying out swampland research for agriculture

[24] Source: BRGM, 2021.
[25] Source: JDIH, 2021

Policy System	Overview
Regulation of Agriculture Minister 14/Permentan/PL.110/2/2009	Concerning the Guidelines for Utilization of Peatlands for Oil Palm Cultivation, that the scope of regulation on the use of peatlands for oil palm cultivation includes: Criteria for Peatlands, Utilization and Guidance and Supervision
Regulation of Agriculture Minister No. 81/Permentan/OT.140/8/2013	Concerning the Technical Guidelines of the Procedure for Sustainable Food Agricultural Land Function Transfer, that the applicant for the conversion of swampland can perform the conversion of swampland after the replacement land requested by the land owner has been fulfilled in accordance with the laws and regulations.
Regulation of Agriculture Minister No. 40.1/Permentan/RC.010/10/2018	Concerning the Guidelines for the 2019 Agriculture-Based Farmers' Welfare Saved Swamp Program
Decree of Agriculture Minister No. 03/Kpts/RC.210/B/02/2019	Concerning the Technical Guidelines for Swampland Optimization to Support SERASI (Selamatkan Rawa Sejahtrakan Petani /Save the Swamp Prosper the Farmers) Activities for the 2019 Fiscal Year, that the purpose of land optimization activities is to optimize the function of swampland into productive agricultural land through improving water management and land management in swamps, thereby increasing the cropping index (IP) and/or productivity.

2.1.4 System and efforts of regional government

Based on the regulation of the Minister of Environment and Forestry of Republic of Indonesia No. P.8/MENLHK/Setjen/KUM.1/2/2020 regarding the assignment of some government affairs in the environment and forestry sector to seven governors for peatland restoration activities, governors are tasked with assisting in activities to accelerate the peatland restoration in their areas and forming the Regional Peatland Restoration Team to support the implementation of the duties and functions of the Peatland Restoration Agency in the regions. In regional governments, there are only seven focal provinces under President’s strict supervision concerning the peatland management and protection: Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua.

In the context of participation in efforts to manage and protect peatlands as in international agreements that have been included in law, several regions also encompass some of the efforts contained in legal systems related to reducing greenhouse gases, controlling forest fires, regulations for forest clearing and sanctions if there are any violations, particularly in the seven focal provinces as in following table.

Table2.1 8 Regional Government Policy System[26]

Provice	Policy System	Overview
Jambi	Regulation of Jambi Governor No. 36/2012	Concerning the Regional Action Plan for Reducing Greenhouse Gas Emissions in Jambi Province contains: policies and strategies for the regional action plan for reducing greenhouse gas emissions on peatlands.
	Regional Regulation of Jambi Province No. 2/2016	Concerning the Prevention and Control of Forest and Land Fires, contains: Prevention of forest and land fires; Forest and land fire control; Controlling the impact of forest and land fires; Community participation; Financing; Investigation; Administrative supervision and sanctions; and Criminal provisions

[26] Source: JDIH BPK RI, 2021.

Provice	Policy System	Overview
	Regulation of Jambi Governor No. 31/2016	Concerning Prevention and Control of Forest and Land Fires, contains: Establishment of duties, authorities and responsibilities of the forest and land fire task force; Sufficient facilities and infrastructure for preventing and controlling forest and land fires; Criteria and procedures for determining the status of forest and land fires; and Community participation.
	Regional Regulation of Jambi Province No. 6/2017	Concerning the Environmental Protection and Management
	Regional Regulation of Jambi Province No. 1/2020	Concerning the Peatland Governance
South Sumatra	Regulation of South Sumatra Governor No. 68/2018	Concerning the Institutional Protection and Management of Peatland Ecosystems to clarify the duties, authorities and responsibilities of peatland ecosystem management institutions in the province
	Regulation of South Sumatra Governor No. 69/2018	Concerning the Community Empowerment in the Peatland Ecosystems Protection and Management to develop community independence and welfare by increasing knowledge, attitudes, behavior, abilities and awareness to support efforts to protect and manage peatlands.
	Regulation of South Sumatra Governor No. 70/2018	Concerning the Provision of Incentives and Disincentives in the Protection and Management of Peatland Ecosystems as an effort to increase the participation of related parties in the framework of more equitable and responsible management of peatland restoration.
	Regulation of South Sumatra Governor 71/2018	Concerning the Pattern of Cooperation in the Peatland Ecosystems Protection and Management as a guideline or reference in efforts to develop capacity and provide access for stakeholders to cooperate with the provincial government.
	Decree of South Sumatra Governor No. 554/KPTS/DLHP/2018	Concerning the Team of Institutional Design Development for the Peatland Ecosystems Protection and Management
	Decree of South Sumatra Governor No. 555/KPTS/DLHP/2018	Concerning the Formation of Team for Drafting Community Empowerment in the Peatland Ecosystems Protection and Management.
	Decree of South Sumatra Governor No. 556/KPTS/DLHP/2018	Concerning the Formation of Team for Drafting Incentives and Disincentives for the Peatland Ecosystems Protection and Management.
	Decree of South Sumatra Governor No. 573/KPTS/DLHP/2018	Concerning the Team for Drafting the Cooperation Plan for the Peatland Ecosystems Protection and Management.
	Regional Regulation of South Sumatra Province No. 1/2018	Concerning the Protection and Management of Peatland Ecosystem
Riau	Regional Regulation of Riau Province No. 12/2017	Concerning the Amendment to Regional Regulation Number 9 of 2009 regarding the Long-Term Regional Development Plan of Riau Province for 2005 – 2025
	Regional Regulation of Riau Province No. 1/2019	Concerning the Technical Guidelines for Forest and/or Land Fire Management
West Kalimantan	Regional Regulation of West Kalimantan Province No. 4/2012	Concerning the Synchronizing Land Use for Mining Business Activities with Other Sector Business Activities
	Regional Regulation of West Kalimantan Province No. 6/2018	Concerning the Sustainable Land-Based Business Management
	Regulation of Governor of West Kalimantan Province No. 103/2020	Concerning the Clearing Agricultural Land Areas Based on Local Wisdom
Central Kalimantan	Regulation of Central Kalimantan Governor No.	Concerning the Guidelines for Land Clearing and Yards for Communities in Central Kalimantan, that the perpetrators of clearing

Provice	Policy System	Overview
	15/2010	land and yards by means of limited and controlled burning must obtain permission from the Regent/Mayor.
	Regulation of Central Kalimantan Governor no.36/2012	Concerning the Regional Action Plan for Reducing Greenhouse Gas Emissions in Central Kalimantan Province which contains: analysis of greenhouse gas emissions; strategy for implementing the regional action plan for reducing greenhouse gas emissions on peatlands.
	Regional Regulation of Pulang Pisau Regency, Central Kalimantan Province No. 1/2019	Concerning the Pulang Pisau Regency Spatial Plan for 2019 – 2039 that the Management of Protected Areas of Protected Forests and Peat Areas
	Provincial Regulation of Central Kalimantan No. 1/2020	Concerning the Land Fire Control
South Kalimantan	Decision of the Regent of Hulu Sungai Utara, South Kalimantan No. 188.45/228/KUM/2019	Concerning the Formation of Coordination Team for the Development of Rural Areas in the Agrominapoliyan Area Based on the Peatland Ecosystem of Hulu Sungai Utara Regency in 2019.
	Provincial Regulation of South Kalimantan No. 7/2017	Concerning the Critical Land Rehabilitation
	Provincial Regulation of South Kalimantan No. 2/2013	Concerning the Sustainable Plantation Development
	Regional Regulation of Barito Kuala Regency, South Kalimantan Province No. 3/2019	Concerning the Forest and Land Fire Control and Prevention
West Papua	Regulation of West Papua Governor No. 10/2019	Concerning the Forest and Land Fire Control System in West Papua

2.1.5 Status of on-site level peat management and conservation efforts

2.1.5.1 Status of efforts to manage and protect peatlands in Indonesia carried out by the central government

Peatlands are spread out, particularly in the three big islands of Indonesia, namely Sumatra, Kalimantan (Borneo) and Papua. The following are some efforts to manage and protect peatlands in Indonesia carried out by central government such as Indonesian ministries and national agencies.

Table2.1 9 Status on site level peat management and conservation by the Ministries and National Agency[27]

Ministry/Agency	Partner(s)	Year	Projects and Goals	Site	Status
Ministry of Environment and Forestry (KLHK)[a)]	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ)	June 2020 - December 2021	The Propeat Project is for more ecologically sustainable land management in peatland and wetland ecosystems. Achievement indicators of the implementation of these technical activities include the formulation of a Plan for the Protection and Sustainable Management of Peatland Ecosystems. At least a guide on backup and utilization compiled from existing research results. These guidelines relate to integrated land use so that they can be function as a benchmark for implementation in the field. Then, the other achievement indicators include three experiences in managing peatland for timber and non-timber sustainably and holistically. In addition, there is also planning for five social forestries on peatlands in North Kalimantan, as well as strengthening three forestry institutions such as the Forest Management Unit, in implementing gender mainstreaming guidelines in planning and implementing sustainable and integrated peatland use.	North Kalimantan	Completed
		2009-now	Measurement of environmental quality index (peat soil and mineral soil): Water quality index achieving 53.53% in 80 rivers in 2020; Air quality index achieving 87.21% over 500 districts; Land cover quality index and land quality index with an achievement of 59.54%.	Indonesia	Ongoing
	BRGM	2015-now	Restoration of peat ecosystems (2015-2020): Peatland Wetting 3.97 million ha; Canal blocking on community land: 1,308 units; Canal blocking in concession land: 29,260 units; Restoration of community land: 46,554.7 ha; Recovery of concession land: 3,643,799.26 ha; Peat villages: 127 villages; KHG Inventory: 207 KHGs	North Sumata, South Sumatra, Central Kalimantan, Papua	Ongoing
		2020- now	Creating a food barn civilization on peatlands with four goals, namely: providing land from forest areas for food barns, studying peat domes and the application of the paludiculture method, restoring peat ecosystems and developing a farm for food cultivation on peatlands, arranging animal corridors to ensure the survival of key wildlife in peatlands. Food storage areas and increase community capacity and intervention in productive economic efforts.	North Sumatra, South Sumatra, Central Kalimantan, Papua	Ongoing
	Bappenas, Kementerian ATR, PUPR, Kemendagri, regional government	2016-now	The Peat Ecosystem Protection and Management Plan is a corrective action effort in managing the peat ecosystem. RPPEG is expected to be able to prevent damage to the peat ecosystem through good peat ecosystem management. The RPPEG directs that the protection and management of peat ecosystems be carried out in a systematic, harmonious and synergistic manner with various other development plans, such as the Long-Term Development Plan (RPJP), Medium-Term Development Plan (RPJM), Regional Spatial Plan (RTRW), Level Forestry Plan National (RKTN) and other strategic or sectoral plans, both at the central and regional levels.	Indonesia	Ongoing
Peat Restoration Agency (BRG) /Mangrove and Peat Restoration Agency (BRGM)[b)]	KLHK	2017-now	The Peat Caring Village Program (DPG). The number of DPGs that successfully assisted were 640 DPGs covering Riau province 153 DPGs, South Sumatra province 88 DPGs, West Kalimantan province 109 DPGs, South Kalimantan province 38 DPGs, Jambi province 53 DPGs, Central Kalimantan province 181 DPGs and Papua province 18 DPGs. The area of peatland in all villages is 4.6 million ha, including a cultivated peatland area of 622,876 ha, peatland without canals 1,701,663 ha, protected peatland with canals 1,671,441 ha, burned area (2015-2017) 640,173 ha and 8,487 ha undefined. The area of peatland included in the peatland restoration target is 1.4 million ha, including a concession area of 772,772 ha, area without permit 518,950 ha and conservation area 136,723 ha.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2017-now	The Peatland Farmer Field School (SLPG) was initiated at the end of 2017 and has been widely developed since 2018, currently with 1,455 schools. The purpose of this program is to inculcate knowledge to farmers and farmer groups to practice making organic fertilizers, soil improvers and natural pesticides, as well as equip them with the ability to build farmer group organizations	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing

[27] Source: (a) Ministry of Environment and Forestry, 2020b, 2021b, 2021c; (b) BRG, 2020; (c) Balittra, 2021; (d) BBSDLP, 2017, 2018, 2019; (e) PUPR,

Ministry/Agency	Partner(s)	Year	Projects and Goals	Site	Status
		2017-now	Methods of Peatland Management Without Burning (PLTB) and environmentally friendly natural agriculture are collected from various innovations of farmers and researchers and developed through SLPG	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2017-2020	Cooperation with the Indonesian Islamic Scholars' Council, the National Agricultural Development Agency, Nahdlatul Ulama, the Central Leadership of Muhammadiyah and the Fellowship of Churches in Indonesia, the result was 548 da'i cadres and 130 pastors care about peatland	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Completed
		2016-now	The peatland wetting is carried out by constructing 6,947 canal blocks, 427 canal embankments and 15,594 drilled wells.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
	KLHK	2016-now	Revegetation is carried out through planting various suitable plants on peatlands, particularly in burned areas. Currently (2016-2020), there are 30 revegetation packages with a total area of 1,709.35 ha.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2016-now	Revitalization of community livelihood sources in an effort to improve the community's economy, a total of 1,214 packages involving 29,664 community members. Revitalization includes three activities, namely land-based, based on the use of water and fishery resources and environmental services. This program is very much in line with the national program to improve food security.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2016-2020	Demonstration Farm (Demfarm) is located on burnt land with a peat thickness of less than 3 meters or is in the function of cultivating the peatland ecosystems. Initially this land was not used by the community, because it was vulnerable to fire. The development of demfarm does not open up new peatlands but involves revitalizing existing rice fields. Improvements to the water system are carried out to ensure that agriculture does not damage the peatland ecosystem.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2016-2020	LiDAR-based mapping has been carried out on eight Peatland Hydrological Units (KHG) spread across five provinces to obtain more detailed data and information. The detailed information include: physical conditions in the field, land cover, topographic conditions and hydrotopography, all of which can be used when conducting peatland restoration plans.	Riau, Jambi, South Sumatra, West Kalimantan and Central Kalimantan	Completed
	BPPT, BMKG, LIPI, FAO, UNDP, UNOPS, WRI Indonesia and partnership.	2016-Now	The Peatland Ecosystem Restoration Information Institution (PRIMS), is an online platform based spatially on providing information on the condition of peatlands in Indonesia and the progress of peatland restoration as carried out by BRG and restoration partners. The PRIMS monitoring page can be accessed via https://prims.brg.go.id and the BRG Information System (SISFO BRG) mobile application.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing

Ministry/Agency	Partner(s)	Year	Projects and Goals	Site	Status
	BPPT and Hokkaido University	2016-Now	Peatland Water Monitoring System (SIPALAGA) in real time. Since 2016 until 2020, 154 units of groundwater level monitoring equipment have been installed in seven provinces of the BRG working area: Riau Province (52 units), Jambi (16 units), South Sumatra (14 units), West Kalimantan (20 units), Central Kalimantan (41 units), South Kalimantan (9 units) and Papua (2 units). The SIPALAGA page can be accessed via https://sipalaga.brg.go.id.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
		2016-Now	System for Earth Observation Data Access, Processing & Analysis for Monitoring (SEPAL) is a near real-time form of remote sensing based on a soil moisture monitoring system updated every five to ten days. Based on remote sensing, SEPAL can monitor soil moisture for seven provinces. SEPAL cooperates with FAO. The integration of these two systems (SIPALAGA and SEPAL) shows a fairly high correlation between the results of monitoring soil moisture and groundwater level. Monitoring peat soil moisture is important as an indicator to measure the impact of restoration and early warning of fire hazards. The use of SEPAL in predicting soil moisture through satellite imagery becomes more accurate after calibrating the TMAT monitor (SIPALAGA). The SIPALAGA-SEPAL guide can read soil moisture and cover a large area accurately and quickly.	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Ongoing
Ministry of Agriculture	-	2019-2020	Environmentally Friendly Integrated Peatland Management Model for Chili and Shallots. This study aims to verify an environmentally friendly integrated peatland management model for chili and shallot plants from previous studies (2017 and 2018). The research is carried by implementing the results or recommendations from previous research results.	Kalimantan	Completed
(Swamp Agriculture Research Institute) [c)]	-	2019	Swamp Land Typology Map Validation in South Kalimantan. This map contains information on the characteristics of swampland which includes land typology, overflow type and/or inundation type. The available swampland typology maps generally have a small scale (1:250,000) and some districts have a larger or operational scale (1:50,000), but for specific purposes or special uses. This research activity aims to develop procedures or methodologies for mapping swampland based on landform and hydrology through redefinition of data and information on actual land resources. The main output of this map updating activity is a swampland map based on the type of tidal overflow and the type of lowland that is updated in 13 districts in South Kalimantan. The updating map shows several changes or shifts in the boundaries of the swamp between low tide and low tide, tidal overflow type and lowland type so that it displays corrections to the area of each swampland typology, both tidal and low tide.	South Kalimantan	Completed
Ministry of Agriculture (Indonesian Center for Agricultural Land Resources Research and Development) d)	LAPAN	2017-2019	Indonesian peatland mapping. In Fiscal Years 2017, 2018 and 2019, the Research Team of the Indonesian Center for Agricultural Land Resources Research and Development (ICALRRD /BBSDLP) has identified and characterized peatlands in the field for the research activity "Identification of Peatlands Supports One Map Policy". This study aims to provide geospatial data/information in the form of a 1:50,000 scale Peatland Distribution Map based on the district/city area to support the One Map Policy.	Indonesia	Completed
Ministry of Public Works and Human Settlements	BRG	2015	Acceleration of Peat Restoration as an effort to accelerate area recovery and restore the hydrological function of peat due to forest and land fires in 2015	Riau, Jambi, South Sumatra, West Kalimantan, Central Kalimantan, South Kalimantan and Papua	Completed
(PUPR)[e)]		2016-now	Water Management for Agricultural Development in Indonesia's Peat Swamps. The goal is to implement sustainable peat management that is protected from floods, droughts, fires, greenhouse gas (GHG) emissions and loss of biodiversity and economic value.	Indonesia	Ongoing

2.1.5.2 The peatland ecosystems restoration in concession area

Concession holders may be required to restore peat ecosystems in their concession areas, establish water table compliance points (places where water depths are to be measured manually or automatically), building rainfall monitoring stations, blocking canals (with or without spillways), building water gates and reservoirs, rehabilitation through replanting with endemic plant species, as well as allowing for the reintroduction of natural succession. Establishment of water table compliance points as well as rules regarding the measurement of water depth at compliance points are stipulated by the Ministry of Environment and Forestry. As of December 2019, there are peat ecosystems restorations by industrial timber and oil palm plantations as in the following table.

Table2.1 10 Restorations of peat ecosystems in industrial timber and oil palm plantations[28]

	Industrial Plantation Forests	Oil Palm Plantations
Number of companies	68	212
Number of companies that have compiled RPEG	59	202
• Peat which must be protected (FLEG)	1,303,133.30 ha	599,912.68 ha
• Peat on which cultivation may occur (FBEG)	923,646.64 ha	647,995.10 ha
Number of Peat Hydrological Units (KHG) affected	87 KHG	170 KHG
Number of canals to block (2017 - 2026)	8,180 units	19,709 units
Number of Water Table Compliance Points (TPTMAT)	5,071	4,507
Number of data logger devices to be set up	597 units	515 units
Number of rainfall monitoring stations to be built	265 units	530 units
Rehabilitation areas:		
Vegetation rehabilitation	4,438.70 ha	
• Enrichment planting and natural succession	306,112 ha	

2.1.6 Basic Information on the Natural Environment of Peatlands

2.1.6.1 Pealand distribution and area

Peatlands in Indonesia develop between two rivers or between a river and the sea, with thicker dome structures of peat developing in the more central areas. It is especially widespread in the northern part of Sumatra, the southern part of Kalimantan, and the western end of Papua..

Table2.1 11 Peatland areas by province and depth class[29]

Provice	Depth Class						Total (ha)
	D1 50 – 100cm	D2 100–200cm	D3 200–300cm	D4 300–500cm	D5 500–700cm	D6 >700 cm	
Sumatera	660,011	1,352,069	1,016,955	1,494,099	782,590	544,838	5,850,561
Kalimantan	672,525	1,332,268	1,199,923	789,175	507,398	42,072	4,543,362
Sulawesi	2,606	11,885	8,506	1,687	99	-	24,783
Papua	1,831,405	740,690	395,740	39,312	4,664	-	3,011,811
Total	3,166,547	3,436,912	2,621,124	2,324,273	1,294,751	586,910	13,430,517

[28] Source: KLHK, 2019 in the State of Indonesia Forest, 2020a
[29] Source: Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment, 2021.

The Indonesian government has established a peat hydrological unit (KHG) for sustainable land management which is a peat ecosystem located between two rivers, between a river and the sea and/or in a swamp (Government Regulation No. 71, 2014). Based on the Decree of the Minister of Environment and Forestry No. SK.130/MENLHK/SETJEN/PKL.0/2/2017 concerning the Determination of the National Peat Ecosystem Function Map, Indonesia has 865 Peat Hydrological Units (KHG) with a total area of 24,667,804 Ha, which is divided into an Indicative of a Peat Ecosystem Protection Function covering 12,398,482 Ha and an Indicative Peat Ecosystem Cultivation Function covering 12,268,321 Ha. KHG is a peat ecosystem located between two rivers, between a river and the sea or swamps. Data on the area of KHG in each province is shown in the table below.

Table2.1 12 Proportion of the Functional Area of Peat Ecosystems in Indonesia[30]

Province	No of KHG	Peatland Ecosystem Function (ha)		KHG Total Area (Ha)
		Protective Function	Cultivation Function	
Sumatera	207	4,985,913	4,618,616	9,604,529
Kalimantan	190	4,094,203	4,310,614	8,404,818
Sulawesi	3	28,305	34,985	63,290
Papua	465	3,290,061	3,305,106	6,595,167
Total	865	12,398,482	12,269,321	24,667,804

2.1.6.2 Degraded peatland

In 2018, the Ministry of Environment and Forestry determined the extent of degraded peatlands and initiated activities to promote their recovery. Approximately 23.96 million hectares, or almost all of the country's peatland ecosystems, can be said to be degraded

Table2.1 13 Peatland areas by the level of degradation (ha)[31]

Degradation level	Undamaged	Mild Damage	Moderate Damage	Severe Damage	Very Severe Damage	Total (ha)
Sumatera	34,261	6,917,767	1,617,199	574,762	16,124	9,160,113
Kalimantan	52,883	7,402,969	762,219	165,449	7,411	8,390,931
Sulawesi	268	42,411	14,908	2,573	0	60,160
Papua	93,730	6,405,442	23,274	2,939	80	6,525,465
計 (ha)	18,142	20,768,589	2,417,600	745,723	23,615	24,136,669

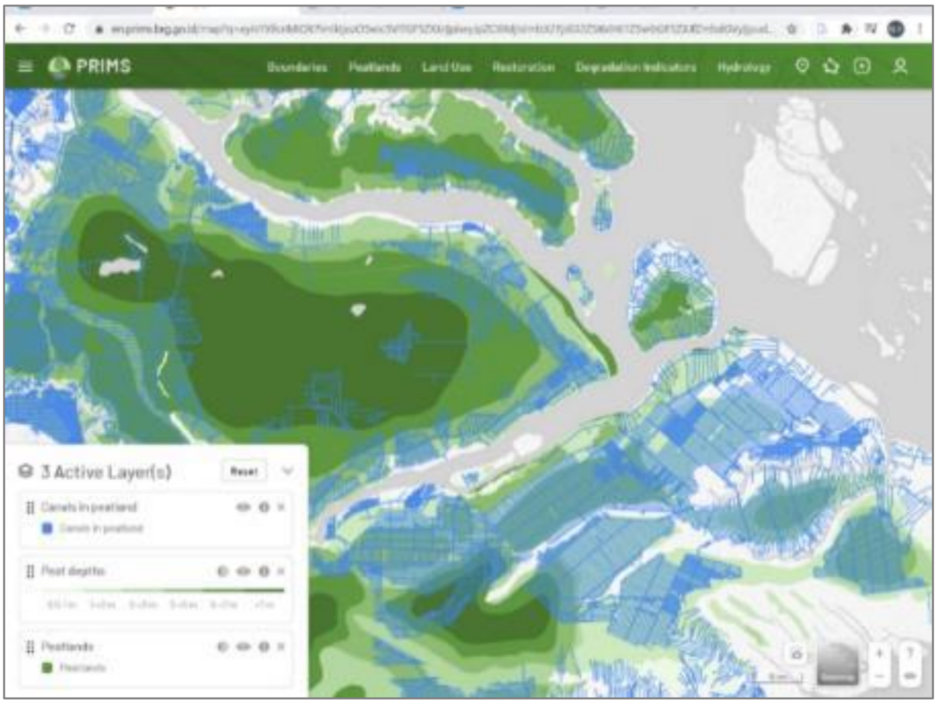
An area of 2,492,527 ha of peat ecosystem was targeted for restoration by 2020 following a Decision made by the Ministry of Environment and Forestry No. 130/Menlhk/Setjen/PKL.0/2/2017 regarding the Determination of the National Peat Ecosystem Function Map (Fungsi Ekosistem Gambut, FEG) government. This includes 684,638 ha in Protected Zones (Fungsi Lindung Ekosistem Gambut, FLEG); 1,410,943 ha in Licensed Cultivation Zones (Fungsi Budidaya Ekosistem Gambut, FBEG); and 396,943 ha in Community

30 Source: Ministry of Environment and Forestry, 2018 in the State of Indonesia Forest, 2020
31 Source: Ministry of Environment and Forestry, 2018 in the State of Indonesia Forest, 2020

Cultivation Zones (also in FBEG). The restoration of peat ecosystems in industrial zones is conducted by drafting a Peat Ecosystem Restoration Plan. The restoration of Community Cultivation Zones is conducted through independent community programs.

2.1.6.3 Peatland Mapping

PRIMS (Pranata Informasi Restorasi Ekosistem), which is the Ecosystem Restoration Information System site (https://en.prims.brg.go.id/map), has maps and information about peat and selected GIS information can be displayed. there are 25 types of information, including those in preparation: i.e. distribution of peatlands, peat depth, canals in peatlands, forest areas, concession areas, indicative restoration, implemented restoration construction, implemented restoration non-construction, research plots, peat restoration implementing units, burn scar area, forest cover loss, hotspots, fire damage rating system, vegetation moisture index- gains and losses, groundwater level, soil moisture, rivers, etc.



Source: JICA Study team

Figure2.1 2 Sample mapping to indicate the peatland distribution, peat depth and canals by PRIMS[32]

Note: Unless otherwise indicated in the footnotes below, figures and tables were prepared by the Information Gathering and Verification Mission for Sustainable Peatland Management and Conservation Cooperation study team.

[32] Source: Gathering and Verification Survey on Sustainable Peatland Management and Conservation Cooperation study team

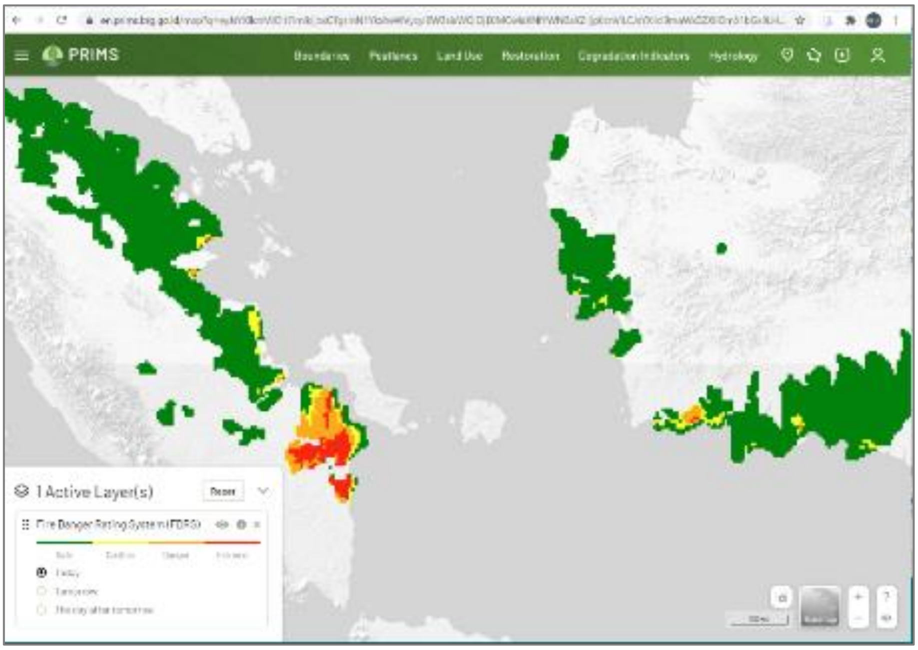


Figure2.1 3 Sample mapping to indicate the Fire Danger Rating System on peatland by PRIMS

The complex environmental conditions of peatland are presented in the form of information of some web GIS and data that can be accessed and visited by all groups. Some of the information provided by the central government such as BRGM, ICALRRD, ESDM, Indonesian Geospatial Portal, BMKG and WRI are as follows:

Table2.1 14 Data, Map and Web GIS Information regarding information on the natural circumstances of peatland in Indonesia

No	Map	Institution	Source /Contact	Type
1.	Peat Hydrological Unit (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS
2.	Peatland Ecosystem Function	BRGM	https://en.prims.brg.go.id/map	Web GIS
3.	Peatland Distribution	BRGM	https://en.prims.brg.go.id/map	Web GIS
4.	Peatland Depths Distribution	BRGM	https://en.prims.brg.go.id/map	Web GIS
5.	Canals in Peatland	BRGM	https://en.prims.brg.go.id/map	Web GIS
6.	Forest Area (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS
7.	Forest and Peatland Moratorium (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS
8.	Concession Area (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS
9.	Indicative Restoration	BRGM	https://en.prims.brg.go.id/map	Web GIS
10.	Implemented Restoration Construction	BRGM	https://en.prims.brg.go.id/map	Web GIS
11.	Implemented Restoration Non-Construction	BRGM	https://en.prims.brg.go.id/map	Web GIS
12.	Peat Care Village	BRGM	https://en.prims.brg.go.id/map	Web GIS
13.	Research Plot	BRGM	https://en.prims.brg.go.id/map	Web GIS
14.	Peat Restoration Implementing Units	BRGM	https://en.prims.brg.go.id/map	Web GIS
15.	Restoration Partners	BRGM	https://en.prims.brg.go.id/map	Web GIS
16.	Burn Scar Area (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS

No	Map	Institution	Source /Contact	Type
17.	Forest Cover Loss on Peatland (on progress)	BRGM	https://en.prims.brg.go.id/map	Web GIS
18.	Hot Spots	BRGM	https://en.prims.brg.go.id/map	Web GIS
19.	Fire Danger Rating System	BRGM	https://en.prims.brg.go.id/map	Web GIS
20.	Vegetation Moisture Index -Gains and Losses	BRGM	https://en.prims.brg.go.id/map	Web GIS
21.	Groundwater Level	BRGM	https://en.prims.brg.go.id/map	Web GIS
22.	Soil Moisture	BRGM	https://en.prims.brg.go.id/map	Web GIS
23.	Restoration Impact Research	BRGM	https://en.prims.brg.go.id/map	Web GIS
24.	Hydrological Modelling: Scenarios, Baselines, Difference and Peat Rewetting Infrastructure	BRGM	https://en.prims.brg.go.id/map	Web GIS
25.	Rivers	BRGM	https://en.prims.brg.go.id/map	Web GIS
26.	Peatland Distribution Map	ICALRRD	pusdatin@pertanian.go.id	Soft file
27.	Soil Distribution Map	ICALRRD	pusdatin@pertanian.go.id	Soft file
28.	Geology Map (Geostructure and Litology)	ESDM	helpdesk.onemap@esdm.go.id https://onemap.esdm.go.id/map/geologi.html	Soft file
29.	Forestry Map	BRGM	tukabad@brg.go.id	Soft file
30.	Topography Map (Seamless Digital Elevation Model and National Bathymetry)	Indonesia Geospatial Portal	info@big.go.id https://tanahair.indonesia.go.id/demnas/#/	Soft file
31.	Rainfall Data	BMKG	https://dataonline.bmkg.go.id/	Soft file
32.	Temperature Data: Maximum, Minimum, Average	BMKG	https://dataonline.bmkg.go.id/	Soft file
33.	Average Humidity Data	BMKG	https://dataonline.bmkg.go.id/	Soft file
34.	Wind Speed Data: Maximum and Average	BMKG	https://dataonline.bmkg.go.id/	Soft file
35.	Wind Direction Data: Most and At Maximum Speed	BMKG	https://dataonline.bmkg.go.id/	Soft file
36.	Sun Exposure Time Data	BMKG	https://dataonline.bmkg.go.id/	Soft file
37.	Concession Area Maps	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS
38.	Hot Spots (VIIRS) Maps	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS
39.	Restorer Maps: Government (on progress)	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS
40.	Restorer Maps: WWF, WII, WRI, MCA-I, IPB, UGM	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS
41.	Restoration Activity Plans	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS
42.	Restoration Activity Verification Maps: Riau, South Kalimantan and Central Kalimantan	WRI	http://www.pantaugambut.id/peta-restorasi	Web GIS

2.1.6.4 Transition of ecosystem and land use of Sumatra island and Kalimantan island

According to the report of the World Bank WAVES Project (Pilot Ecosystem Account for Indonesian Peatlands Sumatera and Kalimantan Islands (2019)), 52% of peat forest was converted to other land cover as plantations and agricultural land between 1990 and 2015 in Kalimantan and Sumatra.

In 1990, 73% of the peatland in Sumatra was covered by forests, while in 2014/2015, 22% of the peatland remained as forests.

Natural forests comprised about 80% of Kalimantan peatland in 1990, but by 2014/2015 32% (1,5Mha) was converted. In 2015, in Sumatra, 48% of peatland was converted to plantations of pol palm and fast-growing tree species for pulp and agricultural land, while in Kalimantan only about 16% was converted (plantations (7%) and agricultural land (8%)). Therefore, changes in land cover in Kalimantan remain ongoing.

Table2.1 15 Transition of peatland ecosystem extent, based on the land cover data of MoEFRI[33]

(unit: 1000ha)

Sumatra	1990	1996	2000	2006	2009	2014
Undisturbed forest	481	450	378	402	281	225
Disturbed forest	4159	3824	2659	2081	1642	1257
Degraded peatland	768	829	1447	1468	1720	1394
Bare land	33	96	213	466	355	380
Plantation forest	7	32	48	262	420	864
Perennial crops	378	535	941	1007	1211	1398
Kalimantan	1990	1996	2000	2006	2009	2014
Undisturbed forest	113	80	68	62	58	50
Disturbed forest	3790	3234	2978	2799	2565	2308
Degraded peatland	589	1083	1335	1432	1500	1532
Bare land	27	44	44	62	94	203
Plantation forest	0	1	0	0	1	300
Perennial crops	59	73	83	131	256	336

NOTE: Undestroyed forests: primary and well-preserved secondary forests; Disturbed forests: degraded secondary forests; Degraded peatland: bush (dry shrub forests), swampy shrub (ruined shrub forests), savannas, grasslands; Bare land: land without any tree species and herbs; Plantation forests: plantations such as industrial plantations mainly for pulpwood production and oil palms; Perennial crops: agricultural land and orchards producing perennial crops

The area of plantations has soared since 2000, comprising 22% and 10% of the total peatland in Sumatra and Kalimantan in 2014.

[33] Source: Indonesia: Pilot Ecosystem Account for Indonesian Peatlands Sumatera and Kalimantan Islands (2019)

Table2.1 16 Total area of plantations in peat areas of Sumatra Kalimantan (1000ha)[34]

	2000	2005/6	2009/10	2014/15
Sumatra	621	1007	1210	1414
Kalimantan	1	131	256	480

Table2.1 17 Product Changes from Peat Areas[35]

Sumatra	2000	2006	2009	2014
Timber production (1000m3)	1893	1482	1094	777
Oil palm (1000t)	10389	16837	20242	23635
Biomass production for pulp (1000t)	620	625	627	561
Kalimantan	2000	2006	2009	2014
Timber production (1000m3)	794	741	666	576
Oil palm (1000t)	14	2185	4282	8022
Biomass production for pulp (1000t)	0	2	24	624

Table2.1 18 Changes in Carbon Stock and Releases in Peatland (Estimation)[36]

Sumatra	1990	1996	2000	2006	2009	2014
Carbon stock (1000t)	2707	2585	2148	1980	1819	1770
CO_2 emissions from oxidation (1000t)	131	146	178	195	225	272
CO_2 emissions from fires (1000t)				183	318	286
Kalimantan	1990	1996	2000	2006	2009	2014
Carbon stock (1000t)	2107	1862	1759	1702	1628	1533
CO_2 emissions from oxidation (1000t)	91	94	95	99	108	115
CO_2 emissions from fires (1000t)				386	325	324

2.1.7 Basic information on climate change impacts and potential contributions of peatland

2.1.7.1 NDC of Forestry sector

The enhanced NDC of Indonesian, submitted to UNFCCC in September 2022, states that by 2030 greenhouse gas emissions will be reduced by 31.89% (unconditional) of their own accord[8] without conditions) and 43.20% (conditional) with the required international assistance of their own BAU by 2010.

34 Source: Indonesia: Pilot Ecosystem Account for Indonesian Peatlands Sumatera and Kalimantan Islands（2019）

35 Source: Indonesia: Pilot Ecosystem Account for Indonesian Peatlands Sumatera and Kalimantan Islands（2019）

36 Source: Indonesia: Pilot Ecosystem Account for Indonesian Peatlands Sumatera and Kalimantan Islands（2019）

The projected deforestation rate for Indonesian BAU between 2013 and 2020 is in line with the Forest Reference Emission Level for REDD + (FREL), with deforestation of approximately 920,000 ha per year. Indonesia's goal is to reduce annual deforestation to an average of 450,000 ha. Forest deforestation for four years from 2013 was close to this level, but exceeded it for the next two years. The six-year annual deforestation rate averages 580,000 ha per year and the average BAU of deforestation is projected to be 820,000 ha per year over the next decade from 2021 to 2030. The Government of Indonesia is targeting a goal of reducing the rate of deforestation in the next decade to an annual mean of 325,000 ha.

2.1.7.2 Greenhouse Gas Emissions

(1) National greenhouse gas inventory

1) Cross-sectoral emissions

In Indonesia, as shown in Figure2.1 4, although national greenhouse gas emissions fluctuate significantly from year to year, peat fires and FOLU (including emissions from peatland decomposition) comprise a large percentage.

Since the actual emissions in 2018 are 1.64GtonCO_2e and baseline emissions based on NDC are 1.86GtonCO_2e, emissions are reduced by 226 million tonCO_2e from the baseline.

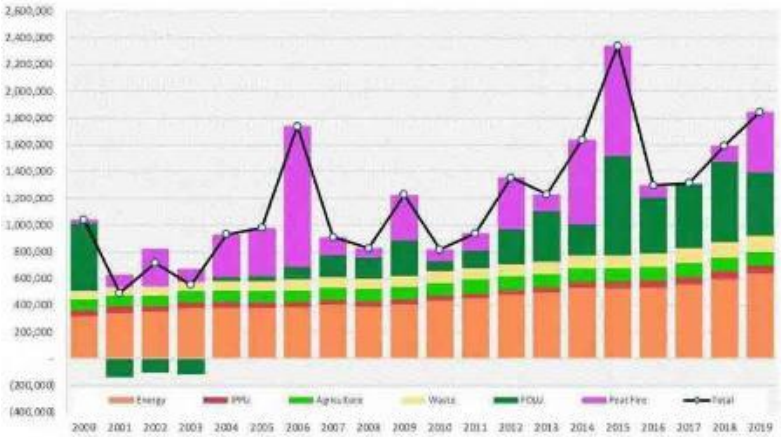


Figure2.1 4 Annual Changes in Greenhouse Gas Emissions by Sector (Units: GgCO_2e)[37]

[37] Source: IndonesiaBUR3

Emissions in the Forestry sector exceed the energy sector and the subtotal of the agriculture and forestry sector comprise more than half of total emissions.

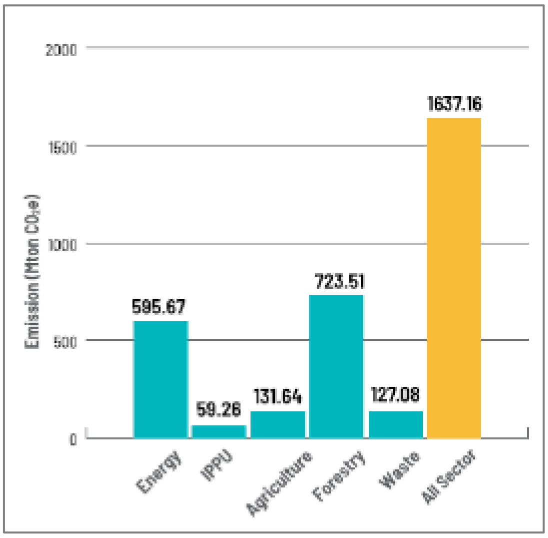


Figure2.1 5 Greenhouse Gas Emissions in 2018[38]

2) Emissions from forestry sector and peatland

Emissions from the forestry sector and peatland averaged 439.8 MtonCO_2e annually from 2000 to 2018. Figure 2.1.6 shows emissions from the forestry sector and peatland. Despite considerable fluctuation by year, decomposition of the peatland and discharge from the peat fire occupy the majority.

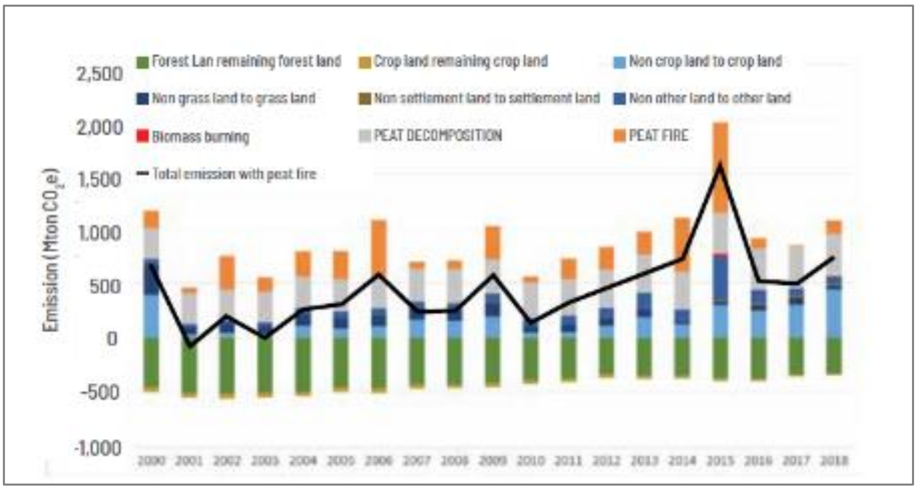


Figure2.1 6 Emissions from the Forestry sector and peatland[39]

Emissions from peat fires vary widely from year to year, but were 822.7 MtonCO_2e in 2015, 90.27 MtonCO_2e in 2016, 12.5 MtonCO_2e in 2017 and 121.32Mton CO_2e in 2018. (See Figure 2.1.7)

38 Source: KLHK,2020
39 Source: KLHK 2020

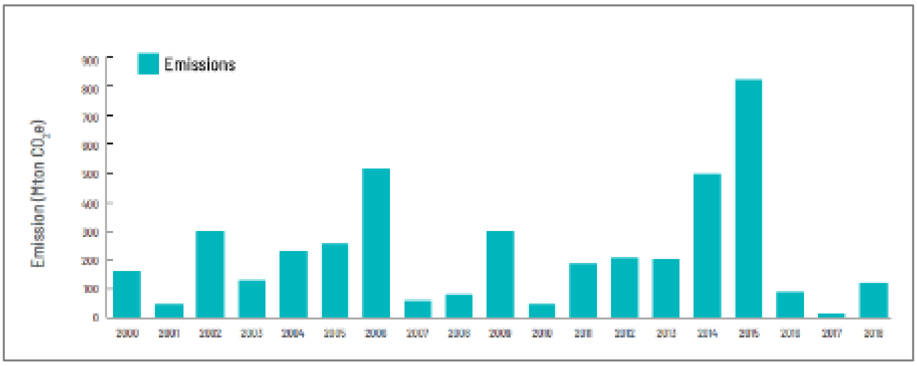


Figure2.1 7 GHG emissions from peatland fire

Source: KLHK,2020d

The NDC targets were generally achieved since 2010, as shown in the table below, except in 2015 due to large peat fires.

Table2.1 19 GHG emissions reductions against NDC targets (all sector)[40]

Year	GHG emissions (Mton CO_2e)								
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Baseline (BAU)	1,334	1,520	1,569	1,611	1,671	1,702	1,769	1,860	1,863
Inventory	810	1,054	1,245	1,331	1,509	2,374	1,336	1,354	1,637
Annual Emission reduction	524	466	325	280	162	-672	433	507	226
Contribution to NDC in 2030 (%)	**18.22**	**16.20**	**11.29**	**9.73**	**5.63**	**23.37**	**15.07**	**17.62**	**7.85**

Table2.1 20 Comparison between GHG inventory and BAU in the Forestry sector (in Mton CO_2 e)[41]

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Inventory (actual emissions)	124.73	311.44	456.49	582.82	714.71	1,565.58	507.65	488.52	723.51
Baseline (BAU)	646.55	769.25	770.84	767.69	766.42	765.09	763.7	801.26	760.76
Annual Emission reduction	521.82	457.81	314.35	184.87	51.71	-800.49	256.05	312.74	37.25
Contribution to NDC in 2030 (%)	18.06	15.84	10.88	6.4	1.79	-27.7	8.86	10.82	1.29

40 Source: KLHK,2020d
41 Source: KLHK,2020d

2.1.8 Examination of methodology for estimating greenhouse gas emission reductions from peat areas

The Science and Technology Research Partnership for Sustainable Development (SATREPS) "Fire and Carbon Management Project in Peatlands and Forests" (hereinafter referred to as JICA-JST SATREPS Project) by JICA-JST was implemented in Central Kalimantan Province, Indonesia, from 2009 to March 2014 and the results were obtained from research and technological developments on carbon management, particularly in peatlands with high carbon stocks. As one of the results, with regard to carbon dioxide emissions, Hirano et al. (2016) showed the relevance between annual CO_2 emission and groundwater level due to peat decomposition (Hirano model). Here, it is shown that the net ecosystem CO_2 exchanges (Net Ecosystem Exchange, NEE) in one year are highly correlated with the annual monthly mean lowest values of groundwater level in three peatland types according to the presence or absence of disturbance (undrained peat forest UF, wastewater peat forest DF and drained fire site DB). This study enabled us to estimate CO_2 emissions associated with peat decomposition in peatlands in Central Kalimantan Province from the groundwater level profile estimated using modelling developed through the JICA-JST SATREPS Project.

Methane (CH_4) is a greenhouse gas that contributes strongly to global warming after carbon dioxide, but there is a great deal of uncertainty about emissions from ecosystems (Saunois et al., 2020). Organic matter is anaerobically decomposed under reducing conditions, whereupon CH_4 is synthesized by methanogens. therefore, the main sources of ecosystems are freshwater wetlands, peatlands and paddy fields. Tropical peat areas have accumulated peat in coexistence with wetland forests (peat forests), but in recent years agricultural land conversion with deforestation and wastewater has progressed. Annual CH_4 emissions from tropical peatlands have also been reported to be lower than those from marshes in boreal, temperate and subtropical regions (Sakabe et al., 2018).

In 2021, we focused on the relationship between groundwater levels and CH_4 emissions at four sites in Borneo (Sakabe et al., 2018; Wong et al., 2020) and two sites in Sumatra (Deshmukh et al., 2020). Except for one site on Borneo (PUF, Central Kalimantan, Indonesia), groundwater levels can explain site-to-site differences in CH_4 emissions, regardless of the degree of disturbance or geographical distribution. In addition to soil-borne releases, the release of CH_4 from waterways in plantations and the release of CH_4 from the trunks of peat forest trees need to be taken into account (Pangala et al., 2013).

2.1.9 Support projects of peatland conservation and management by other donors and the private sector

Several international organizations or institutions that support government efforts to conserve and manage peatlands in Indonesia are as follows:

1) Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) supports Indonesia in environmental management and improvement in the form of projects such as (Ministry of Environment and Forestry, 2021b)

June 2020 - December 2021: Propeat Project to protect and manage peatland ecosystems in North Kalimantan, collaboration with the Ministry of Environment and Forestry. Donor: Germany, EUR 3.000.000.

2) World Resources Institute (WRI) Indonesia supports Indonesia in environmental management and improvement in the form of projects such as the following (WRI, 2021):

a. August 2021 - October 2021: Peatland Restoration Implementation E-Learning Modules Accelerating

Low-Emission Development in Indonesia through Sustainable Land-use Management and Improved Forest Governance. Donor: WRI, IDR 550,000,000.

b. August 2020 – January 2021: Assessment of Sustainable Commodities on Peatland for Independent Peatland Monitoring. The result of the assessment will be incorporated in the independent peatland monitoring platform www.pantaugambut.id with the purpose of increasing demand and investment to peatland-friendly commodities. Donor: WRI, USD 25,000.

c. July 2020 - December 2020: Monitoring of Peatland Management and Protection Activity in Papua. The objective of this activity is to monitor the commitment and investigate the authorized stakeholders' activities on peatland area. Donor: WRI, USD 25,000.

3) **Global Green Growth Institute (GGGI) supports Indonesia in environmental management and improvement in the form of projects such as (GGGI, 2021):**

October 2020 - 30 September 2022: Green Growth Program Phase III Landscapes (GGP3 Landscapes) 2020-2022, to improve the integration and coordination of landscape management across multisector stakeholders and demonstrate sustainable landscape management approaches in selected areas in Indonesia. Partners: Ministry of National Development Planning, Ministry of Finance, Peat and Mangrove Restoration Agency, Environmental Fund Management Agency, Provincial Governments of Central Kalimantan, South Kalimantan, East Kalimantan, North Kalimantan, West Papua and Papua. Donor: NICFI through the Norway Embassy in Indonesia, USD 10,000,000.

4) **United Nations Development Program (UNDP) /Food and Agriculture Organization of the United Nations (FAO) supports Indonesia in environmental management and improvement in the form of projects such as the following (UNDP, 2021):**

a. December 2017 - December 2025: the Strengthening Forest Area Planning and Management in Kalimantan (KalFor) project. The project aims to create significant global benefits related to biodiversity conservation, sustainable land use and mitigation of GHG emission, particularly in the Heart of Borneo (HoB). Donor: Global Environment Fund Trust, USD 6,190,000.

b. May 2016 - November 2019: Support Facility for the Peatland Restoration Agency. Donor: United Nations Development Pro and Government of Norway $12,513,119.

c. January 2016 - December 2021: FAO-EU FLEGT (Forest Law Enforcement, Governance and Trade) Phase III Programme. FLEGT aims to reduce illegal logging and timber production, such as those via illegal timber production – leading causes of forest degradation and deforestation. Donor: EU, DFID, SIDA and FAO, USD 2,400,000.

d. November 2019 - December 2021: Strengthening Indonesian Forest and Land Monitoring for Climate Actions. Forest Monitoring System under the Ministry of Forestry which combines remote sensing and on-ground measurement under the National Forest Inventory system (NFI). Donor: Norway USD 2,080,000.

e. Mid 2019 – December 2021: Global Peatlands Initiative (GPI). FAO is a founding member of GPI, which is comprised of over 28 authorities and institutions, working together on peatland conservation and sustainable management, to keep carbon in the soil rather than in the atmosphere, where it would contribute to climate change. Donor: German IKI, Approx. USD 500,000.

f. January 2021 - December 2021: UN-REDD Technical Assistance to Indonesia. Donor: Norway Approx. USD 400,000.

g. July 2018 - December 2020: Development of an Innovative Peatland Monitoring System – SEPAL. The project successfully improved peatland monitoring systems and the project-level estimations for reporting of greenhouse gas (GHG) emissions. Partners: UNOPS, BRGM. Donor: United Nations Office for Project Services USD 1,670,000.

h. December 2015 - October 2018: Securing tenure rights for forest landscape-dependent communities: linking science with policy to advance tenure security, SFM and people's livelihoods - CIFOR (MSP). To improve how knowledge about forest and land tenure reforms is understood, communicated and used so that decision makers, practitioners and forest-dependent people in developing countries are well-equipped to develop and implement policies and projects that support tenure security, livelihoods and sustainable forest management. Donor: GEF Trust Fund, USD 2,000,000.

5) Center of International Forestry Research (CIFOR) supports Indonesia in environmental management and improvement in the form of projects such as the following (CIFOR, 2021):

a. Feb 2021 - January 2026: Transitions to Climate Resilient Landscapes: Reducing and Mitigating Boreal and Tropical Forest Fires to Promote Sustainable Rural Livelihoods. The aim of the research is to gain a comprehensive understanding of local and regional socio-ecological and resource-use systems, to accurately estimate the social and economic drivers and impact of fire and haze in the region and develop local forest fire reduction and mitigation plans. The project is implemented by an interdisciplinary research team involving experts from the Ministry of Agriculture, Forestry and Fisheries of Japan and CIFOR with in-country partners in the Russian Far East and Indonesia.

b. April 2019 - June 2024: Free Sustainable Land Management in Southeast Asia (MAHFSA). The Measurable Action for Haze-Free Southeast Asia (MAHFSA) is a joint initiative between the ASEC and IFAD. It aims to create a flexible regional coordination platform for engaging all relevant actors, building capacity, harmonizing programs and projects and facilitating multiple sources of finance for promoting haze-free farming and sustainable management of peatlands. Partners: ASEC and IFAD.

c. March 2021 - March 2023: Global Peatlands Initiative (GPI). Under the framework of the Memorandum of Understanding between UNEP and CIFOR and in close consultation with UNEP, CIFOR shall showcase and promote GPI partnership through peatlands-themed interactive sessions and promotional materials including GLF interactive sessions on peatlands as part of the programme jointly. Partner: UN Environment.

d. August 2019 – December 2022: Mitigation and Adaptation Through Sustainable Livelihood in Indonesia's Peat and Mangrove Ecosystem. CIFOR is facilitating the establishment of the Peatland and Mangrove Ecosystem Advisory Committee (PME-AC). This will be led by BAPPENAS. CIFOR is facilitating the establishment of the Peatland and Mangrove Ecosystem Advisory Committee (PME-AC). This will be led by BAPPENAS.

e. October 2020 – September 2022: Developing Research Capacity of Universities in Southeast Asia on Forest Landscape Governance. The project aims to improve their ability to conduct quality and transformative research, as well as leverage that research to support policy development and behavioral change at various levels leading to more equitable, community-oriented forest governance. Partners: RECOFTC and SIDA.

f. December 2020 – May 2022: Restoring Coastal Landscape for Adaptation Integrated Mitigation (ReCLAIM). Some specific objectives could be: To assess the potential of restored blue carbon ecosystems for climate change mitigation and adaptation; To quantify the livelihood and nutritional benefits of maintaining healthy coastal landscapes and restoring degraded blue carbon ecosystems for local communities; To enhance the adaptive capacity of local governments and communities by informing new knowledge generated from the project through regular dialogues and briefing materials. Partners: David and Lucile Packard Foundation

g. December 2019 - October 2021: Improving Indonesia's Forest Reference Emissions Level (FREL) through Refined GHG Accounting in Wetlands and Knowledge Management. This project aims to improve that FREL by generating more accurate emission factors from land-use activities and also by including currently underrepresented land-use dynamics Norwegian Ministry of Foreign Affairs (MFA)

h. October 2019 - November 2020: Supporting fire management with a focus on the dry tropics: mainstreaming fire into landscape decisions and NDCs. This aimed to mainstream fire in land management decisions in those countries that were identified in 2019, with a particular focus on dry ecosystems. Partner: USAID.

i. October 2019 – September 2021: Mainstreaming Wetlands into the Climate Agenda: A multi-level approach (SWAMP-II). The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) and its predecessor the Wetlands Initiative for Climate Adaptation and Mitigation program have been running for a decade. SWAMP continues to generate knowledge to be delivered to policy community and other decision-making bodies, supported by new funding from USAID. Partners: USAID.

j. July 2019 - July 2020: A Participatory Action Research to Community-Based Business Model (CBBM) Development in Selected Integrated Forest and Farming System (IFFS/DMPA) Villages. The Integrated Forestry and Farming System (Fire Caring Villages, DMPA) was launched by Asia Pulp and Paper (APP) in December 2015 during the Conference of the Parties 15 in Paris. The DMPA is increasingly recognized as an effort by the private sector to prevent fire and improve community livelihoods. World Agroforestry and CIFOR collaborated with APP (Phase 1) in 2018 to develop a typology of DMPA villages inside APP tree plantation concessions and develop standards for good DMPA and a policy to scale up DMPA. This project continues that work in Phase 2 in 2019–2020. The work focuses on business model development for representative DMPA villages in Riau.

k. January 2019 - March 2020: Sustainable Lowland Agriculture for Development in Indonesia (SLADI). Through an integrated landscape approach that addresses multiple objectives this project aims to identify alternatives to slash-and-burn techniques and incentives for smallholder farmers to conduct more responsible and sustainable land clearing activities, to propose reforms to governance and incentives around the land management at the national and subnational administration level. Partners: ICRAF and World Bank.

l. December 2018 - January 2019: Gambut Project: Fire Prevention Through Rewetting and Revegetation in Dusun Hilir, Barito Selatan. This collaboration specifically aims to 1) be part of capacity-building to allow transfer of skills and knowledge between CIFOR Scientists and UMP researchers, 2) support degraded peatland restoration activities in Indonesia that will benefit future generations, 3) maintain CIFOR-UMP collaboration to develop research into bioenergy species for Non-Timber Forest Products (NTFPs) that was started through Species Trial CIFOR-UMP 2016 Project. Partners: Universitas Muhammadiyah Palangkaraya and United Nations Office for Project Services (UNOPS)

m. October 2018 – October 2019: Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) 2019. SWAMP program co-implementers the US Forest Service and CIFOR are contributing to USAID's Global Climate Change Sustainable Landscapes program goals by addressing data gaps in carbon and greenhouse gas (dynamics in tropical wetlands). This builds capacity globally for wetland management and monitoring. It also facilitates the development of tools that support sustainable wetland management and help countries incorporate their wetlands into national and international climate change plans. Partner: USAID.

6) **The International Climate Initiative (IKI) supports Indonesia in environmental management and improvement in the form of projects such as the following (International Climate Initiative, 2021):**

a. January 2020 – December 2023: Improving the Management of Peatland and the Capacities of Stakeholders in Indonesia (Peat – IMPACTS Indonesia). A sustainable and climate-neutral solution to the management of peatlands is based on a transformational landscape approach that combines technical and organizational resources and skills in peatland restoration, while being aligned to the needs of public and private sectors. The project also raises awareness among key stakeholders of peat fires and the associated emission risks in relation to peatlands. Support is being provided to integrate peatland management into a broader-based landscape management and the project is also providing skills training for smallholders in the management of paludiculture. The project's efforts are helping safeguard local livelihoods, while communicating the lessons learned is ensuring that insights are shared nationwide. Implementing Organization: ICRAF. Political partners: KLHK, BRG, BAPPENAS. Implementing Partner: FOERDIA and ICALRRD. BMU Grant: € 4,062,457.

b. April 2019 – May 2023: Mitigation and Adaptation Through Conservation and Sustainable Livelihood in Indonesia's Peatland and Mangrove Ecosystem. The project is supporting the widespread retention and effective management of peat and mangrove ecosystems in West Papua and North Sumatra. This will increase the resilience of communities and biodiversity most threatened by the impacts of climate change. The project is based on sustainable economic solutions such as shrimp fishing, non-wood products and the agricultural use of raised bogs and fens, which simultaneously help to establish alternative livelihoods for inhabitants. By avoiding the deforestation of 20,000 ha of mangrove forests and 60,000 ha of peat forests during its lifetime, the project is helping to save around 30 million tonnes of CO_2. Implement organization: Conservation International. Political partners: KLHK, Ministry of Marine Affairs and Fisheries, BAPPENAS. Implementing partners: CIFOR, Wetland International. BMU grant: € 3,967,440.

c. October 2018 – July 2021: Monitoring, Reporting, Verification (MRV) System for Mitigation Actions in Indonesia. The project supports the government in developing the system by helping national and sub-national stakeholders to integrate the existing PEP tool into a new solution. It also helps the 'Secretariat of the National Action Plan on Mitigation' collect data and set up a data management system. The project strengthens the capacity-building of national and sub-national partners regarding the reporting of mitigation measures and also develops guidelines, regulations, training material and communication products, ensuring that the measures achieve a wide-ranging impact. Implementing organization: GIZ GmbH. Political partner: BAPPENAS. Implementing partner: KLHK, BAPPENAS, ICRAF. BMU grant: € 1,960,000.

d. February 2018 – June 2023: the Global Peatlands Initiative: Assessing, Measuring and Preserving Peat Carbon. The Global Peatlands Initiative aims to analyse the state of peatlands worldwide and the role they play in the global carbon cycle. The project will improve and support access to the current body of knowledge while creating a hotspot atlas and a platform on peatland degradation. The project also facilitates networking among researchers, policymakers and other stakeholders. Implementation organization: UN Environment. Political partners: KLHK and BRG. Implementing Partner: FAO. BMU grant: € 1,999,567.

e. June 2018 – January 2024: Strengthening Regional Experiences on Sustainable Peatland Management (ASEAN – REPEAT). This project is financing successful approaches to sustainable peatland management and scaling these up regionally. The project is evaluating approaches in pilot areas in

Indonesia and Malaysia in terms of their effectiveness and financial viability and building on these results to develop specific financing schemes, business models and fiscal policy recommendations. Political partner: ASEAN. Implementing partners: ASEAN secretariat and KLHK. BMU grant: € 4,000,000.

7) **Norway's International Climate and Forest Initiative (NICFI) supports Indonesia in environmental management and improvement in the form of projects such as the following (Norway Ministry of Foreign Affairs, 2021):**

a. May 2019 – May 2023: Eastern Indonesia Forest Facility, to uphold biodiversity, forest ecosystem services and the Human Rights of Indigenous and other forest-dependent peoples and communities in Eastern Indonesia. Grant: up to NOK 132,910,000.

b. October 2020 – September 2022: Global Green Growth Institute Indonesia Country Program – phase III. Organization: GGGI. Grant: Up to NOK 95,000,000.

c. June 2016 – May 2021: Accelerating Low-Emissions Development In Indonesia Through Sustainable Land-Use Management. Expected outcomes. Organization: WRI. The project is co-funded by USAID. Grant: Up to NOK 227,175,000.

d. March 2018 – December 2020: BRG support through UNOPS, to support reducing the GHG emissions from land use and promoting biodiversity conservation from peatland in accordance with Government Regulation 57/2016. Organization: UNOPS. Grant: up to NOK 345,000,000.

e. November 2017 – October 2019: Green Growth Policy Review of Indonesia, to contribute to a better integration of green growth considerations into Indonesia’s economic, environmental and social policies, an improvement in inter-agency cooperation and sharing of best practices via an enhanced policy dialogue, an improved understanding of Indonesia’s progress and challenges toward green growth and a better targeting of related international cooperation efforts. Grant: Norway is one of several donors to the project, Norway's contribution is NOK 1,000,000.

f. May 2018 – June 2019: Global Yield Gap Atlas Palm Oil. to substantially increase the understanding of the benefits of agricultural intensification to relieve the pressure on expanding agricultural to new land located in the most vulnerable areas of the archipelago and forested areas. Partner: University of Nebraska-Lincoln. Grant: Up to NOK 2,000,000.

g. December 2017 – December 2018: Indonesia Sustainable Landscape Management (IDSLM) Trust Fund, to improve the integration and coordination of landscape management across multi-sector stakeholders and demonstrate sustainable landscape management approaches in selected areas of Indonesia. The fund is co-funded with the Australian Government Department of Foreign Affairs and Trade and open for other donors. Grant: NOK 241,000,000.

h. August 2017 – June 2018: Tenure Conference 2017, Forest and Land Tenure and Governance for Equitable Development, to contribute to the pooling of maps, information and case studies on agrarian reform and social forestry to achieve Government targets and a Stakeholders’ Agreement on implementing Social Forestry and Agrarian Reform in Indonesia. Grant: Norway is one of several donors to the project, Norway's contribution is NOK 1,400,000

i. October 2017 – April 2018: Caring for Peatland Villages. Institution: BRG. Grant: Up to NOK 18,000,000.

j. October 2013 – January 2017: REDD+ Support Facility Multi-Donor Trust Fund, to support the Government of Indonesia in the implementation of the REDD+ strategy of the Republic of Indonesia by providing technical support and analytical inputs to help make operational the Indonesian agencies and institutions in charge of the implementation of the REDD+ strategy. Grant: Up to NOK 10,500,000.

2.1.10 Future support policy for other donors and the private sector

According to the Director-General Regulations P. 4/Setjen/Rocan/Set.I9/2020 of the Ministry of Environment and Forestry on the Strategic Planning of the Director-General of the Ministry of Environment and Forestry from 2020 to 2024, to expand the opportunities for citizens to participate in the government, future strategies requiring development are to cooperate with various national and national stakeholders, government-private (business)-communities (NGO/communities) in the context of increased awareness/concern about the performance of the Ministry of Environment and Forestry.

Generally, aspects of collaboration in the environmental and forestry sectors are closely related to the achievement of the global sustainable-development goal agenda, particularly in SDGs Goal 17, a global partnership for achieving the goal. The main aspect of concern when developing and coordinating future external cooperation activities in the Ministry of Environmental and Forestry is to ensure future or ongoing cooperation: (1) Follow national interests, (2) support the Ministry of Environmental and Forestry's strategic plan, (3) the five principles of security (political, judicial, technological, security and fiscal) and foreign cooperative relationships, i.e. mutual trust, respect and interest, are truly beneficial to the beneficiaries, (4) the policy of allocating funds to external cooperation projects is at least 60% for operation. The mechanism is in line with the Act on International Agreements 24/2000, the Act on External Relations No. 39/1999 and the Act on Community Organization No. 17/2016. And in accordance with Governmental Regulation No. 59/2016 on Foreign Public Organizations, it stipulates cooperation through formal institutional relationships between the Ministry of Environmental, Forestry and cooperative partners, referring to programme priorities (Ministry of Environment and Forestry, 2020).

According to the Ministry of Environment and Forestry (2020), the types of services provided are activities/activities that elicit international cooperation in the following forms:

a. Documentation of the analytical results of bilateral, multilateral and regional cooperation and of foreign community organizations: coordinating of bilateral and regional relations and of the implementation of cooperative activities. Provide technical assistance for bilateral and regional cooperation and cooperative management of forest attackers. Coordination of multilateral relations and cooperation and implementation of non-governmental multilateral institutions (OINP). Encourage the use of GEF funds.

b. International Cooperation Agreement documents: Components of facilitation, coordinating, discussion/review of legal opinions/judicial analysis and monitoring and evaluation of follow-up contracts.

TheIndonesian Presidential Regulation No. 1/2016 on the Peatland Restoration Agency (BRG) also discusses international cooperation. In particular, in Chapter 6 on financing, Article 27(2) may be implemented by BRG in cooperation with other parties provided it does not prejudice national and national interests and accounts for its obligations and functions that are not covered by income and expenditure budgets, provided it can be comprised in accordance with the provisions of the Act.

2.1.11 Issues, lessons learned and needs obtained from the ongoing cooperation projects

The release of greenhouse gases and the growth of plants are relevant for peatland management. This SAR was used to estimate the water content in peatland and groundwater level, but since hyperspectral images can be used in future, new techniques should be used to modify and improve the modeling of GHG emissions and other measures should be taken.

In addition, the needs of the cooperating enterprises indicate (1) the need for various equipment and (2) the need for continuous observation and it is necessary to examine how to support them.

2.2 Congo Basin

2.2.1 International frameworks and relevant international conventions and actors related to peatlands

2.2.1.1 Relevant International Conventions, etc.

Currently, the international agreements and conventions related to managing and protecting peatlands that have been ratified by DRC and ROC are listed in Table2.2 1 below.

Table2.2 1 International frameworks and conventions relevant to peatland management and conservation

No.	Treaty title	Signature Date	Date of accession or ratification
1.	Ramsar Convention		DRC: May 18, 1996 ROC: October 18, 1998
2.	Convention on Biological Diversity	DRC: June 11, 1992 ROC: June 11, 1992	DRC: December 3, 1994 ROC: August 1, 1996
3.	UN Framework Convention on Climate Change	DRC: June 11, 1992 ROC: June 12, 1992	DRC: January 9, 1995 ROC: October 14, 1996
4.	Paris Agreement (1985)	DRC: April 22, 2016 RCO: April 22, 2016	DRC: 13 December 2017 ROC: April 21, 2017

The DRC and ROC acceded to the Ramsar Convention in 1996 and 1998, respectively. Currently, four ROC sites (total area 11,906,617 ha) and 14 Congolese sites (total area 13,813,865 ha) are registered under the Ramsar Convention as Wetlands of International Importance.

In 2010, the governments of the DRC and ROC, through the International Union for Nature (IUCN), signed the Central African Regional Program for the Environment (Programme régional pour l'environnement en Afrique centrale (In 2017, the Congolese and Congolese governments agreed to jointly manage three Ramsar sites across the Cuvette Central region in both countries. They agreed to jointly manage the sites.

In addition to those listed in the table below, the resolution on conservation and sustainable management of peatlands adopted in March 2019 as an outcome document at the UN Conference on Sustainable Development (UNEA Resolution on Conservation and Sustainable Management of Peatlands), which was adopted as an outcome document of the UN Conference on Sustainable Development in March 2019. Although not legally binding, it emphasizes the importance of peatlands and the ecosystem services they provide and encourages Member States and other relevant parties to help implement relevant frameworks such as the Paris Agreement, the Ramsar Convention and the Convention on Biological Diversity and strengthen regional and international cooperation to conserve and sustainably manage peatlands. The agreement also encourages Member States and other interested parties to strengthen regional and international cooperation to conserve and sustainably manage peatlands.

2.2.1.2 International framework for peatlands, etc.

1) Global Peatland Initiative, Brazzaville Declaration

The Global Peatland Initiative (GPI) was established at the 2016 Marrakech Climate Conference (UNFCCC COP22) by 13 founding members, including the Ramsar Convention. The Brazzaville Declaration, signed by the DRC, the Congolese and Indonesian governments at the third meeting of the Global Peatland Initiative partners, demonstrates the will and commitment of the three countries to cooperate and exchange knowledge and experiences to conserve and sustainably manage peatlands. The third meeting was signed by the DRC, the Congolese and the Indonesian government.

In October 2018, Indonesia, the DRC and ROC established the International Center for Tropical Peatlands (ITPC).

2) Congo Basin Blue Fond

As of 2019, 16 countries are members (Angola, Burundi, Cameroon, Central Africa, Chad, Congo, Equatorial Guinea, Gabon, Kenya, South Sudan, Tanzania, Equatorial Guinea, Rwanda, Sao Tome and Principe, South Sudan, Tanzania and the Republic of the Congo). Burundi, Cameroon, Central Africa, Chad, Congolese, Equatorial Guinea, Gabon, Kenya, Congo, Rwanda, Sao Tome and Principe, South Sudan, Tanzania, Uganda and Zambia).

The Fund aims to tackle climate change and achieve regional integration and human well-being, funding projects in countries based on green or blue economies. It is funded primarily by the Central African Development Bank (BDEAC).

3) Congo Basin Forest Fund (CBFF)

It was established in London in June 2008 by the United Kingdom, Norway and the member countries of the Commission of Central African Forests (COMIFAC) and is hosted by the African Development Bank. The Fund has the following three objectives:

- Improve the technical capacity of stakeholders in the Congo Basin to implement sustainable management of diverse forest landscape resources and REDD+.
- Promoting forest governance in the Congo Basin for more equitable benefit-sharing among forest stakeholders, including women and ethnic minorities.
- Building the capacity of relevant institutions in the Congo Basin for sustainable management of forests at the landscape level and implementation of REDD+.

To date, more than €84 million in funding has been approved by the CBFF Governing Council for 41 projects; at the end of 2015, 16 of the 41 projects were underway and 18 had been completed.

2.2.2 National-level policy institutions

2.2.2.1 DRC

Currently, there is no formal definition of peatlands in our country and no specific national policy or regulations on peatland conservation, but we have begun to develop a "National Peatland Strategy".Legal documents dealing directly or indirectly with peatland management at the national level of the DRC include the following:

1) Law No. 15/026 of December 31, 2015 on Water

It is the first legal document to directly include provisions on wetlands, including the definition of wetlands and the classification of wetlands in public waters, thereby promoting their conservation and sustainable management and use. The law contains provisions in line with the guidelines of the Ramsar Convention and the commitments under this Convention in the DRC. It contains a more limited definition of wetlands than the Ramsar Convention and does not specifically reference peatlands. By locating wetlands in the public domain of water, the law excludes private appropriation and any form of use incompatible with the conservation of wetlands.

2) Law No. 014/003 of 11 February 2014 on Nature Conservation

The purpose of this law is to conserve biodiversity and preserve traditional knowledge. Article 45, paragraph 1, specifically lists wetlands as ecosystems that require specific protection measures against the risk of introducing alien species. The Ramsar Convention is also listed as an international legal instrument to be complied with.

3) Law No. 011/202 of August 29, 2002 on Forestry Law

There are no specific provisions for peatland forests.

4) Law No. 11/009 of July 9, 2011 on Basic Principles for Environmental Protection

The law aims to protect the environment from the direct or indirect adverse effects of implementing public policies in other sectors, such as mining, oil exploitation, forestry, agriculture, the establishment or expansion of towns and municipalities and infrastructure. The procedural mechanisms by which this law ensures specific protection are organized by the following two decrees:

a. Decree No. 14/019 of August 2, 2014 setting out rules to operate procedural mechanisms for environmental protection.
   This Decree establishes procedures for conducting i) strategic environmental assessments of public policies, plans and programs; ii) environmental and social impact assessments (ESIA); iii) environmental audits; and iv) public inquiries.

b. Decree 14/030, issued on November 18, 2014, establishes the status of a public institution, the "Congolese Civil and Environmental Agency" (Agence Congolaise de l'Environnement: ACE) and designates the ACE to oversee the implementation and approval of the ESIA. It specifies that ACE is the designated public agency to oversee the implementation and approval of ESIAs.

5) Decree of June 20, 1957 on urban planning

It remains the main legal document on land use planning in both urban and rural areas. Currently, the Congolese civil government is implementing spatial planning reform, which is an opportunity to update multi-sectoral spatial governance and national development instruments at all territorial levels.

6) National Strategy for the Conservation of Biodiversity in Protected Areas of the Democratic Republic of Congo (STRATÉGIE NATIONALE DE CONSERVATION DE LA BIODIVERSITÉ DANS LES AIRES PROTÉGÉES DE LA RÉPUBLIQUE DÉMOCRATIQUE DU (CONGO)

Published in 2012 as the first revision of the National Strategy for the Conservation of Biodiversity in the Protected Areas of the ROC, originally published in 2005. It aims to ensure the sustainable conservation and management of biodiversity in the Congolese network of protected areas, with the following five specific objectives:

a. Maintain and develop a network of protected areas that sustain and represent the biodiversity of the DRC.
b. Develop and apply effective systems of sustainable management of natural resources in protected areas.
c. Institut Congolais pour la Conservation de la Nature (ICCN) will have access to sustainable funding.
d. Provide a benchmark framework for planning, partnership and promotion of conservation in the protected areas of the DRC
e. Promote cross-border collaboration and participation of local communities and other actors

A second revision is currently under consideration.

2.2.2.2. ROC

Table2.2 2 lists the laws and decrees related to peatland management and protection in the ROC.

Table2.2 2 Laws, Ordinances, etc. Pertaining to the Protection and Management of Peat Lands

Laws, ordinances, government ordinances, etc.	summary
Law No. 37-2008 of November 28, 2008 on basic policies and general conditions to conserve and manage fauna, growth and habitats and ecosystems sustainably.	The Law defines the types of protected areas (national parks, animal protection areas, etc.), conditions for creating protected areas, rules for the use of natural resources related to the various protected area types and basic policies for the management, governance and planning of protected areas.
Forest Law (No. 16-2000 of November 20, 2000)	The objectives of the project are 1) to establish a legal framework to guarantee the sustainable management of forests based on the appropriate development of resources, 2) to define definitions and criteria, organization and norms of participatory management in the domestic forest sector and 3) to reconcile the development of forest products with the need for forests and biodiversity for sustainable development.
Law No. 003/91 of April 23, 1991	Enacted to strengthen the legal regime in many environmental areas regarding the conservation of flora and fauna and to manage, restore and preserve natural resources and cultural, natural and historical heritage.
Decree No. 2002/437 of December 31, 2002	A government ordinance that establishes conditions for the management and use of forests.
Law No. 13-2003 of April 10, 2003 on Water	Established to ensure the proper use of water resources, prevent harmful effects of water and address water pollution.
Law No. 3-2010 of June 14, 2010 on Fisheries Operations	The law establishes the conditions for developing, conserving and managing biological resources within the legal waters of the Congo Commonwealth.

Source: IUCN (2012): Parcs et réserves du Congo - Evaluation de l'efficacité de la gestion des aires protégées, COMMISSION DES FORETS D 'AFRIQUE CENTRALE PARTENARIAT POUR LES FORETS DU BASSIN DU CONGO (2016): Stratégie de Gestion durable de la Binationale Lac Télé - Lac Tumba (Lignes directrices 2017-2026)

2.2.3 Structure and status of efforts by central government agencies

2.2.3.1 DRC

(1) Central Government Organization Structure

1) Parliament

Responsible for formulating and revising legislation to guarantee the conservation and sustainable management of peatlands and guaranteeing the management by lawmakers of government actions pertaining to the sustainable management of peatlands.

2) Ministry of Environment and Sustainable Development (MEDD)

Its establishment was established by Regulation No. 20/017, dated March 27, 2020, on the establishment of the Ministry of the ROC, to be responsible for implementing national policies related to the sustainable management of the environment and the conservation of biodiversity and ecosystems, the preparation, study and evaluation of plans to implement policies and the sustainable management of forest, water resources, fauna and environmental resources. The departments related to peatland management are as follows:

a. Direction de la Développement Durable (DDD)

Monitor the performance of the DRC in meeting the objectives and targets of their international commitments, including wetlands, climate change, biodiversity, water, restoration, etc. Fulfill reporting obligations as stipulated in international agreements such as the Ramsar Convention, the Convention on Biological Diversity and the Paris Agreement of the UNFCCC. Collect and maintain national greenhouse gas inventories, including estimates of the contribution of peatlands to greenhouse gas removals and emissions. The roles of the various departments within the DDD are as follows:

i. Peatland Management Unit (Unité de Gestion des Tourbière: UGT)

For the institutional management of peatlands, the MEDD Minister signed Decree No. 010 of July 27, 2017, creating the "Peatland Management Unit" within the MEDD's DDD. Its roles are as follows:

- Develop and implement a national peatland strategy
- Ensure coordination of peatland management in the Congolese peatlands between key stakeholders identified in the National Peatland Strategy and interested technical and financial partners. This will include coordination with similar initiatives at the Congo Basin level and elsewhere.
- Promote and ensure a participatory approach to peatland management through participation and consultation with various stakeholders, including forest communities and indigenous peoples.
- Identify and mobilize qualified national and international technical personnel to address on-the-ground peatland management issues.
- Develop effective working relationships with existing national climate change initiatives.
- Develop the peatland theme at international level and ensure the participation of the DRC in international movements in the same field.
- Recognize high carbon storage in peatlands as an incentive to pay for ecosystem services through REDD+ and other sustainable forestry programs/initiatives.

ii. CNREDD

Assist in identifying linkages between interventions as defined in the REDD+ Framework Strategy and the National Peatland Strategy.

b. Climate Change Department

Incorporate peatlands into the revised NDC and national greenhouse gas inventory of the DRC.

c. Biodiversity Department

Promote the protection of biodiversity in peatlands.

d. Direction Ressource en Eau (Department of Water Resources)

Include peatland protection in the National Water Policy (to be developed). Also, as a focal point of the Ramsar Convention, ensure compliance with the Convention and its guidelines in the Congolese population.

e. Direction Inventaire et Aménagement Forestiers (DIAF)

To prepare a forest inventory of national forests, including peatlands and map and monitor forest cover changes, including deforestation and degradation.

3) Congolese Agency for Civil and Environmental Affairs (ACE)

Provide a framework to facilitate social and environmental impact assessments and audits at national, state and local levels.

4) Institut Congolais pour la Conservation de la Nature (ICCN)

Consider the possibility of designating certain areas as protected to enhance the protection of peatlands.

5) National REDD Fund (FONAREDD)

Coordinate and oversee REDD+ efforts in the DRC to build on existing mechanisms to promote sustainable management of peatland forests, including community forestry, community conservation, community management and community customary land tenure.

6) Ministère ayant l'Aménagement du Territoire dans ses attributions (Ministry in charge of development planning in land use)

The Ministry's role in peatland management is as follows:

a. Coordinate the zoning process for various land uses and coordinate diverse interests in the allocation of areas, including peatlands, to make coordinated and harmonious decisions.

b. Strengthen the protection of peatlands by recognizing their superiority in final zoning and allocation.

c. REDD+ integrated programs (Programme intégré REDD+: PIREDD) for provinces with peatlands will be used to strengthen the design and implementation of land use plans and zoning, facilitate mapping of these areas and conduct resource surveys and inventories as needed. PIREDD can also provide examples of how to integrate local, state and national levels to establish institutional arrangements for peatland management and these programs can support communities around peatlands by incentivising sustainable peatland management.

(2) Efforts of Congolese central government agencies

1) National Peatland Strategy[42]

The ROC's Government has started to develop a framework to coordinate and implement national strategies, initiatives, projects and programs on peatlands In July 2019, the first national peatlands information workshop was held and a roadmap for the preparatory phase of peatland management was developed In August 2020, the preparation of the National Peatlands Strategy got underway.

The MEDD presented its national vision for peatland ecosystems at a roundtable meeting in December 2020. This is summarized as "protecting peatlands for nature and people."

With the support of the Congo Peat Project, discussed below, a new map of peatland distribution is expected to be produced in June 2021 and released in 2022.

2) National Strategy for the Conservation of Biodiversity in Protected Areas in the Democratic Republic of the Congo (Stratégie Nationale de Conservation de la Biodiversité dans les Aires Protégées de la République Démocratique du Congo)[43]

Published in 2012 as the first revision of the National Strategy for the Conservation of Biodiversity in the Protected Areas of the ROC, originally published in 2005. It aims to ensure the sustainable conservation and

[42] USAID (2021) : Revue du cadre juridique propice à la gestion des tourbières en République Démocratique du Congo
[43] https://www.developpement-durable.gouv.cg/wp-content/uploads/2018/03/Strat%c3%a9gie-Nationale-de-Concervation-de-la-Biodiversit%c3 %a9.pdf

management of biodiversity in the Congolese network of protected areas, with the following five specific objectives:

a. Maintain and develop a network of protected areas that sustain and represent the biodiversity of the DRC

b. Develop and apply an effective system of sustainable management of natural resources in protected areas

c. The Congolese Institute for Civilian Conservation (Institut Congolais pour la Conservation de la Nature: ICCN) will have access to sustainable funding

d. Provide a benchmark framework to plan, partner and promote conservation in the protected areas of the DRC

e. Promote cross-border collaboration and participation of local communities and other actors

A second revision is currently being discussed at[44] .

3) National Climate Change Adaptation Plan (2022-2026) (Plan National d'Adaption aux Changement Climatique (PNA))

The plan was formulated in November 2021. The basic principles include (1) demographic, gender and social inclusion considerations, (2) climate change measures applied at national level and (3) government-wide efforts and it sets the following two objectives:

- Provide a starting point and general reference for climate change adaptation measures
- Provide research direction and pathways to create a complete and robust PNA

2.2.3.2 ROC

(1) The structure of the Congolese central government institutions:

1) Ministry of Environment, Sustainable Development and Congo Basin (Ministère de l'Environnement, du Développement Durable et du Bassin du Congo)

Responsible for climate change, biodiversity and peatland conservation in the Congo, among others, the ministry changed its name from Ministère du Tourisme et de l'Environnement (Ministry of Tourism and Environment) to the Ministry of Environment, Sustainable Development and the Congo Basin in May 2021 when the cabinet was reshuffled. and addresses more sustainability issues.

For research on peatlands, it has established a 13-year collaboration with the University of Leeds in the UK.

2) Ministry of forestry and economy (Ministère de l'Economie forestière)

It oversees issues related to forest conservation and management in the Congo, as well as REDD+.

a. Centre National d'Inventaire et d'Aménagement des ressources Forestières et Fauniques: (CNIAF)

Part of the Ministry of Forestry and Economy, directly under the Minister of Forestry and Economy. It is the government agency in charge of Congolese mapping. The CNIAF has 13 remote sensing experts with limited experience in peat sampling and mapping in the northern swamps with the support of the U.S. Forest Service (USFS) during the NFI. Mapping in the northern wetlands with limited USFS (U.S. Forest Service) support during NFI.

b. Fauna and Protected Areas Division (Direction de la Faune et des Aires Protégées: DFAP)

It oversees the conservation of fauna and the management of protected areas in the Congo. It has the role of ensuring that appropriate regulations arising from conservation strategies are devised and that their application

[44] https://desknature.com/2022/02/09/rdc-liccn-organise-les-etats-generaux-de-la-conservation-de-la-biodiversite-ce-jeudi

is controlled. The objectives of the Department include: (i) to propose government policies to manage fauna and protected areas sustainably, (ii) to propose inventory programs for fauna and flora, (iii) to manage the application of protected area development plans and (iv) to devise and propose regulations to manage fauna and protected areas sustainably.

3) Agence Congolaise de la Faune et les Aires protégées (ACFAP) (Congolese Wildlife and Conservation Areas Agency)

Established in 2013 to implement policies on wildlife and conservation area management and poaching surveillance.

4) Comité de Gestion et de Devéloppement Communautaire (CGDC) (Community Management and Development Committee)

Lake Télé – Established in 2013 to study the activities of the bilateral sustainable management strategy for Lake Tumba.

(2) Efforts by Congolese central government agencies

Table2.2 3 lists the ministerial ordinances pertaining to the protection and management of peatlands.

Table2.2 3 Ministerial Ordinances to Protect and Manage Peat Lands

Presidential Decree, Ministerial Decree, etc.	summary
Arete No. 6075 of April 9, 2011 on the definition of all and some protected animal species.[45]	A ministerial decree that establishes three levels of protection for all animal species in the Congo. The three levels of protection are A: fully protected (50 species, including the elephant), B: partially protected (48 species that can be hunted) and C: all other species not included in A and B. There is no specific protection framework, but trade, transfer from hunting areas to other areas and trafficking are strictly prohibited.
Decree No. 2002-437 establishing the conditions for the management and use of forests.[46]	It regulates the administrative management of national forests and the use of forests. Chapter II deals with the development of state-owned natural forests and the use of forest products, as well as the development of privately-owned natural forests.

Source: COMMISSION DES FORETS D'AFRIQUE CENTRALE PARTENARIAT POUR LES FORETS DU BASSIN DU CONGO (2016): Stratégie de Gestion durable de la Binationale Lac Télé - Lac Tumba (Lignes directrices 2017-2026)

2.2.4 State government structure and status of initiatives

2.2.4.1. The DRC

(1) Structure at the state level

1) State legislature

It has a role in taking legal action at the state level to enhance peatland conservation. It also has a role in managing the actions of state governments with respect to peatland protection.

[45] http://extwprlegs1.fao.org/docs/pdf/con105724.pdf
[46] https://leap.unep.org/countries/cg/national-legislation/decret-no-2002-437-fixant-les-conditions-de-gestion-et

2) Governor of a state

Prepare plans and gubernatorial decrees to develop the province, taking into account priorities with regard to conserving and managing peatlands.

3) State Planning Department

Ensure that peat conservation and sustainable management are included in state development plans.

4) Ministry in charge of development planning in the State Land Use

Initiate and coordinate the process of developing a state development plan that integrates the protection and sustainable management of peatlands.

5) ACE State Branch

Review and approve strategic environmental assessments of provincial and regional land use plans and impact assessments that may affect peatlands.

(2) Initiatives at the state level

No pertinent information is available at this time.

2.2.4.2. ROC

(1) State-level structure

No pertinent information is available at this time.

(2) Initiatives at the state level

The French Agency for Development (AFD) is implementing projects in the field of climate change and ecosystem conservation in DRC. Projects in the field of climate change are taking place in Cameroon, the DRC and Congo and are being implemented by AFD and the EU[47]. The project aims to improve anti-corruption policies and practices in climate change initiatives such as REDD+ and the forest sector in Central Africa and is expected to elicit the following:

- Use of communities and citizens' enhanced capacities (e.g. participatory research and climate action initiatives) and aptitude for networking.
- To enable victims and witnesses of corruption in the climate change sector to seek solutions to their problems through complaint mechanisms.
- Commitment by relevant actors to improvements that prevent corruption and ensure transparency, accountability and integrity in the climate change sector.

In the area of biodiversity, a project is being implemented in the northern province of Likouala from 2020 onwards. The project is co-financed by AFD and the Fonds français pour l'environnement mondial (FFEM). It aims to support strategies in development at the local level while promoting the conservation of forests and biodiversity and the proper maintenance of land.

[47] https://www.afd.fr/fr/carte-des-projets/lintegrite-dans-les-initiatives-climatiques?origin=/fr/carte-des-projets?view=map&page=all&filter[0]=type_k=page_afd_project&filter[1]=type_k=page_ong_project&filter[2]=type_k=page_research_project&filter[3]=source_k=afd&query=*&from=0&sort=_score,desc&facetOptions[0]=funding_program_k,size,200&facetOptions[1]=funding_type_k,size,200&facetOptions[2]=thematic_k,size,200&facetOptions[3]=country_k,size,200&facetOptions[4]=program_family_k,size,200&facetOptions[5]=year_k,size,200

2.2.5 Status of peatland management and conservation efforts at the field level

2.2.5.1. DRC

(1) Systems at the field level in the DRC

1) Sheikh/Sector Council

- Ensure that the protection and sustainable management of peatlands is integrated into local development plans.
- Ensure the protection and sustainable management of peatlands is integrated into local government development plans.
- Monitor the actions of the sheikh or sector executive committee related to peatland protection.

2) Sector Head/Head

- Prepare regional development plans integrating peatland conservation and sustainable peatland management by order of the chief or sector head.
- Prepare a municipal development plan integrating conservation and sustainable management of peatlands by order of the chief or sector head.

3) City Council Member in charge of planning

Initiate and coordinate the process of preparing a regional development plan integrating conservation and sustainable management of peatlands.

4) City Council Member in charge of land development

Initiate and coordinate the process of developing a land development regional plan integrating peatland conservation.

(2) Peatland management and conservation efforts at the local level

Under the Global Peatland Initiative, the DRC and other member countries will learn from and work with indigenous peoples and local communities to conserve peatlands, with the aim of raising awareness among local communities by 2030, following the example of Indonesia.

2.2.5.2. ROC

No pertinent information is available at this time.

2.2.6 Basic information on the peatland environment

2.2.6.1 Natural environment

The Congo Basin, known as "one lung of the earth," has the second largest forested area in the world after the Amazon in South America. The peat swamp vegetation in the basin includes a range of areas, some of which forested, others swampy palm forests and even herbaceous swamps. Approximately 10,000 species of tropical plants are found in the Congo Basin, 30% of which are endemic to the region. It is also a habitat for 425 species of regionally endemic mammals, including the marumimizo elephant, western lowland gorilla, bonobo and okapi. Because of its valuable ecosystems and biodiversity, 206 protected areas have been designated.

The peatlands of the Cuvette Central within the Congo Basin are known to have begun accumulating about 10,600 years ago and are estimated to have a maximum depth of 5.9 meters, an average depth of 2.0 meters and a peatland area of 145,500 ㎢. The carbon content of the peatlands is estimated to be about 30 billion tons, which is equivalent to 20 years of CO_2 emissions from the United States.

2.2.6.2 Social environment

More than two million people live in the Congo Basin, particularly around Lakes Télle and Tumba, which straddle both the DRC and ROC. The population uses fish and other fishery resources, as well as farming and gathering forest products. The use of fisheries resources supports the livelihood of local communities and the surrounding population and also contributes to trade, playing an important role in supporting the economies of both the Congolese and the DRC. In addition, some of the forests around the peatlands have cultural significance, such as being the object of religious beliefs.

In peatland conservation, various threats exist due to the effects of human activities. Deforestation, of which few examples exist, has been pointed out as a risk leading to fragmentation, destruction and loss of terrestrial and aquatic habitats. Slash-and-burn agriculture has been pointed out as one of the causes of deforestation and destruction and is considered to be a factor that attracts wildfires. Poaching is also practiced in the area and such illegal activities also contribute to the loss of ecosystems and biodiversity in the peatlands. Although fishing is an important means of livelihood, poaching and illegal fishing remine an issue and are one of the causes of problems such as overfishing.

2.2.7 Basic information on the impact and contribution potential of peatlands to climate change

GPI member countries recognize the importance of peatland development and therefore the need to map peatlands, assess their carbon stocks and protect them from wildfires and forests. The Peatland Management Unit (PMU) has been informed that the Centre de Recherche Géologique et Minière (CRGM) has the necessary equipment for peat analysis (quantification of the carbon content of peat samples) and that CRGM is already performing this analysis for FAO. The PMU is considering scope to approach CRGM for this purpose.

2.2.8 Status of Methodology for Estimating Greenhouse Gas Emission Reductions from Peatland Sources

In this regard, the document "Carbon, Biodiversity and Land Use in the Peatlands of the Central Congo Basin" is available. Under the current situation of the DRC, there is no evidence of large-scale degradation of peatlands and therefore no significant anthropogenic greenhouse gas emissions. The Congolese are working on a comprehensive mapping of peatlands and estimating their carbon stocks through a clear definition in the context of the DRC. The process adopted by the Congolese to arrive at this national definition of peatlands is as follows:

i. Allow the necessary time for a national exchange of ideas and consultation to arrive at a commonly accepted definition.
ii. Collectively decide on the main objectives of the definition.
iii. Learn from experiences in other countries.
iv. The following key parameters for climate change action will be considered:
   - Minimum depth of 15 cm
   - Contains more than 5% organic matter
v. Consult with neighboring countries for a common definition.

2.2.9 National and regional legislation and relevant international conventions pertaining to peatland management

(1) Intergovernmental cooperation agreement for the joint management of Lake Tumba-Ledima (Congolese) and Lake Télé (Congolese) (Accord de coopération relatif à la mise en place de la Binationale Lac Tele-Lac Tumba)

Signed in 2010 by the people of the Congo and the leaders of the Congolese Communist Party. The objectives of the Agreement are to:

a. Engage local communities and build capacity for participatory natural resource management.
b. Contribute to sustainable development through local, national, regional and international cooperation in wetland conservation and Wise Use.
c. Promote synergies among stakeholders by exchanging knowledge and harmonizing cross-border management.
d. Raising awareness within the national and international community about the importance of great apes such as bonobos, chimpanzees and gorillas and the diverse people who live among them.

(2) Stratégie de Gestion durable de la Binationale Lac Télé - Lac Tumba (Bilateral Sustainable Management Strategy for Lake Télé - Lake Tumba)

Based on the intergovernmental cooperation agreement signed in 2010 for the joint management of Lake Tumba-Ledima (DRC) and Lake Télé (DRC), sustainable conservation and management of natural resources, maintenance of ecosystem services and functions through transboundary cooperation and effective participation of local populations in the management of these resources A strategy on bilateral sustainable management for the period 2017-2026 was developed in 2016 with the aim of:

(3) Convention on the Conservation and Sustainable Management of Forest Ecosystems in Central Africa and the Establishment of a Central African Forestry Council (Commission des Forêts d'Afrique Centrale: COMIFAC) (Traité relatif à la conservation et à la gestion durable des écosystèmes forestiers d'Afrique Centrale et instituant la Commission des Forêts d'Afrique (Centrale)

Signed in 2005 in Brazzaville by the leaders of ten countries (Burundi, Cameroon, Central Africa, DRC, ROC, Gabon, Equatorial Guinea, Rwanda, Sao Tome and Principe and Chad). The Convention aims to establish a comprehensive legal framework to integrate regional cooperation in the conservation and sustainable management of forest ecosystems. Ratifying countries are obliged to report on ecosystem management.

2.2.10 Overview of projects to support peatland conservation and management by other donors and private sector

(1) Global Peatland Initiative Project (Projet de l'Initiative Mondiale pour les Tourbières)

Three key partners, the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO) and the Greifswald Mille Center, are focusing on skills transfer in efforts being developed in four countries: the ROC, DRC, Peru and Indonesia. In DRC, capacity-building sessions for peatland mapping are being organized for national stakeholders.

(2) Congo Peat

A research project funded by the UK government's Natural Environment Research Council (NERC) and led by Professor Simon Lewis of the University of Leeds, the main aim of the five-year program is to identify information that can be used to build mathematical models of peatland development and understand how peatlands are functioning today and how they may change in future in the context of climate change. Specifically, to analyze peat samples and reconstruct the historical climate record of the Congo Basin, including changes in peat over time; to expand and refine mapping, range and carbon content estimates, including field data collection at DRC; to model various development and disturbance scenarios and estimate future potential impacts in these sensitive ecosystems This includes estimating potential future impacts on these sensitive ecosystems.

(3) IKI project (Project to conserve biodiversity, carbon and water supply in peatlands of the Congo Basin, Projet " Protéger la biodiversité, le carbone et les réserves d'eau dans les tourbières du Bassin du Congo ")

The IKI project concept was presented at the first country information workshop as well as at a meeting of funding and technical partners on peatlands in Kinshasa in July 2019 Consultation on the project design will take place in July 2020. Project documentation is currently being prepared. The program focuses on five axes: i) Enabling Environments; ii) Biodiversity and Growth/Habitat; iii) Water and Climate; iv) Peatlands and Ecosystems; and v) Capacity-Building and Knowledge Management. This effort is supported by the United Nations Environment Programme (UNEP).

The DRC has been conducting readiness-like activities since 2018 with the project's small-scale funding. The activity is working to strengthen the capacity of remote sensing technologies.

(4) Project CHILD (Projet CHILD)

The project is an initiative of the United Nations Environment Programme (UNEP) under the Global EnvironmentFacility (GEF). It focuses on improving the livelihoods of local communities. The program is under design, but part of it focuses on the protection of peatlands.

2.2.11 Future Support Policies of Other Donors and Private Sector CENTRAL AFRICAIN FOREST INISIATIVE (CAFI)

Established during the UN General Assembly in 2015 for the purpose of forest conservation in the Central African region. Funded by Belgium, the EU, France, Germany (current Presidency), Netherlands, Norway, South Korea, UK and others. It funds programs for forest conservation for the DRC, Gabon, ROC, Central Africa, Equatorial Guinea and Cameroon.

On November 2, during COP 26, CAFI and the DRC issued a joint communiqué on "Renewal and Expansion of the Partnership for Greening and Development in the DRC for the period 2021-2031". It was agreed that CAFI would provide US$500 million over a five-year period from 2021 to 2026 to help the DRC combat deforestation. The goals to be achieved by the Congolese side for forest and peatland conservation are set in ten areas: land development, energy, agriculture, forestry, conservation, rehabilitation, land, mining and hydrocarbons, population and administrative and resource mobilization.

(1) IKI Project

The peat core project is scheduled to begin in 2022. The target area is the Télé and Tumba lakes, which straddle both Congolese and Congolese territory, with overall funding amounting to 15 million euros.

2.2.12 Issues, lessons learned and needs from cooperative projects in progress

The DRC need to increase the value of peatlands for people and nature through a national strategy dedicated to peatland ecosystems. This strategy will be based on multi-sectoral data, including mapping, carbon stock assessment, identification of a legal framework for peatland policies and strategies, zoonoses and sustainable livelihood production. The peatland strategy is essentially the implementing arm of the national vision for this ecosystem, a framework to implement programs, projects and initiatives for the management, conservation and valorization of this ecosystem and the alignment of all thematic interventions.

The needs of the parties involved in this cooperative project include (1) institutional support, (2) the need for various types of equipment and (3) the continuation of multi-sector data collection.

2.3 Peru

2.3.1 International Framework for Peat Areas, Related International Conventions and Related Actors

Peru has ratified the four international frameworks related to peatland: the Ramsar Convention, the Biodiversity Convention, the United Nations Framework Convention on Climate Change and the Paris Agreement (Table2.3 1). their Government Focal Points are the three departments of the Ministry of the Environment: the Ministry of the Environment's Strategic Development of Natural Resources, the General Bureau of Biodiversity and the General Bureau of Climate Change and Desertification. Conversely, research, including on peat in the Amazon, is conducted by the Ministry of the Environment and the Amazon Research Institute (IIAP). In May 2021, SERFOR became an organization responsible for conserving and sustainably using ecosystems with large amounts of carbon, such as peatlands.

Table2.3 1 Peat-related international frameworks ratified by Peru

	Accession	Signature	Ratification
1) Ramsar Convention	1992-03-30		
2) Convention on Biological Diversity		1992-06-12	1993-06-07
3) United Nations Framework Convention on Climate Change		1992-06-12	1993-06-07
4) Paris Agreement		2016-04-22	2016-07-25

2.3.2 National policy system

The main national policies and regulations for peatland in Peru are shown in the table below. In the Amazon Basin, peatlands have been known to exist, but in many cases, part of "humedalres" which is a generic term for wetlands, has become peatland. In the National Strategy of Wetlands (MINAM, 2015), "bofedales", which is a wetland of Andean highlands, is referred to as part of peat for the first time. Since then, as the Paris Agreement has come into force, discussions on climate change have rapidly progressed and attention has been paid to the management and conservation of peatland. Workshops on peat have also been held in Peru. As a result, policies and legislation on peatland were developed after 2020 and general regulations on wetland management were enacted in May 2021. In addition, the term "turberas" has become widely used as the Spanish word for peatlands.

Table2.3 2 Policies and laws directly related to peatland

Policies, laws, etc.	Overview
1. National Strategy of Wetlands (MINAM, 2015)	The peatland was mentioned as part of the "bofedales" wetland of the Andean highlands.[48]
2. Guide to assess the state of bofedales (MINAM, 2019)	Guidelines for the Bofedales conservation and restoration processes have been presented and peatlands in bofedales refer to permanent wetlands, describing the carbon-accumulation characteristics of peatlands and their importance as a water resource. And, it was shown that the measuring of groundwater level, thickness of peat and carbon content was crucial for conserving and restoring bofedales.
3. Draft of a Technical Guide to Define Peatlands in Peru (INSH-USAID, 2020)49	This draft was prepared by reviewing existing literature and interviewing a workshop with relevant national organizations and international researchers. In addition, identification of ecosystems as potential peat sites and preliminary peat sites adopted nationwide have been defined and are currently being reviewed in MINAM.
4. "Matrix of Objectives - Indicators - Guidelines - Services for the process of updating the National Environmental Policy" (MINAM, 2021a)50	In February 2021, as part of the process to renew national environmental policies by 2030, SERFOR was identified as an institution responsible for regulating conserving and sustainably using large carbon-bearing ecosystems such as peatlands.
5. "General Provisions for the multisectoral and decentralized management of wetlands" (MINAM, 2021b)51	In May 2021, the Supreme Law, No. 006-2021-MINAM, approved the General Provisions on Other Sectors and decentralized Wetland Management. With reference to the information in the "Draft Guide to Define Peatland", it became the first policy of Peru to define the concept of peatland and peatland. Here, the use of traditional peat is permitted and commercial use is prohibited. Public agencies shall also take special measures to conserve and restore peat, including for sustainable use.
6. Reference Emission Level by Deforestation of Peru in the Amazon Biome, Preliminary Document for Review (MINAM, 2021c)[52]	In the official document submitted to the UNFCCC, peatland is cited as a significant area of carbon accumulation in Peru that is omitted from FREL and the carbon accumulation in peatland in Peru as a whole is 4.41Gt (Page et al., 2011). This is equivalent to 64% of Peruvian aboveground forest carbon (6.9 Gt C; Asner et al., 2014) and mentions that the destruction of peatland forests may result in enormous CO2 emissions.

Source: Prepared by JICA survey team

Among the above, 3."Draft of a Technical Guide to Define Peatlands in Peru (INSH-USAID, 2020) was first documented in 2020 by researchers from related organizations in Peru, comparing the definition and characteristics of peat sites worldwide and the draft definition of peat sites in Peru. Currently, the Ministry of the Environment is conducting review work.

Peatland in Peru is distributed in the Amazon Basin and the Andes Highlands. The peatlands differ greatly in their production environments and constituents and their names vary depending on the region (Figure2.3 1).

[48] Bofedales: A generic name for wetlands in Andean highlands, including peatlands
[49] INSH: Infraestructura Natural para la Seguridad Hídrica (Project Name)
[50] R. M. No. 032-2021-MINAM (https://busquedas.elperuano.pe/download/url/disponen-la-publicacion-de-la-matriz-de-objetivos-indicad-resolucion-ministerial-no-032-2021-minam-1929083-1)
[51] Supreme Decree N°006-2021-MINAM
[52] https://redd.unfccc.int/files/nref_peru_final.pdf

Accordingly, the definition of peat ground is not defined uniformly by "thickness" or "carbon content" and the recommended thickness and carbon content of peat ground are only described as reference (Table2.3 3).

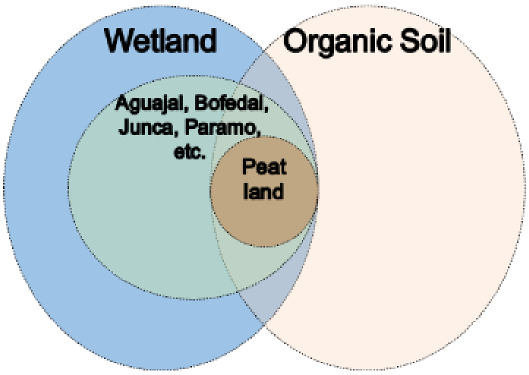


Figure2.3 1 Conceptual Diagram of Peatland, Wetlands and Organic Soil in Peru

Source: Prepared by the survey team

Table2.3 3 Examples of Peat Definitions

Organization	Minimum Carbon (wt%)	Minimum Thickness (cm)
International Peat Society (IPS), International Mire Conservation Group (IMCG)	30	-
RAMSAR	12-18	-
RSPO	35	30
ICRAF	18	50
Ministry of Environment, Indonesia	12	50

Source: Prepared by survey team

■ **Policies and laws indirectly related to peatland**

Major policies and regulations related indirectly to peat sites, including general environmental laws, are shown in the table below.

Table2.3 4 Categorization of Natural Reserves in Peru (Department of the Environment and SERNANP)

Policy and regulations	Source
The General Environmental Law/28611 (MINAM, 2005)	https://www.minam.gob.pe/wp-content/uploads/2013/06/ley-general-del-ambiente.pdf
National Environmental Policy (MINAM, 2009)	https://www.minam.gob.pe/wp-content/uploads/2013/08/Pol%C3%ADtica-Nacional-del-Ambiente.pdf
The National Forest and Wildlife Policy/29763 (MINAGRI, 2017)	http://repositorio.serfor.gob.pe/handle/SERFOR/622
The Forestry and Wildlife Law (MINAGRI, 2020)	https://www.gob.pe/institucion/serfor/informes-publicaciones/1124214-normativa-forestal-y-de-fauna-silvestre
The National Strategy for Climate Change (MINAM, 2015)	https://www.gob.pe/institucion/minam/informes-publicaciones/306226-estrategia-nacional-ante-el-cambio-climatico-2015

Policy and regulations	Source
The Framework Law on Climate Change/30754, (2018)	https://busquedas.elperuano.pe/download/url/ley-marco-sobre-cambio-climatico-ley-n-30754-1638161-1
The Law of Natural Protected Areas/26864, (1997)	https://www.minam.gob.pe/wp-content/uploads/2017/04/Ley-N%C2%B0-26834.pdf
The Environmental Research Agenda 2013-2021 (MINAM, 2013)	http://sia.munipuno.gob.pe/documentos/agenda-investigacion-ambiental-2013-2021
The Water Resources Law (No. 29338, 2009)	https://www.minam.gob.pe/wp-content/uploads/2017/04/Ley-N%c2%b0-29338.pdf
The General Guide for the Environmental Compensation Plan (MINAM, 2016)	https://www.minam.gob.pe/wp-content/uploads/2016/03/RM-N%c2%b0-066-2016-MINAM.pdf

Source: Prepared by survey team

The General Environmental Law (1 of Table2.3 4) refers to the conservation of biodiversity, the sustainable use of natural resources and the sustainable development of countries and provides for Article 99 (vulnerable ecosystems) for wetlands, including peat. In particular, wetlands containing peat are divided into pantanos, bofedales, humedales as vulnerable ecosystems.

1) Article 99(1) of the General Environment Law: Public authorities shall take into account their inherent characteristics and resources in exercising their functions, take special measures for protecting vulnerable ecosystems and consider the relevant with special climate conditions and natural disasters.
2) Article 99, Paragraph 2 of the General Environment Law: Fragile ecosystems include the following: *Desiertos, Tierras semiáridas, montañas, pantanos (marshes), bofedales (Andes wetlands, including highland peats), bahías, islas pequeñas, humedales (ordinary wetlands, including aguaje peats), lagunas alto andinas, lomas costeras, bosques de neblina y bosques relicto.*
3) Article 99(3) of the General Environment Law: States shall recognize the importance of wetlands as habitats for animal and plant species, particularly migratory birds and shall prioritize conservation over other uses.

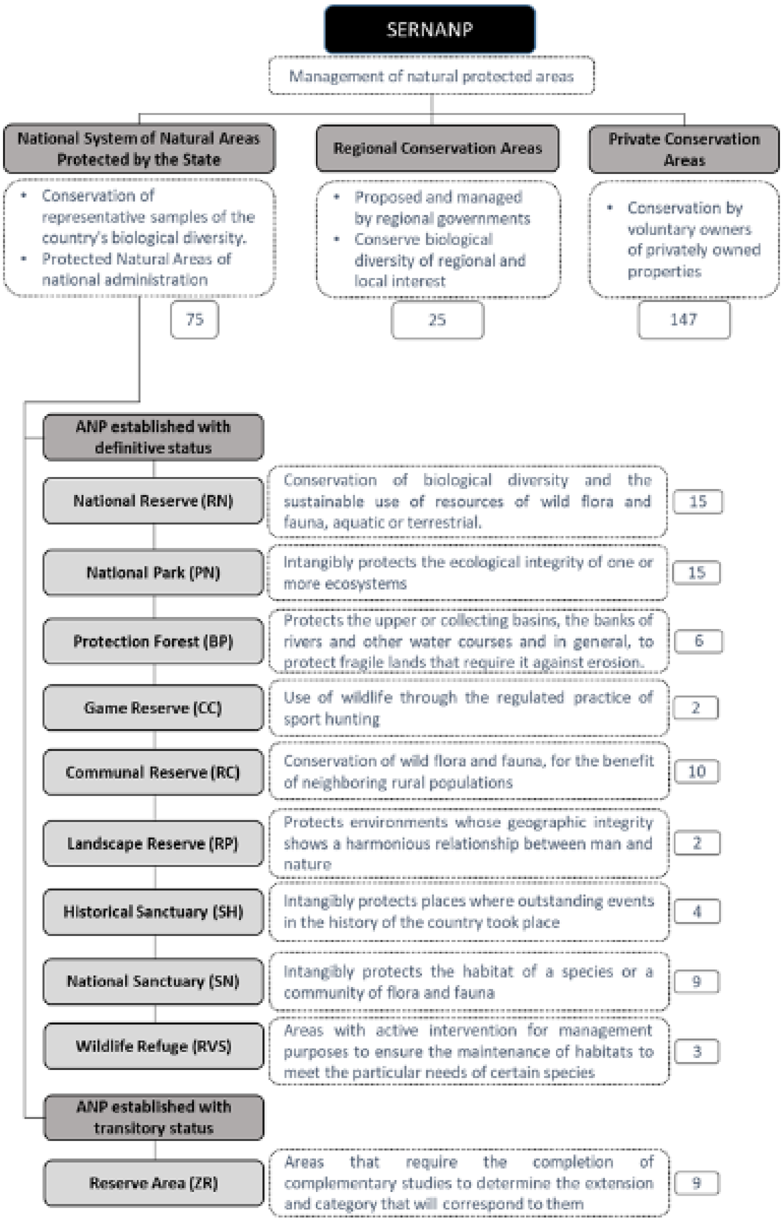


Figure2.3 2 Classification of nature reserves in Peru

(Administrative organization in charge: Ministry of the Environment, SERNANP)

2.3.3 Systems and Activities of Central Government Agencies

The Peruvian Central Government, which is concerned with the administration and conservation of peatlands, has two organizations: MINAM and MIDAGRI (the predecessor is MINAGRI) .

MINAM manages technical regulations in environmental regulations, formulates, directs, supervises and implements national environmental policies and promotes conserving and sustainably using natural resources, biodiversity and reserves. There are three main organizations for peatland:

- IIAP: Overall Survey and Studies Including Peat Basins in the Amazon Basin
- SERNANP: Manage Natural Reserves
- INAIGEM: Managing inventory of the Andean highland peatland "bofedales" (established in 2014)

MIDAGRI (Ministry of Agrarian Development and Irrigation) manages the fields of wild fauna and flora, water resources, agriculture and livestock. There are two main organizations for peatland.

- SERFOR: Equivalent to the Department of Forestry and in May 2021 became an organization responsible for conserving and sustainably using large amounts of carbon-management ecosystems such as peatlands.
- Inventory control of wetlands throughout Peru, including ANA: bofedale (established in 2008)

Before establishing MINAM in 2010, SERNANP's supervisory agencies to manage natural reserves were MIDAGRI. A INAIGEM belonging to MINAM was established in 2014 and is responsible for inventory control of "bofedales" including Andean highland peat. ANA belonging to MIDAGRI was established in 2008 and is responsible for the inventory of the entire wetland, including bofedale. In addition, SERFOR, PRODUCE, OEFA, IIAP, IMAPRE and municipalities belonging to MINAM and MIDAGRI are the organizations involved in wetland management.

The National Climate Change Commission, established in 1993, is responsible for monitoring the public and private sectors of climate change by implementing the Framework Convention on Climate Change and designing and promoting national climate change strategies. All ministries and relevant agencies, as well as local governments, are part of the National Organization Committee and are headed by the Ministry of the Environment. According to the Rules of Operations of the National Climate-Change Commission, MINAM, INAIGEM and IIAP are currently the most relevant institutions for peat sites. The organizational chart of MINAM is shown in Figure below.

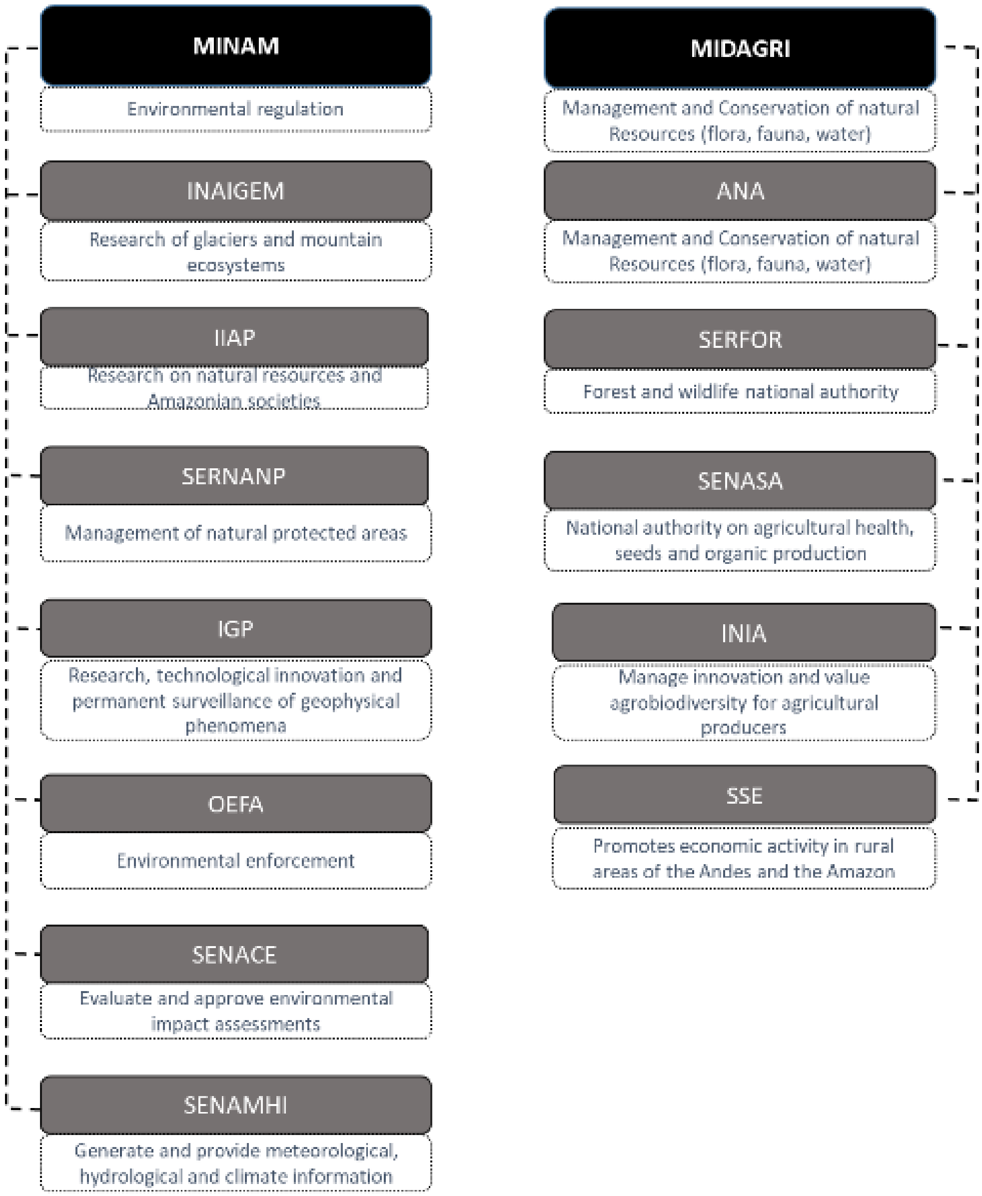


Figure2.3 3 Organizational Chart and Functions of MINAM, MIDAGRI

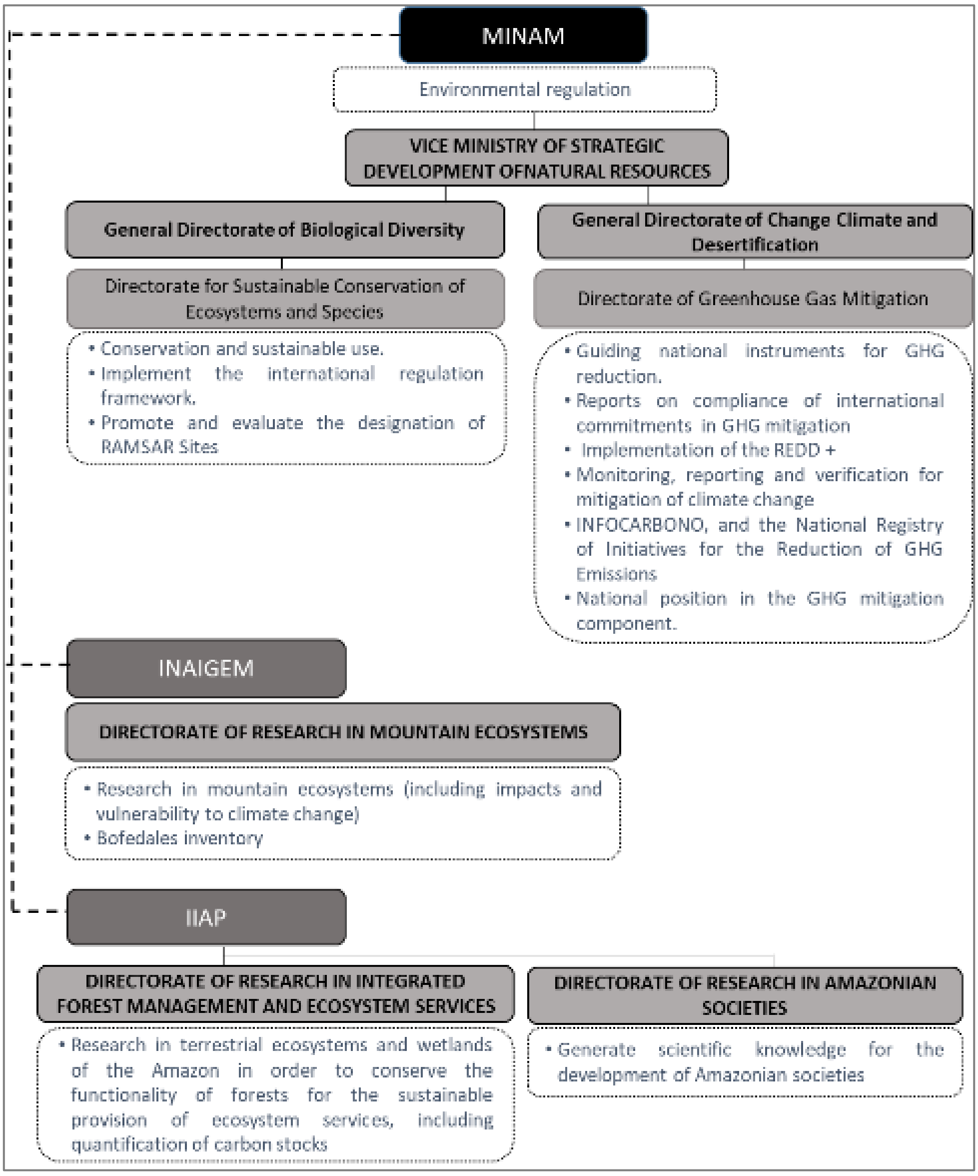


Figure2.3 4 Organizational Chart of MINAM and Organizational Functions

2.3.4 State Government Structure and Initiatives

Local governments usually comprise five management departments: (1) economic development; (2) social development; (3) planning and budget and jurisdictional management; (4) infrastructure; (5) natural resources and environmental management; and (5) peat-related operations. In seven states, such as Loreto, the Global Environmental Management (ARA) has been established in place of the administrative department described in (5) above. ARA has the power to manage environmental issues within the region, control the jurisdiction and manage natural resources sustainably.

Local governments also need to develop and implement regional strategies for climate change and biodiversity, which 15 of the 25 states have already done. It refers to the vulnerabilities and climate-change significance of peat-related ecosystems such as "bofedales," "aguajales," and "paramo."

The impact of IIAP, INAIGEM, CCA, CIFOR, SWAMP and other project-related activities has increased awareness of the importance of peatlands in some regions. However, although it was rare for local governments to take specific measures in peat areas, two states, Loreto and Cajamarca, have taken the following measures.

Loreto State was working to establish a natural reserve in Medio Putumayo Algodon, located in northern GORE Loreto, 2021): Loreto. This area includes oligotrophic soils with peatlands 1 to 3 m thick, with an estimated area of 25,730.98ha. Peat sites in this region are projected to be located differently from other peat sites in other natural reserves in Loreto because they are clear, black waters of Amazon origin in other peat sites, while the water source is a river of Andes origin. Moreover, peatland is a key carbon sink and expected to reduce GHG emissions.

Cajamarca Government (GORE Cajamarca, 2020): Due to the mining issue of organic soil containing peat, San Migel and Sao Pavro prefectures approved the "Ordinance for the Protection of Organic Soil and Vegetation Coverage in Jalca Ecosystems" (O.R. No. 0007-2019-GR.CAJ-CR).

2.3.5 Status of on-site-level peat-time management and conservation efforts

Many peat conservation activities target peat vegetation such as Aguahae and Bofedales (wetlands of Andes highlands). For example, it is intended for the sustainable use of peatlands, such as a method of harvesting fruits without harvesting agriculturally and managing grazing land in Bofedale. Accordingly, the area of peatland under conservation control as a natural conservation area is only about 17.2% for Agha and 5.5% for Bofedares.

The Wildlife Conservation Society (WCS) Peru is also committed to managing and conserving peatlands and making sustainable use, based on community-based expertise and experience. Examples include producing and selling agricultural oils for cosmetics and using shanvilla palm textiles.

2.3.6 Basic information on the environment of peatland

2.3.6.1. Management and conservation of peatland

There are currently 247 National Reserves (in total 403,915.87 ha) in Peru, covering 17.62% of the country (SERNANP, 2020). Some also have ecosystems that may contain peatlands, but no natural reserves are intended to protect or manage peatlands.

Bofedales and aguajales are usually called Peruvian potential peatlands. According to SERNANP, a bofedales of aguajales and 29,888.03 ha of 958,782.98 ha exists in a natural reserve. Thus, 17.2% of Peruvian aguajales and 5.5% of bofedales are protected to some extent. In particular, aguajales in Pacaya Samiria National Reserve (Loreto) is the largest area (791,140.99 ha).

Management plans related to the proper extraction and commercialization of the fruits of Aguaje (Mauritia flexuosa) have been established. Both objectives involve improving the economic income of the population through aguaje management and sustainable use.

Harvesting of aguaje fruits by selective logging of Aguajales female trees has been suggested to reduce aguaje resources, alter forest structure and composition, further promote peat decomposition and stop peat formation over time (Hergoualc'h et al., 2017). The emissions of nitrous oxide and methane from peat by this harvesting process have a major impact on microscales rather than on ecosystem levels (Hergoualc'h et al., 2020). Conversely, initiatives to promote sustainable management and conservation of aguaje have contributed to the conservation and management of IIAP (Leon et al., 2008 and Loreto Region Association (Quinteros et al., 2021).

2.3.6.2. Peat mapping

No nationwide peat maps have been developed in Peru. However, a wetland map, including peat, is prepared by the Ministry of the Environment. In addition to the Ministry of the Environment, 10 maps related to peatlands (pdf file format or GIS file format) and 13 online viewer sites have been published.

i. National Wetlands Map (MINAM, 2012)
ii. National Ecosystems Map and its descriptive memory (MINAM, 2019)
iii. National Vegetation Cover Map and its descriptive memory (MINAM, 2015)
iv. High Andean Grasslands (MINAM, 2010)
v. Peru Climate Classification Map (MINAM, 2020)
vi. Hydrographic map of Peru (MINAGRI, 2009)
vii. Hydrographic map of Peru (MINAGRI, 2009)
viii. Soils Map of Peru (MINAM, 2010)
ix. Map of degraded areas (MINAM, 2018)
x. Tropical and Subtropical Wetlands Distribution version 2 (CIFOR)
xi. National Glacier Inventory (INAIGEM) - online viewer
xii. Descriptive Report Of the Geological Map Of Peru Scale: 1'000,000 Standardized Digital Version - YEAR 2016 (INGEMMET) - online viewer
xiii. Geological map 100,000 bulletins and stripes (INGEMMET) - online viewer
xiv. Geological Map 50,000 (INGEMMET) - online viewer
xv. Hydrogeological map- (INGEMMET) - online viewer
xvi. Geomorphological map- (INGEMMET) - online viewer
xvii. Miner Geological and Cadastral Information System - online viewer
xviii. Geo SERFOR - online viewer
xix. Geoservicios SENAHMI - online viewer
xx. Geo SERNANP - online viewer
xxi. INEI Geographic Information System (Population centers) - online viewer
xxii. Water Observatory ANA - online viewer
xxiii. Geocatemin-Economico-INGEMMET - online viewer

Conversely, the following peat maps have been prepared by overseas researchers and donors on a project basis:

- Tropical peat

i. Amazon region (Gumbricht, 2017)
ii. Pastasa Maranion Basin, Draper et al., Lo. (2014)
iii. Madre de Dios (Householder et al., 2012)
iv. San Martin and Ukayari (JICA, 2021)

- Highland peat

i. Huascarán National Park and surrounding areas of Ancash (Chimner et al., 2019)

2.3.7 Basic information on climate change impacts and potential contributions of peatland

In Peru, it is possible to collect fruits from peatland-specific vegetation "Aguahae" that generate cash income for local residents. However, when the fruit is harvested, it is problematic to harvest the fruit by logging the agricultural hair. For this reason, a method of harvesting fruits over trees without logging has recently been recommended. With such efforts, it is estimated that $277km^2$ of peatlands will escape degradation in the Pastaza-Maranon region (Draper et al., 2014). When converted to carbon dioxide emission reductions, the

IPCC emission factor (default 5.3tC/ha year) spans 540,000 tonnes per year, which is equivalent to about 6% of Peru's target for CO_2 reductions of 89 million tonnes (national GHG reduction target: NDC) by 2030 and is believed to contribute to climate-change measures (Drosler et al., 2014).

In addition, in May 2021, the "Regulatory Regulations on Wetland Management" (No. 006-2021-MINAM) were enacted, as the highest law, because of the impact of peat conservation on climate change and the need to assess its potential to contribute. This is Peru's first peat law, which allows the use of traditional peats, taking into account climate change impacts, but prohibits commercial use. Public agencies also stipulate that special measures should be taken to conserve and restore peat and ensure sustainable use. In addition, discussions at expert meetings on the assessment of carbon stocks and GHG release in peatlands have intensified spurring on the development of basic information, as the preparation of new peatlands conservation and management policies or guidelines based on NDC initiatives.

2.3.8 Examination of methodology for estimating greenhouse gas emission reductions from peat areas

Freitas et al. (2006) and Lähteenojaetal (2009) are the first papers showing the presence of peatland in Peru. According to Freitas et al. (2006), peat in Pacaya Samiria National Reserve shows 77% (346,218,752.11 t of total carbon in aguajal and functions as a carbon dioxide sink for storage of 212 788,23 tC or 780 223,29 tCO_2 annually. Conversely, Lähteenoja et al. (2009) concluded that peat reported in the low Amazon in Peru is estimated to be comparable to that in the tropical peat in Indonesia and that peat in the Amazon in Peru is of global importance in terms of the quantity of carbon stored underground. Draper et al. (2014) reported that Pastaza-Maranon peatland in Loreto is the largest peatland complex in Peru. Carbon accumulation was reported to be 1,391±89.32 t Cha-1.

Bohmia et al. (2018) reported that the carbon accumulation in Pastaza-Maranon river basin was 330~570 Mg Cha-1 in the soil of the upper 1 m. Garcia-Soria et al. (2012) also reported lower carbon stocks (197.86±1.28 t C) than Draper et al. (2014) in Aguaytia river basin of Ucayali. Van Lent et al. (2018) surveyed greenhouse gas emissions along the degraded peat swamp forest (aguajal) in Loreto and concluded that repeated harvesting of aguaje could lead to significant increased CO_2 fluxes and decreased methane emissions. In addition, Del Aguila-Pasquel (2017) reported higher methane emissions in the Pasta-Maranion Basin compared to peatland in Southeast Asia.

Also, for the Andean highland peatlands, Cooper et al. (2010 reported a higher carbon content (18%-35%) in Jalca peatlands in Cajamarca. Chimner et al. (2020) also reported higher mean 2,100MgCha-1 in highland peatland in Ancash.

2.3.9 Outline of Peatland Conservation and Management Support Project by Other Donors and Private Sector

The Government of Peru has entered into an agreement with FAO, CIFOR, the University of Leeds in the United Kingdom and Saint Andrews University. The Amazon Research Institute (IIAP) of the Ministry of the Environment is a Peruvian research institute for these studies that quantifies carbon stocks in organic soils in peat land and assesses carbon dioxide emissions from the degradation of peat land and deforestation (MINAM, 2021). FAO has also implemented several training programmes for mapping peatlands and is supporting the Government of Peru. In addition, SWAMP projects are supporting the assessment. Details are as follows:

■ **FAO/UNEP-Global Peatland Initiative (GPI)**

The project aims to collaborate with all stakeholders in peat management to collect and discuss important information (policy, financial or legal framework) for decision makers. Activities in Peru are as follows:

I. Evaluate the needs of peatland.
II. Build a nationwide profile of peatland and related agencies in collaboration with stakeholders based on secondary information.
III. Develop emission factors for peatland in Peru and develop socio-economic and environmental recommendations.
IV. Make an inventory of good practices in peatlands in Peru.
V. Develop methods for incorporating peatland into the climate change policies and national climate action plans in Peru. For example, a NDC determined nationwide is assumed.
VI. Hold a workshop with stakeholders on peat monitoring.

■ **The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) -CIFOR**

USAID funded a joint effort by CIFOR, USFS and Oregon State University in Peru with the help of Silvacarbon. The project aims to complete a peat map for Peru and neighboring countries (Peru, Ecuador, Colombia) by 2022. In addition, a CO_2 flux tower has been installed Quistocoha Ikitos to measure the differences in CO_2 emissions between natural peatlands and devastated peatlands and to support the methodology for estimating CO_2 emissions for local and central governments. To date, capacity programs and workshops have been held.

■ **St. Andrews University**

Several studies have been conducted on peat. The project is funded by the Scottish Funding Council, the British Council and St. Andrews University.
I. 2018-2019: Valuing intact tropical peatlands 53
II. 2019: Gaining cultural heritage status for Urarina textiles: a pathway to peatland livelihoods and ecological conservation in Loreto, Peru 54
III. 2019-2020: Protecting Biodiversity & Sustainable Livelihoods in the Wetlands of Peruvian Amazonia 55
IV. 2020-2021:Oil exploitation and peatlands in indigenous territories: the impacts of oil at the extractive frontier in the Peruvian Amazon56

■ **Tropical Wetlands Consortium**

A consortium of researchers, including St. Andrews University, Leeds University (UK) and IIAP, funded by the University of Manchester and Newton Foundation in NERC, UNEP-WCMC, CONCYTEC (FONDECYT. The main studies are as follows:
I. (2017-2021): Carbon Storage in Amazonian Peatlands: Distribution and Dynamics57
II. (2019-2022): ARBOLES – A Trait-based Understanding of LATAM Forest Biodiversity and Resilience[58]
III. (2018-2021): Ecosystem dynamics of Amazonian open peatlands during the late Holocen[e59]
IV. (2018-2022): Human impacts on Amazonian peatland[s60]

---

[53] https://tropicalwetlands.wp.st-andrews.ac.uk/en/valuing-intact-tropical-peatlands/
[54] https://risweb.st-andrews.ac.uk/portal/en/projects/gaining-cultural-heritage-status-for-urarina-textiles-a-pathway-to-peatland-livelihoods-and-ecological-conservation-in-loreto-peru(5c1906f3-e21c-4e0a-b277-767ca77df4f9).html
[55]https://risweb.st-andrews.ac.uk/portal/en/projects/protecting-biodiversity--sustainable-livelihoods-in-the-wetlands-of-peruvian-amazonia(f6a67a2c-e144-4acd-abb3-9b98324d58c2).html; https://tropicalwetlands.wp.st-andrews.ac.uk/en/protecting-biodiversity-sustainable-livelihoods/
[56] https://risweb.st-andrews.ac.uk/portal/en/projects/oil-exploitation-and-peatlands-in-indigenous-territories-the-impacts-of-oil-at-the-extractive-frontier-in-the-peruvian-amazon(9bdda4e4-6f01-454c-b53c-7c924e331cc8).html
[57] https://tropicalwetlands.wp.st-andrews.ac.uk/en/carbon-storage-in-amazonian-peatlands/
[58] https://tropicalwetlands.wp.st-andrews.ac.uk/en/arboles/
[59] https://tropicalwetlands.wp.st-andrews.ac.uk/en/ecosystem-dynamics-of-open-peatlands/
[60] https://tropicalwetlands.wp.st-andrews.ac.uk/en/human-impacts-Amazonian-peatlands/

V. (2019-2020): Novel approaches to understand the state of biodiversity and support livelihoods: the distribution and degradation levels of Mauritia flexuosa stands in Amazonia[61]

■ **AGUA-ANDES: Ecological infrastructure strategies for enhancing water sustainability in the semi-arid Andes**

A project developed by the University of Arizona and the University of Peruvian Ayakujo (UNSCH) in collaboration with the Water Competence Centre (CCA, funded by USAID. This project is a hydroecological study that includes characterization of peatlands (bofedales) in Andean highlands and development carbon-measuring and mapping methodologies. Carbon measurement of peat was evaluated jointly with IRD. The project ended in 2018.

2.3.10 Future support policies for other donors and the private sector

■ **FAO /UNEP– Global Peatland Initiative (GPI)**

GPI's activities in Peru have been extended for five years. GPI has held five on-line workshops with the Ministry of the Environment of Peru since COP25 in December 2019. The latest workshop will be held jointly with the people of the Congo and the Congo and Indonesia and will be held at a multilateral high-level meeting (scheduled for July 5, 2021).

■ **The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP)**

The project will continue to support not only the development of methods for estimating carbon dioxide emissions from peat, but also the mapping methods of peatland and the preservation and restoration of peatland. Discussions on NDC for the Amazon peatland will soon begin.

2.3.11 Issues, lessons learned and needs of ongoing cooperative projects

There is an issue in the personnel and budget allocated to the work related to peatland in the counterpart organization. In addition, frequent changes in personnel were also cited as issues and in some cases. Accordingly, it is necessary to show the importance of the work related to peatland, the vision and roadmap related to peatland conservation and secure sufficient personnel and budget. Conversely, due to the increasing debate on climate change, it is important to determine the distribution of peatland and the amount of carbon accumulation accurately. However, the fact that the methodology of definition and mapping of peatland is not sufficiently discussed is also problematic. Needs vary depending on the organization as follows, but there are high needs in peatland mapping, deterioration repair, inventory, etc.

■ MINAM
- Peatland mapping in Peru
- Methodology for peat restoration
- Integration of peatland into NDC (methodology, on-site assessment, etc.)

■ INAIGEM
- Propagation of High Andes Peat Plants for Recovery Project
- Bioremediation capability of peatlands in the high Andes (ongoing)
- Mapping (ongoing) highland Andean peatlands for the inventory of Boffedales.
- Restore Bofederess (with pilot experiment)

[61] https://tropicalwetlands.wp.st-andrews.ac.uk/en/novel-approaches-mauritia-flexuosa/

- IIAP
  - Climate change impacts: monitoring peatlands, such as vegetation, hydrology and carbon, on permanent plots
  - Greenhouse gas inventory
  - Sustainable use of Amazon peatland
  - Restoration of Amazon peatland vegetation (aguajales)
  - Impact of Climate Change on Germination of Plants in Amazon Peat

CHAPTER 3. PEATLAND MAPPING (PEATLAND BORDERING)

3.1 Information Arrangement of Peat Mapping Method in Tropical Peat Areas

A variety of peat maps have been developed in Indonesia, Malaysia, Peru, and the Congo Basin, where tropical peat areas are widely distributed. Since many peatland maps in Indonesia and Malaysia are based on ground boring surveys, there is no mapping technique applied to other areas using satellite images. In Peru, Drapper et al.(2014) carried out mapping using satellite images for the Pastasa-Maranon areas, but since this method uses the Support Vector Machine (SVM), the properties of satellite images in peatland, etc., are not described in detail. As in the former case, this mapping method has not been applied to other areas. In the Congo Basin, although the type of satellite images used for analysis and the reference information (the number of survey points for ground boring surveys and landuse information) are described in Dargie et al. (2017), the applicability and reproducibility for other areas are also low because there is no description regarding the spectral features of satellite images in peatland, etc.[62]

In this paper, we propose a method for analyzing the images of peaty lands in the Congo Basin, which is reported in Dargie et al. (2017).

3.1.1 Peat Mapping Method for the Congo Basin by Dargie et al. (2017)

The peatland mapping technique of Dargie et al. (2017) is divided into three parts: 1) satellite image analysis (peat potential site extraction), 2) field survey, and 3) satellite image analysis by maximum likelihood method based on field survey data. The outline is as follows.

1) Satellite image analysis I (peat potential area extraction): from three types of satellite images (SRTM numerical altitude model, ALOS/PALSAR and Landsat-7/ETM+), a) topographical division (exclusion of highland steep slopes), b) water area extraction (water areas in forests), c) vegetation classification (classification of vegetation related to peat), and peat potential area extraction.
2) Field survey: Nine transects of 2.5~20 km were selected in 40,000 km2 of the northern part of the Republic of the Congo (ROC), which was extracted as a peat potential site, and a field survey was conducted. Among them, peat was confirmed in eight transects, and the characteristics of peat land were reported as follows.

   a. Topographical features of peat lands
   - The four transects extend perpendicularly to the oligotrophic Blackwater River/Likouala-aux-herber River (pH 3.8).
   - The three transects extend perpendicularly to the nutrient-rich steep White Water River/Ubangui River (pH 7.4). The high nutrient White Water River prevents the formation of peat to promote dry peat decomposition, so there is no peat around the abandoned waterways distributed around the White Water River. However, in the case where a high river bank embankment is formed, it is considered that the river water of the White Water River does not mix with peat wetland and does not affect peat formation.
   - The remaining transect is located at the midpoint of these two rivers.

   b. Results of indoor analysis of peat samples

   Peat samples were collected for each 250m in each transect, and the peat thickness increased from the end to the center of the peat site, with the greatest depth of 5.9 m near the midpoint of the two rivers (peat mean depth: 2.4m, 95% confidence interval (CI):2.2～2.6m, score: 211 points). The thickness of these peats is shallower than that of many other tropical peatlands, and the carbon-emitting ages obtained from

[62] One of the pattern recognition models using studies with a teacher

the base peat samples are 10,554～7,137 cal/yr/BP. This age coincides with the early African wetting period (about 11,000～8,000 cal/yr/BP) in the early Holocene.

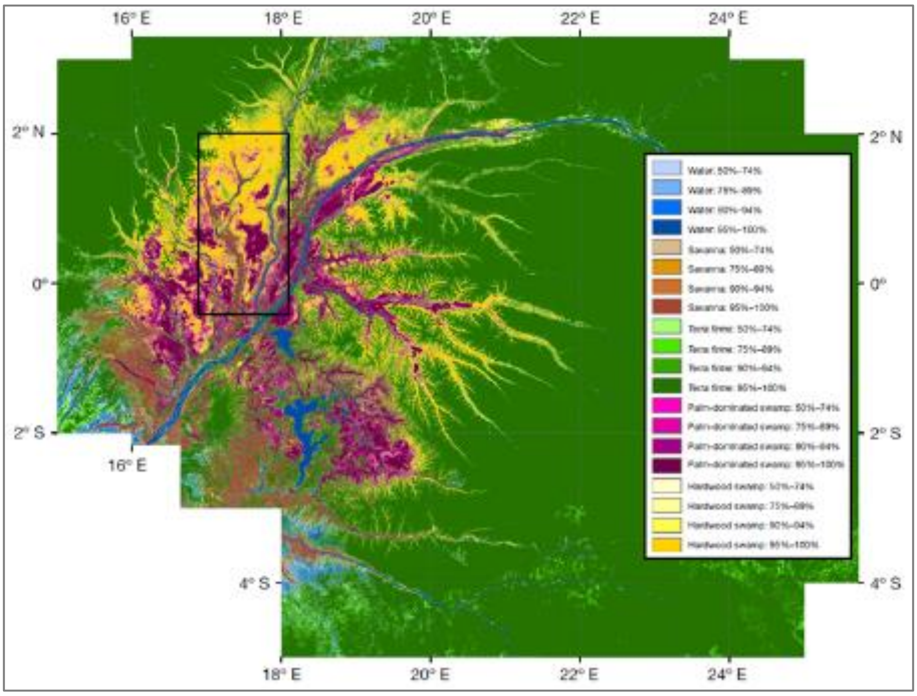
Note that peatland is defined as a sediment having a thickness 0.3 m of peat or more and an organic matter content of 65% or more.

3) Satellite Image Analysis II (Peat Area Extraction by Satellite Image Analysis Based on Field Survey Data)

a. Field surveys have confirmed that peat areas are highly correlated with two types of forests: 1) broad-leaved forests (Uapaca paludosa, Carapa procera, Xylopia rubescens, etc.) and 2) wetland forests centered on palms (Raphia laurentii and Raphia hookeri); and that they have not been identified in 3) terra firma (upland/dryland), 4) seasonal flooded forests, and 5) savannas. Therefore, the peatland in Cuvette Centrale is estimated by satellite-image analysis focusing on the broad-leaved wetland forest and the wetland forest in which palm predominates.

b. Using the 516 site coverage information from the field survey, 1000 maximum likelihood categories were performed for the following eight data, and a 145,500 km2 peat site probability map was generated (Source: Dargie et al., 2017).

   i. ALOS/PALSAR (HV) 50m
   ii. ALOS/PALSAR(HH) 50m
   iii. ALOS/PALSAR(HV/HH Ratio) 50m
   iv. SRTM/DEM 50m
   v. SRTM/Slope 50m
   vi. Landsat-7/ Band-3 50m
   vii. Landsat-7/ Band-4 50m
   viii. Landsat-7/ Band-5 50m



Source: Dargie et al., 2017

Figure3.1 1 Peat Distribution in the Congo Basin

3.1.2 Issues with Mapping Techniques by Dargie et al. (2017)

Dargie et al.(2017) uses site survey information (boring survey, 211 points, land use survey, 516 points) and satellite images (three bands of Landsat-7, two ALOS/PALSAR polarization and ratio calculation values, and SRTM/ altitude and slope) to create a peat site probability map. However, the following points have not been clarified, and therefore, even if an analysis is performed using the same satellite images, reproducibility cannot be obtained.

i. The specific imaging observation dates for Landsat-7 and ALOS/PALSAR are not shown.
ii. Landsat-7 uses the median annual reflectance for 2000, 2005, and 2010, despite the occurrence of noise since 2003.
iii. Since the spectral properties of the three bands (bands 3, 4, and 5) of Landsat-7 in peatlands are not shown at all, the appropriateness of the threshold of vegetation categories is not known.
iv. PALSAR uses data from 2007 to 2010, but it is not known whether the difference between the rainy season and the dry season is considered.
v. In PALSAR images, Backscatter differs greatly depending on the water level and water area distribution. Therefore, it is not possible to accurately evaluate peaty land features even if it is mechanically analyzed.

3.2 Peat Mapping Method of Tropical Peat Area in this Survey

3.2.1 Peat mapping mainly by optical satellite

The method of Dargie et al. (2017) is problematic in that the reproducibility is poor because detailed descriptions such as features of satellite-images used for analysis are not provided. In particular, the Landsat-7 images they used are noisy, and no noise-removal techniques or spectral features of peatland vegetation have been shown. In addition, the characteristics of HH polarization and HV polarization of ALOS/PALSAR in the rainy season and the dry season are unknown. Therefore, the survey is based on the fact that anyone can map peat land using free satellite images and free software, and the method is shown below.

In peatland mapping technique using satellite images, it is important to utilize ground boring survey data and landuse maps besides satellite images. In the case of the Congo Basin of this survey, the ground boring survey data is not available, so it is necessary to utilize the existing landuse map on which the distribution of peatlands is known. If spatial distribution information about peatlands such as location information is available, it can be compared with satellite images corresponding to these places, and characteristics of peatland vegetation can be grasped. As a result, it is possible to evaluate the peatland potential in the surrounding area. This time, the landuse map of Mbandaka located in the center of the Congo Basin was available, and the information was utilized.

3.2.1.1 How to use optical sensor Sentinel-2

1) Jardin Botanique d'EALA land-covering map in the suburbs of Mbandaka

By Greifswald Mire Centre (GMC), a landuse map including peat was prepared in the suburbs of Mbandaka. In this survey, spectrum analysis of Sentinel-2 images corresponding to individual vegetation was carried out using this landuse map, and a mapping technique for peatland was developed. Mbandaka is a medium-sized city of 730000 population located in the equatorial state of the central Congo Basin. There is a wetland "Jardin Botanique d'EALA" containing peatland in the eastern 3 km from its center (

Figure3.2 1). The vegetation of peatlands is broadly classified into the following three categories. Figure3.2 **2** shows that Palm swamp also surrounds hardwood swamp forest.

The peat vegetation in Jardin Botanique d'EALA is mainly as follows.

i. Palm swamp
ii. Hardwood forest mixed with palms
iii. Hardwood swamp forest

Figure3.2 1 Mbandaka and Jardin Botanique d'EALA peatland located in the center of the Congo Basin

Figure3.2 2 Map of peatland vegetation in the suburbs of Mbandaka prepared by Greifswald Mire Center[63]

It is unclear whether in the peat map of Dargie et al. (2017), Mbandaka is divided according to peatland, but the peatland map of 50m resolution of CongoPeat and the location of the peatland vegetation of the GMC map show good agreement (Figure3.2 3). Yellow polygons in Figure3.2 3 represent peatlands in the peatland map of CongoPeat.

63 Source: Coordination of survey teams using Google Maps

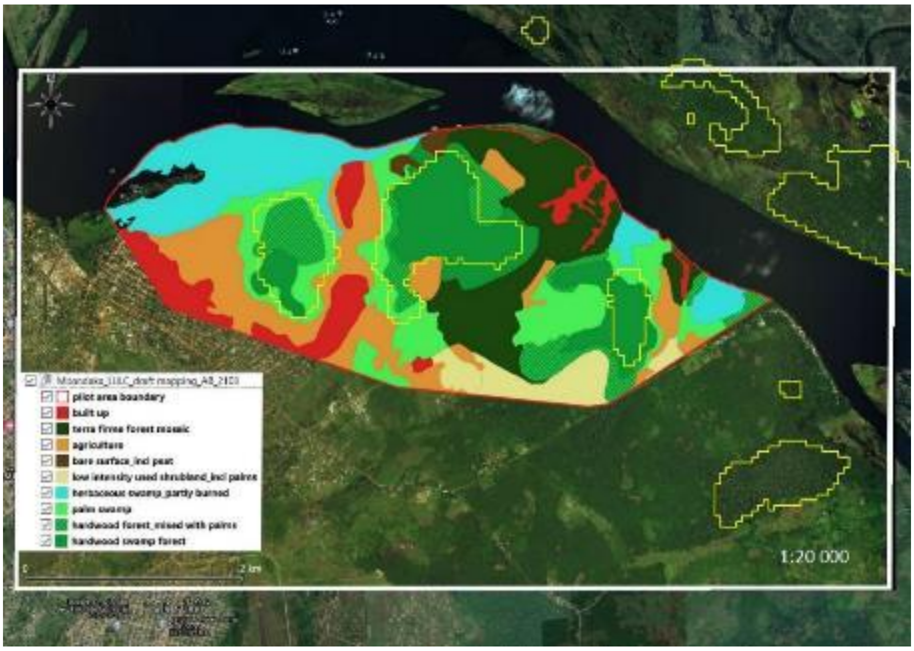


Figure3.2 3 Map of peatland vegetation in the suburbs of Mbandaka and peatland map in Congo Peat prepared by Greifswald Mire Center

Seven types of vegetation including peatland are as follows.

- Palm swamp
- Hardwood forest mixed with palms
- Hardwood swamp forest
- Terrafirma forest mosaic
- Herbaceous swamp
- Low intensity use shrubland including palms
- Agricultural palm swamp

In next table and figure, training sample areas are selected for these seven types of vegetation, and their reflectance spectra are compared.

Table3.2 1 peatland vegetation types

Land-Cover Type	B2	B3	B4	B5	B6	B7	B8A	B11	B12
Palm swamp	0.024	0.052	0.033	0.085	0.228	0.278	0.300	0.168	0.084
Hardwood forest mixed with palms	0.025	0.050	0.033	0.082	0.220	0.268	0.290	0.169	0.081
Hardwood swamp forest	0.026	0.050	0.035	0.084	0.209	0.252	0.276	0.158	0.078
Terrafirme forest mosaic	0.020	0.042	0.028	0.075	0.225	0.291	0.313	0.156	0.072
Herbaceous swamp	0.032	0.075	0.042	0.115	0.319	0.383	0.422	0.213	0.115
Low intensity used shrubland incl palms	0.020	0.046	0.029	0.082	0.236	0.298	0.327	0.172	0.081
Agriculture	0.025	0.051	0.036	0.091	0.243	0.300	0.328	0.178	0.087

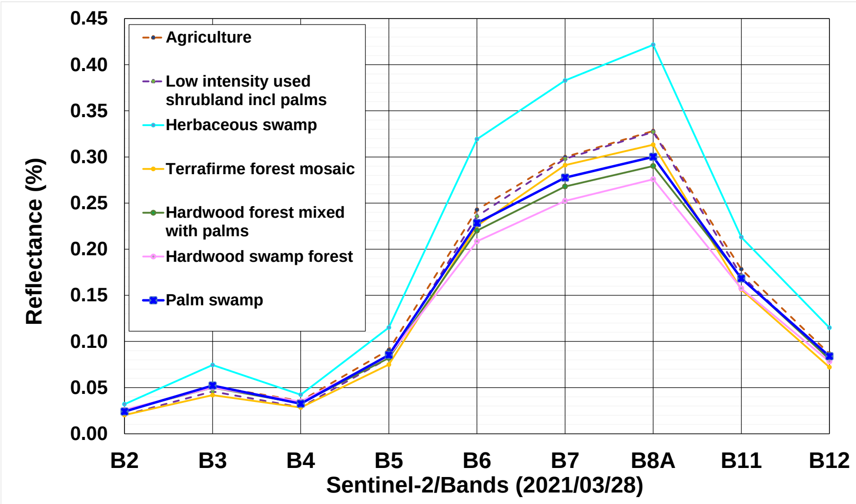


Figure3.2 4 Spectral characteristics of Sentinel-2 images of seven peatland vegetation types

Hardwood swamp forest, a peat vegetation, exhibits the lowest spectral reflectance in bands 5-12, followed by lower spectral reflectance in hardwood forest mixed with palms and palm swamp. All non-peat vegetation have higher spectral reflections than peat vegetation. This means that peat vegetation can be partitioned from other vegetation. In addition, box plots were made to compare the reflections of each spectrum, and detailed spectral characteristics of peat and non-peat vegetation were examined (Figure3.2 5).

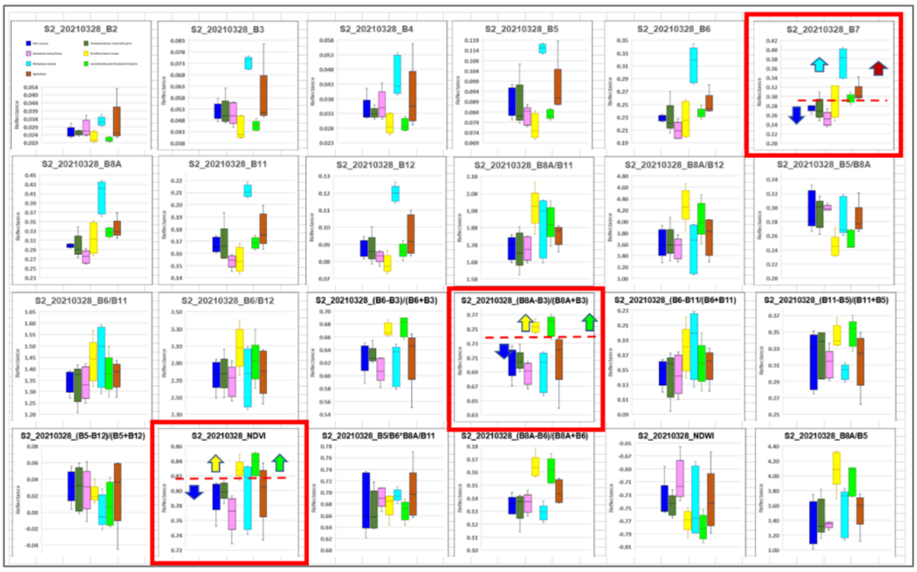


Figure3.2 5 Spectral properties of seven peatland vegetation-type Sentienl-2 images (box-plot diagram)

Step-1: The NDVI threshold is set to 0.6. 0.6 or above is defined as vegetation, and 0.6 or less is defined as non-vegetation

Step-2:(Band8A-Band3)/(Band8A+Band3) is set =0.79. 0.79 or less is defined as peatland vegetation, and higher than 0.79 is defined as terrafirma forest mosaic and low intensity-use shrubland including palms.

Step-3:Band7 is set =0.29. 0.29 or less is defined as peatland vegetation, and higher than 0.29 is excluded as herbaceous and agricultural.

The results of applying the above steps are shown in the below.The range of the peat map in CongoPeat/AfriTron and the extracted peat vegetation (water color in the figure below) roughly coincide. However, since the landuse map of GMC was prepared in 2013, it may differ from the present land use status (vegetation types), and can be corrected by obtaining the latest landuse map or conducting a field survey.

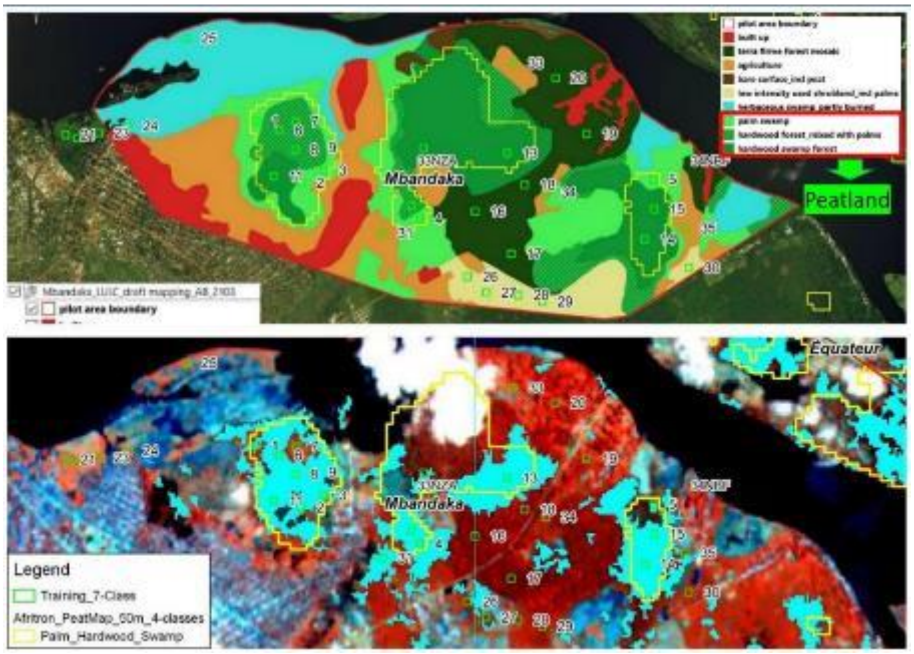


Figure3.2 6 Potential distribution of peat areas based on seven spectral features of peat area vegetation

NOTE: Potential distribution of peatland (blue part in the figure below)

As described above, the results of extracting peatland vegetation with reference to the land classification map of the Greifswald Mire Centre (GMC) for Jardin Botanique d'EALA peatland of Mbandaka using the optical sensor (Sentinel-2) are consistent with the peatland distribution range of the CongoPeat/AfriTron peatland map, and the effectiveness of this method can thereby be confirmed.

2) Notes on Sentinel-2 images

As described above, if a landuse map containing peat is available, peatland can be extracted from spectral and backscatter features of Sentinel-2 and PALSAR images. In the northern region of Sentinel-2 images including the landuse map of Mbandaka, we tried to extract peatland by setting the thresholds of the spectral data of Sentinel-2, resulting in misalignment of the image at the border of the two images, as shown in the figure below.

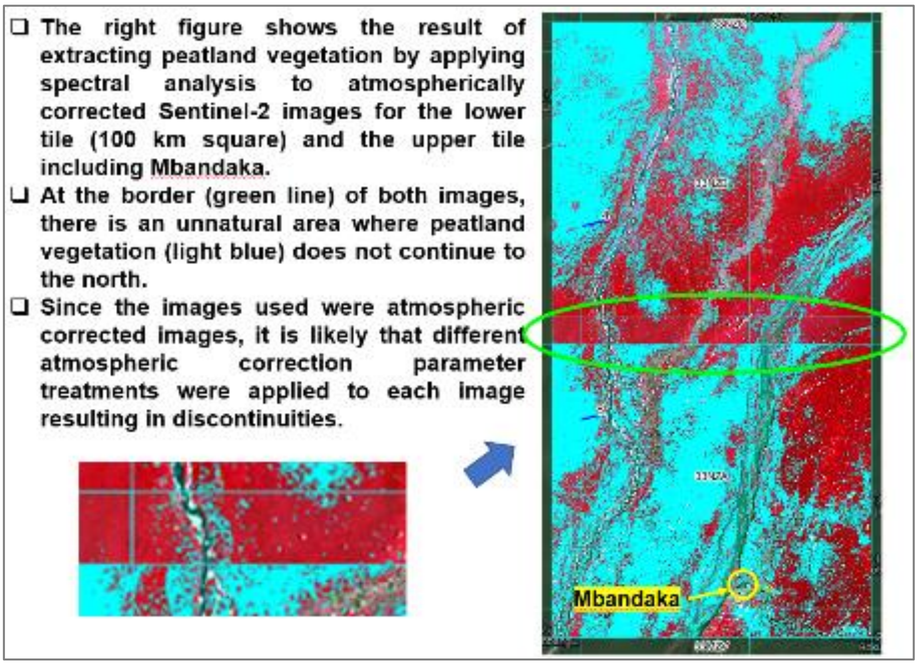


Figure3.2 7 Discontinuities in the image-to-image borders of the graphical Sentinel-2 images

In air-corrected Sentinel-2 images, peat vegetation is discontinuous at the border of the two images. The reason for this is that different atmospheric correction parameters are applied to the different images above and below. Therefore, when (1) the atmospheric corrected image (level 2A) and (2) the non atmospheric- corrected image (level 1C) were compared with DN of the same straight line, it was confirmed that there was no difference in the spectral value in (1) and the spectral value in (2). Therefore, the gap between close images is considered to be due to the atmospheric correction process.

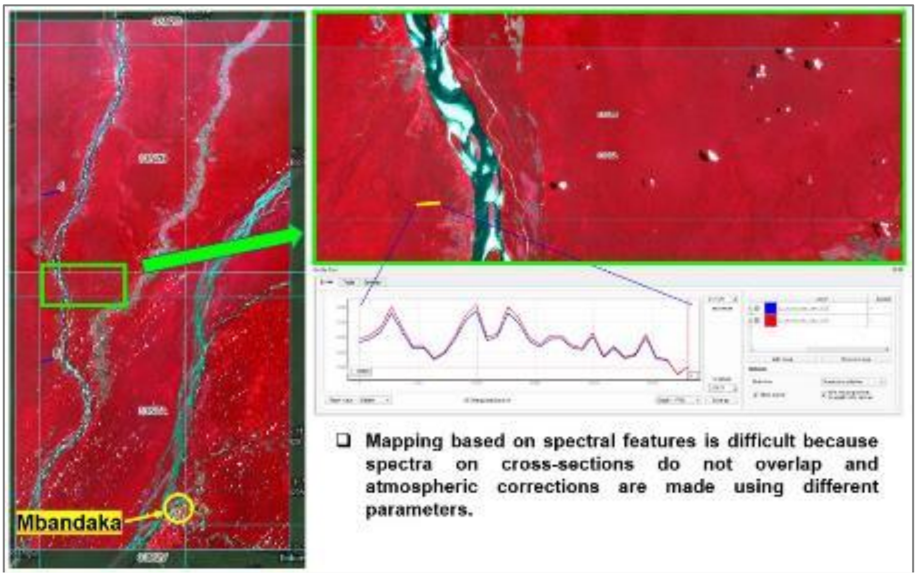


Figure3.2 8 Changes in DN between two Sentinel-2 images with and without atmospheric correction

Based on the above results, we decided to use non atmospheric-corrected images in this method, performed the spectral analysis of the peatland vegetation again on the non atmospheric-corrected images, and set the following spectral conditions. The spectral characteristics are shown in next table and figure. Using these thresholds, peatland extraction was performed over the whole images, and an unnatural gap between two atmospheric-corrected images was not observed in the non atmospheric-corrected images (Figure3.2 9).

Table3.2 2 Spectrum by land coverage of non-atmospheric corrected images (Level 1C)

Land-Cover	B2	B3	B4	B5	B6	B7	B8A	B11	B12
Palm swamp	0.096	0.088	0.061	0.088	0.202	0.260	0.286	0.154	0.064
Hardwood forest mixed with palms	0.096	0.087	0.061	0.086	0.196	0.250	0.276	0.152	0.063
Hardwood swamp forest	0.096	0.088	0.061	0.085	0.189	0.239	0.266	0.143	0.060
Terrafirme forest mosaic	0.092	0.082	0.055	0.080	0.203	0.271	0.299	0.141	0.056
Herbaceous swamp	0.102	0.102	0.070	0.104	0.255	0.325	0.367	0.188	0.086
Low intensity used shrubland incl palms	0.091	0.083	0.056	0.084	0.210	0.272	0.309	0.152	0.062
Agriculture	0.095	0.087	0.059	0.089	0.213	0.275	0.311	0.160	0.066

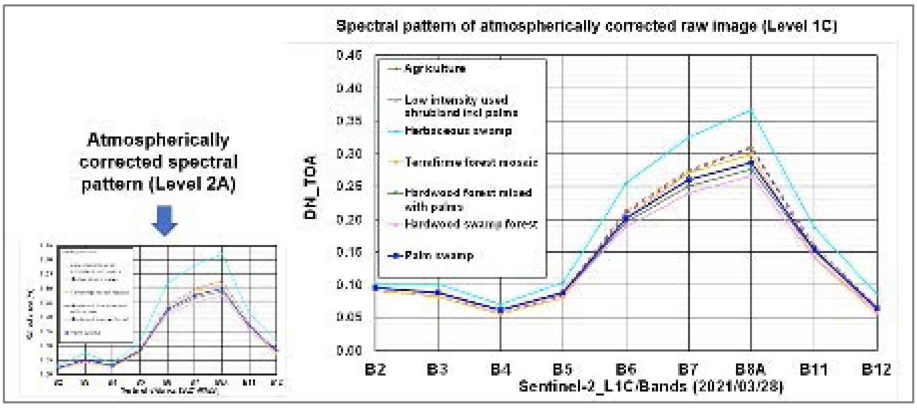


Figure3.2 9 Spectral properties of peatland vegetation in atmospheric-corrected and non atmospheric-corrected Seitinel-2 images

3) Method for extracting peat vegetation (palm & hardwood) using non atmospheric-corrected images

I. Separate vegetation/non-vegetation in Step-1:NDVI>0.6

II. Separate terrafirma and low intensity-use shrubland with Step-2:B5/B8A>0.29

III. Separate herbaceous swamp with Step-3:(B5-B12)/ (B5+B12)>0.14

IV. Remaining peatland vegetation (palm & hardwood)

In addition, peatland was extracted by setting thresholds of the above spectral features for five consecutive images up to Nioki observed on March 28, 2021. As shown in the images, the area around Mbandaka is not covered with clouds, so good results are obtained, but the southern region including Nioki is covered with clouds, and the area extracted as peatland is limited. Field surveys have also shown that peaty areas around Nioki are predominantly palm vegetation, so PALSAR/FBS modal images are useful, unlike Mbandaka vegetation types. In the future, it is possible to improve this method by continuing the collection of field survey data.

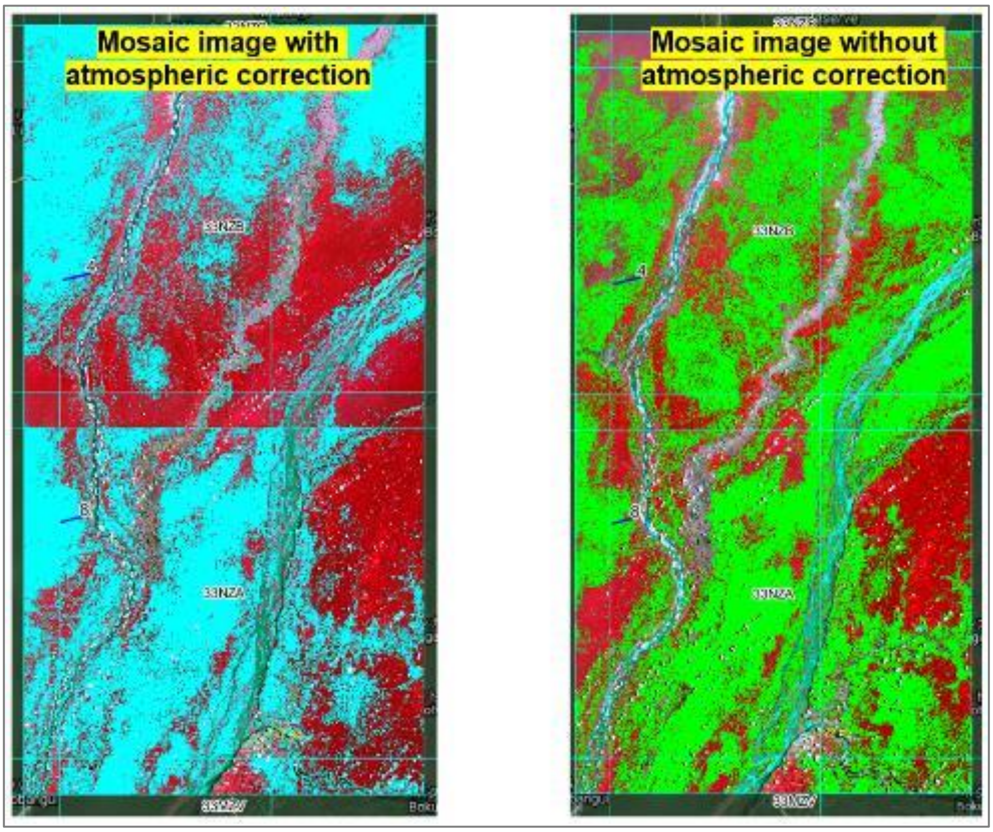


Figure3.2 10 Comparison of peat ground vegetation mapping in atmospheric-corrected and non atmospheric-corrected Seitinel-2 images

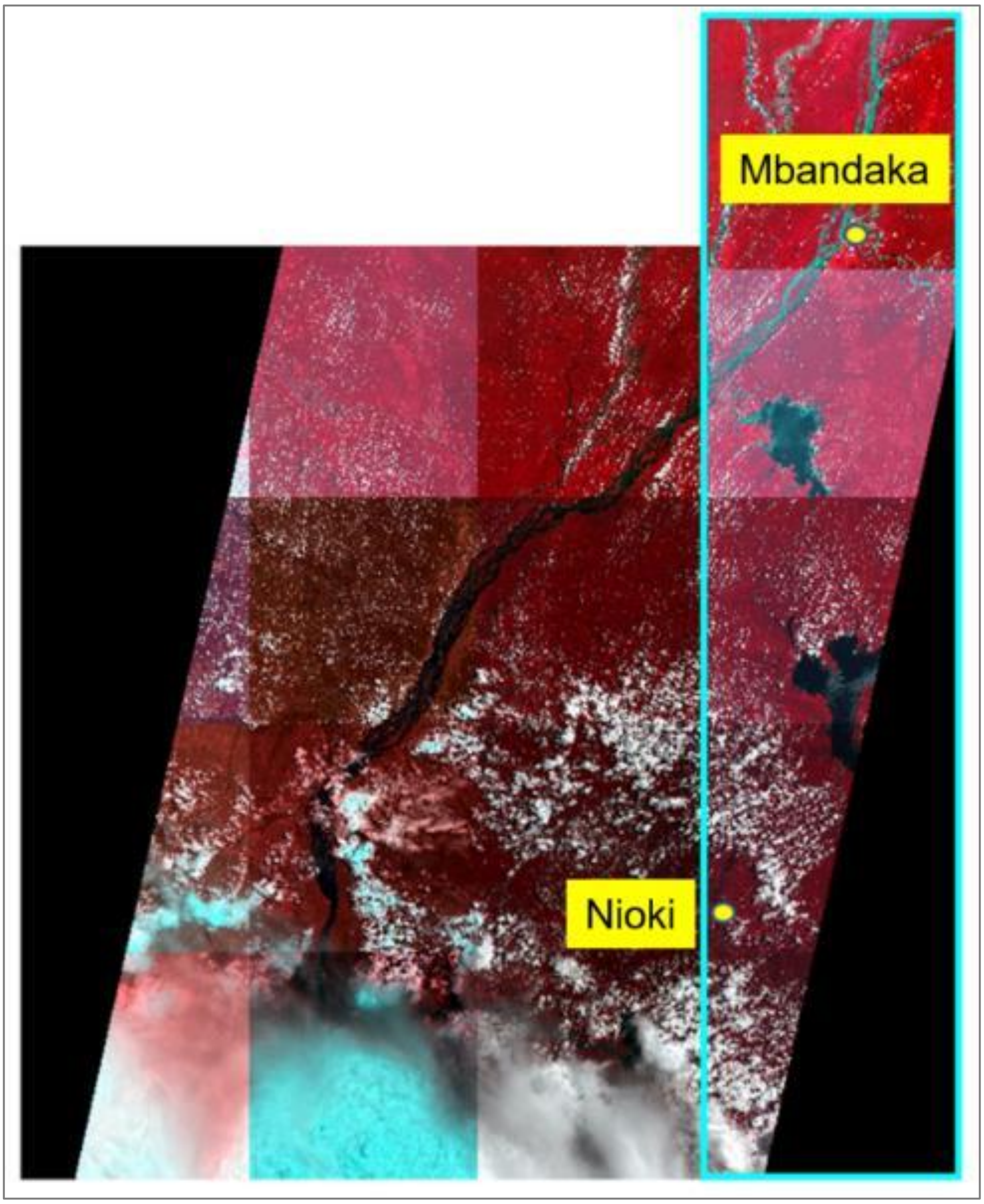


Figure3.2 11 Sentinel-2 images observed on March 28, 2021, including from Mbandaka to Nioki

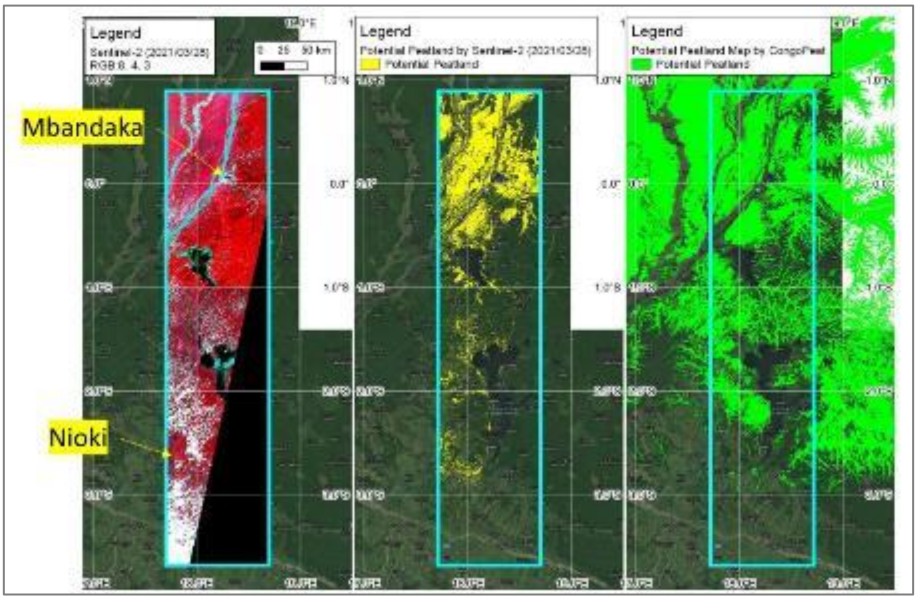


Figure3.2 12 Peatland extraction using Sentinel-2 images observed on March 28, 2021
(Left) Sentinel-2 images, (Center) peatland extractions by this method,
and (Right) peatland maps of CongoPeat

3.2.1.3 Peat potential maps across the equatorial region

A peat potential map for the entire equatorial region was generated using the method described above (Figure3.2 **13**). Since the trajectory of the eastern half of the equatorial state differs from the acquisition date of the satellite image obtained by observing Nioki from Mbandaka (March 28, 2021), the threshold of the spectral analysis cannot be applied, so the eastern half of the existing CongoPeat peat map was revised and integrated with the image analysis of the western half.

Existing CongoPeat peat maps are mapped as peat even on large and small islands scattered in the main stream of the Congo (the brown-color part in the right-hand chart in Figure3.2 **14**). Therefore, after examining the SRTM/DEM elevation values, the area below 330m elevation was removed as non-peatland because the area generally corresponds to the main stream of the Congo River at 330m elevation. Other peatland candidates that were not based on spectral or elevation characteristics of the vegetation were manually modified to the extent of peat.

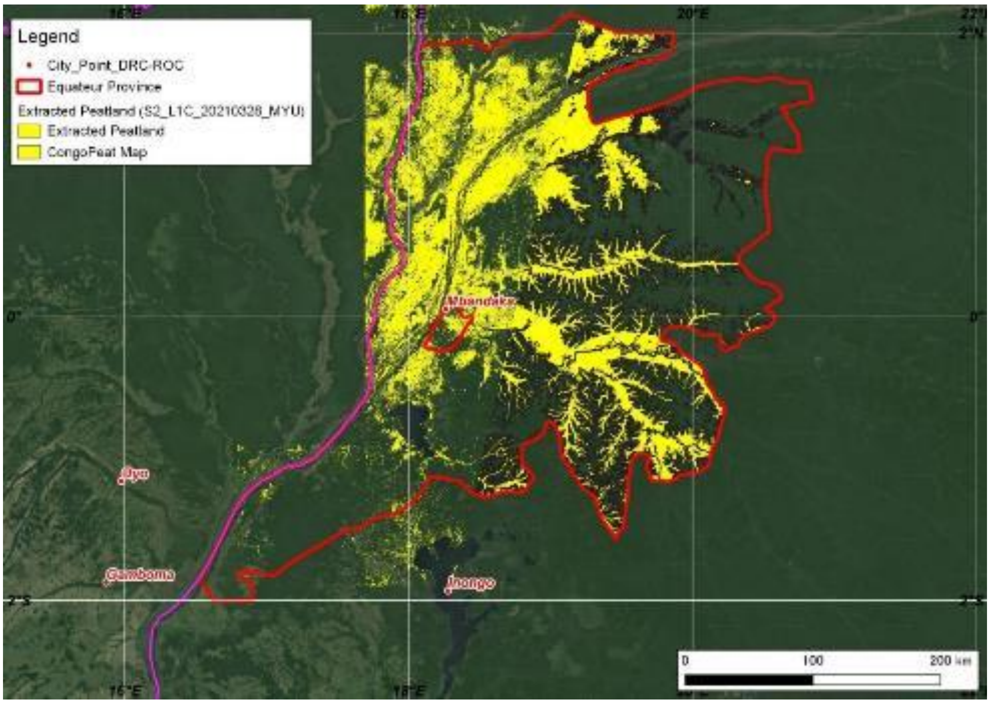


Figure3.2 13 Peatland from equatorial state extracted by Sentinel-2 images taken on March 28, 2021

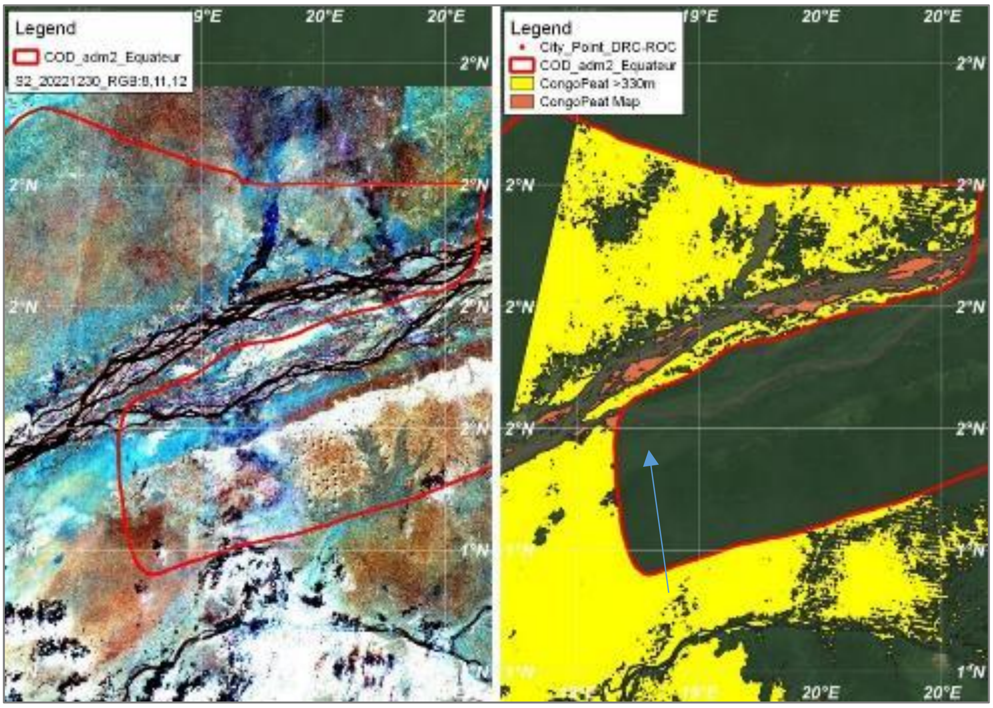


Figure3.2 14 Peatland extractions using Sentinel-2 images observed on March 28, 2021

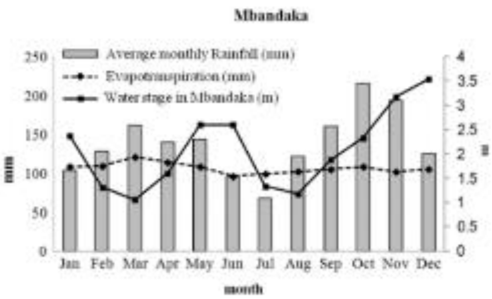
3.2.1.4 How to use microwave PALSAR

The observed PALSAR for the Mbandaka region is 12 scenes in total, half of which are FBS modes acquired in the rainy season (Figure3.2 15).[64]

- **PALSAR Acquisition Date & Mode in Jardin Botanique d'EALA Peatland, Mbandaka**

No	Date	FBS/FBD	Dry/Rainy
1	20061227	FBS	Rainy
2	20070629	FBD	Dry
3	20070929	FBD	Dry
4	20071230	FBS	Rainy
5	20080331	FBS	Rainy
6	20081116	FBD	Rainy
7	20091004	FBD	Rainy
8	20100104	FBS	Rainy
9	20100219	FBS	Rainy
10	20100707	FBD	Dry
11	20101007	FBD	Rainy
12	20110222	FBS	Rainy

- **Average Rainfall and Water Stage in Mbandaka**



https://www.researchgate.net/publication/260281831_Mapping_of_Central_Africa_Forested_Wetlands_Using_Remote_Sensing

Figure3.2 15 Mbandaka land-cover maps and PALSAR/FBS modal images

N.B.: (L) PALSAR images observed around Mbandaka (prepared by survey team),
(R) Rainfall and water level around (R)

FBD modalities are obtained mainly in the dry season and therefore do not show any significant characteristics in backscatter. On the other hand, since FBS is acquired in the rainy season, it is highly likely that flooding in the rainy season will clearly appear as well as differences in forest density. Thus, the backscatter of six scenes was observed, and it was found that the backscatter value of the data acquired on December 27th, 2006 was higher. Compared with the land classification maps, peat vegetation was found to be in good agreement for locations with higher backscatter .[65]

[64] Single polarization mode

[65] Two polarization mode

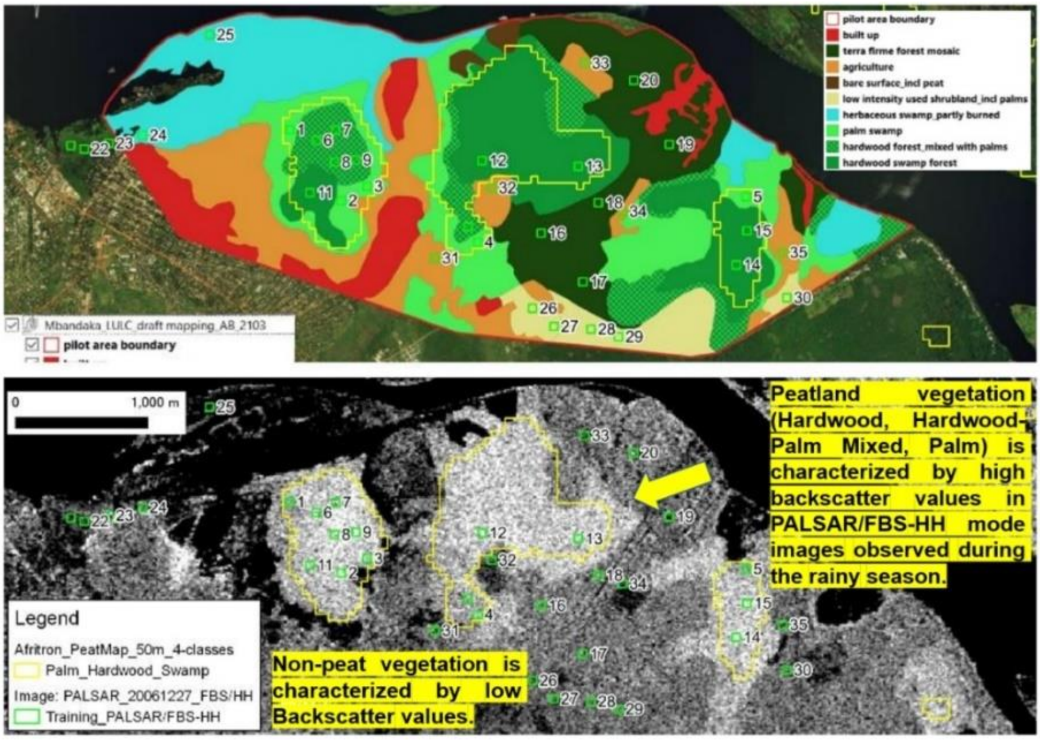
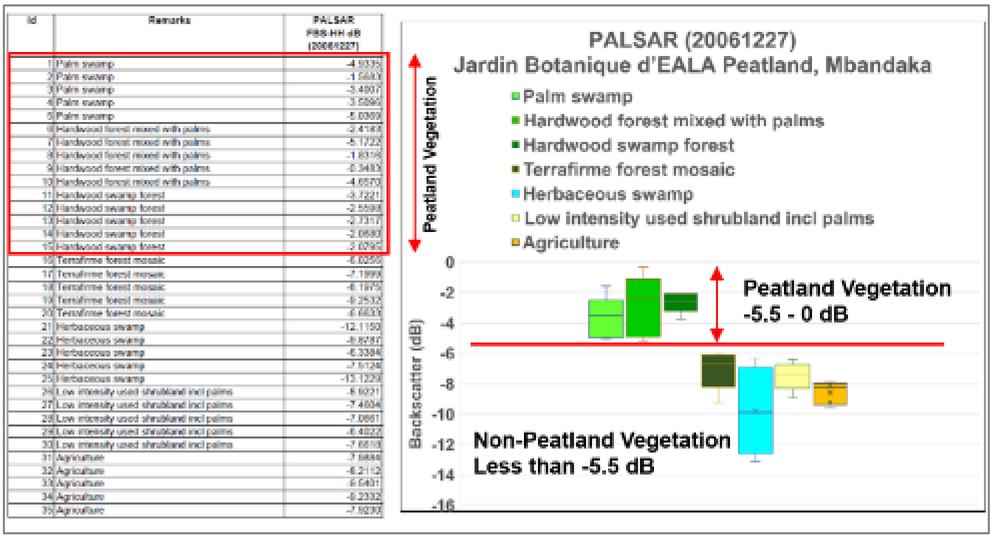


Figure3.2 16 Mbandaka land-cover maps and PALSAR/FBS modal images
N.B.: (Top): Mbandaka land-cover map, (Bottom): PALSAR/FBS modal images

3.2.2 Comparison and verification with international peat mapping methods

Backscatter values for the seven categories of the land classification map were compared, and the backscatter values for peatland vegetation (palm, hardwood, and palm-hardwood mixed forest) fell within the range of 0 to -5.5 dB, while non-peatland vegetation showed values below -5.5 dB (Figure3.2 17). Therefore, locations that exhibit high backscatter values (-5.5 dB) in PALSAR/FBS mode images during the rainy season may indicate peatland vegetation. We searched for areas with high backscatter values around Nioki, which is the closest to Kinshasa, and confirmed that they are distributed from southern Nioki to the eastern part of the area (Figure3.2 17). We also superimposed the CongoPeat/AfriTron peatland map, which coincides with the locations with high backscatter values (upper blue area in Figure3.2 18). Further, looking at the variation of backscatter values along a 5-km cross-sectional line between CongoPeat/AfriTron peatlands and areas with high backscatter values in PALSAR/FBS mode images, the area above -5.5 dB generally corresponds to peatland vegetation (lower panel inFigure3.2 **19**).

In September 2021, the Ministry of the Environment's Forest Inventory Development Bureau (DIAF) and a study group of Ewango professors at Xangani University conducted a field survey (Figure3.2 20) in this region. The peatland in 3.6m was confirmed. Based on the above, it is possible to extract peatland potential areas using PALSAR/FBS modal images of rainy seasons where peatland wetlands are flooded, and where flooded water levels are higher. In addition, by examining the spectral properties of Sentinel-2 images, it is possible to perform detailed mapping of peatland, and by accumulating field survey data in the future, the mapping accuracy of this method will be improved.



Id	Remarks	PALSAR FBS-HH dB (20061227)
1	Palm swamp	-4.5335
2	Palm swamp	-1.5683
3	Palm swamp	-3.4007
4	Palm swamp	-3.5896
5	Palm swamp	-5.0369
6	Hardwood forest mixed with palms	-2.4168
7	Hardwood forest mixed with palms	-5.1722
8	Hardwood forest mixed with palms	-1.8316
9	Hardwood forest mixed with palms	-0.3483
10	Hardwood forest mixed with palms	-4.6570
11	Hardwood swamp forest	-3.7221
12	Hardwood swamp forest	-2.5598
13	Hardwood swamp forest	-2.7317
14	Hardwood swamp forest	-2.0680
15	Hardwood swamp forest	-2.0795
16	Terrafirme forest mosaic	-6.0258
17	Terrafirme forest mosaic	-7.1999
18	Terrafirme forest mosaic	-8.1975
19	Terrafirme forest mosaic	-8.2532
20	Terrafirme forest mosaic	-6.6833
21	Herbaceous swamp	-12.1150
22	Herbaceous swamp	-8.8787
23	Herbaceous swamp	-8.3384
24	Herbaceous swamp	-7.5124
25	Herbaceous swamp	-13.1229
26	Low intensity used shrubland incl palms	-8.9221
27	Low intensity used shrubland incl palms	-7.4604
28	Low intensity used shrubland incl palms	-7.0881
29	Low intensity used shrubland incl palms	-8.4822
30	Low intensity used shrubland incl palms	-7.6618
31	Agriculture	-7.6848
32	Agriculture	-8.2112
33	Agriculture	-8.5401
34	Agriculture	-8.2332
35	Agriculture	-7.9230

Figure3.2 17 Backscatter of PALSAR/FBS modal images in peatland vegetation in Mbandaka

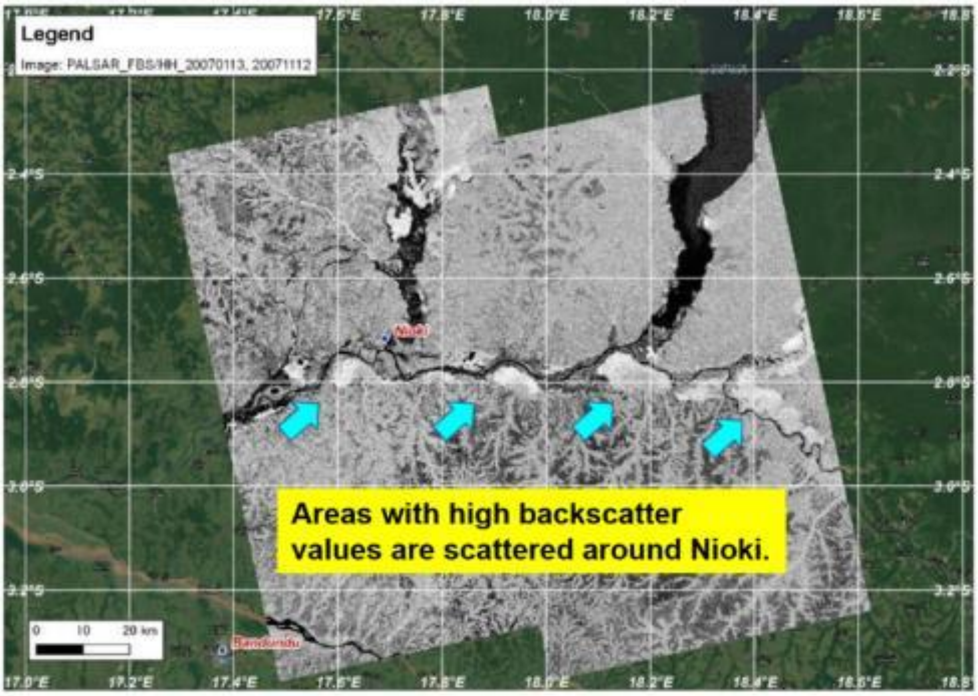


Figure3.2 18 PALSAR/FBS image around Nioki in Figure

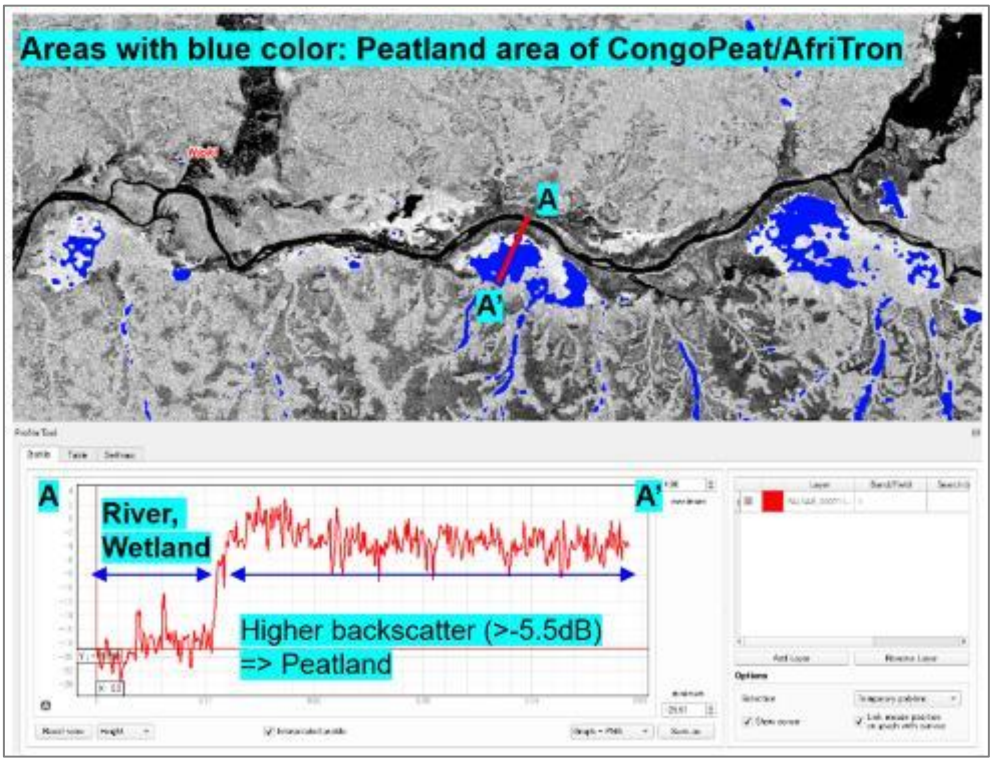


Figure3.2 19 Changes in PALSAR/FBS modal images and CongoPeat/AfriTron peat maps and backscatter around the Nioki

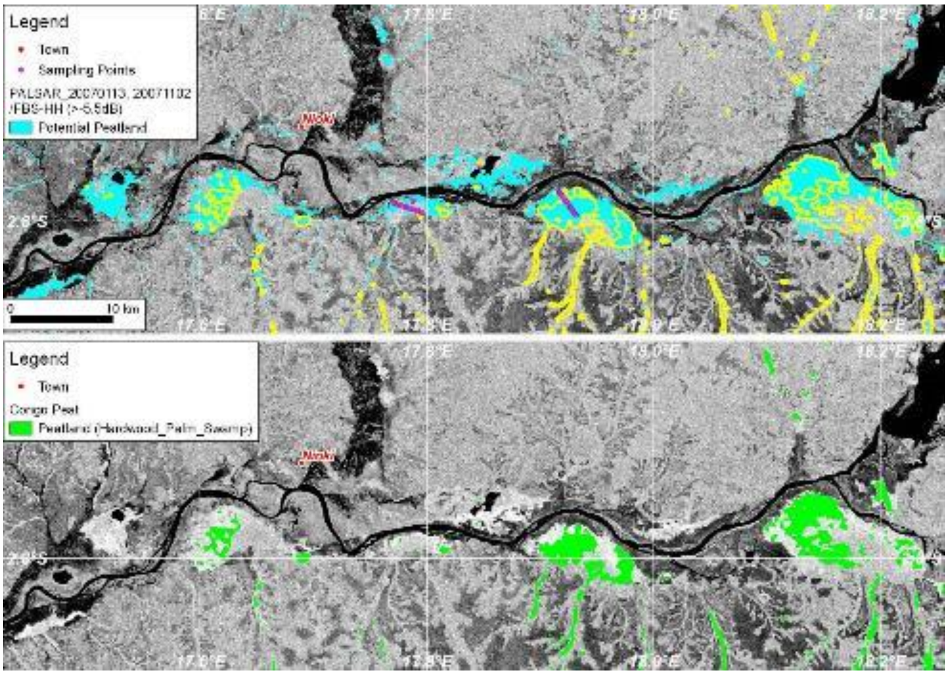


Figure3.2 20 Field survey of peat potential areas around Nioki (2021)

Table3.2 3 Outline of laboratory analyses of samples of sites around Nioki (2021)[66]

Transect	Sites physical characteristics					Peat characteristics		
	Site	*pH*	*Temperature*	*Specific conductivity (μScm^{-1})*	*Water table (cm)*	*Peat depth (m)*	*Bulk density (g cm^{-3})*	*C content (%)*
1	NKI2-0.00	4.2	25.6	20	-5	1.55	0.13	4.10
	NKI2-0.50	3.3	24.5	10	-18	2.37	0.07	3.91
	NKI2-1.00	4.6	24.8	10	-17	3.10	0.13	7.56
	NKI2-2.00	4.5	24.7	80	90	1.80	0.28	6.61
	NKI2-2.90	3.4	24.4	20	14.2	No Peat	No Peat	No Peat
	Average	**4.0**	**24.8**	**80**	**12.84**	**2.21**	**0.15**	**5.55**
	Standard	**0.6**	**0.47**	**29.50**	**45.04**	**0.69**	**0.09**	**1.82**
2	NKI3-0.00	4.0	22.8	50	22.5	2.40	0.09	9.32
	NKI3-PA	3.9	24.6	63	27	0.85	0.31	10.96
	NKI3-1.00	4.1	23.5	40	26.5	1.10	0.18	8.69
	NKI3-2.00	3.3	23.5	20	57	1.70	0.09	4.73
	NKI3-2.13	4.2	23.1	40	33	3.50	0.07	5.04
	NKI3-3.00	4.3	23.5	20	25.5	2.31		
	Average	**4.0**	**23.5**	**38.8**	**31.9**	**2.0**	**0.15**	**8.07**
	Standard	**0.4**	**0.6**	**16.9**	**12.8**	**1.0**	**0.10**	**2.37**

3.2.3 On-site verification survey theGamboma District of the Republic of the Congo, and Inongo District of the DRC

The method was verified in Nioki District, DRC, where the presence of peat was revealed, confirming the validity of the method. In addition, field surveys were conducted in Gamboma District, of the Republic of the Congo, and Inongo District, Mai Ndombe Province, of the DRC.

1) Peatland in Gamboma region

Gamboma is located approximately 250 km from Brazaville, the capital of the Republic of the Congo (Figure3.2 21). The surrounding topography consists of a gentle plateau with an altitude 400～500m, and low wetlands of 300～320m degree are formed along the Nueni River. According to the peatland map of Congopeat, peatland spreads along this low wetland (Figure3.2 22). Field validation surveys were conducted at Luara river basin survey site No. 4 with the assistance of Mariangabi University, which has a wealth of peat surveys. Survey site No.4 is a wetland formed in a topographical dent, and there is no river connected to the Luara river during the dry season, but it is thought to be connected to the Laura river during the rainy season (Figure3.2 **23**). In the Republic of the Congo, spectral analysis was performed on peatland vegetation using the Congopeat peatland map as teacher, since there is no teacher landuse map that can be used, such as that of Mbandaka. The results were in close agreement with the peat distribution in Congopeat, and boring was performed almost in the center of survey site No. 4. The route of the transect is shown by the green line in , right figure.

At point No.4, a typical peat wetland vegetation "Laphia laurentii", flourishes. However, peat is unlikely to be present because the water in the wetland is highly transparent and does not exhibit the peat-specific dark black water color. When boring was carried out, no peat was present, and it reached the clay sandstone of the

[66] Source: Ewango, 2021

base at a depth of 80cm. As a consequence, among the peatland maps of Congopeat used as teacher data this time, it was proven that the peatland map of Congopeat wasnotaccurate, at least at survey site No.4.

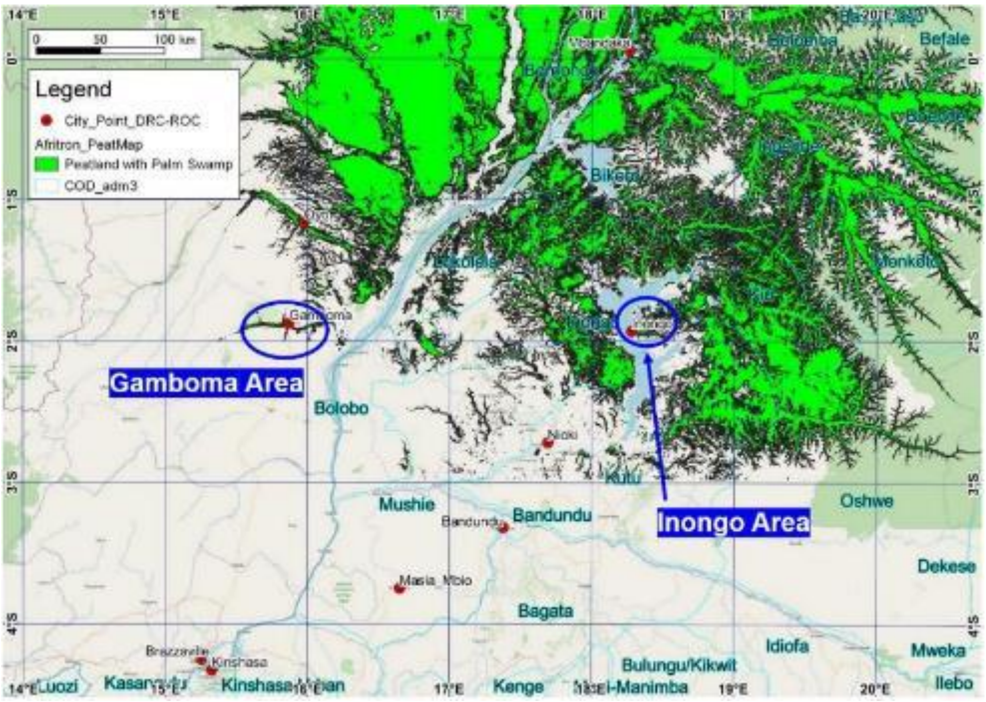


Figure3.2 21 Location map of Gamboma district and Inongo district

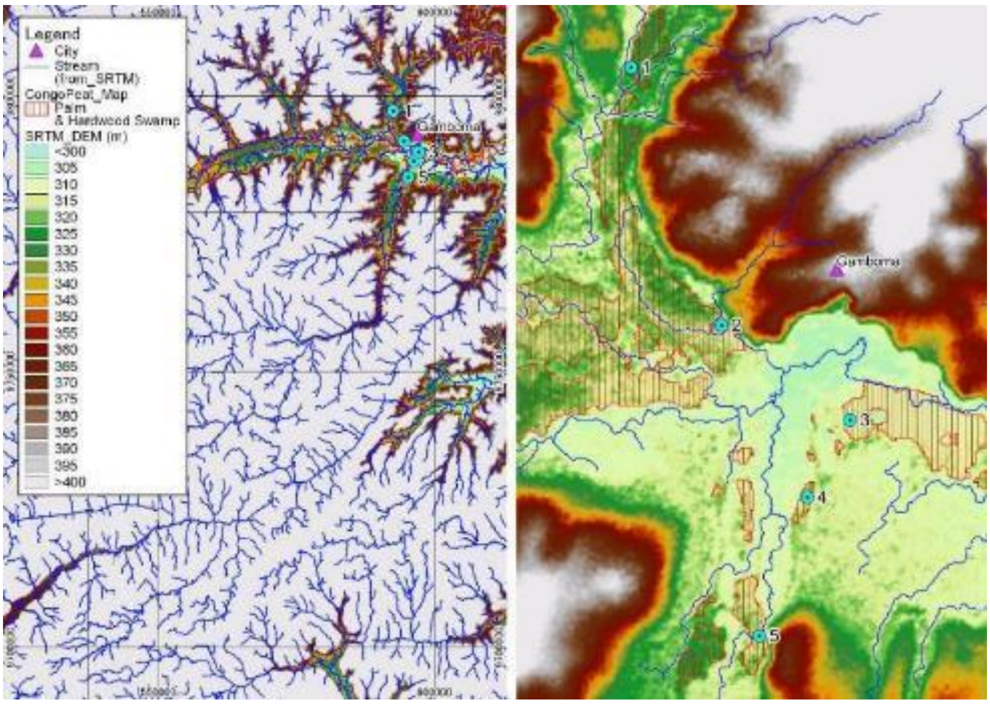


Figure3.2 22 Geographical situation of Gamboma district (left), and peat distribution by CongoPeat peatland map (red vertical part of right)

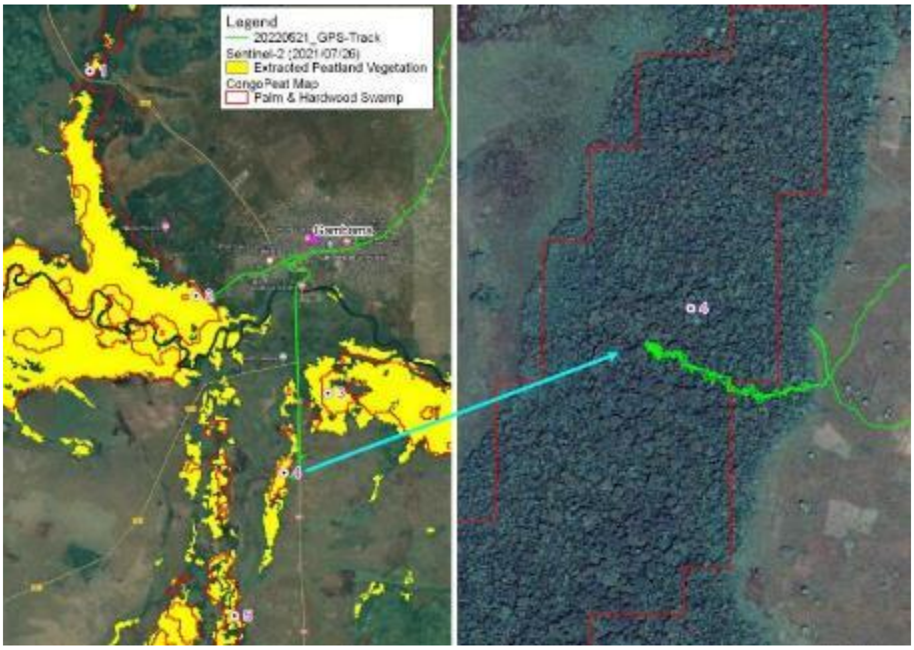


Figure3.2 23 Location of survey point No.4 of Luara river basin in Gamboma district, and the route of the survey (right-hand chart)

2) Peat in Inongo district of Mai Ndombe, Republic of the Congo

Inongo district is located approximately 400 km northeastward from the capital of the Republic of the Congo, Kinshasa . This region consists of the flat topography of the eastern shore of Lake Midnebe with an altitude 300～320m, and rivers and wetlands flowing to Lake Midnebe on the southeastern side are formed in a wide area of largest width approx. 10 km. According to the peatland map of Congopeat, peatland is distributed along this river . The field survey was conducted at survey sites No. 3, No. 6, and No. 7 with the assistance of Professor Ewango of Kisangani University. At all survey sites, the combination of bands 8, 4, and 3 on the satellite image (Sentinel-2) does not reveal any difference in the color tone of peat vegetation, but using the short-wavelength bands 8A, 11, and 12, peat vegetation and non-peat vegetation are divided into two types: the dark brown and light brown, and peat vegetation is characterized by deeper brown.

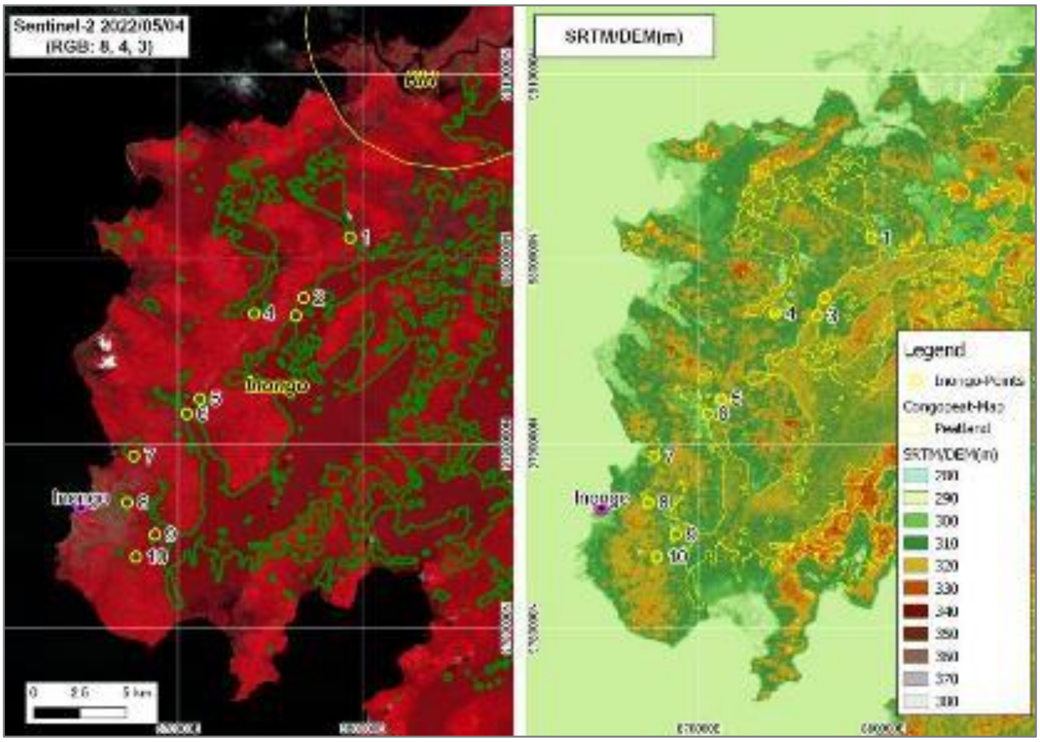


Figure3.2 24 Inongo site location map (left) and altitude (right)

Survey site No. 3 is located in a river/wetland area about 3 km wide near the main channel of the river in the southeast part of the study area. The typical peat wetland vegetation "*Laphia laurentii*" is absent, the

vegetation being formed by wetland-specific species with well-developed strut roots According to Professor Ewango, these species are peat-specific species classified as "hardwood". On the other hand, the topography is characterized by a peat wetland-specific plant "*Lasimirpha senegalensis*". In the dry season, the water level of the wetland rises as the wetland moves toward the inside, and the color of the water also changes to the tone of red-black to dark-black characteristic of peatland. Three borings were carried out near the planned survey, and peat beds with a thickness 1m or more were confirmed. The peat layer also contained plant roots, a relatively soft peat layer. Since the bore did not reach the sandstone or mudstone layer distributed at the base of this area, there must be a peat layer at least 1 m thick. Since this area is considered peatland on Congopeat's peatland map, it is confirmed that the peat distribution on Congopeat's peatland map is correct, at least around this site.

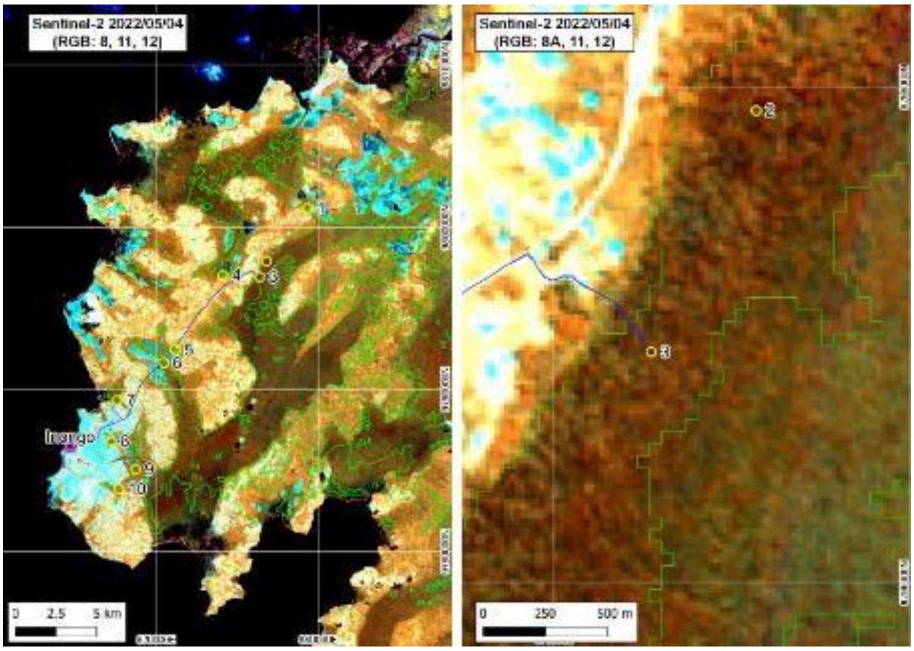


Figure3.2 25 Survey site in Inongo district (No.3)

Figure3.2 26 Vegetation and color characteristics of wetland water at Survey site (No.3) in Inongo District

Figure3.2 27 Status of peat boring at Survey site (No.3) in Inongo District

Survey site No.6 is located along a river surrounded by sandy low wetlands, unlike No.3. On satellite images, sandy low-wetlands are characterized by dark blue to light blue, and No.6 are shown in brown surrounded by them (Figure3.2 28, right-hand panel). In the peatlands of the Congo Basin, "*Raphia laurentii*" is known as a typical palm (Figure3.2 29(1)), but in addition, a palm called "*Raphia sese*" is also distributed (Figure3.2 29(2)).

"*Raphia sese*" was observed at No.6. The "*Raphia sese*" shape is such that the vine-like branches cover the trunk, which is clearly different from "*Raphia laurentii*". A sandy peat bed with a thickness of 30cm was confirmed by boring. Since the borehole site is located near the center of the wetland and is surrounded by sandy low wetlands, the peat seam in this area is expected to be at most around 50cm Figure3.2 29(3)). There are many drainage channels with a width of 1m in the wetlands, which are thought to be used for transporting wind-fallen trees, and fish traps are also scattered about (Figure3.2 29(4)). In the peatland map of Congopeat, this area is considered to be peatland, but the peatland layer is considered to be extremely thin (for example, 20cm or less) from the bore point toward the sandy low wetland. Therefore, to evaluate the accuracy of Congopeat peat maps, it is required to define the lowest thickness of the peat.

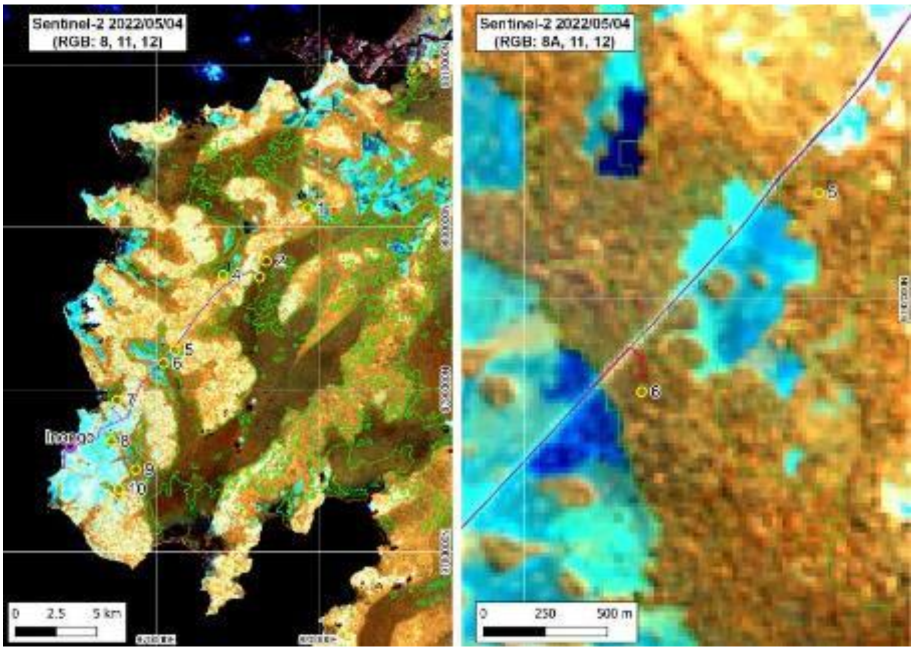


Figure3.2 28 Survey site in Inongo district (No.6)

Figure3.2 29 Status of vegetation and peat boring at Survey site (No.6) in Inongo district

Survey site No.7 is a wetland connected to Lake Midnebe, and peat formation is considered to be strongly affected by the height of the water surface of Lake Midnebe (Figure3.2 30). The peat-specific palm "*Raphia Laurentii*" is rarely found, and near the border of the wetland, "*Musmfa cecropioidas*" with umbrella-shaped leaves flourishes (Figure3.2 31(1)). As *Lasimirpha senegalensis* flourished in the wetland, the wetland boundaries were characterized by "*Musmfa cecropioidas*" and "*Lasimirpha senegalensis*" (Figure3.2 31(2)). A sandy peat bed with a thickness of about 40cm was confirmed by boring (Figure3.2 30Figure3.2 31 (3)). In addition, logging is progressing in the wetlands, and secondary forests are growing rapidly, but it appears that they were cut again for firewood charcoal (Figure3.2 31(4)). In the peatland map of Congopeat, this area is considered to be peatland. Peat of 40cm thickness was found near the border of the peatland, but the lowest peat thickness must be defined for the Congopeat peat map to be evaluated.

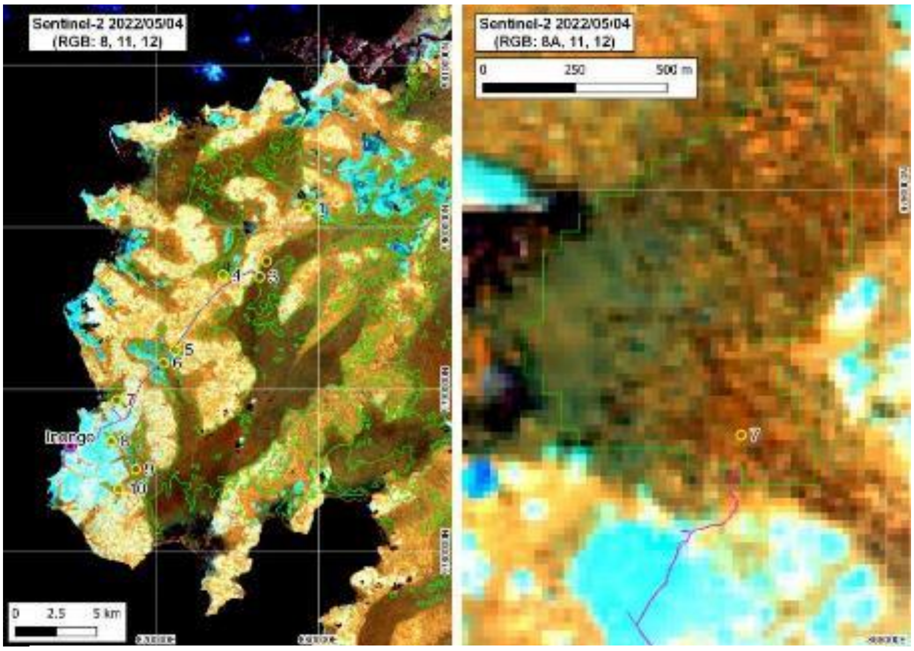


Figure3.2 30 Survey site in Inongo district (No.7)

Figure3.2 31 Status of vegetation and peat boring at Survey site (No.7) in Inongo district

3.2.4 Mapping manual in Peru

The mapping methodology for a technical collaboration project conducted in Peru utilizes optical sensors for Ucayari and San Martin. Therefore, in this fundamental investigation, a technique using microwaves was developed, and the result was summarized as an updated version of the manual prepared in the technical collaboration project .

The effectiveness of PALSAR was investigated at two peat sites in San Martin. In the northwestern part of Moyobamba, 1) in the northwestern district of Yantaro, a peat layer of 2m thickness was confirmed by drilling survey, and there are pure Aguaje forests and mixed forests of Renaco. Second, 2) in the northeastern district of San Fernando, a peat layer of 2m thickness was confirmed by drilling survey, and mainly consisted of mixed forests of Aguaje and Renaco.

1) Northwestern Yantaro

In the southeastern part of the Yantaro northwestern district, pure Aguaje forest extracted from the spectral analysis of Sentinel-2 (09/26/2019) was distributed. Ten 90mx90m ranges were set, and the median, maximum and minimum values within each box and the range of mixed forest distributed in the northwestern part (90mx90m at 10 locations) were compared (Figure3.2.32, Figure3.2 33). The comparative images are shown below.

	Observation date	Mode/Polarization	Rainy/dry season
1	2006/12/06	FBS/HH	Rainy season
2	2007/06/08	FBD/HH	Dry season
3	2007/06/08	FBD/HV	Dry season

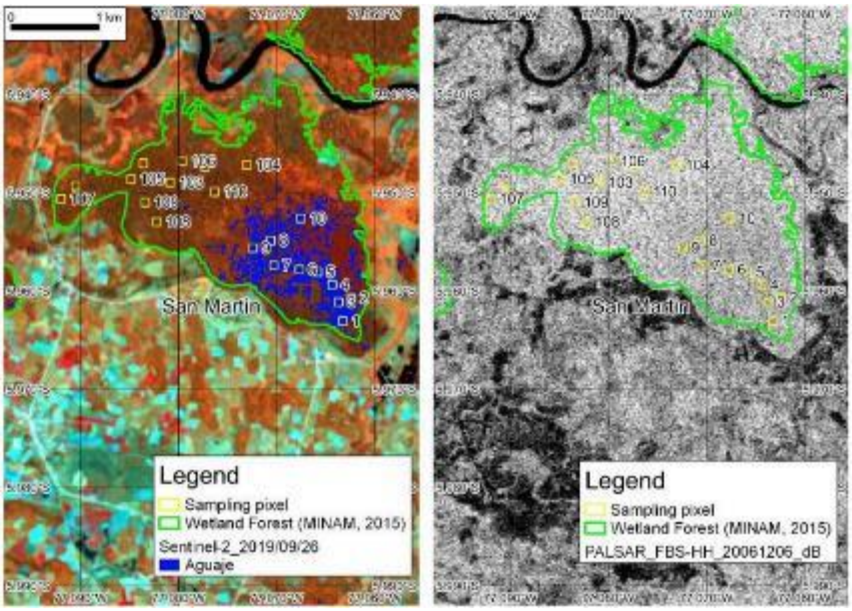


Figure3.2 32 Images of Sentinel-2 (left) and PALSAR/FBS-HH (right) in Yantaro northwest district

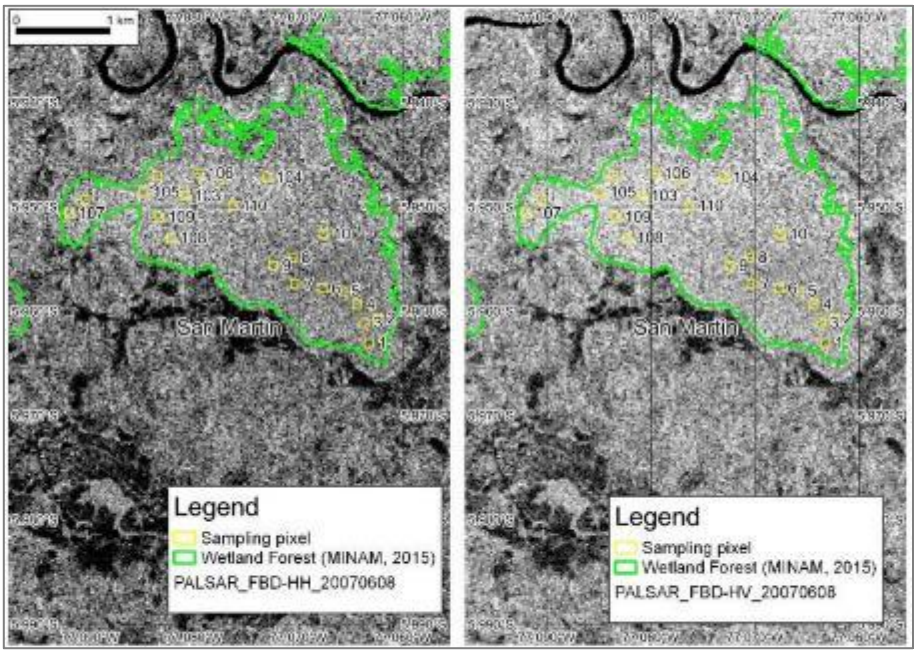
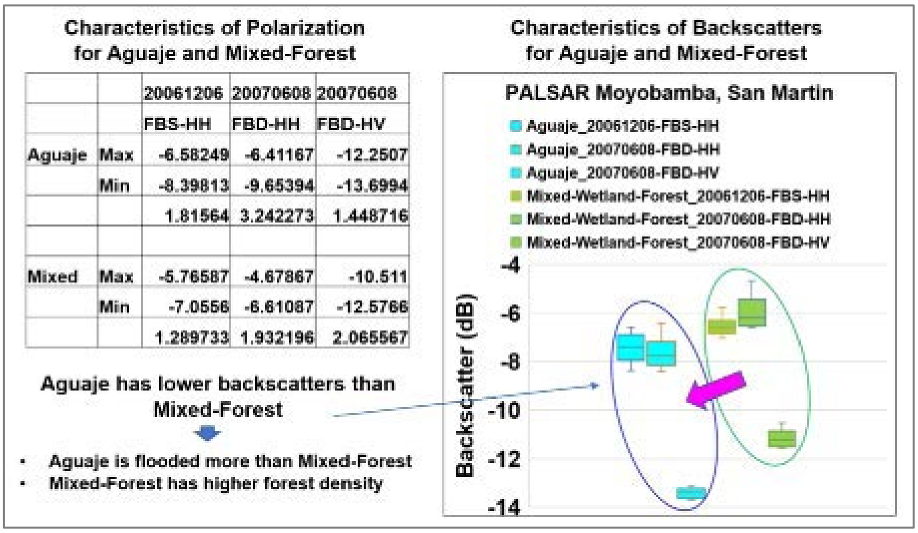


Figure3.2 33 PALSAR/FBD-HH (left) and PALSAR/FBD-HV (right) for Yantaro district

PALSAR/FBS-HH images also showed no extreme differences between PALSAR/FBD-HH and HV, Aguaje and mixed forests, but the following trends were observed in the 10 boxes.



		20061206	20070608	20070608
		FBS-HH	FBD-HH	FBD-HV
Aguaje	Max	-6.58249	-6.41167	-12.2507
	Min	-8.39813	-9.65394	-13.6994
		1.81564	3.242273	1.448716
Mixed	Max	-5.76587	-4.67867	-10.511
	Min	-7.0556	-6.61087	-12.5766
		1.289733	1.932196	2.065567

Figure3.2 34 Polarization characteristics of Aguaje forest and mixed forest

(1) The backscatter of Aguaje is relatively lower than that of mixed forest

(2) Horizontally polarized HH has a wide range of backscatter for Aguaje

(3) For horizontally polarized HH and cross-polarized HV, the backscatter of Aguaje is narrower.

Possible reasons for (1) are that Aguaje has a larger flooded area, and that mixed forests have a higher forest density. As for (2) and (3), possible reasons include the effects of volume scattering and double bounce, in which microwaves reflected at the water surface are reflected by tree trunks.

However, it is necessary to consider other locations, as it was observed that Aguaje showed characteristics of relatively low backscatter values, such as lower backscatter values compared to mixed forests.

2) Northeastern San Fernando

In this district, Aguaje flooded forests were newly extracted from Sentinel-2 and Landsat-8 images. In the map of MINAM (2015), locations that were not extracted as flooded forests were extracted, and in the drilling survey, a peat layer of 183cm thickness was confirmed (Figure3.2 35. Further, the location of backscatter above -6dB in PALSAR2/FBD-HH polarization roughly coincides with Aguaje flooded forests. This is similar to the effectiveness of PALSAR/FBS-HH polarization observed in the northwestern region of Yantaro.

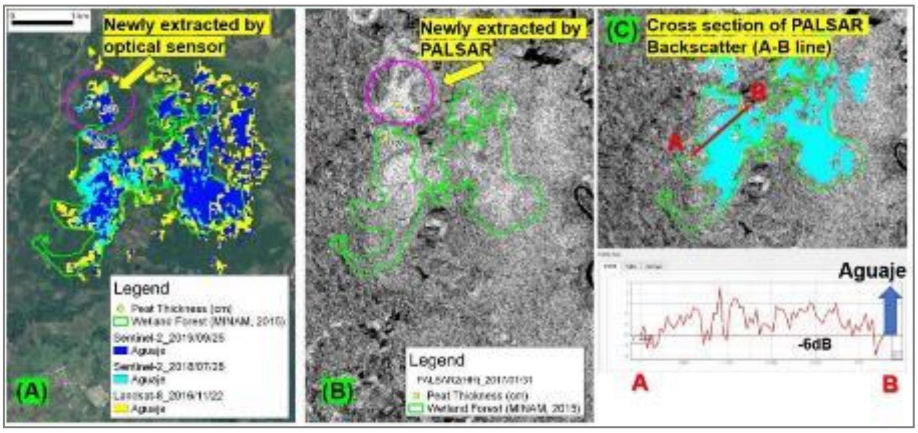


Figure3.2 35 Characteristics of optical sensors and microwaves in a flooded forest in the northeast district of San Fernando

It was confirmed that PALSAR/FBS-HH polarization was effective in the northwestern region of Yantaro, but effectiveness in FBD/HH was also confirmed in this region (Figure3.2 36(1)). On the other hand, in the case of PALSAR/FBD-HV polarization, Aguaje flooded forests do not show a clear difference in backscatter between flooded forests and the surrounding vegetation. However, the HH polarization/HV polarization ratio tends to emphasize HH polarization characteristics and Aguaje flooded forests (Figure3.2 36(2) and (3)).

In addition, comparing eight different scenes for PALSAR/FBS-HH polarization, it can be confirmed that the backscatter of Aguaje flooded forests is clearly different from that of the surrounding vegetation. Since the observations were made during the rainy season (October to March), it is probable that features of double bounce emerged (Figure3.2 37). As described above, the effectiveness of PALSAR/FBS-HH polarization was confirmed in this area too, as in the northwestern district of Yantaro.

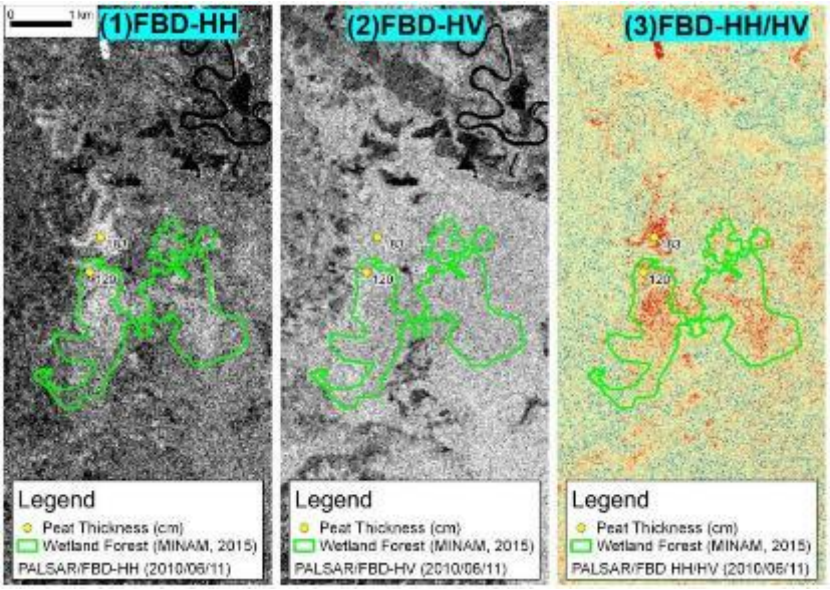


Figure3.2 36 Characteristics of PALSAR/FBD-HH and FBD-HV in the northeast area of San Fernando District

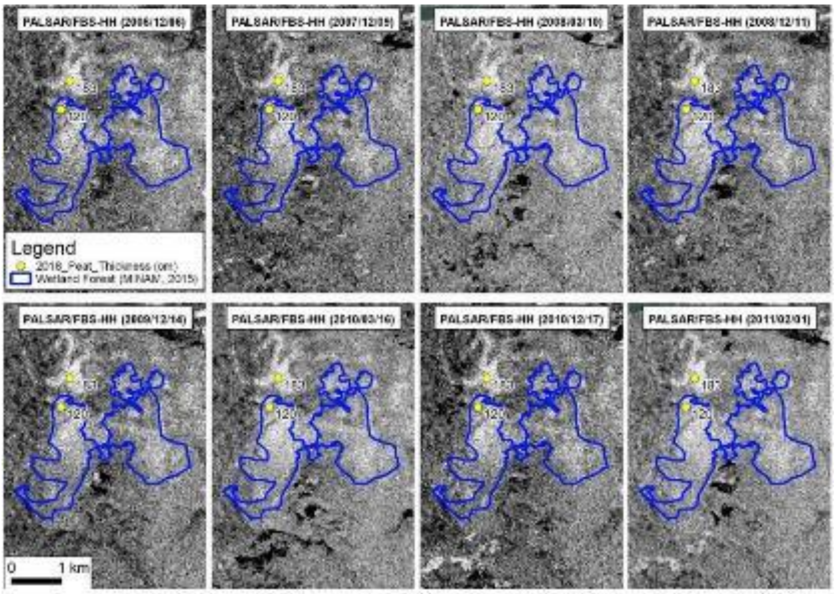


Figure3.2 37 Characteristics of PALSAR/FBS-HH polarization in the northeast area of San Fernando (8 periods)

As described above, PALSAR/FBS-HH polarization can extract Aguaje flooded forest by the double bounce effect in images of the rainy season. On the other hand, in many cases, the characteristics of PALSAR/FBS-HH polarization do not appear. This may be attributed to the water level of the flooded area and the density of Aguaje forest. For example, Figure 3.2.38 is a Sentinel-2 image and a PALSAR/FBS-HH polarization image of Cunchuri district located in central Ucayari. In Sentinel-2 images, spectral analysis revealed that Aguaje forests were extracted in the polygons of (2015) (Figure 3.2.38, left). However, in the right-hand PALSAR/FBS-HH image, the features of backscattering intensity are unclear and the effect of double bounce is not seen. Therefore, the PALSAR/FBS-HH polarization image may or may not show the double bounce effect, depending on where the image was acquired, even in the rainy season. Therefore, the effect of PALSAR/FBS-HH polarization was evaluated for the Aguaje flooded forests extracted by optical sensors.

Figure3.2 38 shows the Sentinel-2 image (left) and PALSAR/FBS-HH polarization (right) in the Cunchuri district, Ucayali Region, where the effect of PALSAR/FBS-HH polarization is indicated by 'A' if the effect is evident, and 'B' if the effect is unclear (Table 3.2 4). The distribution of Aguaje flooded forests and the PALSAR/FBS-HH range used are shown in Figure3.2 38.

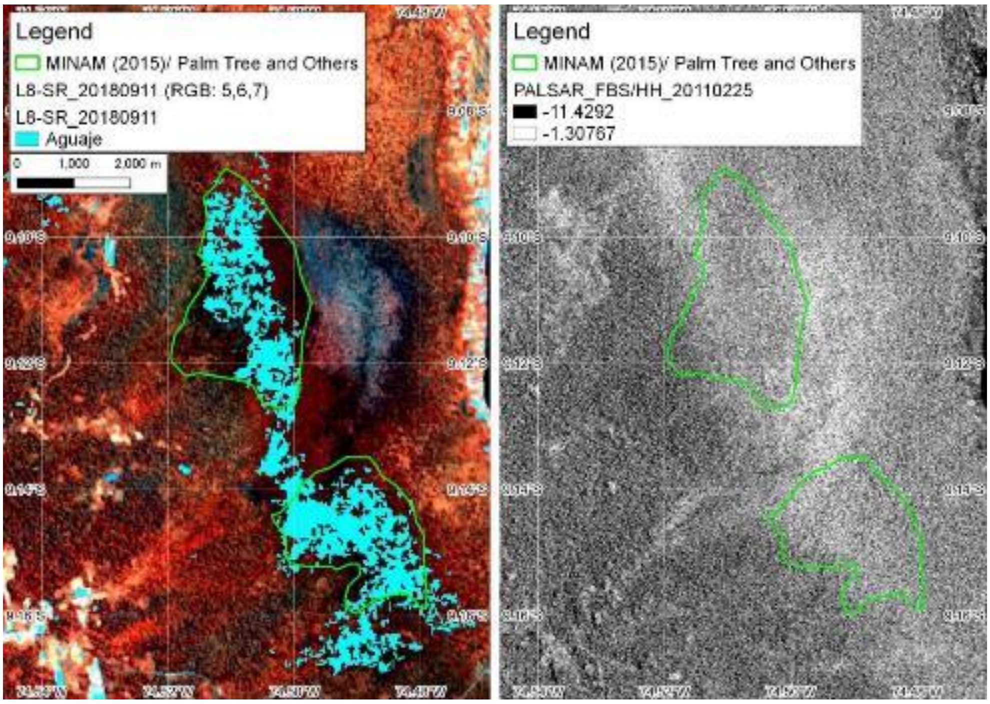


Figure3.2 38 Sentinel-2 image of Cunchuri District, Ucayari (left), PALSAR/FBS-HH polarization (right)

Table3.2 4 Applicability of PALSAR images and area of Aguaje flooded forests in San Martin

ID	Forest Type in MINAM(2015)	Shape_Area (ha)	Aguajales by Optical Sensors	Effectiveness of PALSAR/FBS
1	Bosque inundable de palmeras	10,372	Yes	A
2	Bosque inundable de palmeras	6,960	Yes	A
3	Bosque inundable de palmeras	6,543	Yes	A
4	Bosque inundable de palmeras	4,354	Yes	A
5	Bosque inundable de palmeras	3,014	Yes	A
6	Bosque inundable de palmeras	2,400	Yes	B
7	Bosque inundable de palmeras	2,221	Yes	A
8	Bosque inundable de palmeras	2,187	No	No
9	Bosque inundable de palmeras	1,882	Yes	A
10	Bosque inundable de palmeras	1,689	Yes	A
11	Bosque inundable de palmeras	1,541	Yes	A
12	Bosque inundable de palmeras	1,532	Yes	A
13	Bosque inundable de palmeras	1,467	Yes	A
14	Bosque inundable de palmeras	882	Yes	A
15	Bosque inundable de palmeras	873	Yes	B
16	Bosque inundable de palmeras	855	Yes	A
17	Bosque inundable de palmeras	774	Yes	A
18	Bosque inundable de palmeras	766	Yes	A
19	Bosque inundable de palmeras	712	Yes	A
20	Bosque inundable de palmeras	675	Yes	A
21	Bosque inundable de palmeras	655	Yes	B
22	Bosque inundable de palmeras	642	Yes	A
23	Bosque inundable de palmeras	638	Yes	A
24	Bosque inundable de palmeras	634	Yes	B
25	Bosque inundable de palmeras	625	Yes	B
26	Bosque inundable de palmeras	612	yes	A
27	Bosque inundable de palmeras	565	Yes	A
28	Bosque inundable de palmeras	562	Yes	A
29	Bosque inundable de palmeras	540	Yes	A
30	Bosque inundable de palmeras	480	Yes	A
31	Bosque inundable de palmeras	472	No	No
32	Bosque inundable de palmeras	451	Yes	B
33	Bosque inundable de palmeras	450	No	No
34	Bosque inundable de palmeras	446	Yes	B
35	Bosque inundable de palmeras	427	Yes	A
36	Bosque inundable de palmeras	413	Yes	B
37	Bosque inundable de palmeras	392	Yes	A
38	Bosque inundable de palmeras	389	Yes	A
39	Bosque inundable de palmeras	385	Yes	B
40	Bosque inundable de palmeras	380	Yes	A
41	Bosque inundable de palmeras	377	No	No
42	Bosque inundable de palmeras	346	Yes	B
43	Bosque inundable de palmeras	329	Yes	B
44	Bosque inundable de palmeras	329	Yes	B
45	Bosque inundable de palmeras	328	No	No
46	Bosque inundable de palmeras	324	Yes	B
47	Bosque inundable de palmeras	320	No	No
48	Bosque inundable de palmeras	310	Yes	A
49	Bosque inundable de palmeras	303	Yes	B

ID	Forest Type in MINAM(2015)	Shape_Area (ha)	Aguajales by Optical Sensors	Effectiveness of PALSAR/FBS
50	Bosque inundable de palmeras	300	Yes	B
51	Bosque inundable de palmeras	282	Yes	A
52	Bosque inundable de palmeras	261	No	No
53	Bosque inundable de palmeras	258	Yes	A
54	Bosque inundable de palmeras	229	Yes	B
55	Bosque inundable de palmeras	212	Yes	A
56	Bosque inundable de palmeras	204	Yes	A
57	Bosque inundable de palmeras	200	Yes	B
58	Bosque inundable de palmeras	200	Yes	B
59	Bosque inundable de palmeras	195	No	No
60	Bosque inundable de palmeras	189	Yes	A
61	Bosque inundable de palmeras	166	No	No
62	Bosque inundable de palmeras	165	Yes	A
63	Bosque inundable de palmeras	157	No	No
64	Bosque inundable de palmeras	149	Yes	B
65	Bosque inundable de palmeras	146	No	No
66	Bosque inundable de palmeras	137	Yes	A
67	Bosque inundable de palmeras	132	Yes	B
68	Bosque inundable de palmeras	128	Yes	A
69	Bosque inundable de palmeras	125	Yes	B
70	Bosque inundable de palmeras	124	No	No
71	Bosque inundable de palmeras	122	Yes	B
72	Bosque inundable de palmeras	119	Yes	B
73	Bosque inundable de palmeras	119	No	No
74	Bosque inundable de palmeras	118	No	No
75	Bosque inundable de palmeras	109	Yes	B
76	Bosque inundable de palmeras	107	No	No
77	Bosque inundable de palmeras	103	No	No
78	Bosque inundable de palmeras	103	Yes	A
79	Bosque inundable de palmeras	100	No	No
80	Bosque inundable de palmeras	99	Yes	B
81	Bosque inundable de palmeras	99	Yes	A
82	Bosque inundable de palmeras	99	Yes	A
83	Bosque inundable de palmeras	97	No	No
84	Bosque inundable de palmeras	96	Yes	B
85	Bosque inundable de palmeras	96	Yes	B
86	Bosque inundable de palmeras	88	No	No
87	Bosque inundable de palmeras	81	No	No
88	Bosque inundable de palmeras	73	Yes	B
89	Bosque inundable de palmeras	71	Yes	B
90	Bosque inundable de palmeras	69	Yes	A
91	Bosque inundable de palmeras	66	Yes	B
92	Bosque inundable de palmeras	65	Yes	B
93	Bosque inundable de palmeras	62	Yes	A
94	Bosque inundable de palmeras	60	No	No
95	Bosque inundable de palmeras	60	Yes	B
96	Bosque inundable de palmeras	59	Yes	B
97	Bosque inundable de palmeras	59	No	No
98	Bosque inundable de palmeras	58	No	No
99	Bosque inundable de palmeras	58	No	No

Table3.2 5 Area of Aguaje flooded forests in Ucayari Province, and applicability of PALSAR images

ID	Forest Type in MINAM(2015)	Shape_Area (ha)	Aguajales by Optical Sensors	Effectiveness of PALSAR/FBS
1	Bosque inundable de palmeras	182	Yes	A
2	Bosque inundable de palmeras	70	Yes	B
3	Bosque inundable de palmeras	799	Yes	A
4	Bosque inundable de palmeras	210	Yes	B
5	Bosque inundable de palmeras	206	Yes	A
6	Bosque inundable de palmeras	696	Yes	A
7	Bosque inundable de palmeras	339	Yes	A
8	Bosque inundable de palmeras	2,557	Yes	A
9	Bosque inundable de palmeras	891	Yes	A
10	Bosque inundable de palmeras	212	Yes	B
11	Bosque inundable de palmeras	231	Yes	A
12	Bosque inundable de palmeras	362	Yes	A
13	Bosque inundable de palmeras	60	Yes	B
14	Bosque inundable de palmeras	154	Yes	A
15	Bosque inundable de palmeras	22	Yes	A
16	Bosque inundable de palmeras	41	Yes	B
17	Bosque inundable de palmeras	51	Yes	A
18	Bosque inundable de palmeras	207	Yes	A
19	Bosque inundable de palmeras	366	Yes	A
20	Bosque inundable de palmeras	63	Yes	A
21	Bosque inundable de palmeras	263	Yes	A
22	Bosque inundable de palmeras	120	Yes	A
23	Bosque inundable de palmeras	117	Yes	A
24	Bosque inundable de palmeras	59	Yes	A
25	Bosque inundable de palmeras	117	Yes	A
26	Bosque inundable de palmeras	163	Yes	A
27	Bosque inundable de palmeras	70	Yes	B
28	Bosque inundable de palmeras	162	Yes	A
29	Bosque inundable de palmeras	41	Yes	B
30	Bosque inundable de palmeras	506	Yes	B
31	Bosque inundable de palmeras	24	Yes	B
32	Bosque inundable de palmeras	5,518	Yes	A
33	Bosque inundable de palmeras	430	Yes	A
34	Bosque inundable de palmeras	175	Yes	A
35	Bosque inundable de palmeras	4,998	Yes	A
36	Bosque inundable de palmeras	106	Yes	A
37	Bosque inundable de palmeras	40	Yes	A
38	Bosque inundable de palmeras	264	Yes	B
39	Bosque inundable de palmeras	105	Yes	A
40	Bosque inundable de palmeras	445	Yes	A
41	Bosque inundable de palmeras	3,441	Yes	A
42	Bosque inundable de palmeras	77	Yes	A
43	Bosque inundable de palmeras	76	Yes	B
44	Bosque inundable de palmeras	360	Yes	B
45	Bosque inundable de palmeras	580	Yes	B
46	Bosque inundable de palmeras	616	Yes	B
47	Bosque inundable de palmeras	45	Yes	B
48	Bosque inundable de palmeras basimontano	64	Yes	B
49	Bosque inundable de palmeras basimontano	6	Yes	B
50	Bosque inundable de palmeras basimontano	520	Yes	A
51	Bosque inundable de palmeras basimontano	6	No	B
52	Bosque inundable de palmeras basimontano	12	No	B
53	Bosque inundable de palmeras basimontano	164	No	B
54	Bosque inundable de palmeras basimontano	16	No	B
55	Bosque inundable de palmeras basimontano	109	No	B
56	Bosque inundable de palmeras basimontano	7	No	B
57	Bosque inundable de palmeras basimontano	30	No	B
58	Bosque inundable de palmeras basimontano	3,953	Yes	A
59	Bosque inundable de palmeras basimontano	32	No	B
		31,179		

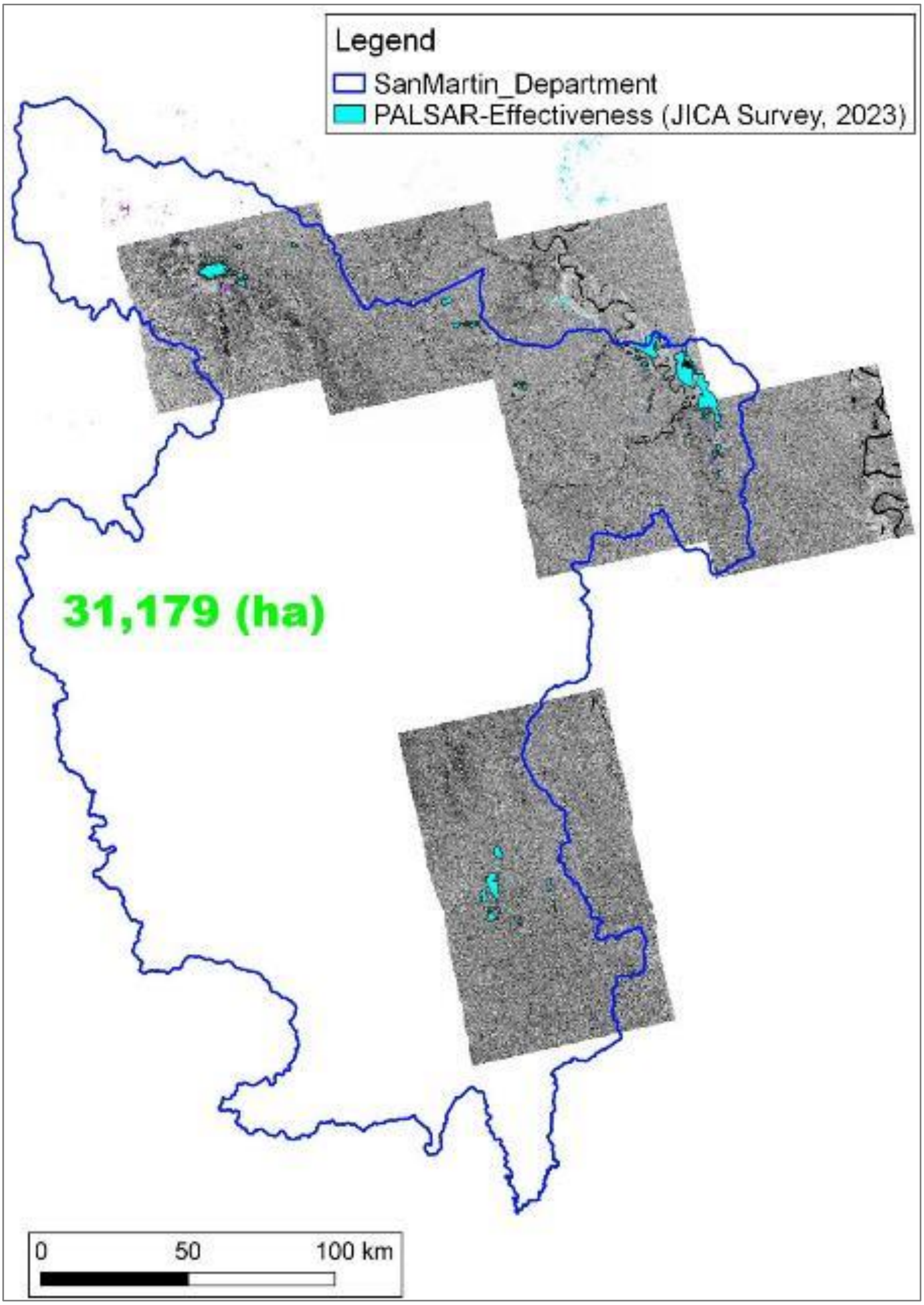


Figure3.2 39 PALSAR image - analysis location in San Martin State

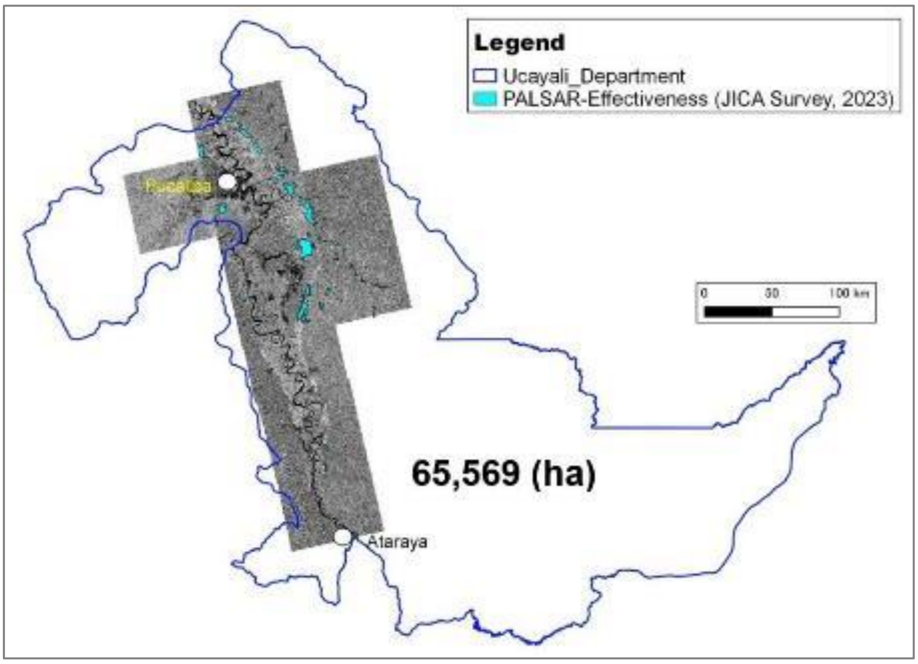


Figure3.2 40 PALSAR image - analysis position in Ucayari Province

3.3 Challenges, lessons and needs in peat mapping

As previously mentioned, on peatlands on the Congolese side, the spectral characteristics of peatland vegetation could be studied using teacher landuse maps (Mbandaka's detailed peatland maps), and peatland potential maps could be produced. On the other hand, in the Congo peatlands, the spectral characteristics of peatland vegetation cannot be studied because teacher landuse maps are not available, and peatland potential maps cannot be produced with the same accuracy as for the Congolese people. Thus, the availability of teacher landuse maps for peatland mapping is a challenge.

Chapter 4. PROGRAM DEVELOPMENT AND VERIFICATION OF GROUNDWATER LEVEL ESTIMATION MODEL BASED ON HIGH-PRECISION SOIL MOISTURE MAP

4.1 Outline of the program to be developed

4.1.1 Program development

Program development is expected to be a core result of this work, but on the other hand, it was an urgent task to clarify specific development policies while considering a limited work period. Japan continued to support exchanges of opinions, including technical meetings with the main members of a separate Domestic Support Committee and academic experts with expertise in peat management in Indonesia. The items agreed upon at previous meetings and other meetings will be summarized by five major outcomes.

1) Soil moisture mapping

WRF (Weather Research Forecast) groundwater level estimation of 1 km resolution is performed using the model, and future prediction is not included. In addition, SAR images will be combined with the aim of achieving a 1 km resolution with high accuracy (about 10 m). The basic policy for using SAR images aims at a high precision of water level distribution based on Level 2.1 products and backscatter factor, and depending on the result, polarimetric analysis, InSRA analysis, and gamma analysis using Level 1.1 will also be examined on a trial basis.

2) Groundwater level estimation model

Basically, it is linked to the work of 1), and future prediction is not included.

3) GHG emission estimation model by groundwater level estimation model

It is noted that, especially in the development of a methane emission estimation model, experimental parameters in the chamber are not used, and that the field observation data in the flux tower is used.

4) Model for predicting the frequency and intensity of peat fires

The frequency and intensity of peat fires that occurred in the past determine the likelihood of peat fires recurring. Subdivision of above-ground vegetation closely related to this is necessary, and specifically, the development of technology to classify *keselampasaran* and ferns is required. A promising technology for this purpose is the use of the ISS onboard hyperspectral sensor "HISUI". However, it is assumed that the hyperspectral sensor will not be utilized for re-commissioned work, and that drone images and existing data will basically be used.

5) Peatland bordering (boundary area) estimation model

Note that the term "bordering" here means to refine the area outside the existing peat map, and at the same time, we aim to subdivide (three types) the area of the former peat fire site in accordance with past intensity and current conditions. Similar to 4) above, the use of hyperspectral sensors is expected. However, as a subcontracting operation, bordering will be performed using existing vegetation maps and additional drone images based on the soil moisture map described in 1) above. It should be noted that the use of hyperspectral sensors is a matter for consideration.

4.1.2 Confirmation of attainment points related to program development

Specific results of program development undertaken in this work were discussed with experts. As a result, the following problems were clarified.

- Based on a past literature survey of SAR data, it is considered difficult to obtain accuracy as high as that expected in the initial stage. Estimating soil moisture and underground moisture with high accuracy is inevitably limited to good conditions such as imaging conditions and surface conditions.
- Given the effectiveness of future acquisition of SAR data and the limited utilization of SAR data, it is considered premature to position SAR as a technical element proposed to the Indonesian government in the next technical assistance project (hereinafter referred to as "LULUCF Technical Professional Project"), which is expected to utilize the results of this project.
- On the other hand, regarding WRF which has already achieved a certain result, high-precision to 1 km mesh is possible, and it is concluded that it is reasonable to position this as a technology to propose.

An overview of the above problems is shown below.

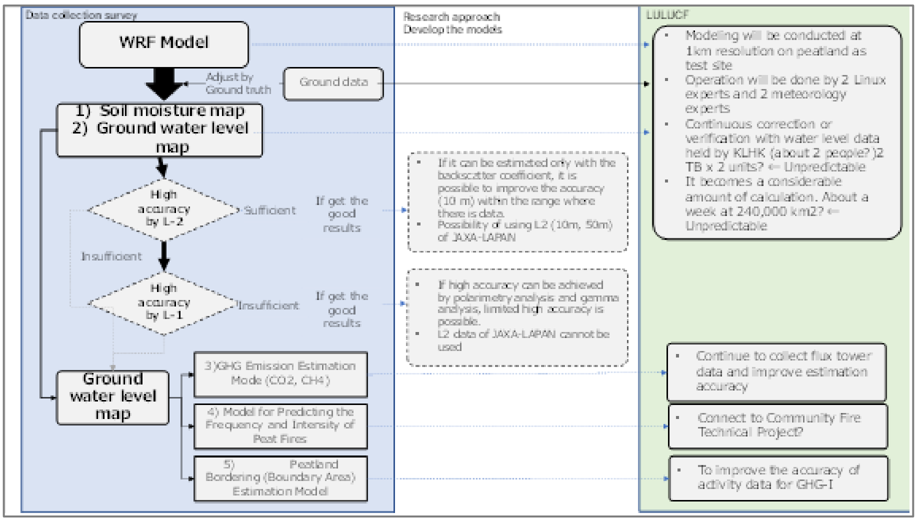


Figure4.1 1 Delivery of technical elements and LULUCF projects to be developed in this survey

On the above draft arrangement, an online conference was held between the parties concerned, mainly the domestic support committee members, and the validity of the conference was discussed. The results are shown below.

- Recognizing the limitations of the use of SAR, the Government of Indonesia will carry out development with an awareness of the significance of verifying its performance, with a view to ensuring that the Government of Indonesia properly understands SAR.
- It is possible to measure the ground subsidence of peat by the photogrammetry technique using drone aerial reconnaissance images, and availability will be considered together with SAR technology.
- If soil moisture mapping can be performed in units of 1 km by using WRF, it may be considered as a main axis.

・ In view of the above, program development was undertaken by a domestic subcontractor (Kyoto University).

4.1.3 Relationship between the model maps to be developed and the image of its output

The relation between the model maps developed through this study is shown in the following figure.

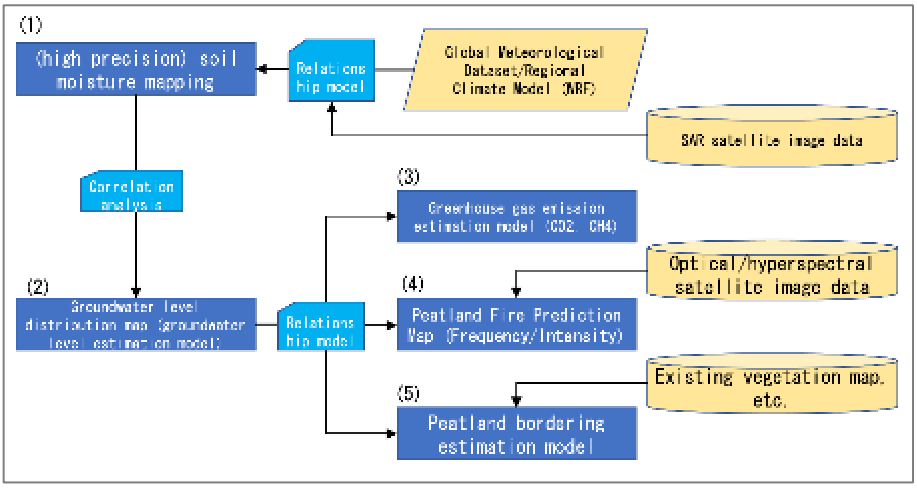


Figure4.1 2 Overview of program development based on assumed (high-precision) soil moisture mapping

In order to create each model map, there is necessary data (input data), and each map is output based on the data. The following shows the relation between the data (input data) required to create a series of model maps and the corresponding maps (output data).

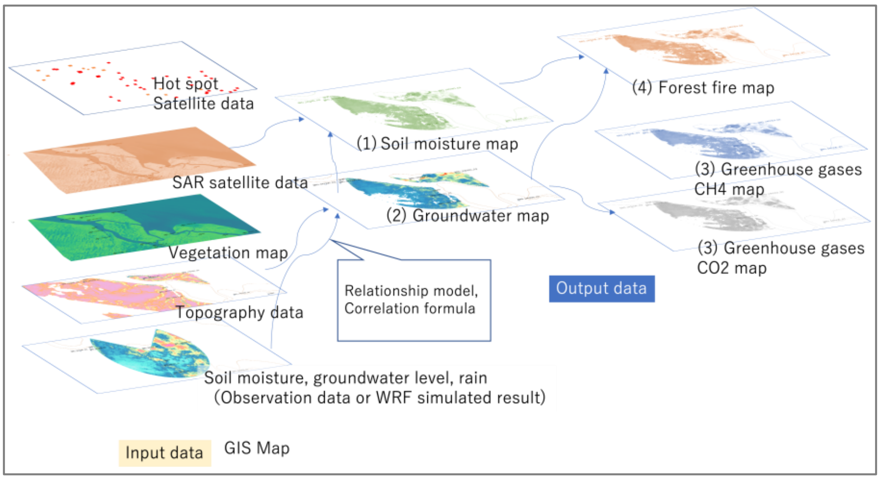


Figure4.1 3 Image of layers in a map display system

Table4.1 1 Relationship between input data to map display system and output results

Input data	Output data	
WRF simulation results	(1) Soil moisture map	Archive from SAR Analysis Results
SAR satellite image data	(2) Groundwater level map	Archive from WRF Simulation Results
Field observation data (soil moisture, groundwater level, rainfall, etc.)	(3) Peat area fire forecast map	Calculate KBDI from GSMaP
Vegetation distribution map	(4) CO_2 and CH_4 maps of greenhouse gases	Archive if mapped
	(5) Peatland bordering	Display existing peatland maps and results of (1) to (4) superimposed

4.1.4 Data used in program development

The main data collected in the development of this program are as follows.

(1) Observed data

Table4.1 2 Data obtained for program development

From	Term	Temporal resolution	Number of stations	Item	Area	Source
BMKG ground observation	2015/1～2021/4	Day 1	68	[1] Temperature, [2] Precipitation, [3] Solar radiation time, [4] Humidity, [5] Wind speed, [6] Wind direction	Sumatra、Kalimantan	BMKG
BMKG radiosonde	2015/1～2021/4	Day 1	10	[1] Temperature, [2] Wind speed, [3] Wind direction, [4] Atmospheric pressure, [5] Humidity, etc.	Sumatra, Kalimantan airports	BMKG
BRG Groundwater Level, etc.	2017/1～2019/3	10 minutes	43	[1] Temperature, [2] soil moisture content, [3] groundwater level, [4] precipitation	Sumatra、Kalimantan	BPPT
	2018/10～2020/5	1 hour	173	[1] Soil water content, [2] groundwater level, [3] precipitation	Sumatra、Kalimantan	BPPT
	2018/10～2021/3	1 hour	8	[1] Soil water content, [2] groundwater level, [3] precipitation	Riau	BPPT
	2019/7～2021/11	1 hour	3	[1] Soil water content, [2] groundwater level, [3] precipitation	Riau	BPPT
Midori	2012～2020	10 minutes	6	[1] Water level (rivers and groundwater), [2] Precipitation	Sumatra、Kalimantan	Greenery engineering

(2) Measured data at sites

Overview	Term	Max. connected nodes	Item	Area
Rainy season survey	2022/5	11	[1] Soil water content, [2] soil temperature, [3] soil sampling, [4] vegetation, [5] land use and water system survey by drones, [6] peat thickness by GPR, [7] boring, and [6] hearing survey (for local inhabitants who control BRG observation station. The question items are fire/vegetation history, ground subsidence, maintenance status of observation station, etc.).	Riau
Dry season survey	2022/8	11	[1] Soil water content, [2] Soil temperature, [3] Survey of land use and water system by drones and fire survey, [4] Peat thickness by GPR, [5] Boring	Riau

4.1.5 Areas where field surveys were conducted

In the development of this program, field survey by the subcontractor was carried out twice, in the rainy season (May, 2022) and dry season (August, 2022).

Figure4.1 4 Survey area for program developmentand Figure4.1 3. Figure4.1 4 show the area, location information, schedule, and survey items of the field survey. Field surveys were conducted at up to 11 of 1 5 BRG stations in Riau, Indonesia.

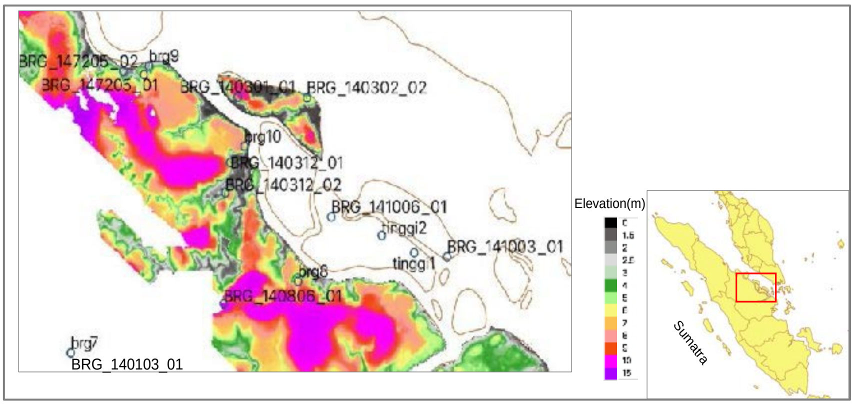


Figure4.1 4 Survey area for program development

N.B.: 140103_01 and brg7 are about 600 m apart.

Table4.1 3 Location of the BRG station

BRG Observatory	(latitude, longitude)	Region	Type of equipment
1(140312_01)	1.24083, 102.06222	Bengkalis	SIPALAGA
2(brg10)	1.30934, 102.13142		SIPALAGA
3(brg9)	1.65019, 101.66923	Dumai	SESAME
4(147205_01)	1.61361, 101.64554		SIPALAGA
5(140301_01)	1.51944, 102.09917	Bengkalis	SIPALAGA
6(140302_02)	1.51639, 102.43306		SIPALAGA
7(141006_01)	1.01217, 102.55142	Meranti	SIPALAGA
8(141003_01)	0.84342, 103.1117		SIPALAGA
9(140806_01)	0.64428, 102.03163	Siak	SIPALAGA
10(140103_01)	0.43498, 101.29881	Kampar	SIPALAGA
11(brg7)	0.43490, 101.29379		SESAME

Table4.1 4 Survey date and items in the rainy season

Date	Name of BRG station or region	Survey items					
		Soil moisture/ soil temperature	Groundwater level (major)	Boring	Underground Radar	land use and water system distance by Drone	Soil sampling
May 17, 2022	1(140312_01)	✓	✓	✓	✓	✓	✓
	2(brg10)	✓			✓	✓	✓
May 18, 2022	3(brg9)	✓	✓		✓	✓	✓
	4(147205_01)	✓	✓	✓	✓	✓	✓
May 19, 2022	5(140301_01)	✓			✓		✓
	6(140302_02)	✓	✓	✓	✓	✓	✓
May 20, 2022	7(141006_01)	✓	✓				✓
May 21, 2022	8(141003_01)	✓	✓	✓			✓
May 22, 2022	9(140806_01)	✓	✓	✓	✓	✓	✓
May 23, 2022	10(140103_01)	✓	✓	✓	✓	✓	✓
	11(brg7)	✓	✓		✓	✓	

NOTE :The survey conducted was marked with a check mark.

Table4.1 5 Survey dates and survey items in the dry season

Date	Name of BRG station or region	Survey items					
		Soil moisture/ soil temperature	Groundwater level (major)	Boring	Underground Radar	land use and water system distance by Drone	Drone fire survey
August 18, 2022	Pralurawan						✓
August 24, 2022	1(140312_01)	✓ (defective TDR sensor. Measured at a later date)	✓	✓	✓		
	2(brg10)	✓ (defective TDR sensor. Measured at a later date)	✓	✓	✓		
August 25, 2022	3(brg9)	✓ (defective TDR sensor. Measured at a later date)	✓	✓	✓		
	4(147205_01)	✓ (defective TDR sensor. Measured at a later date)	✓	✓	✓		
August 26, 2022	5(140301_01)	✓	✓	✓	✓	✓	
	6(140302_02)	✓	✓	✓ (twice)	✓		
August 27, 2022	9(140806_01)	✓	✓	✓	✓		
August 28, 2022	10(140103_01)	✓	✓	✓	✓		
	11(brg7)	✓	✓	Solid ground	Vegetation flourishes		
August 29, 2022	1(140312_01)	✓					
	2(brg10)	✓					
August 30, 2022	3(brg9)	Flooding					
	4(147205_01)	✓					

NOTE: The survey conducted was marked with a check mark.

4.2 High-precision soil moisture map (estimation of groundwater level based on soil moisture)

4.2.1 Study of soil moisture map

Basic data (groundwater level, precipitation) was organized for soil moisture mapping. Data and error data were checked for WRF and SAR matching. Dates that overlap and observations that are obviously strange were omitted.

4.2.1.1 Initial value data used

The default value used is ds083.03 of NCEP/NCAR. Others used default WRF data.

4.2.1.2 Calculation period

October 31, 2018 to December 1, 2018 (rainy season of the year when the El Nino phenomenon occurred)

The simulation result is not used as the initial time in the first 24 hours.

July 31, 2019 to September 1, 2019 and July 31, 2020 to September 1, 2020 are not used because there is no applicable local observation data.

4.2.1.3 Calculation area

As shown in Figure4.1 2, a 27 km mesh area was taken to include all of Indonesia (domain 01), with 9 km mesh (domain 02), 3 km mesh (domains 03 to 05), and 1 km mesh (domains 06 to 10) for the main areas. The time step was 120 seconds.

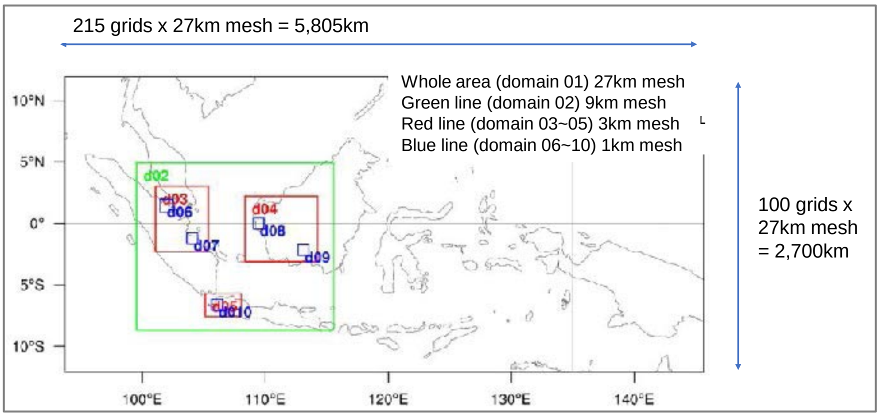


Figure4.2 1 WRF simulation calculation area

The soil moisture content of four layers (0-10 cm, 10-40 cm, 40-100 cm, and 100-200 cm from the ground surface) was extracted from the analysis result of WRF using statistical calculation software R. The results of the soil moisture content estimated by WRF for a certain period during the calculation target period are described below.

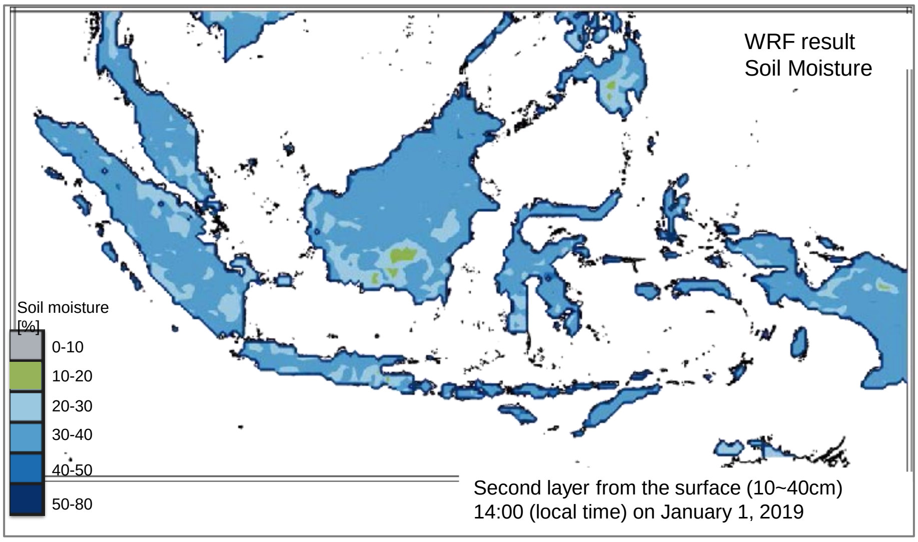


Figure4.2 2 Example of WRF results at 14:00 (local time) on January 1, 2019 (soil moisture content in the second layer from the surface)

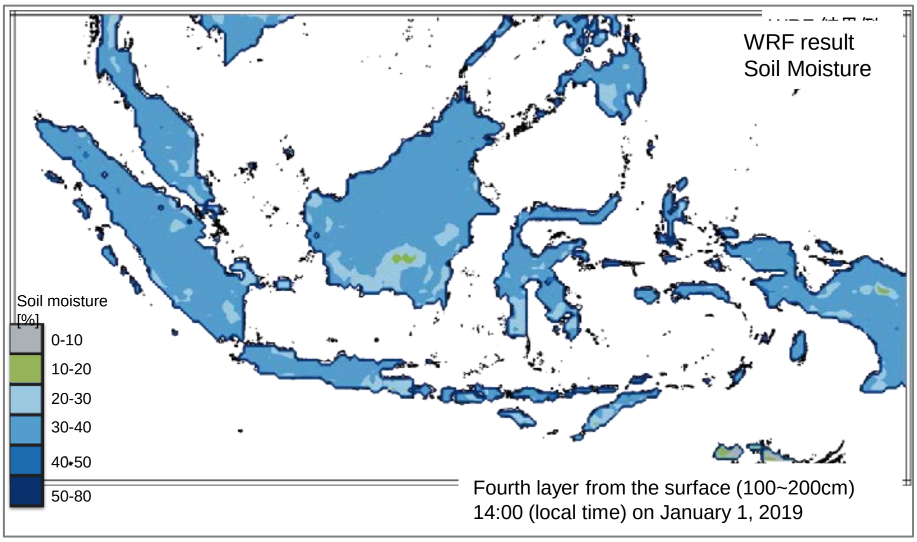


Figure4.2 3 Example of WRF results at 14:00 (local time) on January 1, 2019 (soil moisture content in the fourth layer from the surface)

The results of hourly rainfall by WRF are shown in the figure below.

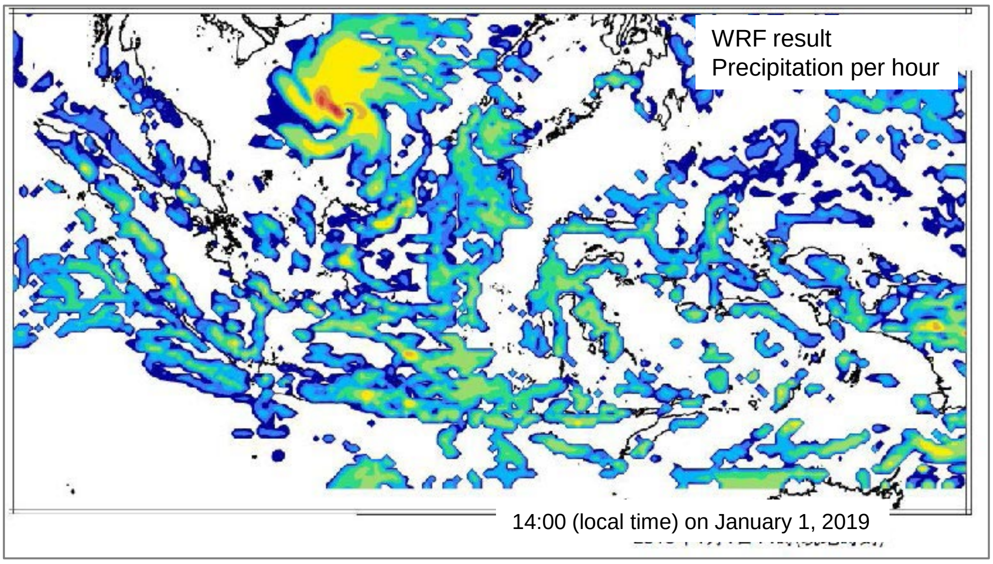


Figure4.2 4 Example of WRF results at 14:00 (local time) on January 1, 2019 (precipitation per hour)

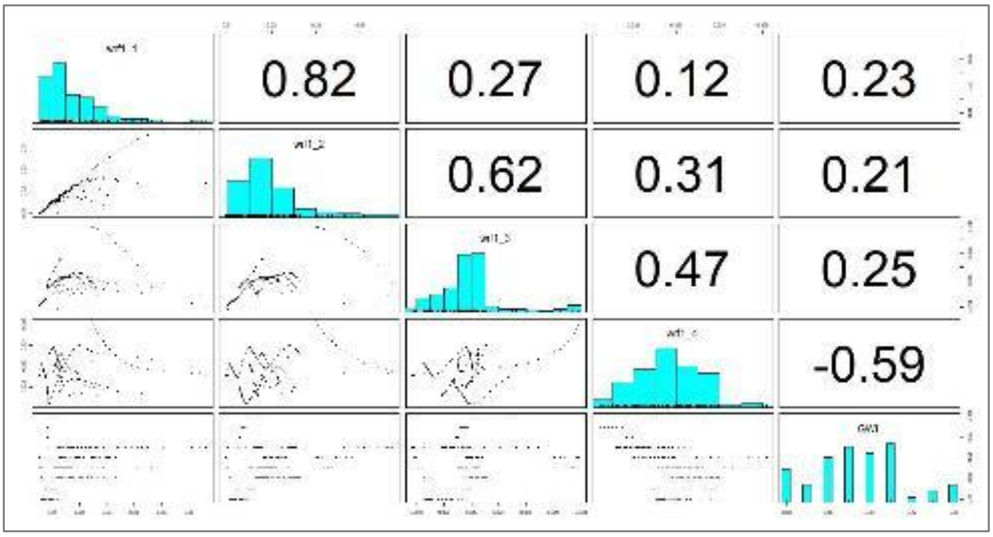
4.2.1.4 Formula to calculate groundwater level from WRF results by multiple regression analysis

Scatter plots of field observation data (groundwater level) and WRF results (soil moisture content) were prepared from the extracted data.

Four window regions of 1×1, 3×3, 9×9, and 27×27 were taken as a center for comparison, and the size of the window region was examined. As a result, among 32 points, the correlation tended to be higher when a large window area was taken, i.e., 3 points in the 1×1 window area, 4 points in the 3×3 window area, 7 points in the 9×9 window area, and 18 points in the 27×27 window area.

Next, optimization of the calculation period in the WRF was performed by comparing the values of 7 days, 10 days, 15 days, 20 days, and 30 days. As a result, there were 3 points on 7 days, 10 points on 10 days, 4 points on 15 days, 10 points on 20 days, and 5 points on 30 days. In other words, there was a wide division between the points where a 10-day calculation should be performed and the points where a 20-day calculation should be performed, but it can also be said that they are scattered.

As an example of a scatter diagram, we show a diagram of the relation between WRF-simulated results and groundwater levels at the Kalbar1 point, where the windows are 1×1 and the WRFs are calculated for 7 days (Figure4.2 **5**). This shows that the correlation between groundwater level and WRF results is 0.23 for the first layer (0-10 cm), 0.21 for the second layer (10-40 cm), 0.25 for the third layer (40-100 cm), and-0.59 for the fourth layer (100-200 cm).



NOTE : Window area 1 × 1, WRF calculation period 7 days

From the top and left, observations of WRF soil moisture level in Layer 1 (0-10 cm), Layer 2 (10-40 cm), Layer 3 (40-100 cm), Layer 4 (100-200 cm), and groundwater level

Numbers are correlation coefficients, bar graphs are daily values, scatter plots are correlation distributions.

Figure4.2 5 Correlation of groundwater level with estimated groundwater content by WRF at Kalbar1

As a result of multiple regression analysis, 26 points (81%) out of 32 points with a determination coefficient exceeding 0.6 and 22 points (68%) with a determination coefficient exceeding 0.7 were found to be excellent results when the optimal window area and the optimal number of calculation days were taken.

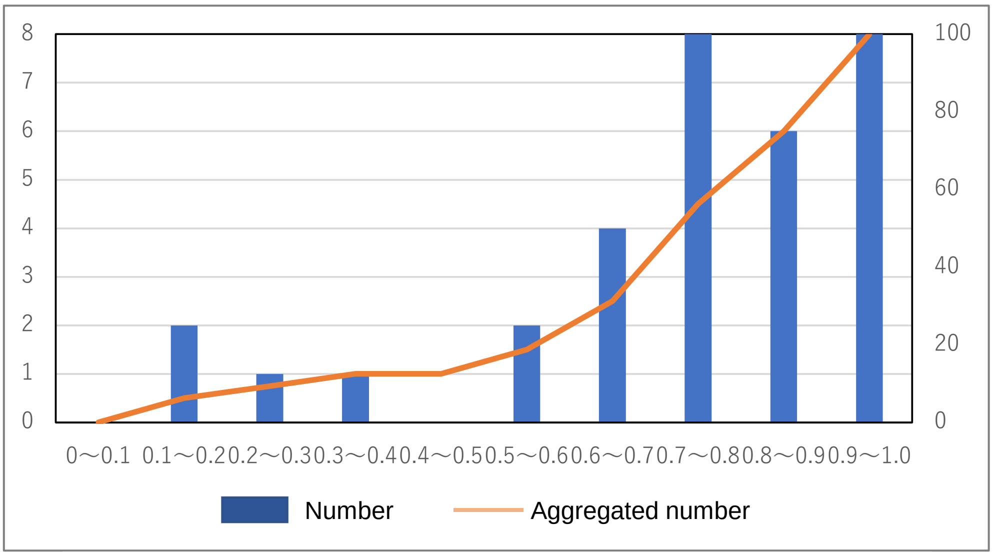


Figure4.2 6 Absolute coefficients for groundwater level estimation by simulation with WRF

In the future, the multiple regression equation over a wide range will be constructed based on this result, when the groundwater level simulation is carried out. The coefficients of the multiple regression equations for determining the groundwater level are as shown in the table below.

Table4.2 1 Multiple regression equations for determining groundwater levels at 32 Locations

			推定式									調整済み決定係数	使用メッシュ	解析日数
1	Seleh2	y=	-0.50613	x$wrf27_2	2.14066	x$wrf27_3	-0.08195	x$wrf27_4	-0.56306			0.9222	27	30
			***		***		*		***					
2	Tinggi1	y=	-0.42590	x$wrf9_2[1:169]	4.17750	x$wrf9_3[1:169]	-20.49830	x$wrf9_4[1:169]	4.83230			0.7399	9	7
			***		***		***		***					
3	Tinggi2	y=	-1.07924	x$wrf27_2[1:169]	1.08012	x$wrf27_3[1:169]	-0.37203					0.1803	27	7
			***		***		***							
4	Batok1	y=	-0.40570	x$wrf27_2[1:361]	3.91870	x$wrf27_3[1:361]	-4.44270	x$wrf27_4[1:361]	-0.88260			0.8633	27	15
			***		***		***		***					
5	Batok2	y=	-1.38390	x$wrf27_2[1:241]	10.86570	x$wrf27_3[1:241]	-32.19080	x$wrf27_4[1:241]	4.48480			0.9399	27	10
			***		***		***		***					
6	Brg2	y=	-0.42480	x$wrf3_1[1:481]	0.56180	x$wrf3_2[1:481]	-1.31100	x$wrf3_3[1:481]	6.90840	x$wrf3_4[1:481]	-2.14030	0.7905	3	20
			**		*		***		***		***			
7	Brg3	y=	-1.94510	x$wrf27_2[1:241]	2.39040	x$wrf27_3[1:241]	12.97170	x$wrf27_4[1:241]	-5.01570			0.5423	27	10
			***		***		***		***					
8	Brg4	y=	-1.02710	x$wrf3_2[1:169]	1.40070	x$wrf3_3[1:169]	-9.71620	x$wrf3_4[1:169]	2.56790			0.9571	3	7
			***		***		***		***					
9	Brg5	y=	0.26990	x$wrf1_2[1:169]	-2.39290	x$wrf1_3[1:169]	-8.25060	x$wrf1_4[1:169]	2.83980			0.7824	1	7
			***				***							
10	Brg6	y=	0.32420	x$wrf27_1[1:169]	-1.68100	x$wrf27_2[1:169]	6.56890	x$wrf27_3[1:169]	-2.69610	x$wrf27_4[1:169]	-1.13350	0.8387	27	7
			*		***		***		*		**			
11	Brg7	y=	0.12949	x$wrf9_1[1:481	-0.53024	x$wrf9_2[1:481]	1.78743	x$wrf9_3[1:481]	-9.04546	x$wrf9_4[1:481]	0.75717	0.8891	9	20
					***		***		***		***			
12	Brg8	y=	0.00124	x$wrf27_2[1:169]	-2.49784	x$wrf27_3[1:169]	3.78859	x$wrf27_4[1:169]	-1.14844			0.3646	27	7
					***		***		***					
13	Brg9	y=	1.65320	x$wrf3_1[1:241]	-1.90640	x$wrf3_2[1:241]	4.20180	x$wrf3_3[1:241]	3.60850	x$wrf3_4[1:241]	-3.08550	0.6151	3	10
			***		**		***		***		***			
14	Brg10	y=	-0.94033	x$wrf9_2[1:481]	1.62951	x$wrf9_3[1:481	-8.06996	x$wrf9_4[1:481]	1.61806			0.8406	9	20
			***		***		***		***					
15	Brg11	y=	0.85051	x$wrf27_2[1:361]	-0.71143	x$wrf27_3[1:361]	3.93249	x$wrf27_4[1:361]	-2.63710			0.9110	27	15
			***		*		***		***					
16	Brg12	y=	0.75919	x$wrf27_1[1:361]	-1.07762	x$wrf27_2[1:361]	4.15239	x$wrf27_3[1:361]	1.41402	x$wrf27_4[1:361]	-2.62140	0.9339	27	15
			**		**		***		***		***			
17	Brg13	y=	-0.92305	x$wrf27_2[1:481]	1.37661	x$wrf27_3[1:481]	4.34887	x$wrf27_4[1:481]	-2.24772			0.9451	27	20
			***		***		***		***					
18	Brg14	y=	0.80537	x$wrf27_1[1:361]	-0.77332	x$wrf27_2[1:361]	2.81841	x$wrf27_3[1:361]	-1.17716	x$wrf27_4[1:361	-0.77055	0.6924	27	15
			***		*		***		***		***			
19	Brg15	y=	0.71354	x$wrf9_1[1:361]	-1.77520	x$wrf9_2[1:361]	4.31049	x$wrf9_3[1:361]	-1.61897			0.7793	9	15
			*		***		***		***					
20	Brg16	y=	-0.75901	x$wrf27_2[1:361]	0.92985	x$wrf27_3[1:361]	2.44876	x$wrf27_4[1:361]	-1.15423			0.9161	27	15
			***		***		***		***					

			推定式									調整済み決定係数	使用メッシュ	解析日数
21	Brg17	y=	-0.73920	x$wrf1_1[1:169]	4.98240	x$wrf1_3[1:169]	-26.66050	x$wrf1_4[1:169]	7.29800			0.7166	1	10
			***		***		***		***					
22	Brg18	y=	2.15700	x$wrf1_2[1:169]	4.59930	x$wrf1_3[1:169]	22.29190	x$wrf1_4[1:169]	-10.03590			0.7431	1	10
			***		***		***		***					
23	Brg19	y=	-1.14470	x$wrf27_1[1:361]	2.96910	x$wrf27_2[1:361]	-3.27100	x$wrf27_3[1:361]	-3.13640	x$wrf27_4[1:361]	0.47070	0.5005	27	15
			**		***		**		***		***			
24	Brg20	y=	0.82920	x$wrf27_1[1:481]	-3.70700	x$wrf27_2[1:481]	11.75660	x$wrf27_3[1:481]	-14.18440	x$wrf27_4[1:481]	1.08200	0.7118	27	20
			*		***		***		***		***			
25	Jambi1	y=	-2.45020	x$wrf3_2[1:169]	-29.49250	x$wrf3_4[1:169]	9.19260					0.8065	3	7
			***		***		***							
26	Kalbar1	y=	0.34820	x$wrf27_1[1:169]	-1.09820	x$wrf27_2[1:169]	8.53510	x$wrf27_3[1:169]	-19.30550	x$wrf27_4[1:169]	3.38500	0.7421	27	7
					**		***		***		***			
27	Kalteng1	y=	0.34096	x$wrf9_2[1:361]	1.93317	x$wrf9_3[1:361]	-3.81728	x$wrf9_4[1:361]	0.09175			0.6770	9	15
			*		***		***							
28	Lumpur1	y=	-0.64437	x$wrf27_1[1:361]	0.86735	x$wrf27_2[1:361]	-0.80159	x$wrf27_4[1:361]	-2.98902			0.1568	27	15
			***		***		***		***					
29	Lumpur2	y=	-0.52751	x$wrf27_3	10.85712	x$wrf27_4	-4.03911					0.9688	27	30
			*		***		***							
30	Muba2	y=	-16.87680	x$wrf27_2[1:361]	49.64890	x$wrf27_3[1:361]	-20.95840	x$wrf27_4[1:361]	-7.94450			0.2128	27	15
			***		***		***		***					
31	Oki2	y=	0.92930	x$wrf9_1[1:241]	-0.50150	x$wrf9_2[1:241	4.58070	x$wrf9_3[1:241]	25.79030	x$wrf9_4[1:241]	-7.82100	0.8795	9	10
			***				***		***		***			
32	Seleh1	y=	-0.43357	x$wrf9_1	0.90471	x$wrf9_2	-0.62561	x$wrf9_3	0.86527	x$wrf9_4	-4.69285	0.6284	9	30
			***		***		***		***		***			

N.B.: In November 2018, we also examined the window area and calculation period.

In the previous analysis, multiple regression equations were set for each station. Then, the data of each observation station was combined into one data set to create a multiple regression equation for the whole of Indonesia. The time horizon covered by the calculation is from 8:00:00 on November 1, 2018 (time = 25) to 23:00:00 on November 15, 2018 (time = 384), and the calculation area is represented by 27 km meshes.

Based on the results of multiple regression analysis, a predictive model was developed throughout Indonesia. The multiple regression equation is as follows.

$$GWL = -2.70133 \times 2nd\ layer - 2.62319 \times 3rd\ layer + 3.64690 \times 4th\ layer - 0.40890$$

However, the determination coefficient is 0.01555, which is not high.

In practice, the predictive equation created is applied to the outcome of WRF, and the predicted groundwater level is calculated. In this case, the groundwater level at 12:00:00 p.m. on November 16, 2018 throughout Indonesia was predicted.

A manual for the installation of the WRF and the method of estimating groundwater levels from the WRF output was prepared for reference in the trial demonstration described next page

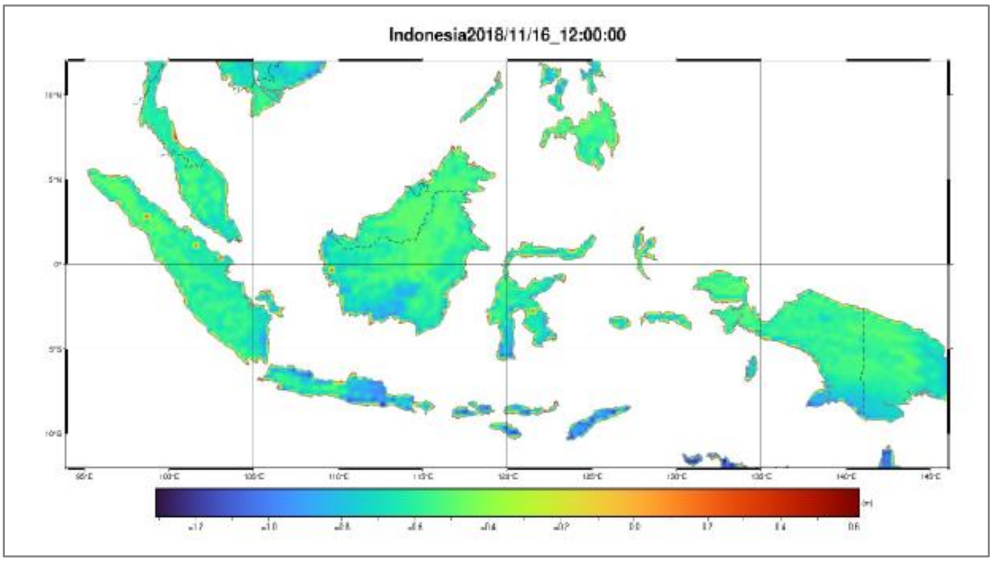


Figure4.2 7 WRF simulated groundwater level map for all of Indonesia (November 16, 2018)

4.2.1.5 Examination of groundwater level estimation formulae over a wide range Using WRF

As a high-precision soil moisture content map, the soil moisture content of four layers (0 to 10 cm, 10～40 cm, 40～100 cm and 100～200 cm from the ground surface) was extracted from the analysis results of WRF obtained in the first stage, and the results for one of these layers are shown inFigure4.2 8. The target area is Riau. The spatial resolution is 1 km meshing.

In simulating the groundwater level, multiple regression equations over a wide range were examined based on the results of the multiple regression equations for each index point in the figure below.

Figure4.2 8 Daily mean of soil moisture content (first layer) obtained from WRF (August 16, 2019 (local time))

NOTE: Resolution is 1 km gridded. Yellow plot points are BRG Observatories.

The estimated soil moisture content (second layer from the surface of the ground) of three surveyed states is shown in Figure4.2 9using the soil moisture content estimation formula developed for the Bengkalis district in Riau.

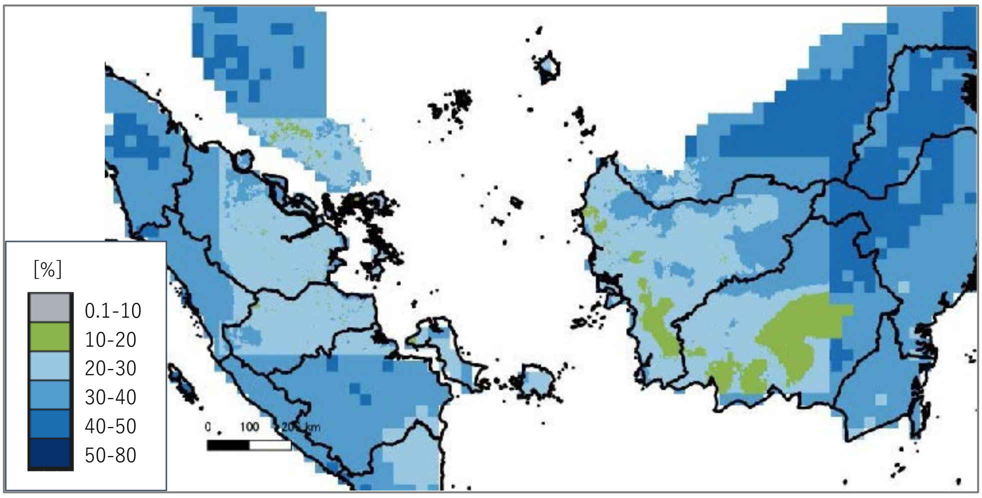


Figure4.2 9 Soil moisture content in three states estimated from WRF (second layer)

NOTE: The resolution is a 3 km grid for D03, D04 (August 16, 2019),
and a 27 km grid for D01 (November 16, 2018).

PALSAR2 images are used to estimate the water content of the soil using multiple regression equations for each point shown in the table above.

4.2.2 Estimation of soil moisture content using SAR data

As for combining SAR images, an estimation of soil moisture content using SAR data was performed aiming at a high-precision (about 10 m) of 1 km resolution proposed in technical meetings, etc..

4.2.2.1 Data used

- SAR images, detailed data: 122 SAR images. This was provided by JAXA through JICA-JAXA co-operation.
- Groundwater level, soil moisture content, and precipitation data: Data used during WRF analysis

The following table lists the SAR data used.

Table4.2 2 List of SAR data used to estimate soil moisture

L2.	センサ	運用	シーンID	観測パ	中心フ	偏波	州名
1	PALSAR-2	SM3	ALOS2143660000-170119	151	0	HH+HV	Riau
2	PALSAR-2	SM3	ALOS2143660010-170119	151	10	HH+HV	Riau
3	PALSAR-2	SM3	ALOS2147060010-170211	150	10	HH+HV	Riau
4	PALSAR-2	SM3	ALOS2149643600-170301	36	3600	HH+HV	Riau
5	PALSAR-2	SM3	ALOS2151713590-170315	36	3590	HH+HV	Riau
6	PALSAR-2	SM3	ALOS2151713600-170315	36	3600	HH+HV	Riau
7	PALSAR-2	SM3	ALOS2164133580-170607	36	3580	HH+HV	Riau
8	PALSAR-2	SM3	ALOS2164133590-170607	36	3590	HH+HV	Riau
9	PALSAR-2	SM3	ALOS2165463600-170616	35	3600	HH+HV	Riau
10	PALSAR-2	SM3	ALOS2165690000-170617	150	0	HH+HV	Riau
11	PALSAR-2	SM3	ALOS2169830010-170715	150	10	HH+HV	Riau
12	PALSAR-2	SM3	ALOS2176780000-170831	151	0	HH+HV	Riau
13	PALSAR-2	SM3	ALOS2176780010-170831	151	10	HH+HV	Riau
14	PALSAR-2	SM3	ALOS2176780020-170831	151	20	HH+HV	Riau
15	PALSAR-2	SM3	ALOS2182250000-171007	150	0	HH+HV	Riau
16	PALSAR-2	SM3	ALOS2195410000-180104	151	0	HH+HV	Riau
17	PALSAR-2	SM3	ALOS2195410010-180104	151	10	HH+HV	Riau
18	PALSAR-2	SM3	ALOS2195410020-180104	151	20	HH+HV	Riau
19	PALSAR-2	SM3	ALOS2198810010-180127	150	10	HH+HV	Riau
20	PALSAR-2	SM3	ALOS2200880000-180210	150	0	HH+HV	Riau
21	PALSAR-2	SM3	ALOS2205020000-180310	150	0	HH+HV	Riau
22	PALSAR-2	SM3	ALOS2205760000-180315	151	0	HH+HV	Riau
23	PALSAR-2	SM3	ALOS2205760010-180315	151	10	HH+HV	Riau
24	PALSAR-2	SM3	ALOS2205760020-180315	151	20	HH+HV	Riau
25	PALSAR-2	SM3	ALOS2209160010-180407	150	10	HH+HV	Riau
26	PALSAR-2	SM3	ALOS2211970000-180426	151	0	HH+HV	Riau
27	PALSAR-2	SM3	ALOS2211970010-180426	151	10	HH+HV	Riau
28	PALSAR-2	SM3	ALOS2211970020-180426	151	20	HH+HV	Riau
29	PALSAR-2	SM3	ALOS2215370010-180519	150	10	HH+HV	Riau
30	PALSAR-2	SM3	ALOS2226460000-180802	151	0	HH+HV	Riau
31	PALSAR-2	SM3	ALOS2226460010-180802	151	10	HH+HV	Riau
32	PALSAR-2	SM3	ALOS2226460020-180802	151	20	HH+HV	Riau
33	PALSAR-2	SM3	ALOS2229860010-180825	150	10	HH+HV	Riau
34	PALSAR-2	SM3	ALOS2231930000-180908	150	0	HH+HV	Riau
35	PALSAR-2	SM3	ALOS2246420000-181215	150	0	HH+HV	Riau
36	PALSAR-2	SM3	ALOS2247160000-181220	151	0	HH+HV	Riau
37	PALSAR-2	SM3	ALOS2247160010-181220	151	10	HH+HV	Riau
38	PALSAR-2	SM3	ALOS2247160020-181220	151	20	HH+HV	Riau
39	PALSAR-2	SM3	ALOS2250560010-190112	150	10	HH+HV	Riau
40	PALSAR-2	SM3	ALOS2252630000-190126	150	0	HH+HV	Riau
41	PALSAR-2	SM3	ALOS2253370000-190131	151	0	HH+HV	Riau
42	PALSAR-2	SM3	ALOS2253370010-190131	151	10	HH+HV	Riau
43	PALSAR-2	SM3	ALOS2258840000-190309	150	0	HH+HV	Riau
44	PALSAR-2	SM3	ALOS2264460010-190416	152	10	HH+HV	Riau
45	PALSAR-2	SM3	ALOS2272000000-190606	151	0	HH+HV	Riau
46	PALSAR-2	SM3	ALOS2276880010-190709	152	10	HH+HV	Riau
47	PALSAR-2	SM3	ALOS2280280000-190801	151	0	HH+HV	Riau
48	PALSAR-2	SM3	ALOS2280280010-190801	151	10	HH+HV	Riau
49	PALSAR-2	SM3	ALOS2280280020-190801	151	20	HH+HV	Riau
50	PALSAR-2	SM3	ALOS2283680010-190824	150	10	HH+HV	Riau
51	PALSAR-2	SM3	ALOS2285750000-190907	150	0	HH+HV	Riau
52	PALSAR-2	SM3	ALOS2290630000-191010	151	0	HH+HV	Riau
53	PALSAR-2	SM3	ALOS2290630010-191010	151	10	HH+HV	Riau

54	PALSAR-2	SM3	ALOS2290630020-191010	151	20	HH+HV	Riau
55	PALSAR-2	SM3	ALOS2292700000-191024	151	0	HH+HV	Riau
56	PALSAR-2	SM3	ALOS2306450000-200125	150	0	HH+HV	Riau
57	PALSAR-2	SM3	ALOS2146167170-170205	132	7170	HH+HV	Kalbar
58	PALSAR-2	SM3	ALOS2146167180-170205	132	7180	HH+HV	Kalbar
59	PALSAR-2	SM3	ALOS2146167190-170205	132	7190	HH+HV	Kalbar
60	PALSAR-2	SM3	ALOS2150823610-170309	32	3610	HH+HV	Kalbar
61	PALSAR-2	SM3	ALOS2150823620-170309	32	3620	HH+HV	Kalbar
62	PALSAR-2	SM3	ALOS2151047190-170310	133	7190	HH+HV	Kalbar
63	PALSAR-2	SM3	ALOS2159103610-170504	32	3610	HH+HV	Kalbar
64	PALSAR-2	SM3	ALOS2159103620-170504	32	3620	HH+HV	Kalbar
65	PALSAR-2	SM3	ALOS2177957190-170908	133	7190	HH+HV	Kalbar
66	PALSAR-2	SM3	ALOS2179287170-170917	132	7170	HH+HV	Kalbar
67	PALSAR-2	SM3	ALOS2179287180-170917	132	7180	HH+HV	Kalbar
68	PALSAR-2	SM3	ALOS2179287190-170917	132	7190	HH+HV	Kalbar
69	PALSAR-2	SM3	ALOS2196587190-180112	133	7190	HH+HV	Kalbar
70	PALSAR-2	SM3	ALOS2197917170-180121	132	7170	HH+HV	Kalbar
71	PALSAR-2	SM3	ALOS2197917180-180121	132	7180	HH+HV	Kalbar
72	PALSAR-2	SM3	ALOS2197917190-180121	132	7190	HH+HV	Kalbar
73	PALSAR-2	SM3	ALOS2206937190-180323	133	7190	HH+HV	Kalbar
74	PALSAR-2	SM3	ALOS2213147190-180504	133	7190	HH+HV	Kalbar
75	PALSAR-2	SM3	ALOS2214477170-180513	132	7170	HH+HV	Kalbar
76	PALSAR-2	SM3	ALOS2214477180-180513	132	7180	HH+HV	Kalbar
77	PALSAR-2	SM3	ALOS2214477190-180513	132	7190	HH+HV	Kalbar
78	PALSAR-2	SM3	ALOS2227637190-180810	133	7190	HH+HV	Kalbar
79	PALSAR-2	SM3	ALOS2248337190-181228	133	7190	HH+HV	Kalbar
80	PALSAR-2	SM3	ALOS2249667170-190106	132	7170	HH+HV	Kalbar
81	PALSAR-2	SM3	ALOS2249667180-190106	132	7180	HH+HV	Kalbar
82	PALSAR-2	SM3	ALOS2249667190-190106	132	7190	HH+HV	Kalbar
83	PALSAR-2	SM3	ALOS2260757190-190322	133	7190	HH+HV	Kalbar
84	PALSAR-2	SM3	ALOS2266967190-190503	133	7190	HH+HV	Kalbar
85	PALSAR-2	SM3	ALOS2275247190-190628	133	7190	HH+HV	Kalbar
86	PALSAR-2	SM3	ALOS2281457190-190809	133	7190	HH+HV	Kalbar
87	PALSAR-2	SM3	ALOS2291807190-191018	133	7190	HH+HV	Kalbar
88	PALSAR-2	SM3	ALOS2302157190-191227	133	7190	HH+HV	Kalbar
89	PALSAR-2	SM3	ALOS2314577190-200320	133	7190	HH+HV	Kalbar
90	PALSAR-2	SM3	ALOS2150673660-170308	29	3660	HH+HV	Kalteng
91	PALSAR-2	SM3	ALOS2158953660-170503	29	3660	HH+HV	Kalteng
92	PALSAR-2	SM3	ALOS2179653660-170920	29	3660	HH+HV	Kalteng
93	PALSAR-2	SM3	ALOS2181947140-171005	130	7140	HH+HV	Kalteng
94	PALSAR-2	SM3	ALOS2185863660-171101	29	3660	HH+HV	Kalteng
95	PALSAR-2	SM3	ALOS2187933660-171115	29	3660	HH+HV	Kalteng
96	PALSAR-2	SM3	ALOS2192073660-171213	29	3660	HH+HV	Kalteng
97	PALSAR-2	SM3	ALOS2194143660-171227	29	3660	HH+HV	Kalteng
98	PALSAR-2	SM3	ALOS2200577140-180208	130	7140	HH+HV	Kalteng
99	PALSAR-2	SM3	ALOS2204493660-180307	29	3660	HH+HV	Kalteng
100	PALSAR-2	SM3	ALOS2204717140-180308	130	7140	HH+HV	Kalteng
101	PALSAR-2	SM3	ALOS2210703660-180418	29	3660	HH+HV	Kalteng
102	PALSAR-2	SM3	ALOS2216913660-180530	29	3660	HH+HV	Kalteng
103	PALSAR-2	SM3	ALOS2227263660-180808	29	3660	HH+HV	Kalteng
104	PALSAR-2	SM3	ALOS2231627140-180906	130	7140	HH+HV	Kalteng
105	PALSAR-2	SM3	ALOS2233473660-180919	29	3660	HH+HV	Kalteng
106	PALSAR-2	SM3	ALOS2239683660-181031	29	3660	HH+HV	Kalteng
107	PALSAR-2	SM3	ALOS2245893660-181212	29	3660	HH+HV	Kalteng

108	PALSAR-2	SM3	ALOS2252103660-190123	29	3660	HH+HV	Kalteng
109	PALSAR-2	SM3	ALOS2252327140-190124	130	7140	HH+HV	Kalteng
110	PALSAR-2	SM3	ALOS2255137130-190212	131	7130	HH+HV	Kalteng
111	PALSAR-2	SM3	ALOS2258313660-190306	29	3660	HH+HV	Kalteng
112	PALSAR-2	SM3	ALOS2264523660-190417	29	3660	HH+HV	Kalteng
113	PALSAR-2	SM3	ALOS2270733660-190529	29	3660	HH+HV	Kalteng
114	PALSAR-2	SM3	ALOS2281083660-190807	29	3660	HH+HV	Kalteng
115	PALSAR-2	SM3	ALOS2285447140-190905	130	7140	HH+HV	Kalteng
116	PALSAR-2	SM3	ALOS2287293660-190918	29	3660	HH+HV	Kalteng
117	PALSAR-2	SM3	ALOS2293503660-191030	29	3660	HH+HV	Kalteng
118	PALSAR-2	SM3	ALOS2299713660-191211	29	3660	HH+HV	Kalteng
119	PALSAR-2	SM3	ALOS2305923660-200122	29	3660	HH+HV	Kalteng
120	PALSAR-2	SM3	ALOS2312133660-200304	29	3660	HH+HV	Kalteng
121	PALSAR-2	SM3	ALOS2318343660-200415	29	3660	HH+HV	Kalteng
122	PALSAR-2	SM3	ALOS2324553660-200527	29	3660	HH+HV	Kalteng

4.2.2.2 Implementation procedure

1) Conversion to vrt Files

Using the VRT creation tool for ALOS-2, "LED-***" in the acquired SAR image folder. Convert "5RUD" to ".vrt" file (ArcGIS Pro)

2) Conversion to Geotiff

Convert ".vrt" file to Geotiff for loading into SNAP (ArcGIS Pro)

3) Selection of noise processing method

All of the noises on SNAP are sampled on a trial basis, and the processing methods are determined. Eight noise-processing methods, Refined Lee, Median, Lee Sigma, Lee, and IDAN, Gamma Map, Frost, and Boxcar, were tested this time.

4) Noise processing

Noise-handling by setting Target Window Size "3×3", "Look "3", "Filter size "7×7" and sigma "0.6"

5) Extraction of necessary observation points

Spatial search of all images and observation points to extract only the required observation points (ArcGIS Pro)

6) Extraction of pixel values

※Only one point was extracted by setting up a model builder in ArcGIS Pro, but all points were entered manually because 3×3 automation was not possible.

7) Processing on R

Processing is performed on R.

a) Combining observed data

A plurality of field observation data are adjusted to have the same format.

b) Applying the shooting time of each image to the extracted pixel value

The shooting time is automatically set to UTC+8.

c) Combining the data of 1 and 2 with the observation point and time.

Missing parts are automatically omitted.

8) Multiple regression analysis

Multiple regression analyses are performed with Excel based on the data outputted by R.

9) Band degradation

The raster function decomposes the image into bands 1 and 2. (ArcGIS Pro)

10) Creating a Diagram from a raster operation

The equation obtained in the multiple regression analysis is raster-calculated to create a diagram. (ArcGIS Pro)

4.2.2.3 Multiple regression equation at the observation point

In the window regions 1×1 and 3×3, there were a plurality of measured values, and the points with the highest priority were created on the basis of a multiple regression equation for only one point. In addition, as a result of R processing, there were clusters of observation points that can be used this time (aggregates), and therefore, clusters with the highest priority among them were created based on multiple regression equations of a plurality of points.

The multiple regression equation for each site is as shown in the table below, but in the window region 1×1 or 3×3, even those with high multiple correlation coefficients are 0.32 and 0.34, showing relatively low correlation.

Table4.2 3 Multiple regression equations at observation locations

Point	Window area	Multiple regression equation	Multiple correlation coefficient
Ij2 point	1×1	-0.0150491414519643*ban d 1-0.00128110034598675* band 2+43.9575141882965	0.32
Three points of brg13,brg15,kalteng1: "Assembly ③ij2 Drawing"	1×1	-0.0000923521383430543*B and 1-0.00271728617786997 *Band 2+35.7838863477497	0.15
Only one location in brg10	3×3	-0.000241466781029246*B and 1-0.00048883735456631 4*Band2+26.7279053563167	0.34
Three points of brg13,brg15,kalteng1 "Assembly ③ij2 Drawing"	3×3	0.000944065190415274*Band 1-0.0024251699553205* band 2+30.2292252027411	0.12

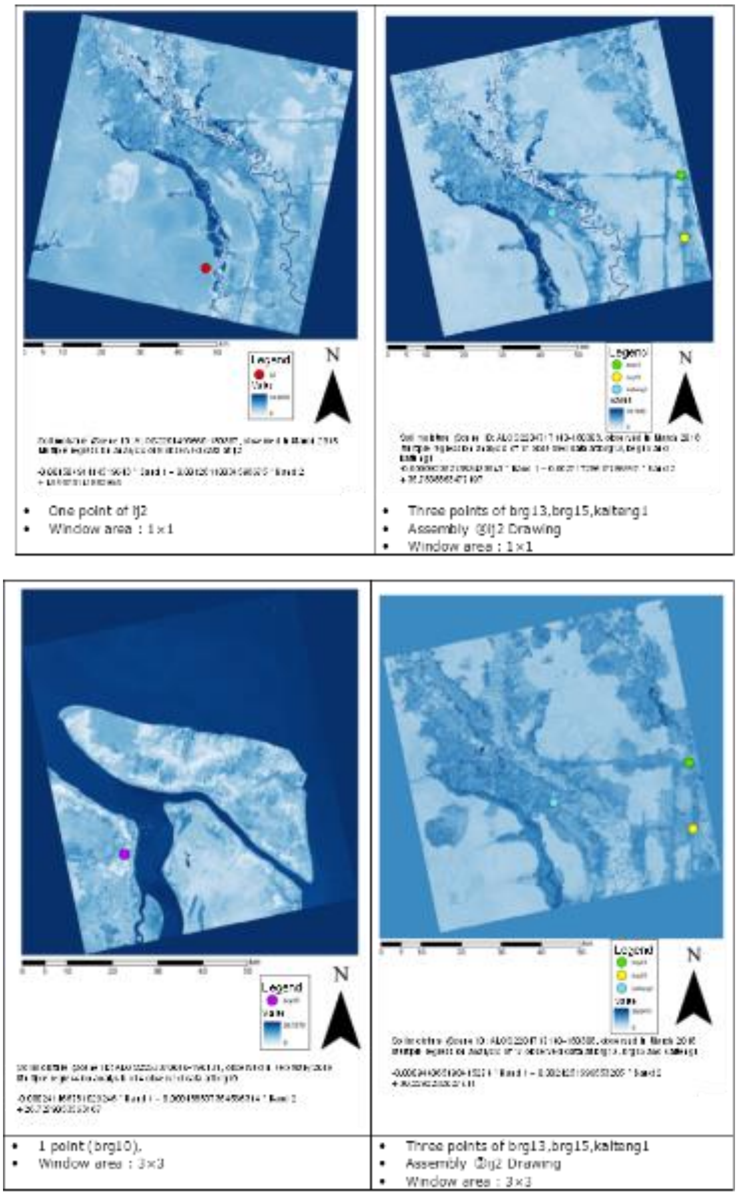


Figure4.2 10 Soil moisture maps estimated by PALSAR2

The soil moisture content estimation map using the multiple regression equation for each point shown in the table above using PALSAR2 images is shown below.

4.2.2.4 Multiple regression equation at all stations

Multiple regression equations were calculated for all observation points. As a result, when all observation sites were taken, the multiple correlation coefficient was higher when the window region was 3×3 than for 1×1, but it was not high at 0.21.

Table4.2 4 Multiple regression equations at all stations

Point	Window area	Multiple regression equation	Multiple correlation coefficient
All stations	1×1	-0. 00101323138890318*Band 1+ 0.00119064194653928* band 2+ 29.1743091261637	0.16
All stations	3×3	-0. 00160130637486663*Band 1+ 0.00173207989345127*Band 2+ 30.7414111645802	0.21

Manuals related to the above-mentioned SAR analysis procedures were prepared to serve as a reference for the trial demonstration described later.

4.2.2.5 Survey of multiple regression analyses with SAR images in survey areas

Using the automated analysis system in 4.2.2.2, multiple regression analyses were performed using data from four BRG stations in the Riau region and five SAR images. Quality checks for the presence or absence of outliers were completed for the four BRG stations, and were used for additional analyses. The target area was divided into three regions according to the area of SAR images: ① the north side of Dumi, ② the south side of Dumi, and ③ the island of Bunkalis.

For multiple regression analysis, two patterns were analyzed: (A) for all regions combined, and (B) for each region. In the case of (A), the F value was 0.0505 and the multiple correlation coefficient was 0.72. In the case of (B), the F-values were ① 0.49 and ② 0.12 for each region. In ③, since the t value was an abnormal value of 65535, there was no F value. The multiple correlation coefficients were ① 0.86 and ② 0.99.

Multiple regression analysis revealed that the two analysis patterns were not both significant. With the exception of some regions, both the F value and the multiple correlation coefficient are larger in the analysis method for each region according to (B). However, since outliers were also observed, the more versatile method is the method of combining all regions in (A).

A multiple regression equation by method (A) is shown by the following.

$$SM = -0.00319 \cdot B1 - 0.00865 \cdot B2 + 71.51$$

The following equation shows the multiple regression equation for each region in (B). However, this is the case of area ①.

$$SM = 0.00856 \cdot B1 - 0.02176 \cdot B2 + 52.01$$

Where SM: soil moisture content [%], B1, B2: the backscattering factor of HH and HV, respectively.

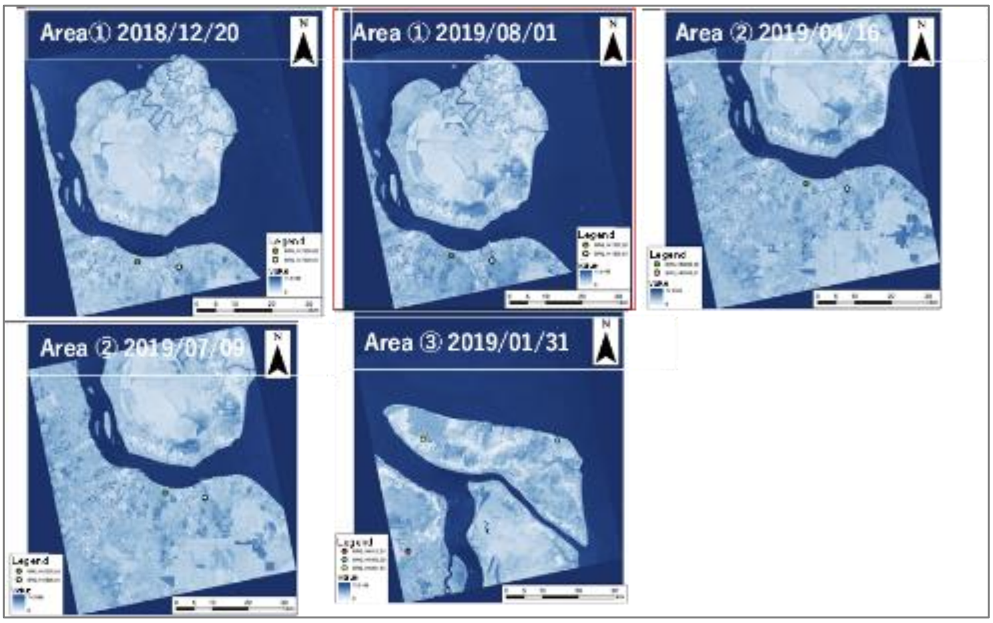


Figure4.2 11 Estimation of soil water consumption for all areas

NOTE :In the upper left of the images, the types of three areas and SAR observation date and time (UTC) are shown.

4.2.2.6 Validation of SAR based on WRF

In examining the estimated soil moisture content in SAR, we detected a grid in which the estimated soil moisture content in SAR was more definite, and compared the soil moisture content in WRF (the first layer of soil) and SAR in the grid.

The L-band SAR data used in this study can penetrate vegetation layers relatively well compared to X- and C-band (e.g., Sentinel), which have shorter wavelengths (Ottinger and Kuenzer, 2020). Also, the observation value of soil moisture quantity estimated by such SAR fluctuates even between adjacent grids due to the physical property of ground surface and relief, ruggedness, inclination, etc.. A specific verification method is as follows.

1. Prepare SAR images for the dry and rainy seasons.
2. Extract the bare land area from World Cover (Zanaga et al., 2020).
3. Average the soil moisture estimated from SAR over a 0.001 degree resolution grid (about 100 m).
4. For bare land areas, detect locations where the estimated soil moisture content is greater by SAR in the wet season than in the dry season.
5. At the locations detected in 4., compare the soil moisture content of SAR (approximately 100 m grid (0.001 degree grid)) and WRF(1 km grid).

In this work, the soil moisture content estimated by SAR in the grids detected in Section 4 above was averaged over an approximately 100 m grids. Averaging on several 10 m grids was also considered, but averaging over an approximately 100 m grid was adopted because the analysis was time-consuming.

The locations detected in Section 4 above are assumed to be adequately represented by the water content estimated from SAR. Then, in Section 5, we compare the estimated soil moisture content for SAR and WRF, respectively.

Multiple regression analyses were performed in the following two ways to estimate soil moisture content by SAR.

1. Method that combines all regions
2. Methods to analyze by region

Figure4.2 **12**shows a scatter plot of soil moisture and WRF estimated by SAR using two multiple regression methods, (A) and (B). In (B), the estimated soil moisture variation in SAR is about 10-75%, which is less than that in (A) (about 0-75%). The correlation coefficient was 0.15 for (A) and 0.26 for (B). From the above, the trend of soil moisture content is strong for each region. However, when estimating the soil moisture content from SAR over a wider range, it is necessary to grasp the trend of soil moisture content in each region in advance, and to prepare a multiple regression equation for each region.

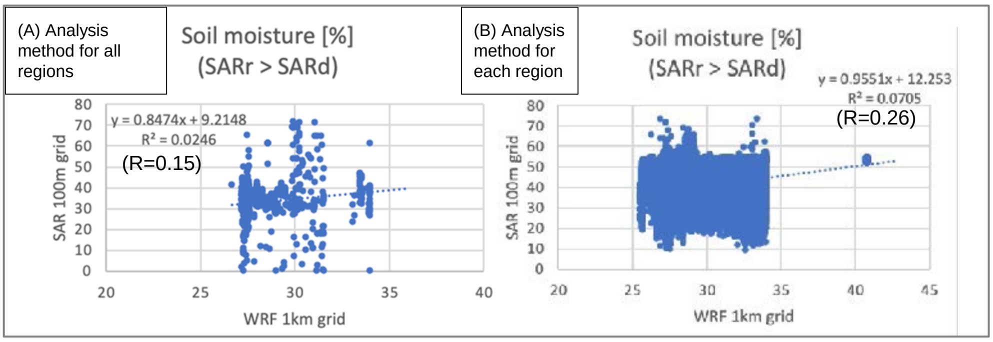


Figure4.2 12 Comparison between WRF and SAR on soil moisture

NOTE :The date and time are 00:00 on August 2, 2019.

Figure4.2 13 Left shows the soil moisture content map (10 m grids) for bare land prepared in the manner described in (B). The figure on the right shows the same as the left figure, averaged over an approximately 100 m grid.

Left: Soil moisture map (10 m grid) of bare land in one area (Dumai) created in Method (B))

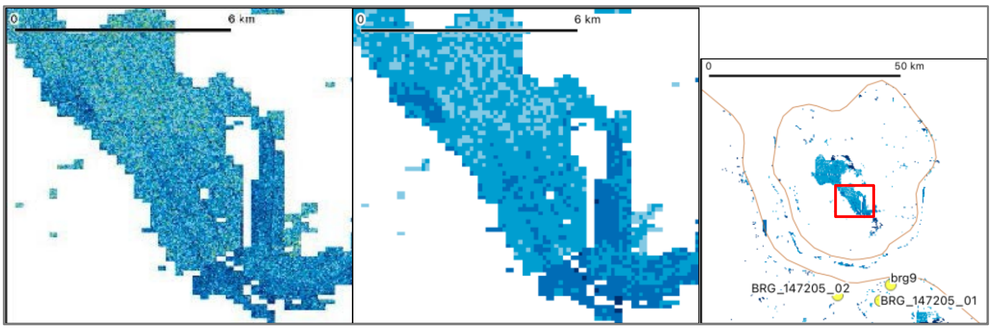


Figure4.2 13 Map of soil moisture of bare land in one area (Dumai) Area prepared by regional analysis method (above (B))

Right: The diagram on the left averaged over an approximately 100 m grid.

NOTE :The date and time are 00:00 of local time on August 2, 2019.

4.2.2.7 Verification of SAR by using drone images

In this paper, drone images (orthomosaic images) were used to confirm SAR data qualitatively, while getting more accurate ground surface conditions. Figure4.2 **14**compares the backscatter factor and drone orthomosaic images of three SAR images, including the rainy and dry seasons, when transmission and reception were performed with horizontally polarized waves. The target location is in the vicinity of the 147205_01 BRG station in Dumaiy.

Focusing on roads with relatively few tall trees, oil palm plantations, etc. (in the figure surrounded by ○), the backscattering coefficient is larger in the rainy season than in the dry season. Since the backscattering factor decreases when flooded, the region is not likely to be flooded in the rainy season. In general, the higher the soil moisture content, the higher the backscattering coefficient (Fukami, 1993). This is because the dielectric constant of water is higher than that of dry soil. Therefore, it was confirmed that the difference in soil moisture content in the dry season and rainy season was reflected to some extent in SAR data.

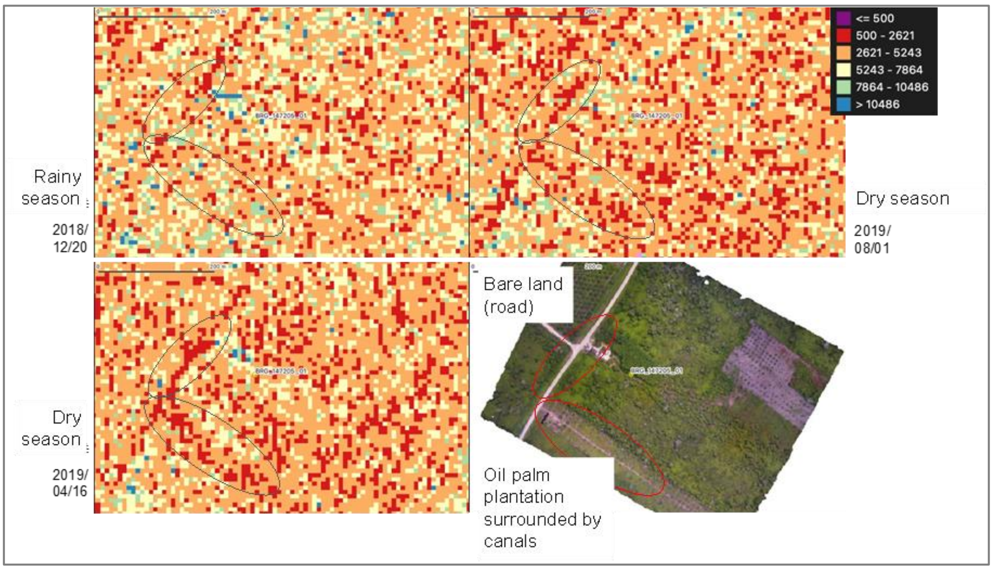


Figure4.2 14 Backscatter factor for three SAR images including the rainy season and the dry season when transmission and reception is performed with horizontally polarized waves, and orthomosaic images by drones in the same area

N.B.: The date and time given beside SAR images is UTC of SAR.

4.3 Groundwater level estimation model (map)

4.3.1 Relationship with land use

Using the regression equation obtained by the multiple regression analysis carried out in 4.2, a survey was carried out on the widening of groundwater level (groundwater level mapping) from the viewpoint of land use.

The land use status of the observation points of the data used in 4.2 was estimated from existing land use maps, and classified into eight land use types as follows.[67]

Table4.3 1 Land use classification on land use map

Number	Details of land use	Classification
1	Primary and secondary mangroves	Undisturbed mangrove forests (primary mangrove forests) and disturbed mangrove forests (secondary mangrove forests)
2	Primary and secondary wetland forests	Undisturbed Wetland Forest (Primary Wetland Forest) and Disrupted Wetland Forest (Secondary Wetland Forest)
3	Plantation forest	Industrial afforestation for pulp material production
4	Plantation	Plantations and orchards that produce perennial crops
5	Oil palm	Oil palm plantations
6	Shrub, mixed arid agricultural land, swamp shrub	Shrub forests, arid agriculture producers and wet shrubs
7	Bare land	Non-growing land with trees and plants
8	Rice field	Fields

The relation between the coefficients (A1-A4, and B) obtained as a result of the multiple regression analysis in 4.2 and land use is shown in the figure below.

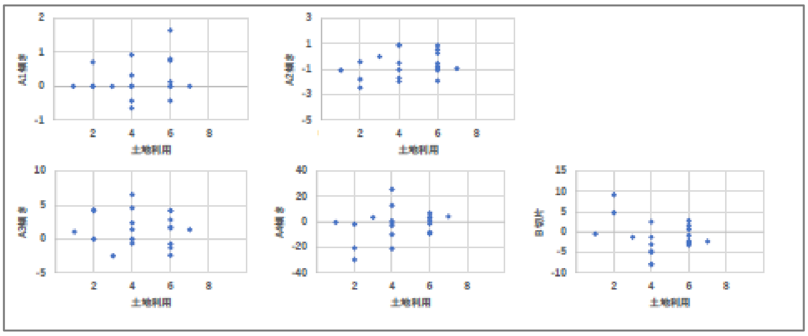


Figure4.3 1 Relation between multiple regression analysis coefficients and land use

4.3.2 Relation between soil moisture and groundwater level

From the coefficients (A1-A4, and B) obtained as a result of multiple regression analysis, groundwater is estimated by the following equation.

$$GWL = (A1 \times SM1 + A2 \times SM2 + A3 \times SM3 + A4 \times SM4 + B) \times 100$$

where,

A1-A4 and B: Coefficients obtained by multiple regression analysis

[67] https://nfms.menlhk.go.id/peta

GWL: Groundwater level (cm)
SM1～SM4: Soil moisture content () of soil layer close to 1-4 from the ground surface, obtained from WRF (abridged author abst.)

Groundwater level for a certain land use was calculated from the above estimation formula. The relationship between water levels estimated from WRF and actual observed values is shown below.

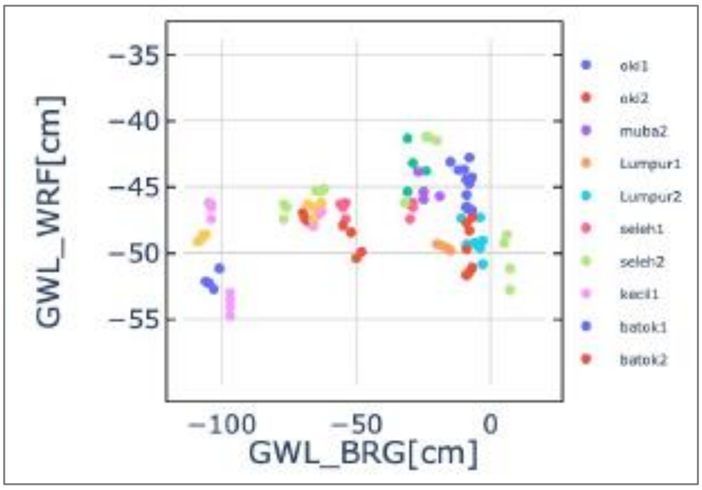


Figure4.3 2 Example of the relationship between groundwater levels calculated from WRF and observed values

NOTE :The coefficients (A1-A4, B) were roughly set according to land use based on the results of multiple regression analysis.The number of days of analysis and the mesh used are uniform this time.

From the figure above, the correlation between actual observations and estimated results is still low. However, as described later, as the error between actual observation and station data was about 5 cm when the area around the actual observatory was measured during field verification, other data at other stations are considered to have not so much error.

4.3.3. Wide-area estimation of soil moisture

On the basis of the previous analysis results, the soil moisture status was estimated over a wide area. Multi-regression equations were investigated for all BRG Observatory sites (including Sumatra, Kalimantan, etc.). The groundwater level is estimated by the following equation based on the results of tuning the multiple regression analysis. The adjusted determination coefficient was 0.00155.

$$GWL = (-2.7SM_2 - 2.62SM_3 + 3.64SM_4 - 0.4) \times 100$$

where,
A1～A4 and B: Coefficients obtained by tuning multiple regression analyses (A1 : 0, A2 :-2.7, A3 :-2.62, A4 : 3.64, B:-0.4)
GWL: Groundwater level (cm)
SM1～SM4: Soil moisture content (m3m-3) of the first to fourth nearest soil layer from the surface obtained from WRF

Figure4.3 3 shows the results of estimating the groundwater level over a wide area. In contrast to existing observation data, there are areas with low groundwater levels in coastal areas. This is considered to be due to the fact that WRF does not consider the pushing up of the groundwater level by sea water.

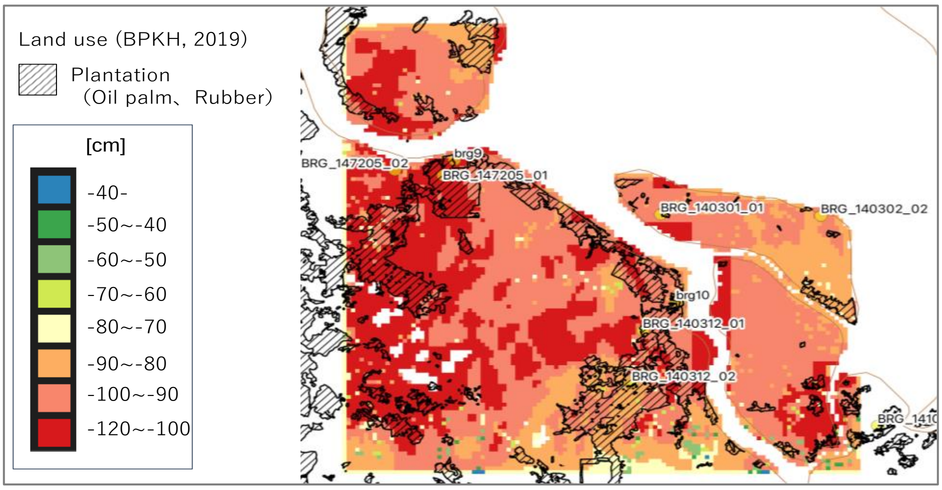


Figure4.3 3 1 km mesh-groundwater level estimated from WRF (August 16, 2019 (local time))

NOTE :1 km grid groundwater level in the Riau region. Yellow plot points are BRG Observatories. The shaded area is the area of the plantation. This paper is based on the 2019 land-use map by BPKH (Balai Pementapan Kawasan Hutan of the Ministry of Environment and Forestry).

Figure4.3 2 shows the groundwater levels estimated from WRF (3 km grid and 27 km grid) data for the three provinces surveyed using the groundwater level estimation equation developed for the Benkalis district in Riau.

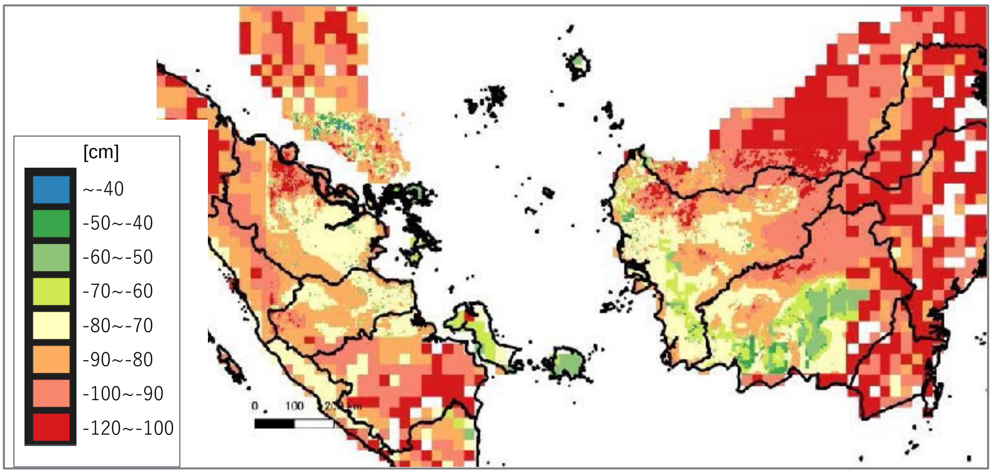


Figure4.3 4 Groundwater levels for the three states estimated from WRF

NOTE: The resolution is 3 km grid for D03, D04 (August 16, 2019), and 27 km grid for D01 (November 16, 2018).

There was an area where the groundwater level was low in the coastal area. This was considered to be due to the fact that WRF did not consider the pushing up of the groundwater level by seawater. Therefore, in order to correct the estimation of the groundwater level by WRF, the relationship between the tide level and the groundwater level was investigated.

In this work, we used sea level data collected and analyzed from the Global Tide Level Observation Network (Permanent Service for Mean Sea Level: PSMSL) at a location in Malacca. Raw data is hourly.

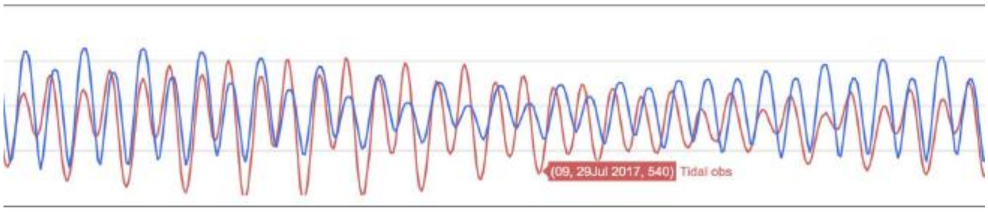


Figure4.3 5 Time maximum value of tidal data obtained

N.B.: ① Red: Observed by permanent service for Mean Sea Level (PSMSL (Malacca),
② Blue: Tide Forecast System (Buncaris), Indonesian Ocean Research Centre[68,69]

NOTE : The time was converted to local time, and ① and ② were superimposed.

There was no clear trend in the response of the groundwater level to the monthly tide level. No correlation was obtained except when there was high rainfall. On the other hand, as shown in Figure4.3 6

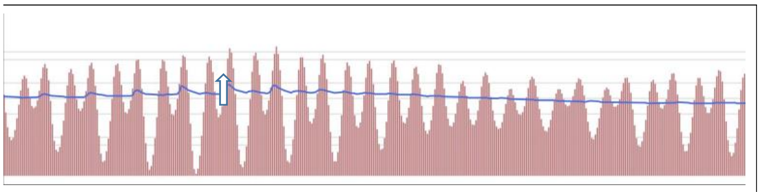


Figure4.3 6 Relation between tide level and groundwater level (max. time)

N.B.: Permanent Service for Mean Sea Level (PSMSL) tidal data and BRG observation data

Comparison of groundwater level data of BRG Observatory and tide level data of PSMSL with monthly maxima revealed that when the cumulative monthly rainfall was less than 80 mm, only one point of 147205_02 was correlated with a coefficient of 0.56. At this time, the regression equation is expressed by the following equation.

[68]Permanent Service for Mean Sea Level (PSMSL): Sea level data collected and analyzed from global tide level observation networks (e.g., GLOSS). https://www.psmsl.org/data/obtaining/stations/1746.php。 *Latest data ■ Up to December 2020 Downloaded data is UTC.

[69]Indonesian Ocean Research and Observation Centre Tide Forecasting System (Badan Riset dan Observasi Laut (BROL-under Ministry of Sea and Fisheries) and Indonesian Navy). http://bpol.litbang.kkp.go.id/imro-ofs/index.php#show_form
*Real-time data available. Downloaded data is UTC.

$$GWL = 0.0185Tidal \quad - 97.051$$

where GWL: Groundwater level [cm], Tidal: Tide level [mm].

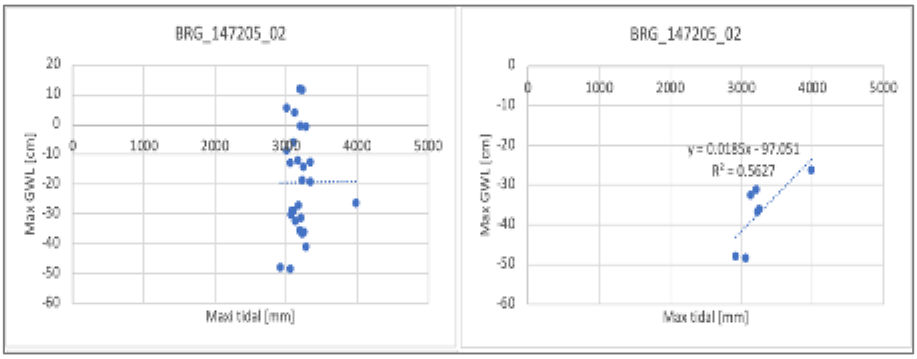


Figure4.3 7 Scatter plots of tide level and groundwater level. Maximum value for each month

NOTE :The groundwater level at point 147205_02 of BRG Observatory.
Left is no threshold. This is a scatter plot for a monthly cumulative rainfall of 80 mm.

However, since the tide level in this region is generally around 1 m, the altitude in DTM of 147205_02 is 2.64 m, and it is difficult to say that the tide level is significantly affected. In fact, no time-based responses were observed at this site even in field observations. On the other hand, at brg9 located at an altitude of 2 m, a response was observed every hour. Therefore, in this project, it was decided to correct the groundwater level obtained from WRF using the above regression equation in low-lying areas at or below an altitude of 2 m.

Since the monthly maximum tide level at the time when WRF was simulated (August 2019) was 3080 mm, the monthly maximum groundwater level would be -40.071 cm if it was substituted into the above equation. In this work, the groundwater level was taken to be a uniform -40.071 cm in flat areas with an altitude of 2m or less and an inclination angle of 0.05 or less.

Figure4.3 8 shows the relation between the slope calculated from the LiDAR altitude in the Riau region and the groundwater level (normal groundwater level) on the previous day when the no-precipitation period obtained from the BRG Observatory started. Based on this relationship, the groundwater level is relatively low in areas where the tilt angle is greater than 0.05. Therefore, if the altitude is lower than 2m and there is a slope, the groundwater level is corrected by the following regression equation.

$$GWL = -253.23slope \quad - 39.315$$

where GWL: groundwater level [cm], slope: slope [mm].

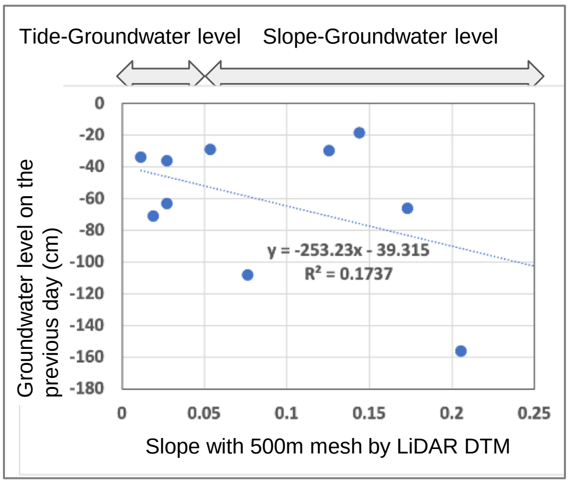


Figure4.3 8 Relation between the slope calculated from the elevation of LiDAR and the groundwater level on the previous day when the no-precipitation period obtained from the BRG Observatory started

Figure4.3 shows the corrected groundwater level estimated by WRF. It can be seen that the correction was made mainly in the coastal areas of Sumatra and Bengkalis Island, and in the low altitude areas along the river. At a boundary altitude of approx. 2 m, there are also places where the groundwater level is changing stepwise. This means that the slope is relatively large (0.05 or more) at the boundary about the altitude of 2m. The altitude data used for corrections are DTM 500 m grids of LiDAR and ETOPO1 (1.8 km grids by satellite data, partially used).

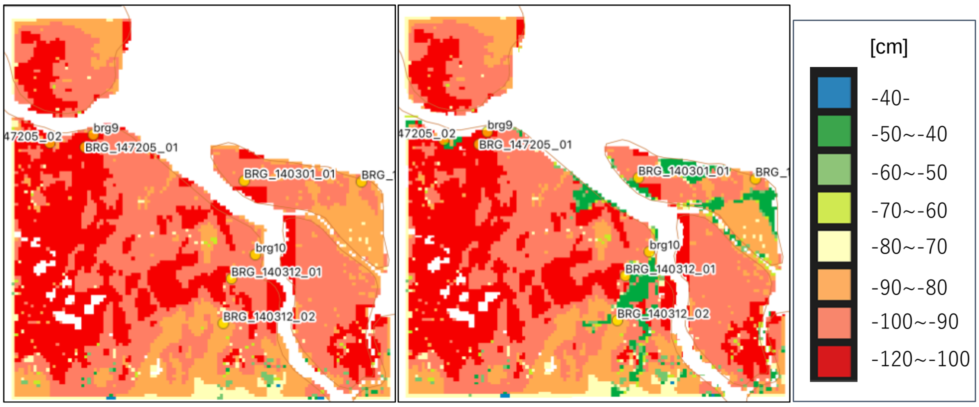


Figure4.3 9 Results of correcting the groundwater level estimated from WRF results (August 16, 2019 (local time))

NOTE: Left is before correction, right is after correction.

NOTE: Elevation data used for corrections are DTM 500 m grids of LiDAR and ETOPO1 (1.8 km grids based on satellite data)

4.4 Development and verification of a model for estimating reduction of greenhouse gas emission (carbon dioxide) by the groundwater level estimation model

4.4.1 Literature review

Here, the literature on the relation between CO2 emission and groundwater level is reviewed.

Concerning carbon dioxide emission, a formula is devised based on the analytical results so far, referring to the relation diagram of water level and CO2 of Hatano (2019). The following chart is used to estimate CO2 from groundwater level data.

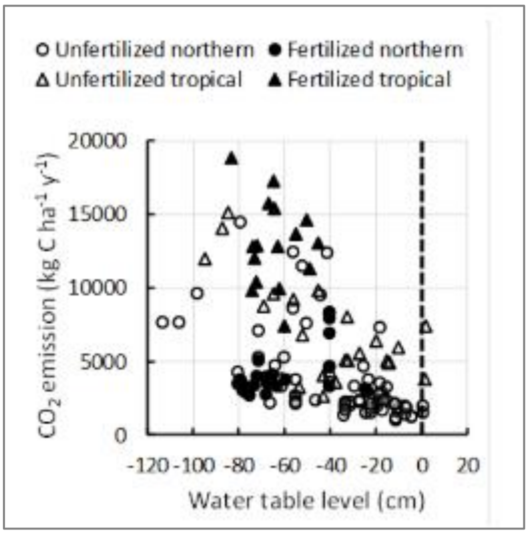


Figure4.4 1 Relation between groundwater level data and CO2 emissions

4.4.2 Relationship between CO2 emissions and groundwater level

Regarding carbon dioxide emission, we focused on net ecosystem production (NEP) referring to Hirano et al. (2016), and examined the relation with water level. In Hirano et al. (2016), a linear relationship was established only in forested areas (no fire site), and the fire history and vegetation volume (LAI/NDVI) must be considered in order to apply this relationship. The estimation formula so far has not been able to consider the interannual fluctuation of groundwater level. It was also necessary to consider carbon sequestration by the amount of carbon lost in the fire, and biomass recovered after the fire.

This time, we focused on the relation between NEP (NEE) and groundwater level. As shown inFigure4.4 2, a linear relation (determination coefficient R2=0.82) was observed for forested areas and areas without fires (UF, DF).[70]

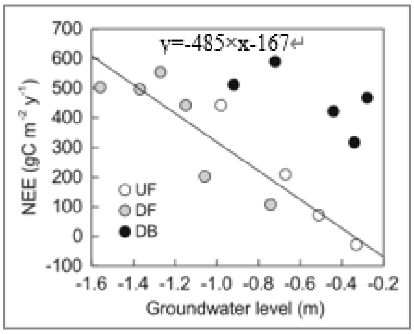
$$y = -485x - 167$$

For forests, we use the equation y =-485×x-167.

[70] Ecosystem Exchange Volume (NEE: Net Ecosystem CO2 Exchange) is the volume of CO2 exchanged between the ecosystem and the atmosphere per unit time and per unit of land area. Net Ecosystem Production (NEP) is the net ecosystem carbon uptake, which is the difference between total primary production and total community respiration.

On the other hand, DB is not on this straight line (R2=0.44). The regression line is given by the following equation.

$$y = -251x + 327$$



Monthly mean relation between NEE and groundwater level (Hirano et al., 2016).
※Observations of two-site flux towers in Palangkaraya.
UF: Undrained Peat Forests
DF: Drained Forests
DB: Drained Forests formerly fired

Figure4.4 2 Relation between ecosystem exchange volume and the monthly average of groundwater level (Hirano et al., 2016)

Fire-affected areas and areas with artificial changes such as deforestation tend to have greater CO2 emissions and fixed quantities. For this reason, CO2 balance should be assessed separately in areas with artificial changes such as fires and deforestation. Okubo et al. (2021) have measured CO2 flux in Parankaraya for about 13 years. The site experienced two burnouts in 2009 and 2014.

In this work, the above two estimation formulas are used depending on whether there was a site where there had been a fire. Between 2000 and 2020, the above two formulas were applied separately to sites of fires detected by MODIS satellites, and other regions. The daily mean 1 km grid groundwater levels estimated by WRF were used to map the physical quantities for carbon dioxide emissions (Figure4.4 2). Originally, the monthly minimum mean value of the groundwater level was used, but here, the daily mean value of the groundwater level was used in August when the risk of fire was relatively high.

Focusing on areas that are not fire sites, areas where the estimated groundwater level is high (groundwater level between -50 and -100 cm on the south side ofFigure4.4 2) have the largest ecosystem exchange amount (400 g cm-2y-1) (orange), and areas where the groundwater level is low (groundwater level between -120 and -100 cm on the northwest side ofFigure4.4 2) have a smaller ecosystem exchange amount than the largest ecosystem exchange amount (500 g cm-2y-1 (red)). It was confirmed that the amount of ecosystem exchange varies according to the height (depth) of the groundwater level.

On the other hand, the largest ecosystem exchange in former fire sites is 600 g cm-2y-1 (purple), which is larger than that in regions without former fire sites (500 g cm-2y-1).

Therefore, in estimating the amount of carbon dioxide emission, the estimation is made by using a formula corresponding to the presence or absence of a fire site.

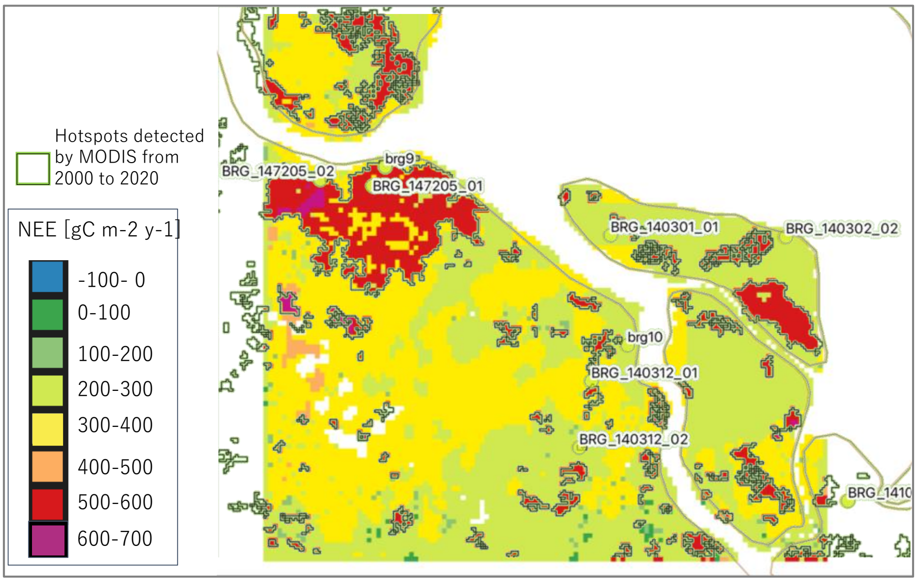


Figure4.4 3 Estimation of net ecosystem CO2 exchange (NEE) Estimated from WRF (Local Time, August 16, 2019)

NOTE: Calculated using daily averages of 1 km grid groundwater levels in the Riau region. Yellow plot points are BRG Observatories.

NOTE: The solid lines indicate the sites where fires were detected by MODIS satellites between 2000 and 2020.

In addition, Figure4.4 4 shows the ecosystem exchange volume estimated from WRF (3 km grid and 27 km grid) data for the three states surveyed using the ecosystem exchange volume estimation equation developed for the Bengkalis district in Riau.

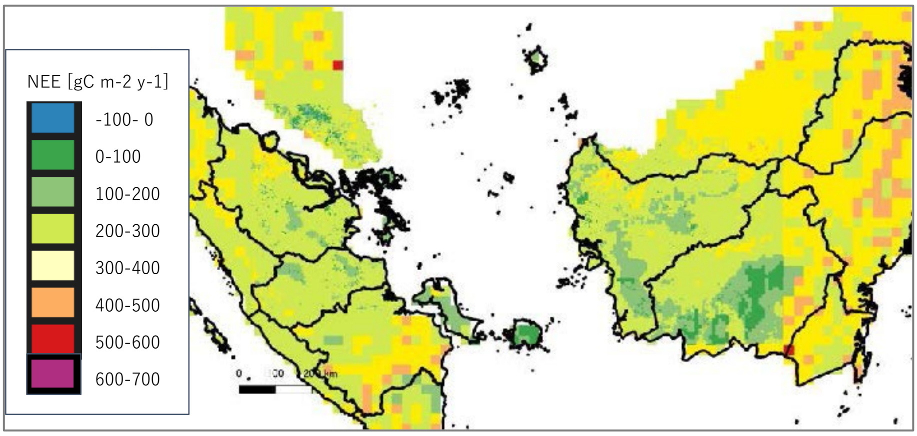


Figure4.4 4 Estimated net ecosystem CO2 exchange (NEE) in the three states from WRF

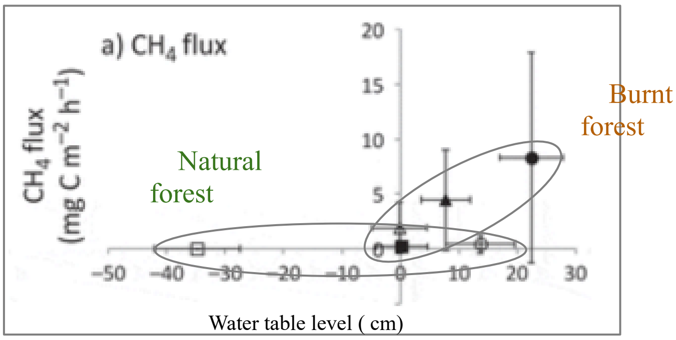
NOTE: The resolution is a 3 km grid for D03, D04 (August 16, 2019), and a 27 km grid for D01 (November 16, 2018).

4.5 Development and verification of a model for estimating greenhouse gas (methane) emissions reduction by estimating groundwater level

4.5.1 Literature review

A literature review was undertaken on the relation between methane emissions and groundwater levels.

Regarding methane emission, since acid soil is neutralized for oil palm production during the conversion from peat swamp forest to plantation, when flooded anaerobic tropical peat soil was adjusted from pH 3.4 to pH 6.6, methane production increased by about 26 times on the 67th day (unpublished data by Ito et al.), and we expressed this by a formula. Adji et al.(2014) reported that methane emission increases according to the groundwater level at the site where a fire occurred. Therefore, the following chart is used to estimate methane emission from groundwater level data.



(Adji et al., 2014)

Figure4.5 1 Relation between groundwater level data and CH4 emissions

In addition, since Hatano (2019) also refers to the following land use history, it has been clarified that at least the land use data of the fire history is required to refer to Hatano (2019). Also, since it is necessary to count the carbon lost in the fire in (1) below, it is necessary to consider carbon fixation by the amount of biomass recovered after the fire in the case of a more detailed analysis.

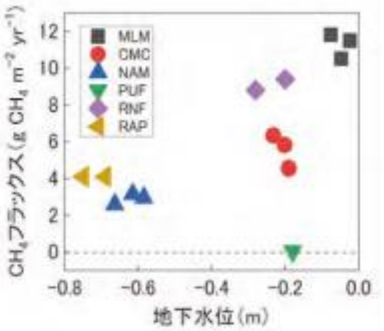
(1) CO2 depends on whether fertilizers are used

(2) CH4 shows the history of fires

(3) (N2O depends on whether fertilizers are used)

As a result, we focused on the relation between ecosystem scale flux (emission) and groundwater level, as shown in the following figure (Hirano, 2021). Four sites on Borneo/Kalimantan Island (Sarawak, Central Kalimanta) and two sites on Sumatra Island (Riau) were observed. The results (PUF) for Central Kalimantan (Palangkaraya) deviate from the linear equation, but the results for the other five sites on Sarawak and Sumatra can be approximated by a single curve regardless of the degree of disturbance or geographical distribution. The determination coefficient is 0.55.

$$y = 8.2e^{1.56x}$$



MLM: Undrained Peat Forest in Sarawak, Malaysia (Borneo), CMC: Peat Forest Secondary Forest in Sarawak; NAM: Abrayashi Plantation (Wong et al., 2020) in Sarawak; PUF: Undrained Peat Forest (Sakabe et al., 2018) in Kalimantan, Central Indonesia (Borneo), RNF: Undrained Peat Forest in Sumatra, Indonesia; RAP: Acacia (pulp material) Plantation (Deshmukh et al., 2020)

Figure4.5 2 Relation between annual mean groundwater level and annual cumulative CH4 fluxes (emissions) in tropical peatland in Southeast Asia [71]

The daily mean groundwater level of 1 km grids estimated by WRF was substituted into the above equation to map the physical quantities related to methane emissions. We originally used the annual average value of the groundwater level, but since the methane emission does not become an abnormal value due to slight fluctuations of the groundwater level, we carried out experimental mapping of methane emissions.

Methane emissions are high where the groundwater level is higher, such as east of Bunkalis Island and south of Riau Province. On the other hand, in oil palm plantations (broken line in Figure4.4 3, including rubber), which are likely to be heavily fertilized, it is highly probable that a large amount of methane will be emitted even if the groundwater level is low. In this area, we tried to devise a formula for estimating the amount of methane released. However, since places where the groundwater level is high are not agricultural land and are generally not fertilized, it is difficult to specify the relationship between water level and methane emissions under oil plantation conditions (fertilizer application conditions). Therefore, it was decided not to define the methane emission estimation formula according to oil palm plantations.

[71] Source: Hirano (2021)

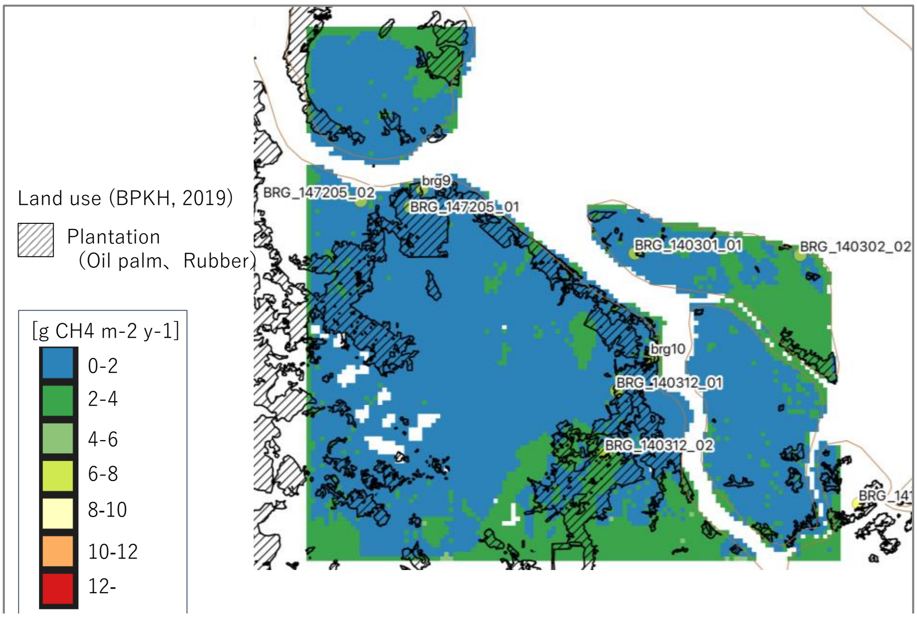


Figure4.5 3 Estimated methane release from WRF (August 16, 2019 (local time))

NOTE: Calculated using daily averages of 1 km grid groundwater levels in the Riau region. Yellow plot points are BRG Observatories.

NOTE: The shaded area is the area of the plantation. This paper refers to the 2019 land-use map by BPKH (Balai Pementapan Kawasan Hutan of the Ministry of Environment and Forestry).

Following figure shows methane emissions estimated from WRF (3 km grid and 27 km grid) for the three states surveyed using the methane emissions estimation formula developed for the Benkalis district in Riau.

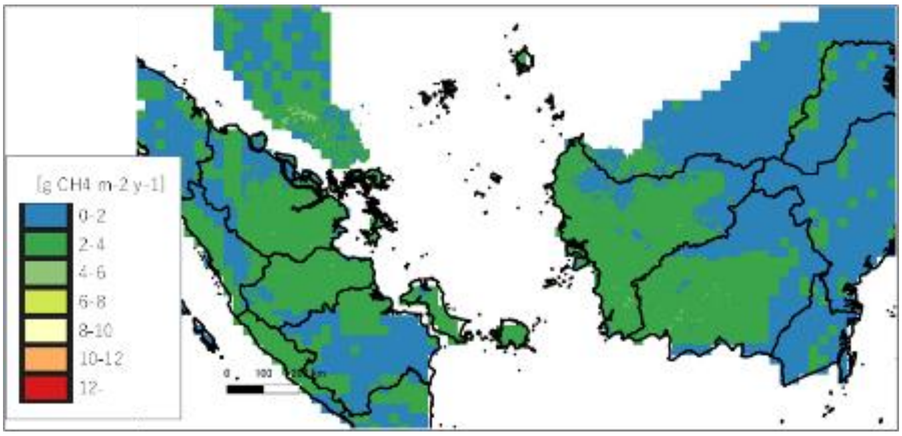


Figure4.5 4 Methane emissions in three provinces estimated from WRF

NOTE: The resolution is a 3 km grid for D03, D04 (August 16, 2019), and a 27 km grid for D01 (November 16, 2018)

4.6 Development and verification of prediction model for frequency and strength of peat fire by groundwater level estimation model

4.6.1 Fire index

In assessing fire risks, KBDI (Keetch-Byram Drought Index has been used as a fire index, but Taufik et al. (2019) proposed a new index, mKBDI (Modified Keetch-Byram Drought Index, in the Acacia Plantation in Southern Sumatra, using ground weather observations and soil moisture content to improve KBDI, the conventional fire index. Here, daily rainfall and groundwater surface coefficient of the preceding rainfall were taken in addition to input information of conventional daily rainfall, annual mean rainfall and daily maximum temperature. The groundwater surface coefficient is composed of the moisture content of the soil surface layer and various correction coefficients (described later).

Taufik et al. (2022) proposed a further refinement of the Fire Index (mKBDI) and a modified index, PFVI (Peatland Fire Verification Index. In the calculation of the groundwater surface coefficient, soil moisture characteristic curve information obtained in the laboratory was taken from collected soil. When various corrective factors were adjusted to minimize the differences between the fire index DIobs and PFVI obtained from the observed soil moisture content, the fire index could be expressed as a result of evaluations using three indices such as KGE (Kling-Gupta Efficiency).

When considering this model, use of the Modified Keetch-Byram Drought Index (mKBDI was originally considered, but in this model we used PFVI because mKBDI was improved to PFVI by Taufik et al (2022). Then, the results calculated by GSMaP and rain gauge were compared, and the possibility of widening was examined.

4.6.2 Changes in groundwater level and soil moisture

In this study, we first analyze the changes in groundwater level and soil moisture content in Kalimantan and Sumatra during small and heavy rains in order to manage land use in consideration of disaster prevention from peatland fires.

In the heavy rain season, we analyze the response of groundwater level to effective rainfall. Regression analysis of both was performed using the method of Masuyama (2009). We considered using 500 m-mesh terrain models (DTM: Digital Terrain Model) (Vernimmen et al. 2019) and land-use maps (Prayoto et al. 2017) obtained from LiDAR measurements.

In the low rain season, we analyze the relation between the groundwater level before decrease and the amount of groundwater level decrease when 14 consecutive days without precipitation are assumed for a continuous period of no precipitation extracted in advance. We also analyze the relation between the number of consecutive precipitation-free days and soil moisture content. The results of the above two analyses in the low rain season are considered using the land-use map (Prayoto et al. 2017) and the oxygen-activation index by NDVI obtained from Landsat8 satellites.

We further analyze the relationship between groundwater level and soil moisture content by land use. This targets all rainfalls, not limited to little rain or the rainy season.

Finally, global satellite precipitation maps (GSMaP) are used to apply to PFVI and KBDI. The applicability of the fire index to satellite rainfall is investigated using DI_{obs} obtained from PFVI and KBDI by ground rain gauge and measured soil water content. The trend of fire occurrence by region is investigated from all the obtained fire indices. To investigate the trend of fires, we use hot spots detected by satellite observations from MODIS and VIIRS, existing peat topographical maps, and DTMs topographical information (Vernimmen et al 2019).

Regarding the response of groundwater level to rain, the relation between groundwater level decrease and pre-decrease groundwater level was obtained when the continuous no-precipitation period was assumed to be 14 days.

In the same vegetation types, it was basically confirmed that the greater NDVI (the greater the activity of the plant), the greater was the largest reduction in groundwater level. Comparing the soil moisture content in consecutive precipitation-free periods with the same vegetation types, it was also confirmed that the greater NDVI, the lower was the soil moisture content.

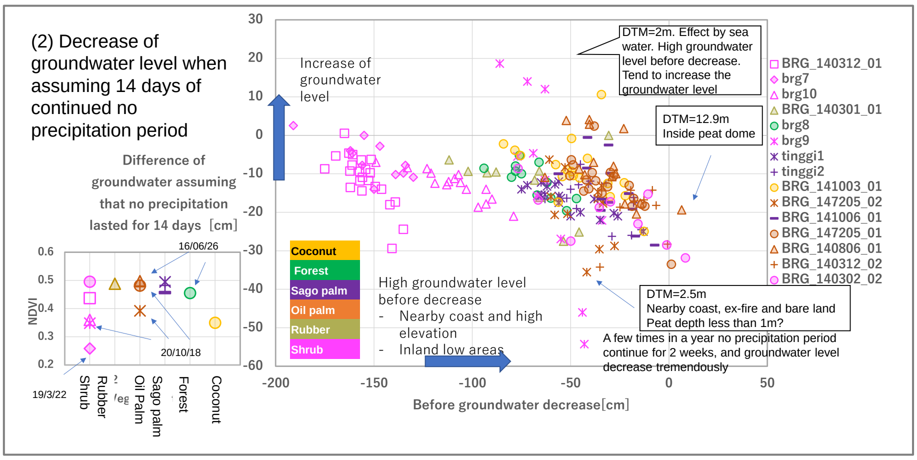


Figure4.6 1 Groundwater level reduction and pre-decrease groundwater level assuming a continuous no-precipitation period of 14 days

On the other hand, it was confirmed that the soil moisture content during consecutive precipitation-free periods was lower as NDVI was higher when comparing the soil moisture content with the same vegetation types.

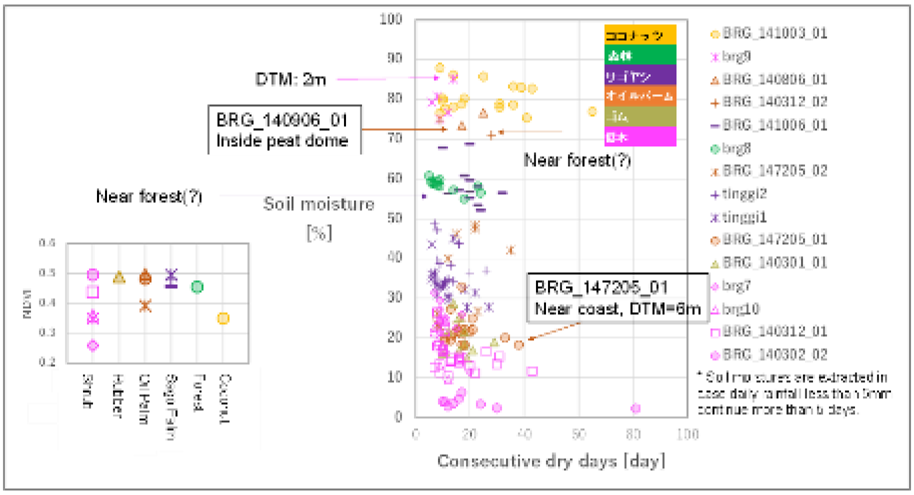


Figure4.6 2 Soil moisture content during continuous precipitation-free periods

4.6.3 Estimation of peat fire index

So far, mKBDI (Taufik et al. 2015) has been considered as a method of peat fires indexing. mKBDI (Taufik et al. 2015) is a modification of KBDI (Keetch et al. 1968) to suit the area of the wetlands. As input values, groundwater surface coefficients (information of groundwater level and soil moisture characteristic curves) were added to conventional daily rainfall and daily maximum temperature. In addition, Taufik et al. 2022 proposed a new PFVI: Peatland Fire Verification Index. The maximum value of the scale was modified from the conventional 203 to 300. The conventional KBDI and modified PFVI equations are shown below.

$$KBDI^t = KBDI^{t-1} + DF^t - RF^t$$

Where [mm], typically the drought factor
({DF}^t), is: DF^t: $Drought\ Index$ $[mm]$,
RF^t: $Rain\ factor, KBDT^{t-1}$: $index\ of\ previous\ day$ $[mm]$.

$$DF^t_{(Ro,ET)} = \frac{(300 - PFVI^{t-1})\left(0.968e^{(0.0875\times T_m+1.552)} - 8.3\right)\times 10^{-3}}{1 + 10.88e^{(-0.001736\times R_0)}}$$

When the daily rainfall is greater than or equal to 5.1mm, the rainfall factor lowers the fire-index.

$(R^t - 5.1), R^t \geq 5.1$ mm/day, 1^{st} rainy day
$R = \{\ R^t, R^{t-1} \geq 5.1$ mm/day, 1^{st} subsequent rainy days
$0, R^t < 5.1$ mm/day, mm day

Modified KBDI have now been proposed that take into account local climatic data, soil-and hydrological properties. Adjusted drought factor DF considering both the modified mean annual rainfall and evapotranspiration for use in equatorial climates in Southeast Asia are as follows:

$$DF^t_{\mathrm{adj}(Ro,ET)} = \frac{(300 - PFVI^{t-1})\left(0.4982e^{(0.0905\times T_m+1.6096)} - 4.268\right)\times 10^{-3}}{1 + 10.88e^{(-0.001736\times R_0)}}$$

Thus, the modified KBDI considering regional climate-information are as follows:

$$mKBDI^t = mKBDI^{t-1} + DF^t_{adj(Ro,ET)} - RF^t - WTF^t$$

$mKBDI$Is a modification of. A groundwater surface coefficient was newly introduced.$KBDIWTF$

$$WTF^t = a_H - b_H \times \{(1 - \theta(h)^t)\} \times 300$$
$$\theta(h) = (1 + [\mathrm{h}/\alpha]^n)^{-m}$$
$$DI_{\mathrm{OBS}} = 300 * [1 - \frac{(\theta_t - \theta_{fc})}{(\theta_s - \theta_{fc})}]$$

Here,

WTF^t : Groundwater surface factor [mm],

θ_t : daily soil water content, θ_{fc}: Lower limit of actual soil moisture, θ_s: Saturated soil moisture,

R_0: Annual average rainfall [mm], T^m: Daily maximum temparature [°C],
h: daily groundwater level $[m]$, $\theta(h)$: moisture contents

According to Taufik et al. (2022), as a new index (PFVI:Peatland Fire Verification Index), the maxima of the scale were modified from the conventional 203 to 300.

$$PFVI^t = PFVI^{t-1} + DF^t_{adj(Ro,ET)} - RF^t - WTF^t$$

In this model, use of mKBDI was originally considered, but since mKBDI was improved to PFVI by Taufik et al (2022), PFVI was used this time.

Using PFVI and KBDIadj by the ground rain gauge and DIobs obtained from the measured soil moisture content, the applicability of the fire index to satellite rainfall was examined. Since the fire index is susceptible to rainfall and this time, the accuracy of rainfall estimation by WRF in Indonesian peatlands was not sufficiently verified, it was decided not to verify the accuracy of the fire index using WRF.

In order to examine the adaptability of the fire AFAVCindex to a wide area, the data of GSMaP, which is wide area data, was used in addition to the calculations based on the data of one observation point (BRG data). The variation in KGE accuracy according to the station was smaller for KBDIadj than for PFVI (Figure4.6 3). For both BRG and GSMaP, PFVI may have a minimal KGE of about -1.5 and very poor PFVI accuracy. Soil-moisture profile data from Taufik et al.(2022) are used, so it may not be possible to express them in this region. Also, GSMaP may or may not be representative of the region's typical rainfall, although PFVI calculated in GSMaP may be higher than KGE=0.71 (140312_01). It is considered appropriate to use a KBDIadj with relatively stable accuracy, and calculate it from GSMaP as a possibility of adapting the fire index to a wide area. In the case of PFVI, the geographical characteristics of groundwater level and soil moisture content are required.

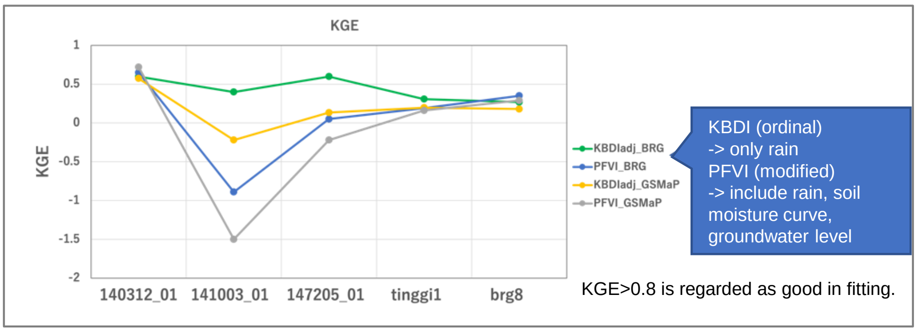


Figure4.6 3 Comparison of fire index accuracy

In creating a map of the fire index, we used the outcome of a 1 km grid groundwater level map estimated in WRF and applied it to KBDIadj (Figure4.6 4). Fire indexing maps using GSMaP were not prepared because the relationship between GSMaP and groundwater level was insufficient. PFVI was not used to create a map of fire indices, because it needs to be informed of the soil-moisture characteristic.

The fire index was relatively low near the coast, with understandable results on peatlands. Note that KBDIadj does not use groundwater level information, so the results are a function of rainfall information.

On the other hand, the groundwater level map results showed that groundwater levels were higher near the coast, in contrast to locally observed data. As a result, the results were able to take account, to some extent, of the characteristics of groundwater levels near the coast in peatlands.

Areas of former fire sites (pink in the figure below) detected during the one-month period of August 2019 by MODIS satellites are distributed in areas with higher fire indices (orange in the lower part) on the south side of Riau Province.

In primary and secondary wetland forest areas (hatched areas in4), there are relatively few areas of former fire sites. In natural forests, evapotranspiration is prevalent, and the groundwater level may drop significantly during the dry season. However, since the surface layer is moist, there is little fire. Therefore, the possibility of excluding primary and secondary wetland forest areas (especially primary wetland forest areas) from the fire forecast and alarm models is also considered.

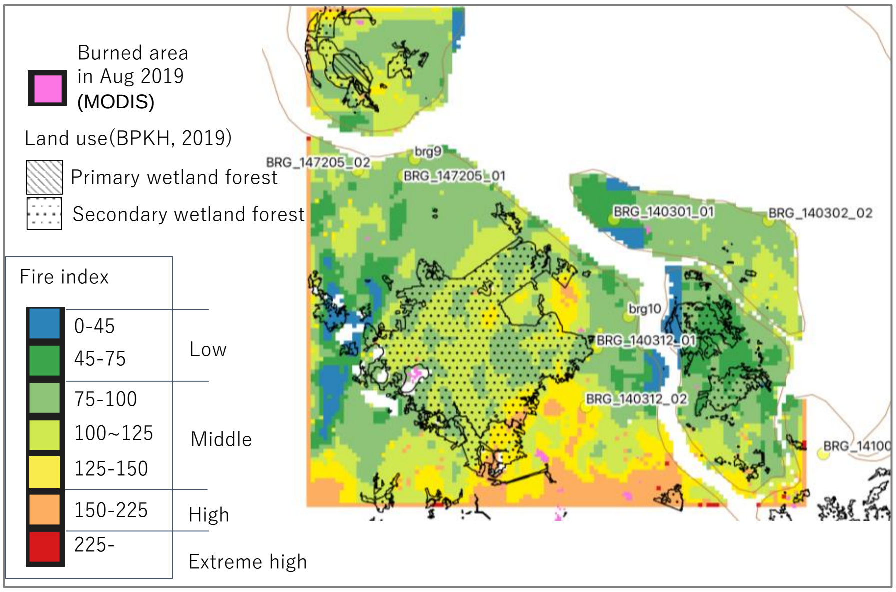


Figure4.6 4 Estimated fire index KBDIadj (2019 August 16 (local-time) based on WRF

NOTE :Calculated using 1 km grid-groundwater level in the Riau region.
Yellow plot points are BRG Observatories.

The primary and secondary wetland forests were hatched with hatched lines and dots, respectively. The sites of fires according to MODIS satellites was colored pink.

The fire index KBDIadj estimated from WRF (3 km grid and 27 km grid) data for the three states surveyed using the fire index KBDIadj estimation equation developed for the Bengkalis district in Riau are shown in following figure.

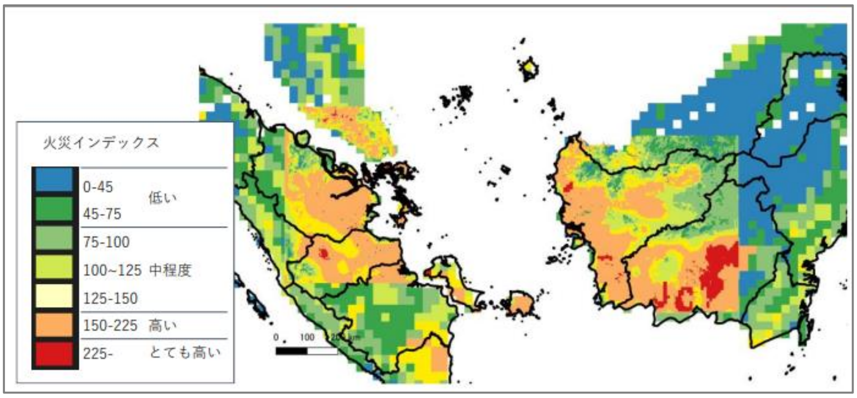


Figure4.6 5 Fire index KBDIadj for three provinces estimated from WRF

NOTE: The resolution is a 3 km grid for D03, D04 (August 16, 2019)
and a 27 km grid for D01 (November 16, 2018).

4.6.4 Relationship between fire frequency and fire index

Fire incidence trends by region were investigated from the fire index. As a survey of fire-prone trends, hot spots detected by satellite-based observations from MODIS and VIRS are used, and vegetation data confirmed by field surveys and land-use maps by Prayoto et al. (2017) are used in observatories that have not conducted field surveys.

The study of the relationship between hotspots and KBDIadj calculated from BRGs showed that the number of cases with 4 or more hotspots per day was 2 for the "high" fire danger class and 15 for the "highest" class. Here, the number of hotspots is defined as the total number of hotspots detected from satellite observations from MODIS and VIRS over a 10 km square area, indicating that when KBDIadj is classified as the "highest class", hotspots are also relatively easy to detect.

Figure4.6 5 shows the relation between KBDIadj and groundwater level calculated from BRG for more than one hot spot per day. Attention was focused on August to October, when fires frequently occur. Considering the soil moisture content of the consecutive precipitation period according to land-use, three of the five KBDIadj stations used to calculate BRG were classified as "highest risk" in KBDIadj, but the number of hot spots per day was as low as one. Of the remaining two, the 141003_01 coconut area detected a relatively high level of soil moisture at around 70% during the continuous no-precipitation period, but one to five hot spots per day. This area is located in small islands and near the shore. Although the soil moisture content is high, it is necessary to pay attention to the fire hazard in the dry season, because a relatively large amount of hot spots are detected. For the oil palm plantation at 140312_01, the amount of water in the non-precipitation period was low (10-20%) and the number of hot spots per day was at most eight, which was the highest among five areas for which KBDIadj was calculated.

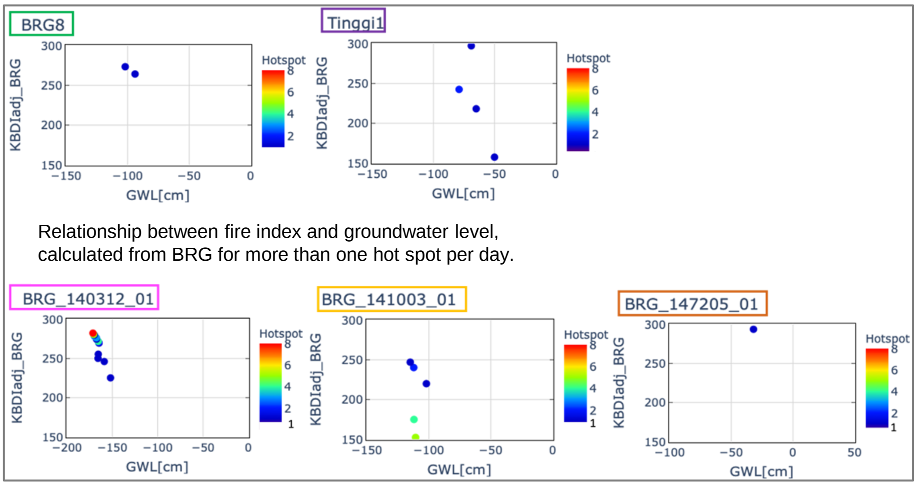


Figure4.6 6 Fire index (KBDIadj) and scatter plot of groundwater level daily max calculated from five BRG Observatory data

N.B.: Only when the number of hot spots per day in August to October is one or more, was the data plotted.

4.6.5 Drone-based fire monitoring

Regarding the monitoring of fires, how early fires can be detected and fire extinguishing activities performed is important to prevent the spread of fire. On the other hand, it is difficult to detect incipient fires because the information of hot spots using MODIS, etc., is only rough when the resolution is 10 km. This section presents the results of monitoring fires using drones conducted on August 18, 2022, in Riau, eastern Palawan.

The cameras used are a visual camera (Phantom 4 Pro) and an infrared camera (Inspire1 and thermocamera). The area of the maps created is 2.280ha. In operation of the drone, the following automatic navigation was carried out. Regarding visual cameras, the overlap rate is 85%, the side lap rate is 85%, and the altitude is 50 m. For the infrared-camera, the overlap rate is 90%, the side lap rate is 90%, and the altitude is 50 m.

The left side of Figure4.6 7is a screen capture of an aerial video taken on August 18, 2022 at Riau, eastern Palawan. The right of Figure4.6 7is a map of the ortho image of the visible camera. In both the left and right images, the difference in color can be clearly distinguished between a fire site and a site where there was no fire. Also, smoke can be seen from the left image in various places. From the image on the right, it can be confirmed that the oil palm has spread out. During the rain on the day of the accident, photography was completed by autonomous navigation amid concerns about battery deterioration.

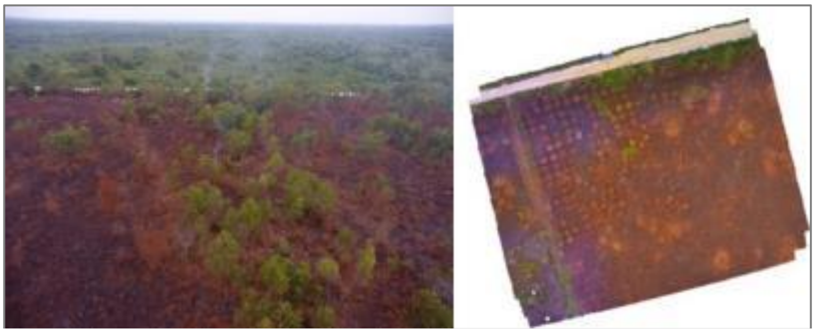


Figure4.6 7 Mapping of visual images of drones and ortho images of visual cameras in Riau, eastern Palawan (shot on August 18, 2022)

The left side of Figure4.6 8shows the analysis result using orthographic images of a thermal infrared camera (the images are combined and mapped). The fire point detected from the thermal infrared camera image is displayed in red. The threshold temperature was set to 60 degrees. In the red portion, more than 100 degrees was found.

The right side of Figure4.6 8shows the results of taking pictures of the same location as the fire points A and B detected by the thermal infrared camera with a visible camera. No smoke is seen in A, but smoke is observed in B.

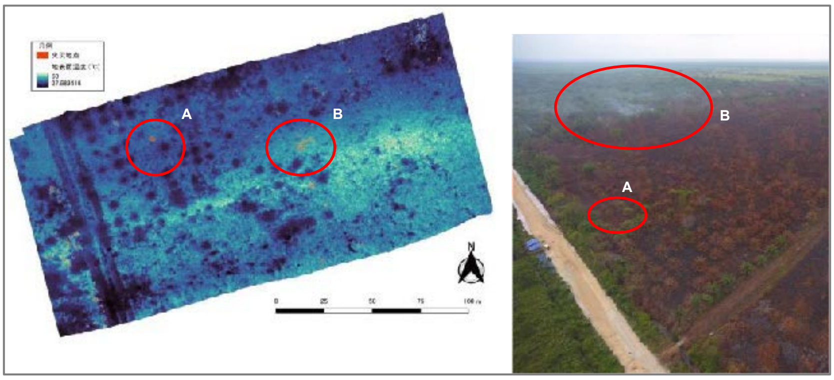


Figure4.6 8 Comparison of analysis results of thermal infrared camera using orthographic images and photographs taken by visual camera at the same location (photographed August 18, 2022)

NOTE :Left: The fire point detected from the thermal infrared camera image is displayed in red. Right: Result of shooting the same location as the fire points A and B detected by the thermal infrared camera with a visual camera

Also, Figure4.6 9 shows hot spots detected in MODIS and VIIRS from August 16 to 18 (UTC), 2022, in red. including 2 days prior to the day of drone monitoring. The monitoring location is around the red circle. No hot spots from satellite images were detected at the location monitored by the drone.

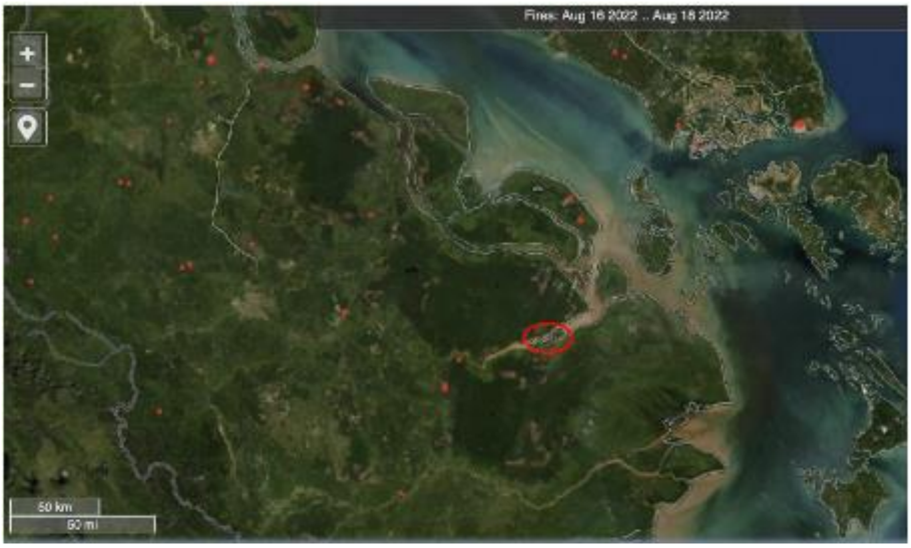


Figure4.6 9 Hotspots detected in MODIS and VIIRS from August 16 to 18, UTC, 2022

N.B.: Hot spots detected in MODIS and VIIRS from August 16-18, UTC, 2022 are shown in red (FIRMS: https://firms.modaps.eosdis.nasa.gov/map/). The monitoring location is around the red frame.

Source: JICA Survey Team

From the above, it was proven that the fire monitoring of the drone using the thermal infrared was useful for fires which could not be caught by smoke and MODIS. In the practical use of fire monitoring by drone, it is important to find the fire area as soon as possible because it may cover a wide range to some extent.

4.7 Peat mapping using groundwater level estimation model

4.7.1 Comparing existing border data

Boundary information provided by BRGM and the Indonesian Bureau of Land Intelligence BIG were compared from various satellite data, such as the GSMaP soil moisture map and LiDAR terrain data. An example of the results of the comparison is described below.

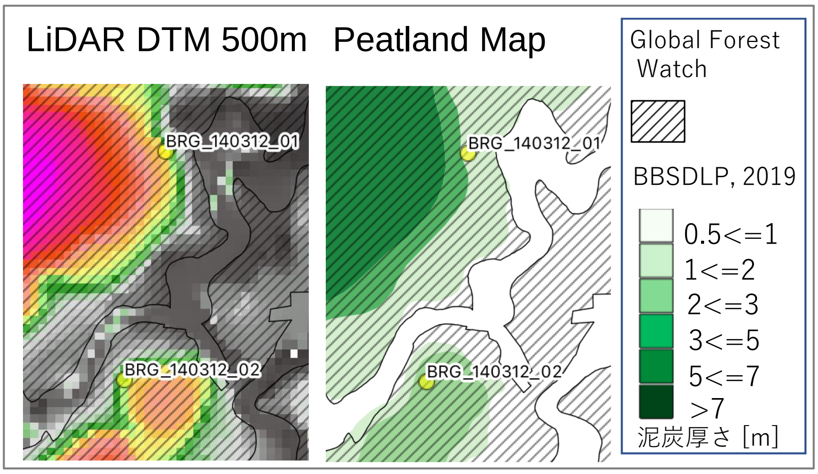


Figure4.7 1 Comparison of existing boundery data

According to the figure above, BBSDLP (green in the figure on the right) is smaller in the area of peatland than Global Forest Watch (GFW (hatched in the figure on the right), but the LiDAR DTM altitude model (left) is along the boundary of GFW. In addition, the resolution of BBSDLP appears to be slightly coarser than that of LiDAR DTM or GFW. Thus, the existing boundary data seemed to have a completely different boundary depending on the resolution, etc., and therefore, it was necessary to verify the existing peat site mapping.

In the Peatland Bordering Data (BBSDLP, 2019) published by the Indonesian Agricultural Resource Research and Development Centre (BBSDLP), peat thickness is divided into six categories, from 50 cm to 7m and above (see the legend inFigure4.7 1). This peat map is created by satellite-based altitude, boring surveys, vegetation and climatic data (BBSDLP, 2020).

In the examination of peatland mapping, the present peatland map (BBSDLP, 2019) was compared with the local measurements of handover boring and underground radar (GPR) (Figure4.7 2), and bordering data of altitude maps, hydrology, vegetation data, and Global Forest Watch (GFW by LiDAR were also referred to and discussed. Figure4.7 3shows a schematic diagram of the peat map (BBSDLP, 2019), the boring survey, and the field images.

Here, the appropriate dielectric constant was examined in obtaining peat thickness from GPR. This is because the GPR which is measured depth-wise changes according to the dielectric constant. The dielectric constant varies depending on the material. For example, the dielectric constants of dried sand, concrete, and wet clay are 3-6, 6-8, and 8-15, respectively (IDS, 2013). In order to use a more appropriate dielectric constant, peat thickness was estimated from GPR at the 1(140312_01) point in August, where the measured groundwater level was lowest, using dielectric constants close to the three-pattern materials (6.2, 8, and 12, respectively). Their results and the dielectric constant when the boring results are closest were investigated. This is because when the groundwater level is high, the attenuation increases and it becomes difficult to distinguish the target. The device used this time was IDS TR80, with a 600 mHz frequency-antenna. To measure the depth of the ground several meters to 10 m, the frequency is 200 mHz, but 600 mHz was used due to trouble with the antenna.

The optimum permittivity was found to be 8, which is around the upper limit of concrete or the lower limit of wet clay. Therefore, 8 was used as the dielectric constant this time.

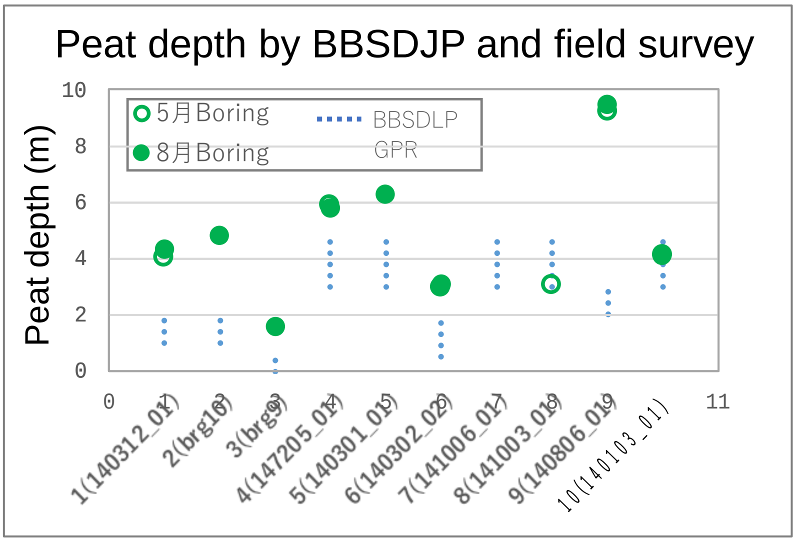


Figure4.7 2 Comparison of peat thickness using hand auger boring and peat thickness on BBSDLP Peatland Map

NOTE: Green points are hand auger boring, and the blue dotted lines are a peatland map (BBSDLP, 2019). The peat map was plotted from the lower limit to the upper limit of the class of peat thickness.

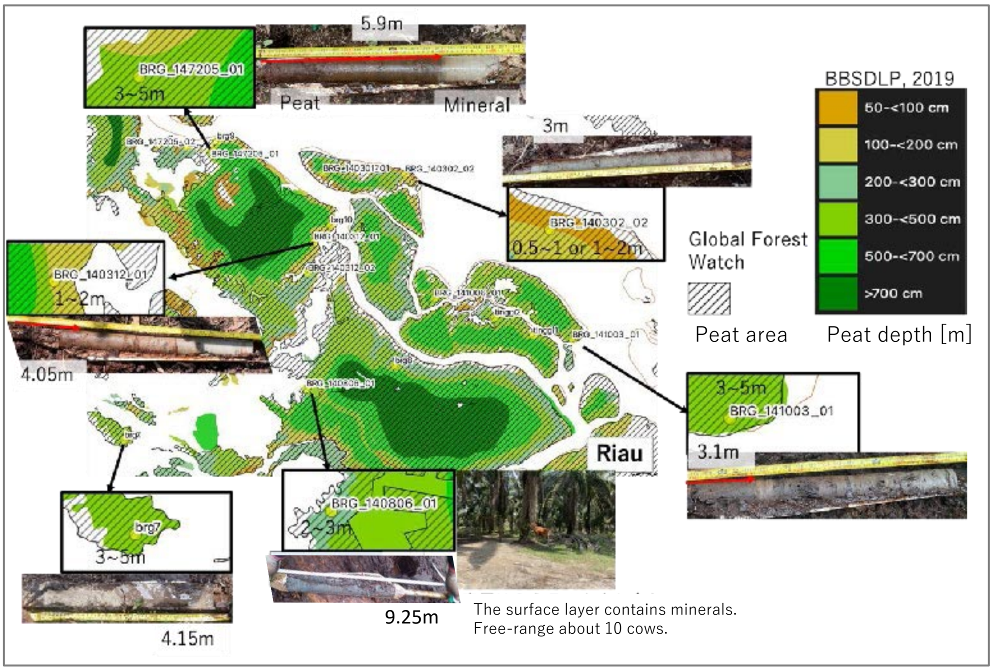
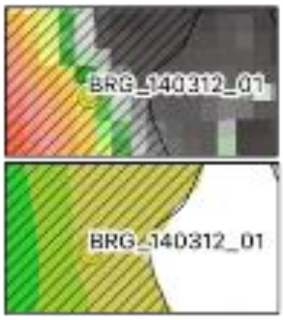
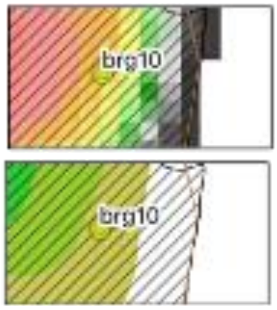
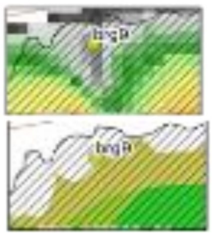
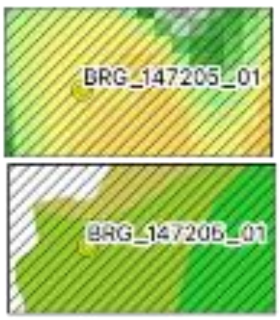


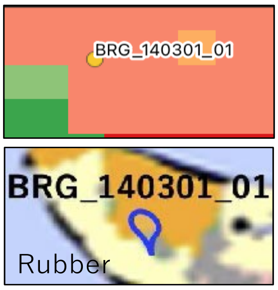
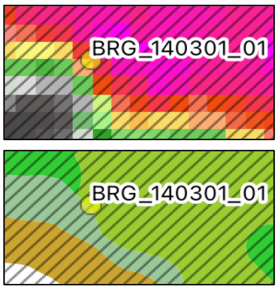
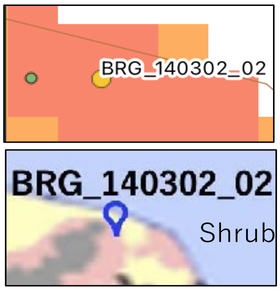
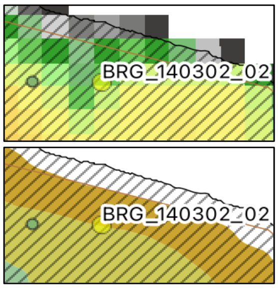
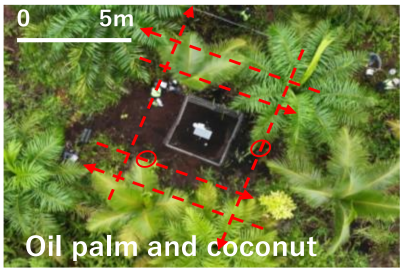
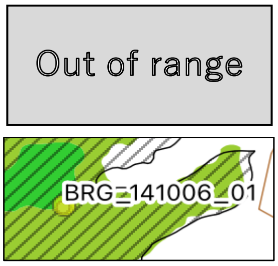
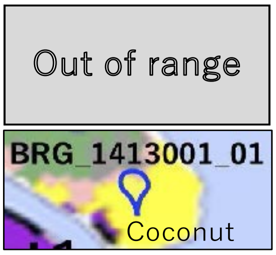
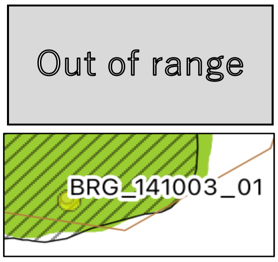
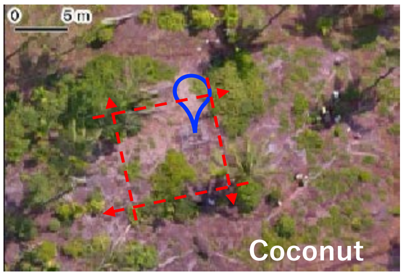
Figure4.7 3 Pictures of the location where hand auger boring was performed, site images, and peatland maps (BBSDLP, 2019)

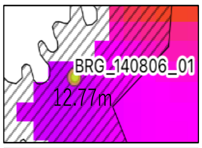
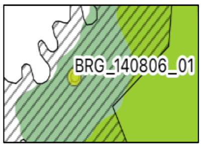
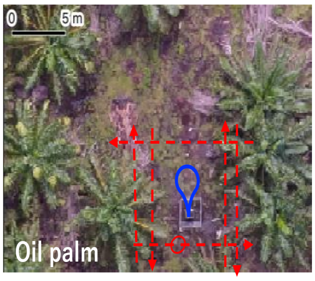
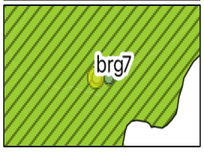
NOTE: Images used were taken in May and August 2022

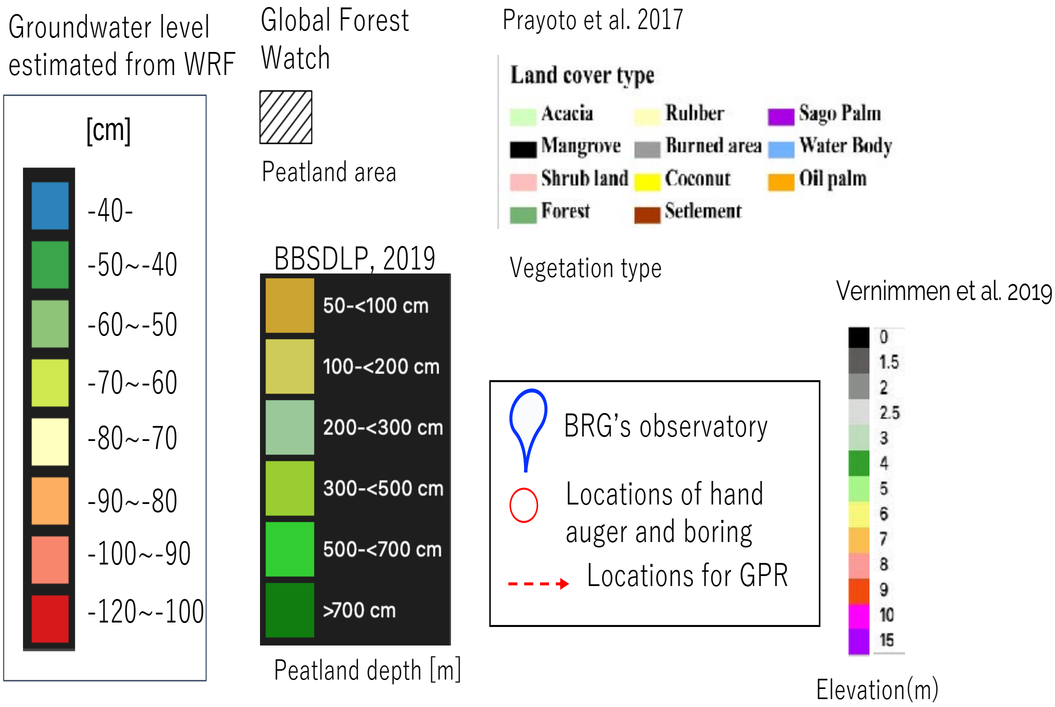
In addition, a 1 km grid groundwater level map estimated by WRF, vegetation distribution map (Prayoto et al., 2017), and orthomosaic images generated from drone images are shown in Table 12 for peat maps (BBSDLP, 2019) and altitude maps (Vernimmen et al., 2019).

Table4.7 1 Comparison of images by Observatory

No. Station	Groundwater level map/ Direct measurement/ Landcover map	BBSDLP Peatland map/ LiDAR Elevation map	Drone photo (vegetation)/ Sites for GPR or boring (depth)
1 140312_01	 GWL(WRF) -0.79m GWL(direct) -0.79m		
2 brg10	 GWL(WRF) -0.92m GWL(direct) no data		
3 brg9	 GWL(WRF) -1.03m GWL(direct) -0.47m		 Ferns around brg9 station (red broken lines) Expanded image of red-color square of image C
4 140205_01	 GWL(WRF) -1.04m GWL(direct) -0.61m		

5 140301_01	 GWL(WRF) -0.93m GWL(direct) no data		
6 140302_02	 GWL(WRF) -0.92~-0.90m GWL(direct) -0.45m		
7 141006_01	 GWL(WRF) no data GWL(direct) -0.34m		
8 141003_01	 GWL(WRF) no data GWL(direct) -0.39m		

9 140806_01	Out of range  GWL(WRF) no data GWL(direct) -0.2m	 	
10 140103_01	Out of range  GWL(WRF) no data GWL(direct) -0.2m	Out of range 	  There are 2 observatory stations for Brg7, with about 600m distance. The data from the observatory in the right figure are used for the BRG's online data。



NOTE: Left-to-left column 1: Groundwater level estimated by WRF in the upper row and vegetation map in the lower row (Prayoto et al., 2017). The table below shows the measured groundwater level (at the time of the survey in May), and the groundwater level estimated by WRF.

Left-to-left column 2: The upper row is an elevation map (Vernimmen et al. 2019) with 500 m grids measured by LiDAR, and the lower row is a peat map (BBSDLP, 2019). The hatched area is also a peat map (GFW).

Column 3 from the left: Orthomosaic or aerial images analyzed from aerial images of the drone.

(The red dashed line indicates GPR measurement path, the red circle indicates the boring position, the yellow dots indicate information of the station obtained from BRIN, the blue and green dots indicate the location of the station detected from the drone image, and GPR and the boring survey position indicate the location at the survey in August preferentially).

Features in peat land were analyzed with peat thickness, vegetation, hydrological environment, topographical, water system distance, etc.. Based on land use and topographical conditions, the following three categories are classified, and the results of verification of peat maps based on the classification are listed below.

Table4.7 2 Relationship between soil moisture content types, land use and topographical conditions

Soil moisture content type	Land use and topographical information	Relation between observation stations (results of soil moisture content data and field surveys from 2017 to 2021)	Description and fire information
A	Flat areas in peat domes (oil palm), Meranti island area (coconut and boxwood), near the coast and close to waterways (ferns). [Exception] High slope but close to waterways (oil palm)	BRG_140806_01, BRG_141003_01, BRG_141006_01, brg9, [Exception] 140312_01	The soil moisture content is always high at 40% or more. Ferns are growing at brg9, which is thought to be the site of a fire. Fire in 2021 5-6 km from 141003_01. Fire in 2014 about 1km ahead of 140806_01.
B	The slope is relatively high. Oil palm, coconut, gum, ferns, moss	Brg7, brg10, BRG_140302_02, BRG_140312_01, BRG_140301_01	Soil moisture content is always low, less than 50%. 140302_02 has many dead leaves and dead branches. No change in vegetation here as coconuts survived the 2014 fire. 140301_01 caught fire 700 m away in 2018. brg7 fire 2-4 km away in 2014, and 5 km away in 2021.
C	Area of rubber near the shore	BRG_147205_01	Wide variation in soil moisture content from a minimum of about 20% to a maximum of more than 50% throughout the low and high rainfall periods.

NOTE: Only observatories visited in the field survey of this work are described. Information on fires was obtained from interviews with local residents managing observatories. The mention "exception" reflects the results obtained from a field survey.

(a) Soil moisture content type B: In a slope (140312_01,140302_02, brg10), the peat thickness of the peat map (BBSDLP, 2019) has a large error from GPR or the boring survey

At 140312_01, the peat thickness from the borehole is approximately 4 m. The distance from the channel here is about 20 m and the water surface from the channel surface is also high. Groundwater levels may therefore be high in some locations. Since moss was also found in various places, it appears that the soil tends to become moist. Soil moisture content is also high, at around 70-80%. The groundwater level estimated by WRF is lower than that of the surrounding area. It is not known whether this is affected by slopes. However, WRF data (August 16, 2019) and the measured groundwater level (May 17, 2022) differ in timing. It should be noted that the groundwater level estimated in WRF is used to confirm the relative groundwater level according to the topography.

The BBSDLP Peatland Map appears to have a coarser spatial resolution than LiDAR elevation map. For example, at 140302_02, a small vertical valley is formed along the shore, but no such topographical feature is seen in the BBSDLP Peatland Map (Figure4.7 1). Since Brg10 is also a sloping area, the error between the BBSDLP Peatland Map and GPR is large.

(b) Soil moisture content type C: In coastal areas (brg9), the BBSDLP Peatland Map has large errors (peatland borders).

The accuracy of existing bordering data for Brg9 near the coast was confirmed at a limited number of sites. The peatland thickness of BBSDLP in this region is below 0.5m and is out of scope. On the other hand, it is included in the peatland area of GWF. According to GPR, peat thickness was confirmed to be 3 to 6.5 m. From the viewpoint of water retentivity of soil, groundwater level is considered to be periodically raised by the inflow of seawater, because the altitude is low here, near the sea coast, and the distance from the water channel is short. Therefore, there is a possibility that the soil moisture content has been kept high. From the viewpoint of hydrological environment, the possibility that peat exists to some extent cannot be denied.

(c) Soil moisture content type A: The flat area (140806_01) on the peat dome has a locally deep peat thickness.

The BBSDLP Peatland Map and GPR and boring survey also showed large errors in the relatively flat area of 140806_01. The peat thickness obtained in the boring survey was more than 9m in both May and August. In GPR, the peat thickness of 1.5～4 m was measured. BBSDLP is 2 to 3 m. The high-resolution altitude map by LiDAR shows that the altitude is locally high, but the BBSDLP Peatland Map does not show such a difference in the local peat thickness (Figure4.7 1).

As a characteristic of this region, mineral soil was mixed in the vicinity of the surface layer. The area around the BRG administrator's house, which is 100-200 m away from the observatory, is clearly soil-colored, so it is considered that the area around this area contains mineral soil.

As for the reason why the error between GPR and boring outcomes is large, the peat thickness due to GPR may contain the error. As for 9(140806_01), this is located on the flat surface of the peat dome and the groundwater level is constantly higher (both May and August -20 cm). There is a possibility that the deep peat could not be distinguished by GPR because it contains a large amount of water. Figure4.7 4shows GPR at Observatory 9 (140806_01).

As mentioned above, when the results of GPR contain errors, peat thickness was found to change on a more detailed spatial scale according to the boring results, and there were some parts which were not represented by peatland maps.

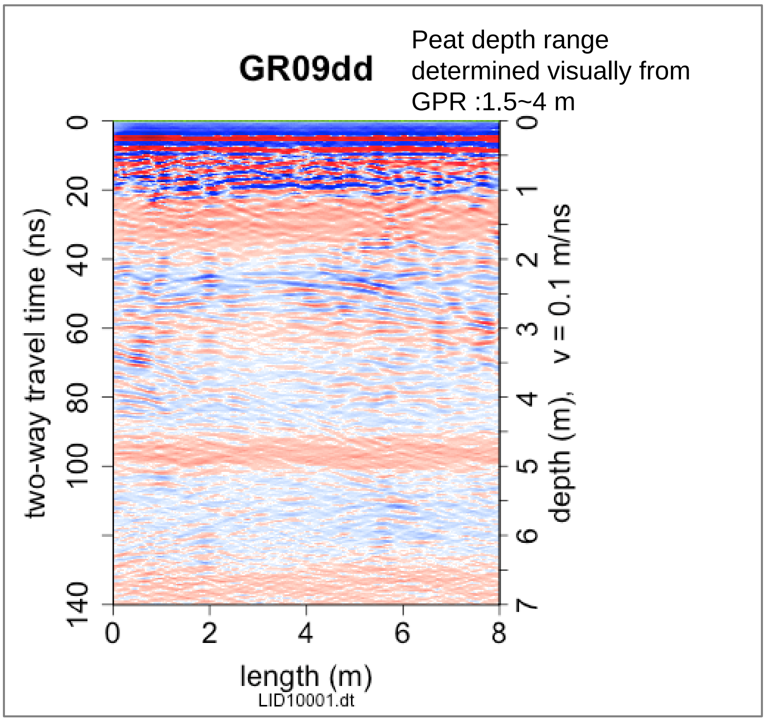


Figure4.7 4 Sample GPR measurement at Observatory 9 (140806_01)

N.B.: Conducted in August 2022.

Summarizes the validation of these five locations (140312_01, brg10, 140302_02, brg9, 140806_01).

- Existing bordering data (BBSDLP) are compared with altitude maps, boring surveys and GPR. The existing bordering data tend to overlook local peat thickness variations due to low resolution, and to not express the border or slope of peat.
- It was possible to explain the results by also using vegetation information to confirm the water retention of peat soil.
- Since the bordering informations of BBSDLP does not include a peat thickness 0.5m or less, there is a tendency that bordering data is not properly expressed in low-altitude areas near the shore.
- The result of the boring investigation in this region shows that peat thickness is of a certain degree, and it is a region where the soil moisture content is always high from hydrological and topographical information.

In addition, BBSDLP of the other points except the above five points showed values roughly close to those obtained by boring or GPR.

4.7.2 Peatland mapping with a groundwater level estimation model

This section describes peatland mapping using groundwater level estimation models (3 km grids) and existing geospatial information (BBSDLP Peatland Map, Landuse Map (2019), SRTM altitude maps, and drilling survey data by the Japanese Ministry of the Environment (2016 & 2017), etc.).

(1) Groundwater level estimation (3 km grid) and BBSDLP Peatland Map (Central Kalimantan)

InFigure4.7 5, the areas where the groundwater level is shallow are shown in deep blue (maximum -30 cm), and areas where it is deep are shown in light blue (maximum -120 cm). In addition, the depth contours -70 cm and -75 cm of the groundwater level are shown in light green and magenta. In Figure, when the BBSDLP Peatland Map was superimposed in order to grasp the distribution of groundwater level and peatland, it was found that the groundwater level contour (-70 cm, -75 cm) roughly corresponds to the distribution of peatland in central Kalimantan. In central Kalimantan (northern Palankaraya), there are shallow areas of groundwater level (in the yellow dotted circle in Figure). It was found that there is a place where there is a high possibility of the existence of unidentified peatland, which is not mapped by the of BBSDLP Peatland Map (2019), mainly in which the groundwater level is shallow from the -50 cm to -40 cm level.

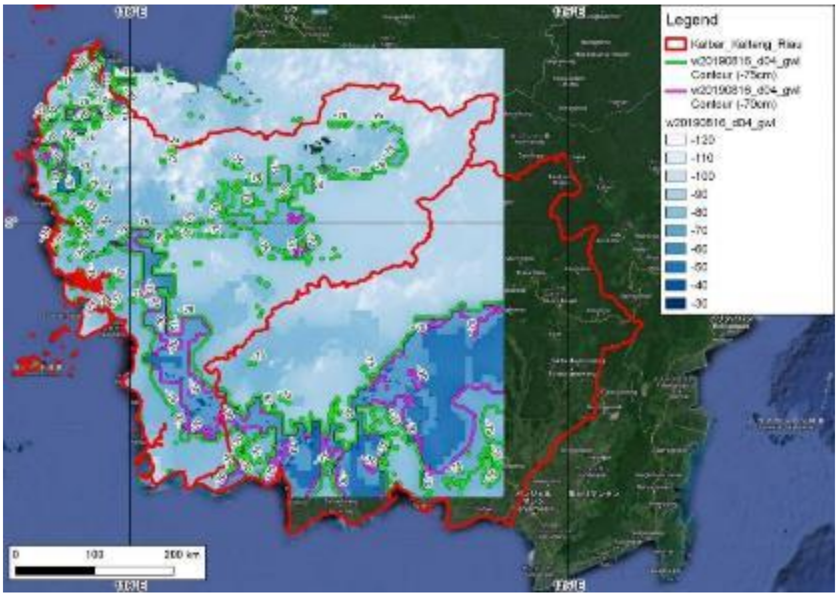


Figure4.7 5 Distribution of WRF/ groundwater level (-70 cm, -75 cm depth contour) in central and western Kalimantan provinces

Following figure shows the histogram of WRF groundwater level for each peatland thickness on the BBSDLP Peatland Map in central Kalimantan province. This is the result of extracting WRF groundwater level of 3 km grids for each peatland polygon on the BBSDLP Peatland Map. Peatland thickness is divided from D1 to D6 as shown in the legend on the right inFigure4.7 6. The deepest groundwater level is approximately of the order of -80 cm～-75 cm, and the -75 cm groundwater level contour shown in next figure can be the borderline of peatland. In addition, when compared for each peatland thickness, peaks of the histogram are observed near -75 cm to -65 cm for D1～D3, but these are widely distributed from -75 cm to -45 cm in D4, and the peaks are shifted to -50 cm in the thickest peatlands in D5 and D6.

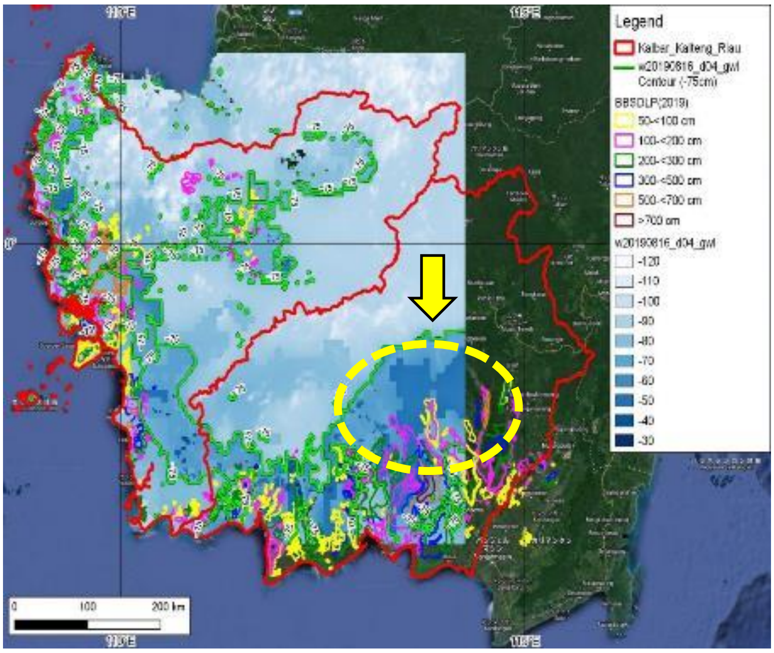


Figure4.7 6 Peatland distribution and groundwater level contour (-75 cm) in Central and Western Kalimantan Province

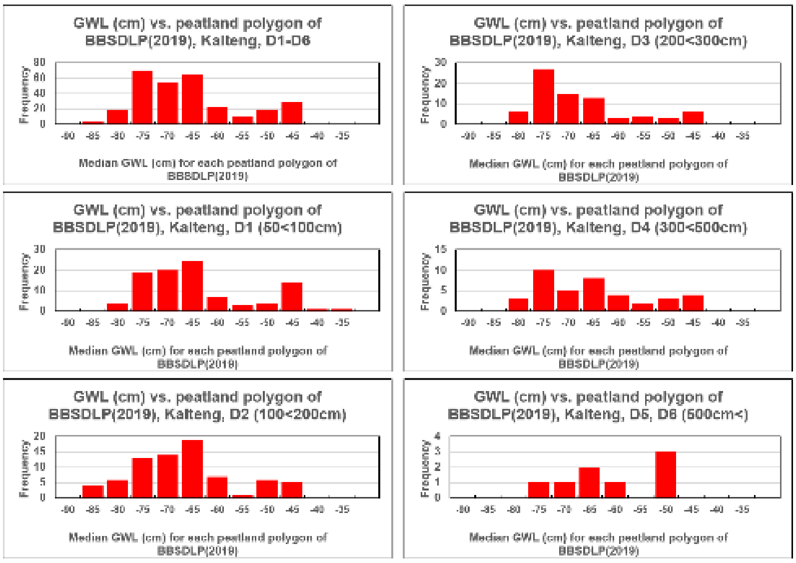


Figure4.7 7 Histogram of groundwater level frequency for each peatland thickness on the BBSDLP Peatland Map in Central Kalimantan Province (after extracting WRF groundwater level of 3 km grids in each peatland map polygon)

(2) Groundwater level estimation (3 km Grid), BBSDLP Peatland Map and Landuse Map (2019)

The groundwater level contour (-75 cm), BBSDLP Peatland Map and Landuse Map (2019) for the northern part of central Kalimantan are shown in Figure4.7 8The peatland distribution in the left-hand image almost matches the areas of 04_Secondary Swamp Forest on the Landuse Map (2019) in the right-hand image, and the northern border of the peatland is in contact with the yellow-green 02 Secondary Dry Forest, which is non-peatland vegetation. Therefore, the Landuse Map (2019) was found to be useful for bordering peatland.

On the other hand, as the yellow dotted circle of 04_Secondary Swamp Forest shows that some peatland areas do not overlap the peatland distribution area, there is an unidentified peatland area in the 04_Secondary Swamp Forest that almost coincides with the peatland area distribution.

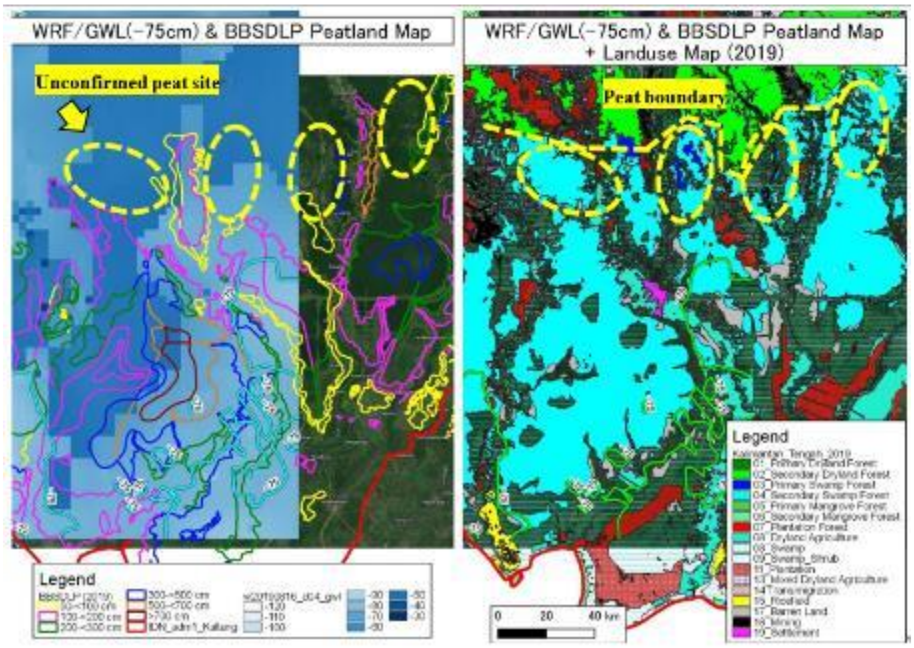


Figure4.7 8 Groundwater level contours (-75 cm), BBSDLP Peatland Map (left), and Landuse Map (right)

(3) Comparison of BBSDLP (2019) Peatland Map and SRTM/DEM elevation values

In order to investigate the elevation values in the peatlands of the BBSDLP (2019) Peatland Map, the elevation values of SRTM/DEM for each peat thickness were examined. Figure4.7 8shows the BBSDLP (2019) Peatland Map and SRTM/DEM in Central Kalimantan Province, and Figure4.7 9shows the BBSDLP (2019) Peatland Map and SRTM/DEM elevation value histograms in the three provinces.

In Central Kalimantan and Riau provinces, peatlands generally show an elevation of 50m or less. West Kalimantan has some elevation values of about 75 m. In addition, when compared by peat thickness, relatively thick peatlands tend to have higher elevations. For example, in Central Kalimantan D5-D6 (more than 500 cm) are located at altitude 20-35 m, West Kalimantan D5 (500-700 cm) at altitude 5-25 m, and Riau D6 (700 cm or more) at altitude 20 m-35 m, respectively. Although SRTM/DEM indicates tree height rather than ground height, it is considered to represent the topographical features of so-called peat domes.

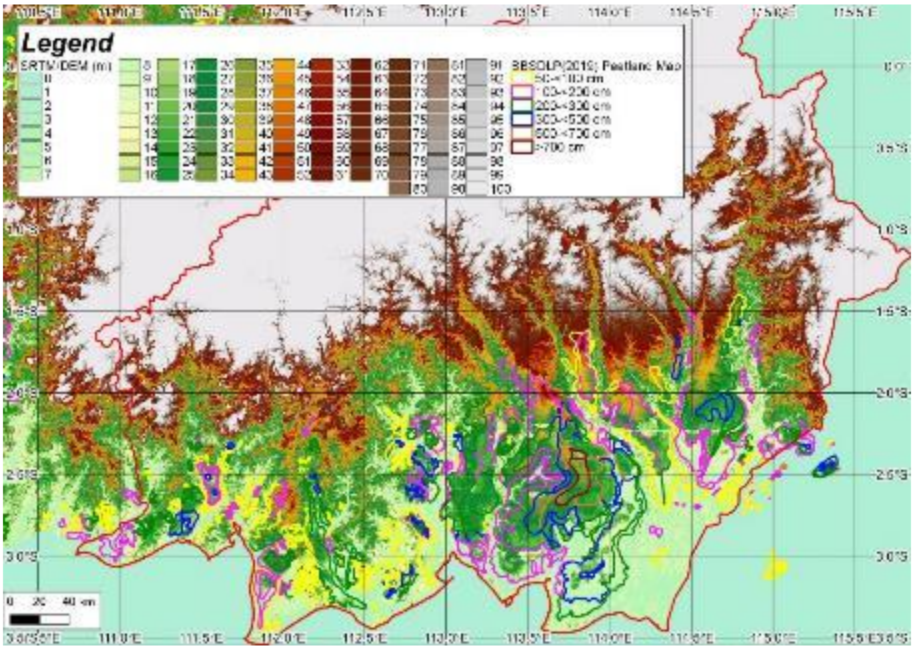


Figure4.7 9 BBSDLP (2019) Peatland Map and SRTM/DEM elevation values for Central Kalimantan Province

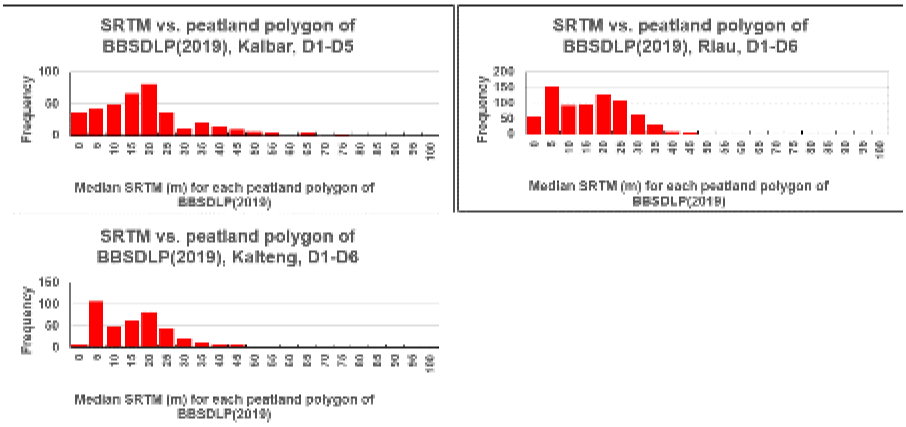


Figure4.7 10 Histogram of elevations of peatlands on BBSDLP Peatland Map, and SRTM/DEM elevation values in three provinces

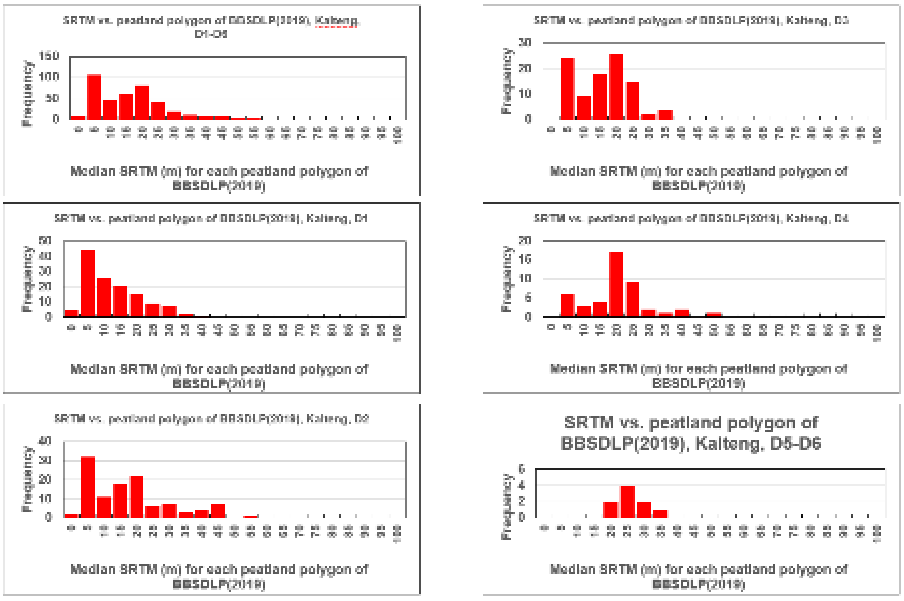


Figure4.7 11 Histogram of elevations of peatlands on BBSDLP Peatland Map, and SRTM/DEM elevation values in West Kalimantan Province

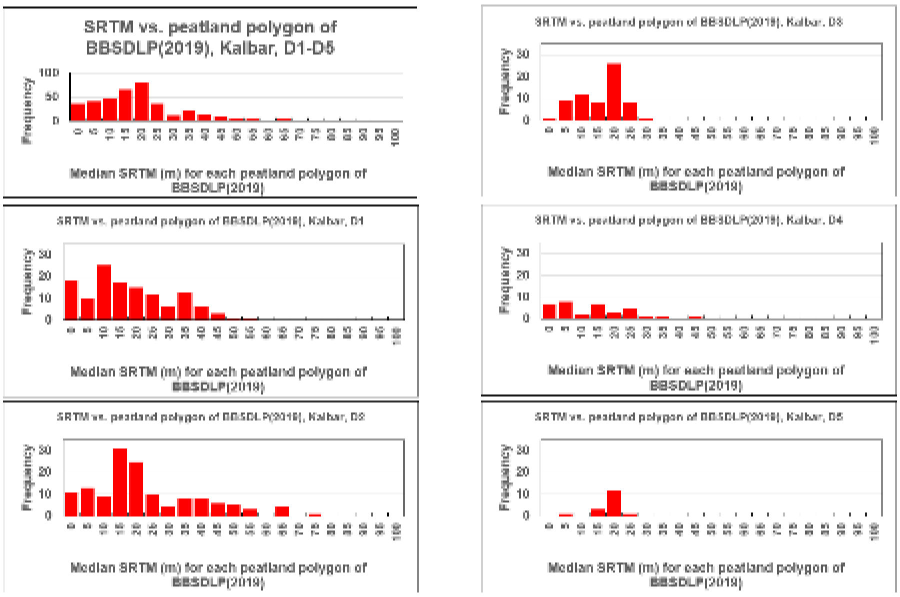


Figure4.7 12 Histogram of elevations of peatlands on BBSDLP Peatland Map, and SRTM/DEM elevation values in Central Kalimantan Province

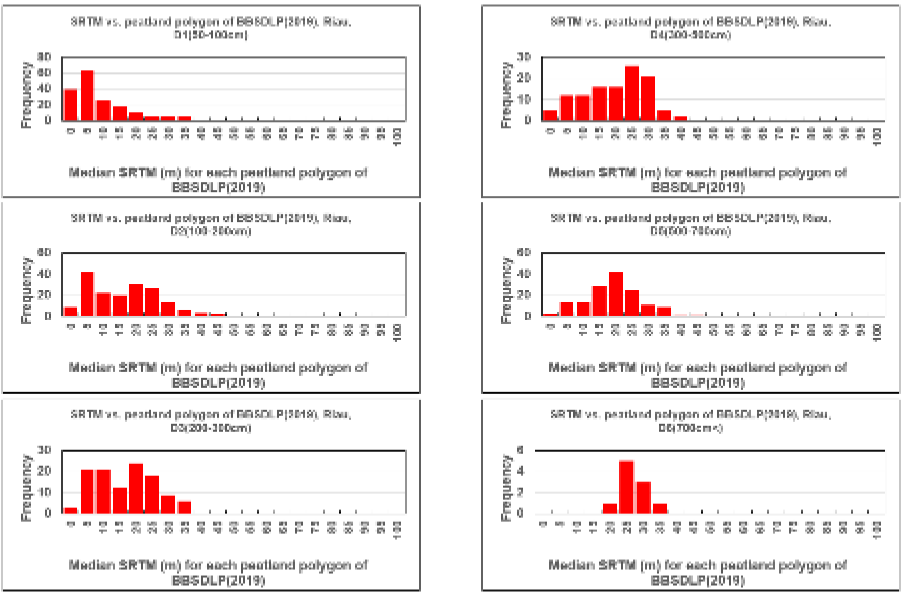


Figure4.7 13 Histogram of elevations of peatlands on BBSDLP Peatland Map, and SRTM/DEM elevation values in Riau Province

(4) Evaluation of unidentified peatland areas by drilling survey of Ministry of the Environment (2016 & 2017)

As mentioned above, an unidentified peatland exists in the central part of Central Kalimantan Province, and a drilling survey (136 holes in total) for peatland potential evaluation in the region was conducted for unidentified peatland areas in 2016 and 2017 by the Japanese Ministry of the Environment (Comprehensive Environmental Research "Project for the Development of a Wide-Area Evaluation System for Carbon Dynamics in Tropical Peat Forest in Borneo"). If the location of the drilling, the peatland thickness, and the range where peatland was confirmed by drilling in 2016 and 2017 are shown by the yellow grid, red grid line, and blue grid line, the unidentified peatland area covers a wide range (Figure4.7 14).[72] Furthermore, when examining the elevation value of the boring sites with the elevation value of SRTM/DEM, it is found that the elevation value is generally less than 80 m (Figure4.7 15).

[72] https://www.erca.go.jp/suishinhi/seika/db/pdf/end_houkoku/2-1504.pdf

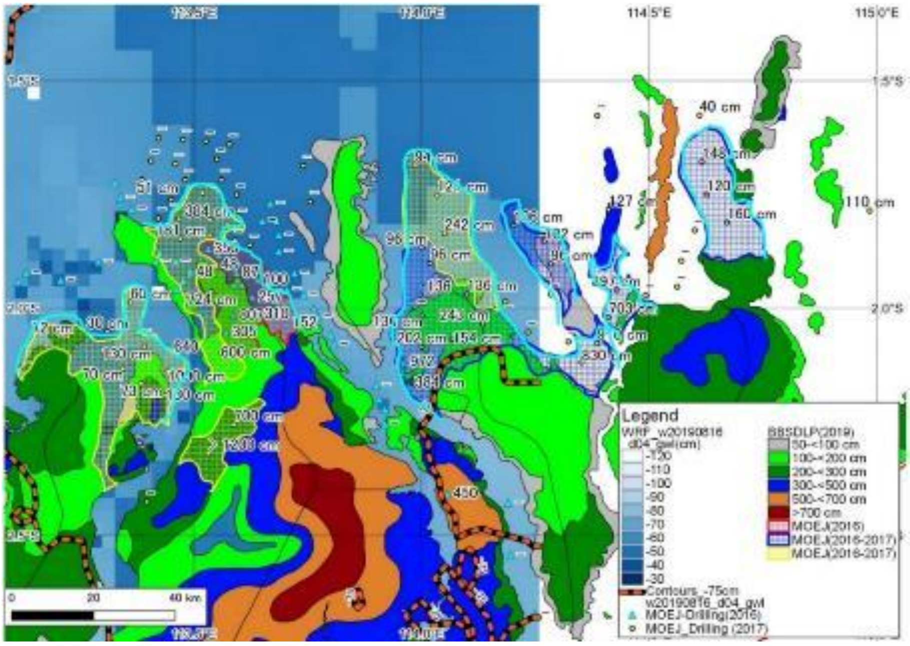


Figure4.7 14　Groundwater level contour (-75 cm), BBSDLP Peatland Map, and peatland confirmed by drilling survey by the Japanese Ministry of the Environment (2016 & 2017) (the newly confirmed peatland area is within the red and black lines indicated by the light blue line)

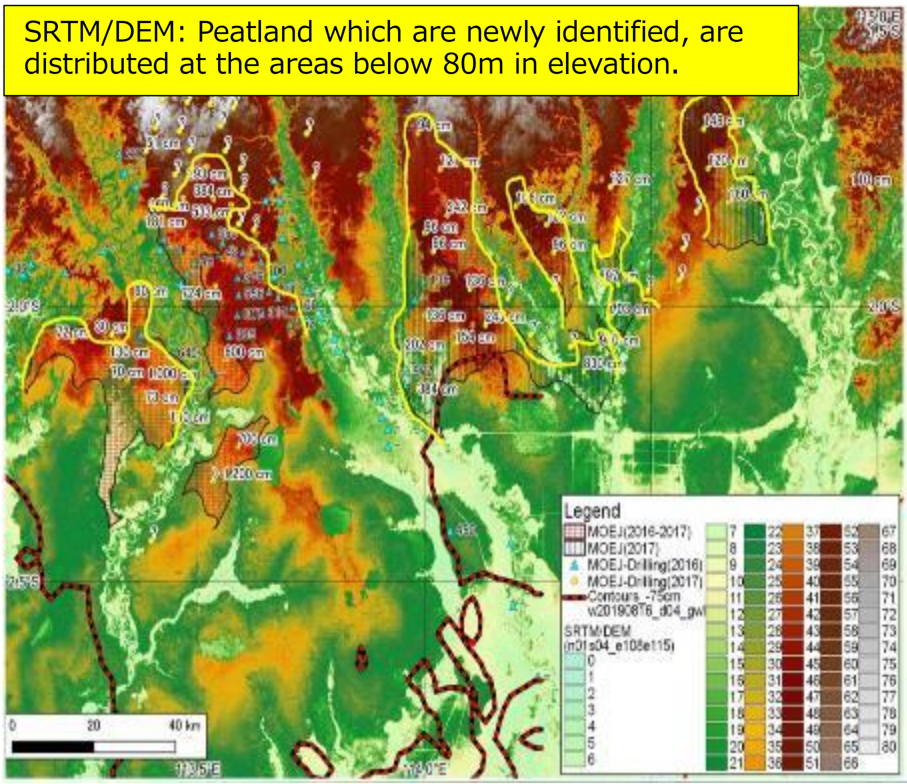


Figure4.7 15　Elevation of the peatland confirmed by BBSDLP Peatland Map, and drilling survey by the Japanese Ministry of the Environment (2016 & 2017) in Central Kalimantan

From the above, peatland mapping using the groundwater level estimation model can be performed by the following procedure.

1) Identify areas shallower than the groundwater level of –90 ~ -50 cm.
2) Identify areas shallower than 80 m in elevation in SRTM/DEM
3) Identify the areas classified as 03_Primary Swamp Forest or 04 Secondary Swamp on the Landuse Map (2019)

By the process of 1)~ 3), peatland mapping becomes possible (the peatland boundary is grasped). However, although it is classified as 03_Primary Swamp Forest or 04 Secondary Swamp on the Landuse Map (2019), the areas, which are not classified as peatland on the BBSDLP Peatland Map, are considered as unidentified peat areas (potential peatland areas).

(5) Comparison of groundwater level, BBSDLP Peatland Map and Landuse Map (2019) (West Kalimantan)

From the distribution of groundwater level and the BBSDLP Peatland Map, in order to find a useful groundwater level contour for peatland mapping, a groundwater level contour of 1 cm interval was prepared, and the BBSDLP Peatland Map (around southern Ketapang, West Kalimantan Province) was superimposed (Figure4.7 16left-hand image). In Central Kalimantan, -75 cm of the groundwater level contour was useful for peatland mapping, but in the region, key peatlands were distributed from -82 cm to-75 cm of the contour for groundwater, and in some cases overlapped the depth line for groundwater from -60 cm to -50 cm (Figure4.7 **16**16, magenta line) (in the upper yellow dotted circle in Figure4.7 **16**16.

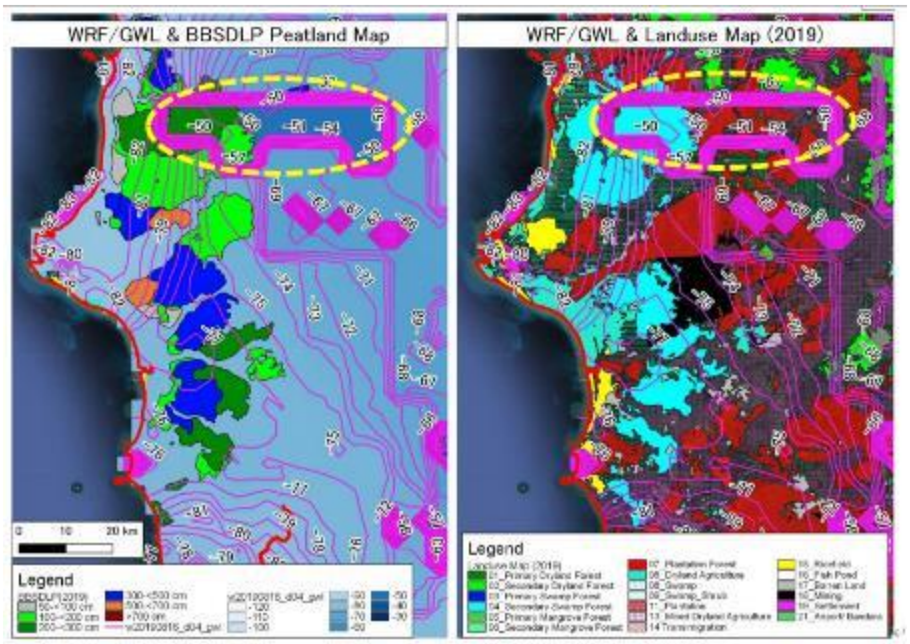


Figure4.7 16 Contours of groundwater level in 1 cm around central Kalimantan, West Kalimantan, BBSDLP Peatland Map and Landuse Map (2019)

Figure4.7 17 shows the histogram of WRF groundwater level for each thickness of peatland on the BBSDLP Peatland Map in West Kalimantan. The thickness of peatland in West Kalimantan is divided from D1 to D5.

In all thicknesses from D1 to D5, the groundwater level is generally concentrated between -80 cm and -75 cm, and the -80 cm groundwater level depth contour line can be considered the peatland boundary. When compared by peat thickness, the peak groundwater level is concentrated at -75 cm, including the thickest peat, D5, which differs from the trend in Central Kalimantan.

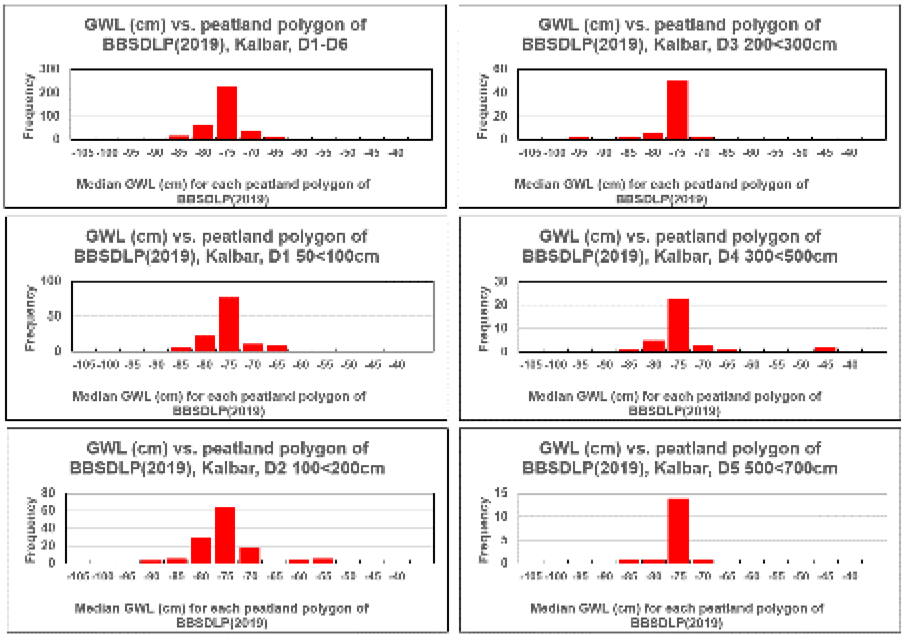


Figure4.7 17 Distribution of groundwater level frequency for each peat thickness on BBSDLP Peatland Map in West Kalimantan Province (after extracting 3 km grid WRF groundwater level values in each peat map polygon)

Further, on the Landuse Map (2019), the distribution of peat was almost similar to that of 04 Secondary Peatswamp Forest in Central Kalimantan, but it shows a similar trend in West Kalimantan (Figure4.7 18). In addition, as in Central Kalimantan Province, three unidentified peatlands not mapped by the BBSDLP Peatland Map can be confirmed in Figure4.7 18 (inside the yellow dotted lines). Area K-1 is likely to contain peat, in a peat thickness of 300-500 cm. Area K-2 would have a peat thickness between 100-200 cm and 200-300 cm, but satellite images show sparse vegetation, so the potential is not as high as area K-1. In area K-3, forests along rivers are also seen on satellite images, and there is a high possibility that peat exists. Area K-4 area is a lowland of less than 100 m elevation that extends about 1 km to the east of 50-100 cm thick peat, and if peat exists at all, it would be very thin (less than 100 cm). In area K-5, the groundwater level is shallow at about -50 cm, and as it is in contact with peat of thickness 200-300 cm, there is a high possibility that peat exists. Since oil palm plantations can be seen widely on satellite images, there may not be any peat at all.

As shown above, the 04 Secondary Peatswamp Forest on the Landuse Map (2019) is useful for peatland bordering, because its distribution is almost identical to the distribution of peat. Comparing the Landuse Map (2019) and BBSDLP (2019) Peatland Map, the locations where no polygons (peat) are set on the peat map and where 04 Secondary Peatswamp Forest is present, can be considered as peatland potential areas. Therefore, if the polygons of the 04 Secondary Peatswamp Forest are extracted from the Landuse Map (2019) and joined to the BBSDLP (2019) Peatland Map, a revised BBSDLP (2019) Peatland Map will be obtained (the red dotted areas in Figure4.7 18 are new potential peat sites).

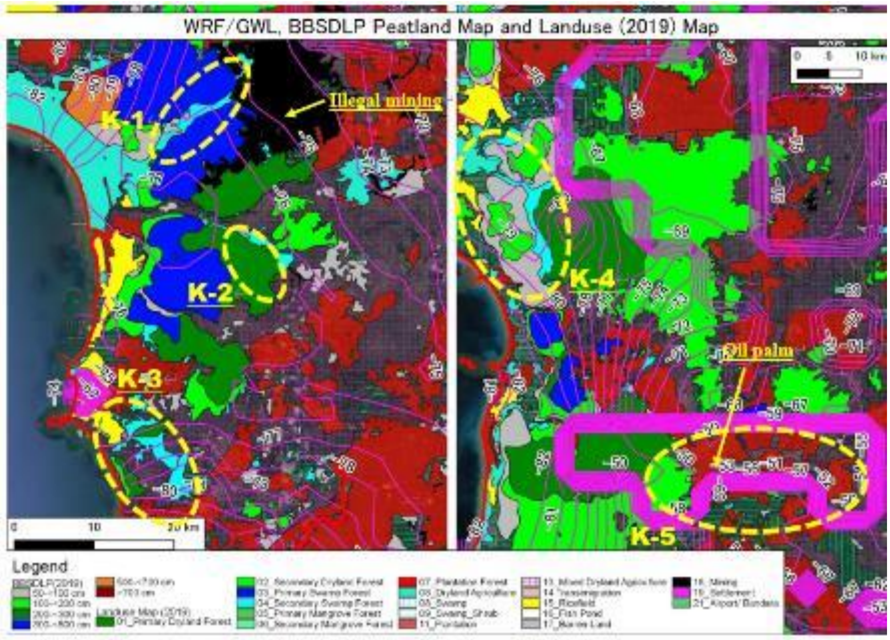


Figure4.7 18 Peatland potential (from K-1 to K-5 indicates potential area) assumed from the BBSDLP Peatland Map and Landuse Map (2019)

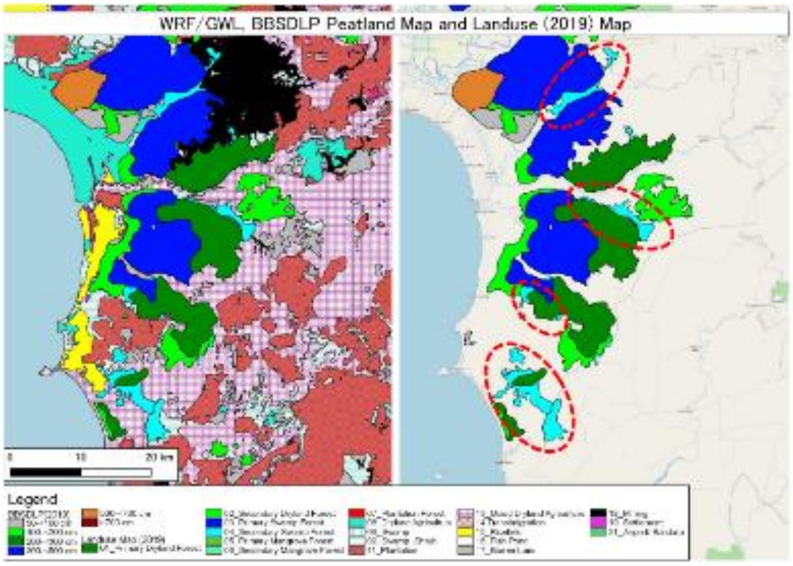


Figure4.7 19 Peatland potential (from K-1 to K-5 indicate potential areas) assumed from of BBSDLP Peatland Map and Landuse Map (2019)

(6) Comparison of groundwater level, BBSDLP Peatland Map, and Landuse Map (2019) (Riau Province)

Figure4.7 20 shows the groundwater level profile in Riau Province, and the BBSDLP Peatland Map. Compared with the provinces of Central Kalimantan and West Kalimantan, there is a large variation in the density of the groundwater contour, and a nearly constant contour (-70 cm) is distributed in the area where thick peat is distributed in the southeastern region. On the other hand, although peatland exists in the northwestern region, the groundwater level is extremely deep, and it is difficult to identify peatland potential from groundwater level information alone.

Figure4.7 21 shows the histogram of WRF groundwater level for each thickness of peatland on the BBSDLP Peatland Map in Riau Province. Groundwater level is generally concentrated in -75 cm, but in D1, it is distributed over a wide area up to -120 cm of the groundwater level when compared for each peatland thickness. On the other hand, from D2 to D4, the lower limit is widely distributed to the extent of -110 cm, but there is a clear peak of frequency in -75 cm, and as in the central Kalimantan and West Kamantan, the groundwater level contour of -80 cm may be the borderline of peatland. In addition, the thickest peatlands D5 and D6 have a -75 cm concentration of groundwater levels, which is similar to that in West Kalimantan, although differing from that in Central Kalimantan.

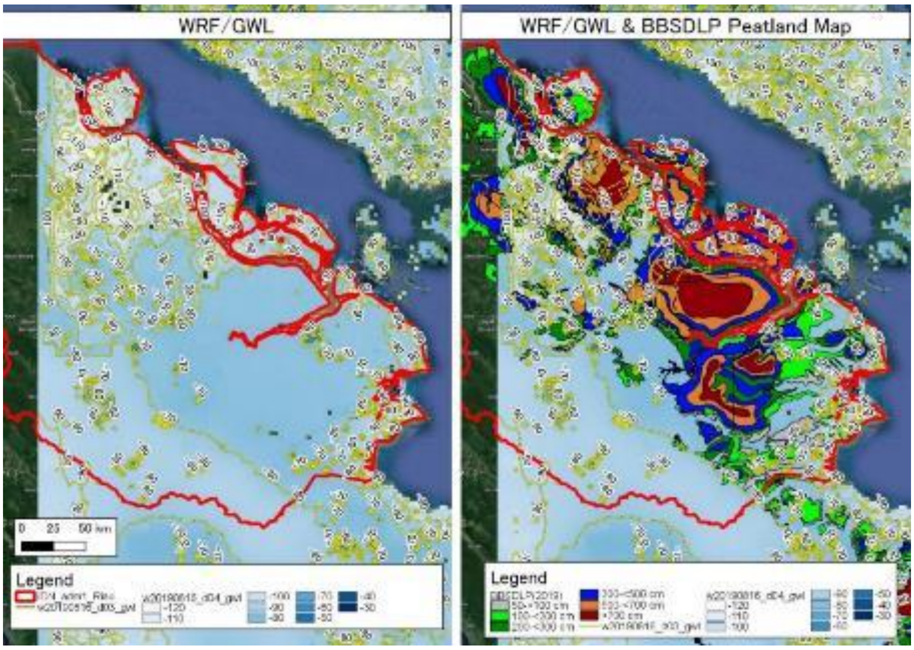


Figure4.7 20 Groundwater Level in Riau (in 10 cm), and BBSDLP Peatland Map

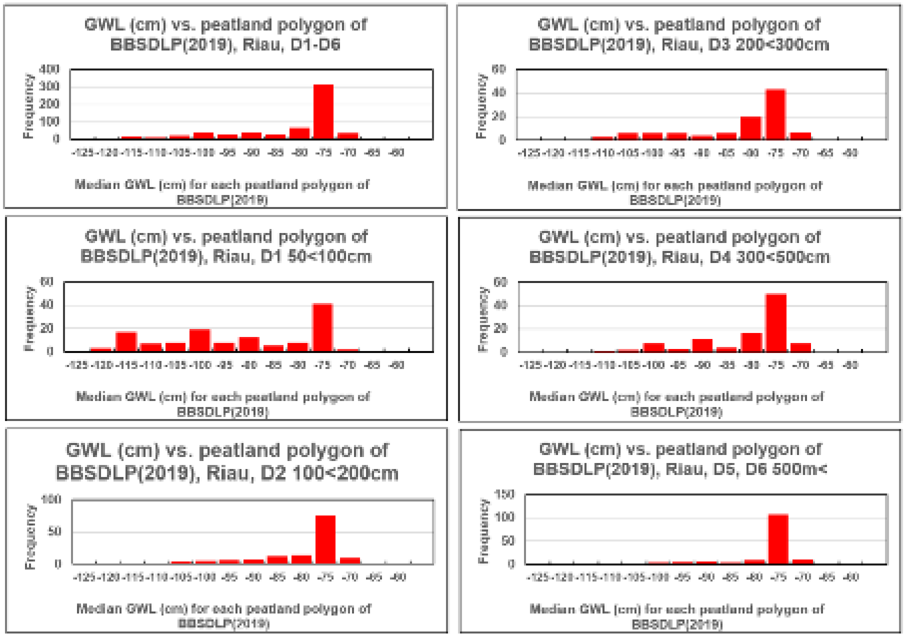


Figure4.7 21 Distribution of groundwater level frequency for each thickness of peat on BBSDLP Peatland Map in Riau province (obtained by extracting 3 km grid WRF groundwater level in each peat map polygon)

On the other hand, when the Landuse Map (2019) is superimposed, 04 Secondary Swamp Forest of the land areas where peat sites are likely to exist almost coincides with the BBSDLP Peatland Map (Figure4.7 22) as in the central Kalimantan and western Kalimantan provinces. However, although it is difficult to border the peat potential site because very few polygones of 04 Secondary Swamp Forest are not mapped on the peatland map, as in Central Kalimantan and West Kalimantan, there is a slight 04 Secondary Swamp Forest in the yellow dotted circle line in the middle of Figure4.7 23.

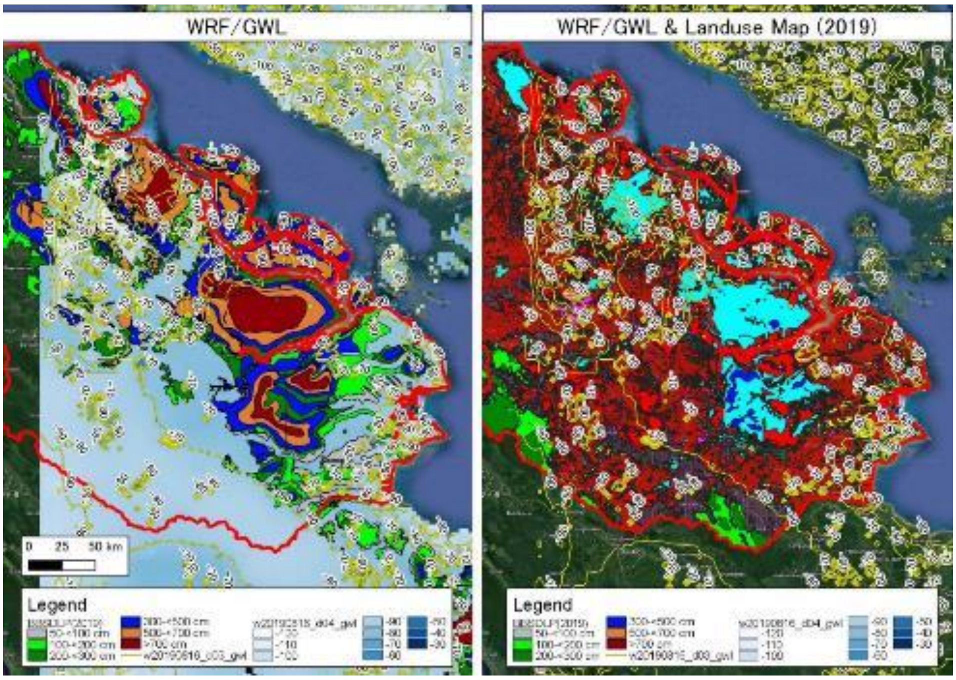


Figure4.7 22 Groundwater level contours (in 10 cm), BBSDLP Peatland Map, and Landuse Map (2019)

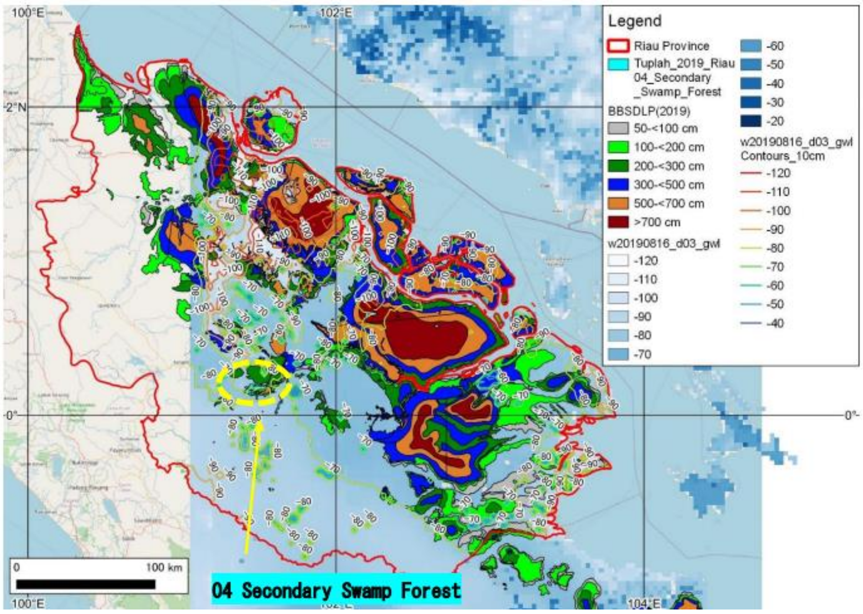


Figure4.7 23 Peatland potential site in Riau (light blue area in yellow dotted line)

4.8 Remaining issues related to international development of groundwater level estimation models, and future responses

Through this survey, we have developed and examined a groundwater level estimation model, but the following issues remain in the international development of new groundwater level estimation models.

- Publication through a series of papers on a series of programs, including new groundwater level estimation models
- Further improvement of a series of programs, including new groundwater level estimation models
- Confirmation of effectiveness and comments when compared with similar programs by other organizations

Future responses (proposals) to the above-mentioned remaining issues are as follows.

(1) Publication through a series of papers on a series of programs, including new groundwater level estimation models

In order to inform relevant organizations that the content of the new program, etc., is a program prepared through JICA cooperation, and to secure the ownership of the content of the program, an early paper will be submitted. This paper will be prepared by the subcontractor (Kyoto University, Nara University) who was in charge of the actual analysis.

(2) Further improvement of a series of programs, including new groundwater level estimation models

This model program was developed by a subcontractor through this project, but by adding further improvements and analysis, it becomes a better model program. Therefore, it is desirable to improve the program through JICA projects to be implemented in the future, or voluntary activities of subcontractors (universities).

- Use of HISUI to modify and improve modelling of GHG emissions

・ Expansion of peatland border

(3) Confirmation and publication of effectiveness when compared with similar programs by other agencies

Various model programs developed through this project have not been compared with similar programs published by other organizations in Indonesia. Therefore, it is desirable to improve the program through JICA projects to be implemented in the future, or voluntary activities of subcontractors (universities).

4.9 Relationship of the groundwater level estimation model with the national strategy and behavior plans

Existing soil moisture maps and other maps in Indonesia include those prepared by the Ministry of Environment and Forestry (MOEF) and the Peatland Mangrove Restoration Agency (BRGM) based on Government Regulation No. 71/2014 and Government Regulation No. 57/2016, among others, as follows**.**

Table4.9 1 Existing Soil Moisture Maps in Indonesia

Relevant ministries and agencies	Map name	URL
Ministry of the Environment and Forestry (MOEF)	Soil Moisture Map	http://pkgppkl.menlhk.go.id/v0/en/(Link)
	Water Level Monitoring data (TMAT)	http://pkgppkl.menlhk.go.id/v0/corrective-action-tata-kelola-gambut/(Link)
Peat Mangrove Restoration Agency (BRGM)	SIPALAGA (Sistem Air Air Lahan Gambut)	https://sipalaga.brg.go.id/(Link)
	PRIMS (Peatland Restoration Information and Management System)	https://en.prims.brg.go.id/(Link)

Source: JICA Survey Team

Of the above, the contents and problems of the following three systems are described below.

(1) Water Level Monitoring data (TMAT)

The Ministry of Environmental and Forestry has developed a water level and rainfall monitoring database (TMAT) for concessions and rural areas. In particular, it is targeted at pilot areas where community-based peat restoration activities are conducted. This information base was developed to provide data on the progress of peatland recovery through analyzing eat land water level monitoring data (TMAT), developing re-wetlanding infrastructures, and vegetation recovery monitoring.

The information provided will primarily be used to (1) provide a basis for developing guidelines for improved water management in peatland ecosystems; (2) monitor progress in the implementation of peatland ecosystem recovery; (3) provide water balance; (4) provide information on early warnings against potential forest and peatland fires; (5) provide information for compliance and law enforcement; and (6) calculate greenhouse gas emissions reductions from peatland ecosystem recovery activities.

By 2020, the system had acquired online water level monitoring data for 10,857 peat sites nationwide and rainfall data from 861 rain gauges. SiMATAG-0.4m also provides an indication of whether TMAT data is 0.4m or less below ground. The provision that this groundwater level should be less than 0.4 metres is set out in Article 23 of Government Regulation 71/2014.

The function of SiMATAG-0. 4m is integrated with satellite images, and the water level and vegetation restoration data are checked against soil moisture landuse data. The potential for high soil moisture in peatlands has been identified using Sentinel-1 C-Band-based limosene technique through SEPAL platforms. However, it is known that the permeability of microwaves to soil varies with wavelength. Since Sentinel-1 used by SiMATAG-0.4m is C-band, it is doubtful that it will correctly reflect surface soil moisture content.

(2) SIPALAGA (Sistem Air Air Lahan Gambut)

The Peat Reconstruction Agency (BRG) has developed a peat groundwater monitoring system (SIPALAGA), which is a monitoring system for real-time data provided by the Water Level Monitoring Tool (TMA) that [cuts the moisture, rainfall level, air temperature and humidity, wind direction and speed of peat soils at the Foundation Tektech house]?.

As of December 2018, the BRG installed 142 TMA monitoring devices in seven states of Peat Reconstruction Priority. Measurement of water levels in peatlands is important to prevent fires and greenhouse gas emissions in forests and peatlands, and in addition, water level monitoring contributes to preventing groundwater from flowing out of peat lands. Decreases in peat groundwater have adverse effects such as reduced water level, reduced peatland area, CO_2 emissions, fires and droughts.

(3) Peatland Restoration Information and Management System (PRIMS)

As a peat monitoring system in Indonesia, there is a peatland restoration monitoring system (PRIMS:Peatland Restoration Information and Monitoring System) developed by BRGM in cooperation with FAOs and other organizations. PRIMS is an on-line platform for spatial databases that provide updates on the status of Indonesian peatland, and the progress of peat land restoration activities.

PRIMS supports monitoring and reporting of 2 million hectares of peatland conservation and restoration activities in seven Indonesian priority states carried out by the Peat Mangrove Restoration Agency (BRGM), Regional Peat Restoration Teams (Tim Restorasi Gambut Daerah, TRGD), and other central and local governmental agencies.

PRIMS was developed to track present peatland conditions and monitor the progress of remediation activities and their impacts. The data displayed on this platform uses official public information provided by the relevant ministries and agencies.

BRG developed these platforms with partners such as the World Resources Institute (WRI) Indonesian Office, the Agency for Technical Assessment and Applications (BPPT), the Food and Agriculture Organization (FAO), the United Nations Development Programme (UNDP), and the United Nations Project Services Organization (UNOPS). The data layers of boundaries, peatland, land use, recovery activities, devastation indicators, and water level indicators overlap, and the status of peat in the seven priority states and recovery status can be checked online.

Table4.9 2 Layers of data used in PRIMS

Layers	Indicator	
Boundaries (Boundary)	Provinces, provinces, counties, villages	Boundaries of province, district, sub-district and village
Peat (Peatlands)	Peat ecosystem function	Peat ecosystem function
	Peat	Peatlands
	Peat depth	Peat depths
	Peat forest	Peat forest cover

Layers	Indicator	
	Activities within the Peat Water Utility Unit	Intervention in Peat Hydrological Unit (PHU)
	Channel in peat	Canals in peatland
Land use (Land use)	Mangrove recovery activities	Accelerated Mangrove Rehabilitation
	Forest area	Forest area
	Forest and peat moratorium	Forest and peatland moratorium
	Concession	Concession area
Recovery (Restoration)	Referenced drawings	Indicative map
	Reconstruction Activities (Infrastructure)	Implemented Restoration Construction (SISFO)
	Reconstruction activities (non-infrastructure)	Implementation Restoration Non-Construction
	Village Development Planning Target Villages	Peat Care Village
	Research plot	Research plots
	Peat recovery implementation unit	Peat restoration implementing units
	Reconstruction partners	Restoration partners
Devastating factor (Degradation indicators)	Hot spot	Hot spots
	Former fire site	Burn scar area
	Fire hazard system	Fire Danger Rating System (FDRS)
	Peat motion	Peat motion
	Vegetation moisture index	Vegetation Moisture Index – gains and losses
Hydrology (Hydrology)	Groundwater level	Groundwater level
	Soil moisture, linear trends, annual averages	Soil moisture – linear trend, yearly average
	Recovery effect study	Restoration impact research
	Hydrological model (scenario, baseline, difference, peat wetlanding facility)	Hydrological modeling: baseline, difference and peat- related infrastructure
	Rivers	Rivers

Source: JICA Survey Team

Pixel-by-pixel characteristics of seasonal linear trends in surface soil moisture have been derived from Sentinel-1 C band radar data upscaled to 100 m pixels from 2016 to 2020 from the Land Data Assimilation System (LDAS) using PYSMM algorithms.

However, it is known that the permeability of microwaves to soil varies with wavelength (Figure4.9 1). Since Sentinel-1 used by PRIMS is C-band, it is doubtful whether it correctly reflects surface soil moisture content.

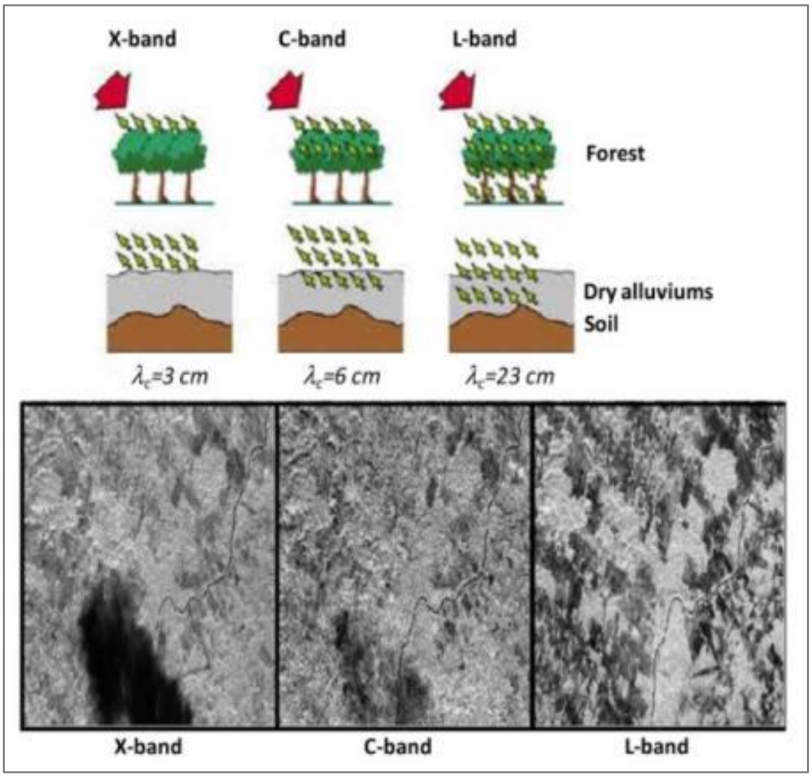


Figure4.9 1 Permeability of different microwaves in vegetation and soil [73]

4.10 Recommendation and implementation system for social implementation of a model for estimating groundwater level (Draft)

While travel to Indonesia was dangerous due to the corona pandemic, the method of social implementation was continuously examined. Initially, domestic subcontractors and members of the Japanese delegation visited Indonesia to explain matters to the relevant organizations and confirm their capacities. At the same time, a program to be developed was planned to be installed in the local organizations (e.g., BRIN(LIPI, BPPT), and a trial was planned at the site.

However, in situations where it is difficult for Japanese members to travel, the spread of the Omicron variant will strengthen regulations in Indonesia, and the regulations will be irregularly changed. Therefore, the Ministry of Foreign Affairs considered an alternative plan to implement the plan without traveling to the country.

As it became possible to travel to Indonesia from March 2022 onwards, it was decided to implement the project in a flexible manner, depending on the installation status of servers and other equipment, data migration status, etc., such as trial implementation by remote before and after on-site verification of the recommissioning organization, and face-to-face implementation during on-site verification of the recommissioning organization. Specifically, the implementation was carried out as follows.

[73] Source: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/p-band

- Assuming that BRIN would not be able to procure the equipment and materials they were supposed to procure at home, they installed WRF and statistical software ® on the equivalent PC from Japan. They brought them to the site (the PCs were purchased by the subcontractor).
- Data and programs were shared with local organizations via cloud, etc., and installed through an online explanation.
- This time, as described below, WRF installed in the personal computer installed in the Indonesian cooperative organization (BRIN) was operated to perform soil-moisture mapping.
- On May 13, WRF and other installations were completed, and the library was organized in the offices of BRIN personnel. In addition, WRF test runs were performed (Figure4.10 1). Although WRF worked despite a problem in the library, it did not produce an appropriate outcome (left-hand side ofFigure4.10 2. Therefore, the library was checked after returning from the on-site verification. As a result, a test run was performed again after returning
- After checking the library, WRF was again tested on-line on June 15, 2022 (to the right of Figure 4.10.1.2).

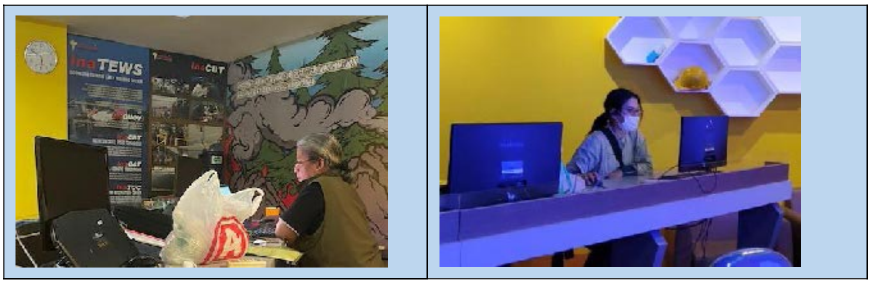


Figure4.10 1 A lecture on installing WRF (May 13, 2022, BRIN Global Systems Technical Centre)

In the trial implementation conducted on May 13, 2022, the computer used in Indonesia was shared with the Japanese side through ZOOM. Two Japanese analysts from Japan, one Japanese analyst from Indonesia and BRIN researchers participated.

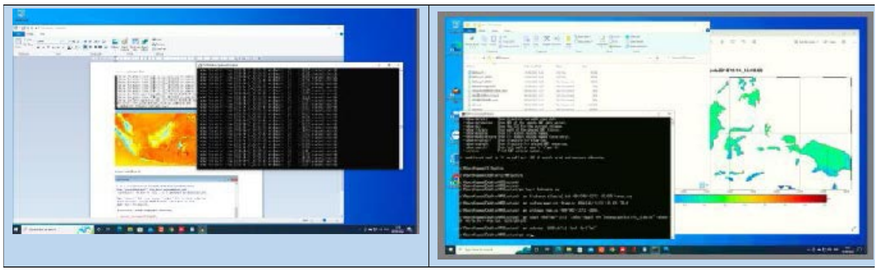


Figure4.10 2 Status of WRF test runs on personal computers installed in local Indonesian organizations

NOTE: Left: Status when implemented on May 13, 2022. Right: Situation at the time of implementation on June 15, 2022.

Since a sufficient amount of server space is required for the operation of the program, we checked the servers that can be utilized by related Indonesian organizations. As of February 2022, it was discovered that BPPT that was supposed to be installed locally was in the midst of reorganization into BRIN, that the result that was originally obtained in BPPT could not be used, and that the equipment that was supposed to be procured in BPPT could not be procured. Following the reorganization of BPPT into BRIN, the equipment used for the trial introduction of the program/system at the time of the on-site verification and on-site implementation in May 2022 is summarized in the following table.

Table4.10 1 Equipment required for local implementation

Hardware	Specification	Purpose	Affiliation and procurement status	This response
Computer A: Generator and Monitoring Computer	MSI Desktop MEG Trident X-1217 i7-10700K, 32GB, 1TB+1TB SSD RTX2070S 16GB	Input: Raw Radar Bengkalis Application: Phyton For real-time computation of radar and KBDI	BRIN Procured with other funds	Even if it can be procured, it is necessary to make adjustments such as installing calculation software and image output software, and cannot be used immediately. For this reason, the Kyoto University PC will be substituted for the time being.
Computer B: Tower Workstation	Thinkstation P340 Tower Workstation, Intel ® Xeon ® W-1290P Processor, 32GB DDR4, 1TB SSD	Input: Raw NCEP Application: WRF For offline computation of WRF	BRIN Procured with other funds	In this on-line trial implementation, the offline computation of WRF was performed.
Server (Storage/ Web server /NAS)	My cloud 4×10TB	For WRF Storage of archived data and real-time calculations (groundwater level maps, soil moisture content maps, greenhouse gas maps, KBDI, radar rainfall)	BRIN Procurement completed. (After the organizational change, it can be used as soon as the office is finalized)	In the trial implementation in this online, a Kyodai server or rental server was utilized.
Server (PC x 1, Web server)	PC: Mac mini M1, 8GB RAM, 256GB SSD KU server: Synology 720+, 4TB Rental server: Intel(R) Xeon(R) CPU E5-2650 v3 @ 2.30GHz, 32GB, 200GB volume	KBDI, radar rainfall, real-time data, etc.	Kyoto University	In the trial implementation in this online, a Kyodai server or rental server was utilized.

N.B.: NAS: Network Attached Storage: Network-compatible hard disk

Based on the experience of simple implementation of the groundwater level estimation model described above, the proposal and implementation system (draft) for future social implementation in Indonesia is considered as follows.

- Equipment: The corresponding equipment needs to be installed because it handles large-capacity data, and uses software that requires considerable specifications for analysis.
- Data: Data can be shared online, but security needs to be tight so that there is no other leakage except for the data which is publicly available.
- Data: In addition, data from BRG observations, tidal data, data from peatland boring, etc., are available on-line, but it is crucial that field surveys be used in conjunction, such as actual local groundwater level status, siting conditions (vegetation, soil, etc.), and photography by drones.

- BRIN, which is participating in this trial implementation, is a comprehensive scientific organization in Indonesia. For this reason, BRIN should be positioned as a central institution, and a system in which BRG and other institutions cooperate as a source of data should be appropriate.

On February 6, 2023, the Sub-contractor (Kyoto University) and JICA survey team explained the results of this survey to researchers in BRIN who participated in the field survey and the trial implementation online.

CHAPTER5. IDENTIFICATION OF CANDIDATE AREAS FOR PEATLAND MANAGEMENT, AND CONSERVATION PROJECT FORMATION AND PROJECT NEEDS

5.1 Candidate site selection process, and reasons

5.1.1 Past JICA projects for tropical peatland management

From 2008 to 2013, JICA implemented the "Fire and Carbon Management in Indonesian Peat and Forest" under the International Science and Technology Cooperation Program for Global Issues (SATREPS) in Central Kalimantan, Indonesia, which covers more than half of the world's tropical peat area. The study proposed the world's only MRV system that accurately assesses carbon emissions from peatlands by combining both ground and satellite data. The system was designed to comprehensively manage tropical peatlands, control carbon emissions, and manage carbon. In this MRV system, eight monitoring targets were selected to comprehensively understand the carbon dynamics of peatlands, and technology development related to the quantification of CO2 emissions using ground-based measurements and satellite data was conducted.

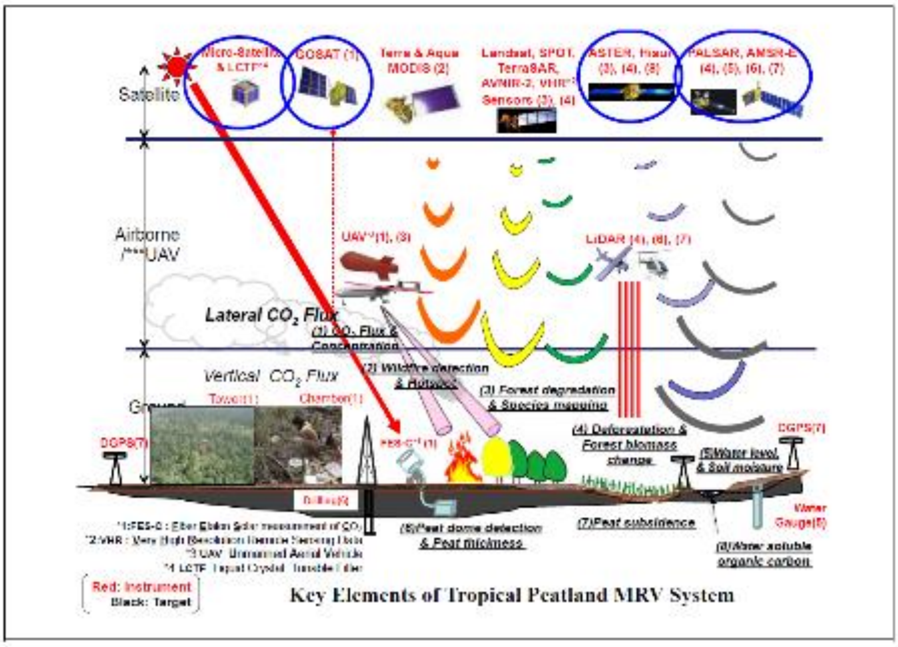


Figure5.1 1 MRV system for tropical peat management in the JICA-JST/SATREPS "Fire and Carbon Management in Indonesian Peat and Forest" project [74]

A peat management system similar to the above is still in operation in peatlands in West Kalimantan by Sumitomo Forestry Co. In Sumitomo Forestry's monitoring system, CO2 emissions are measured by the eddy correlation method as above, but groundwater level and meteorological data are obtained using sPOTEKA, which can be completely remote-controlled (Figure5.1 1).

[74] Source: https://www.jst.go.jp/global/kadai/pdf/h2004_final.pdf

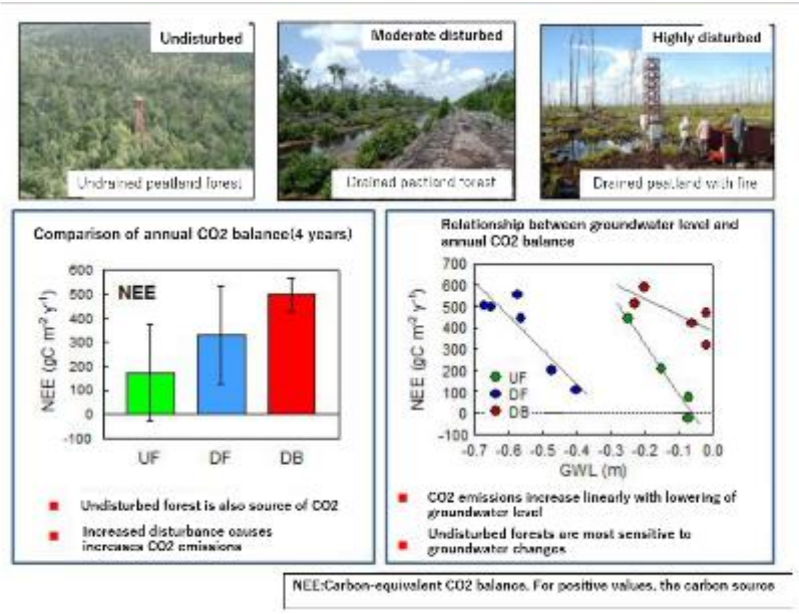


Figure5.1 2 Comparison of annual CO2 balance, and groundwater level (GWL) vs. annual CO2 balance [75]

Sumitomo Forestry Co., Ltd. manages 150,000 hectares of peatland, of which approximately 4,000 hectares are covered by sPOTEKA to observe CO2 fluxes, meteorological data and groundwater levels. The acquired data is transferred via satellite communication, and the groundwater level is managed to keep it at a constant level. On the other hand, such a peatland management system for Indonesia would be difficult to apply to the Congo Basin, where the peatland formation process is different, and no model of CO2 emissions has been established in the Congo Basin to date, utilizing flux towers and meteorological observation meters. However, as carbon neutrality is being discussed on a global scale, it will become increasingly important to clarify the CO2 emission mechanism in the Congo Basin, where a huge amount of carbon (30.6 gigatons) is stored.

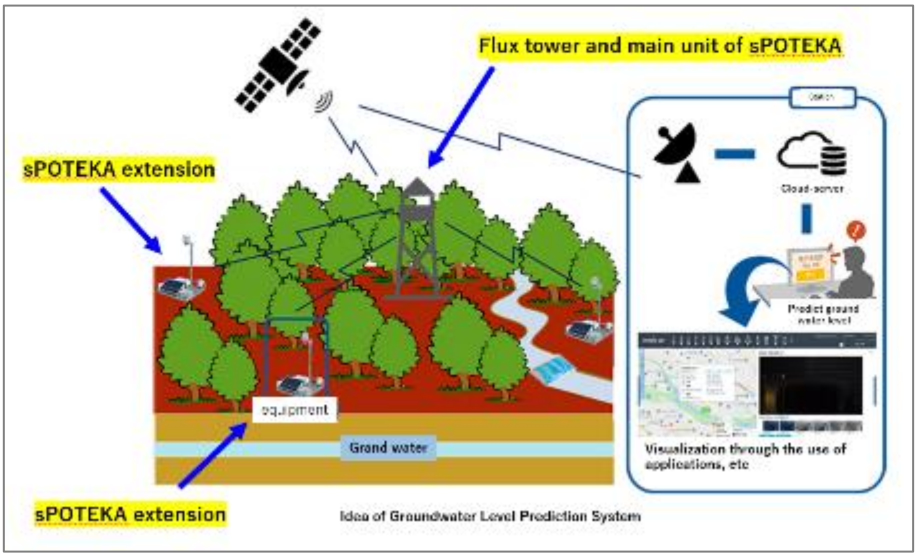


Figure5.1 3 Example of operation of a flux tower and weather observation equipment (sPOTEKA) [76] **by Sumitomo Forestry Co.**

75 Source : https://www.jst.go.jp/global/kadai/pdf/h2004_final.pdf
76 Source: https://www.ihi.co.jp/ihi/all_news/2021/aeroengine_space_defense/1197434_3351.html

5.1.2 Potential study sites for peatland management and conservation projects in the Congo Basin

(1) Congo, People's Equatorial State

In the Congo Basin, peat surveys have been conducted by British researchers in the Congo, but few surveys have been conducted in the Congolese population, and there is little existing information (landuse maps, topographic maps, etc.) to elucidate CO_2 emission mechanisms. However, there is a landuse map produced by the Greifswald Mire Centre (GMC) for the Jardin Botanique d'EALA peat swamp near Mbandaka in the Equatorial Province. (Figure5.1 4).

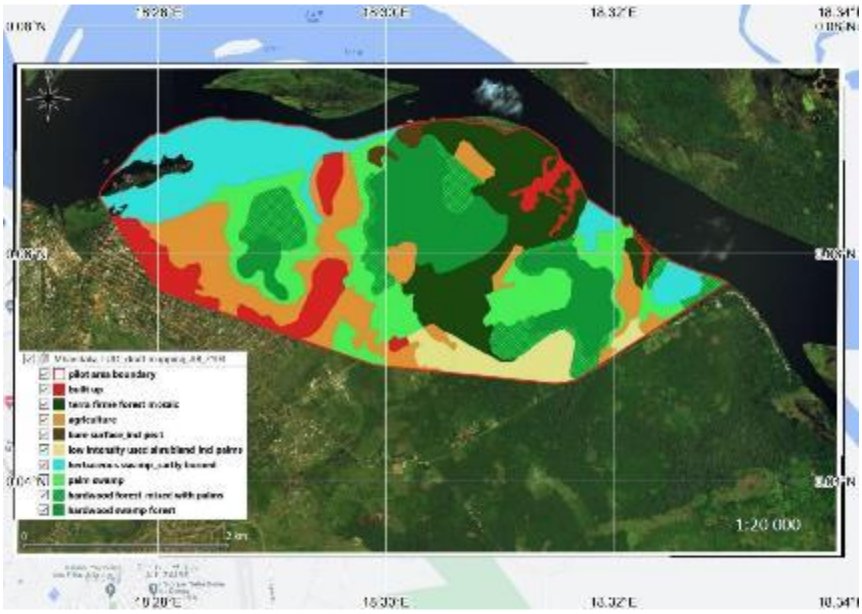


Figure5.1 4 Jardin Botanique d'EALA Peat Swamp Landuse Map near Mbandaka, Equatorial Statez

The Jardin Botanique d'EALA peat swamp is located in the center of the Congo Basin, and extends about 5 km from east to west and 3 km from north to south. The peatland vegetation is located almost in the center of the site, with palm surrounding hardwood.

i. Palm swamp
ii. Hardwood forest, mixed with palms
iii. Hardwood swamp forest

The Jardin Botanique d'EALA peat swamp is located approximately 2 km east of Mbandaka, and has very good access to peatlands. The availability of GMC landuse maps makes it easier than in other locations to determine the location of meteorological and groundwater level measurement equipment. Furthermore, easy access to urban areas has the advantage of allowing for quick response to equipment failures. If a 10 km square peatland including the Jardin Botanique d'EALA peat swamp is to be monitored, there are peatlands within a 10 km radius to the south where CO_2 measurement equipment and the sPOTEKA parent unit can be installed. Sentinel-2 images of the candidate peatlands show no evidence of disturbance, and are considered to be suitable as survey sites for future peatland management and conservation projects.

Note that CO_2 fluxes have been measured since 2020 in Yangambi, about 600 km east of the peatlands of the Congo Basin. However, since it is not a peatland, CO_2 emissions are measured only from tropical forests.

(2) Areas other than the equatorial state

On the other hand, apart from the Jardin Botanique d'EALA peat swamp near Mbandaka, lack of existing information available and poor accessibility to the study site make other areas unsuitable as candidate sites for peatland management and conservation projects.

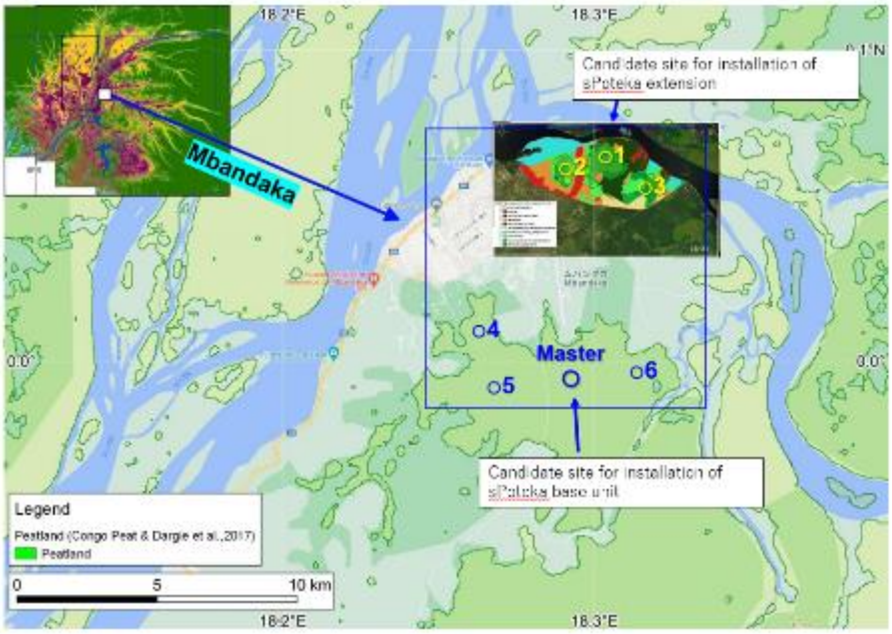


Figure5.1 5 Location map of Jardin Botanique d'EALA peat swamp near Mbandaka, Equatorial State

If we consider a region other than Mbandaka, Equateur Province, it would be MaiNdombe Province, given its accessibility from Kinshasa and the distribution of peatlands. As shown in Figure5.1 6, peatlands in MaiNdombe Province extend from the center to the north according to CongoPeat. Although basic surveys have identified peatlands in the southeastern part of Nioki, their limited distribution makes them unsuitable as construction sites for flux towers. On the other hand, the peatlands shown in Figure5.1 6, A to C, are suitable as potential sites for flux towers due to the presence of peatlands in clusters.

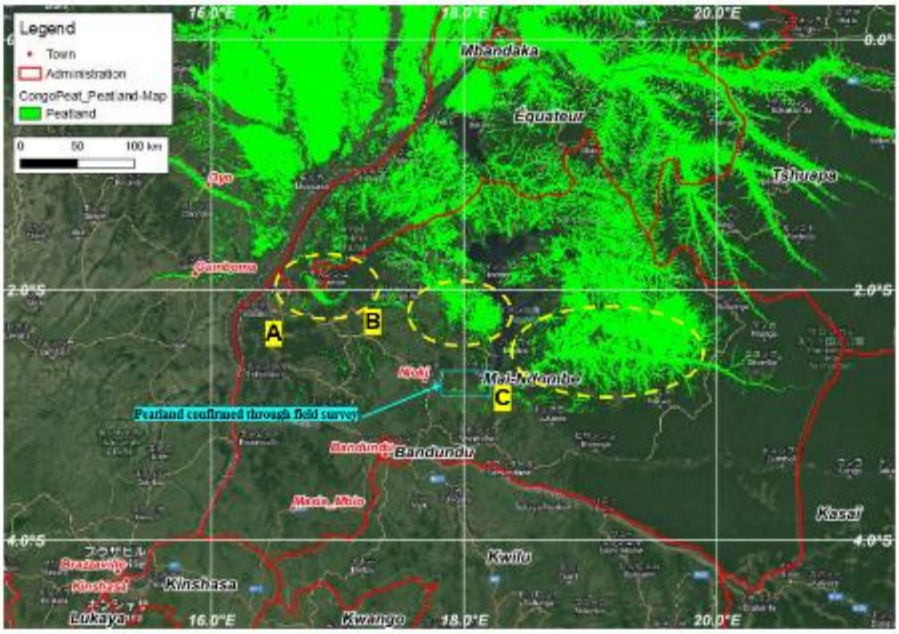


Figure5.1 6 Peatlands near Mai Ndombe, Equateur, and Tshuapa provinces, Congo [77]

5.2 Relevance of candidate sites to the National Strategy and Action Plan

In developing this project for the Congolese people, we took care to carefully explain and involve the government of the destination country to ensure that the maps and ground data that would be the outcome of the project would be utilized to a high degree. This was based on the experience of other donors in the past, where the use of the final results did not progress due to a lack of explanation to the government agencies. This activity was assisted by Mr. Onaka, an expert dispatched as an environmental policy advisor to the Ministry of Environment of the Congolese People's Government, who provided input to the Undersecretary of the Ministry of Environment and the peat coordinators as needed.

As a result, the Congolese government had high expectations for Japanese assistance in the peat sector, and as a result, the Undersecretary of the Ministry of Environment issued a letter of request (dated August 3, 2021) to the head of JICA's Congolese office regarding future assistance in the peat sector.

Regarding the identification of candidate areas for peatland management and conservation projects, and work to confirm project needs, further discussions will be continued and followed up by keeping a close eye on the above-mentioned trends.

5.3 Conditions and candidate projects at the candidate sites

5.3.1 Candidate projects (draft) and potential analysis

In connection with the request letter (dated August 3, 2021) from the Undersecretary of the Ministry of Environment to the Director of the JICA DRC Office regarding future assistance in the peat field, preparations for a request for Japanese grant assistance (digital grant), including the installation of flux towers,

[77] Source: peatlands created using Congo Peat data

meteorological and groundwater observation equipment, etc.. on a pilot basis in peat areas, have begun, and the JICA DRC Office has also begun to consider conducting a survey of requests for technical cooperation on peatlands. Although realization of this technical cooperation is under consideration as of 2023, the following recommendations have been made regarding the necessary strategies.

(1) Business strategy

Based on the discussions at the third meeting of the Support Committee of the study, and with the aim of creating the environmental conditions for private funding to be invested in peatland conservation and management in the Congo Basin in the future, the project will support the development of a peatland mapping and monitoring system for GHG emissions from peatlands in the Congo Basin and policy development to ensure that the peat component contributes to achieving NDC in both the Congo and the Congo Basin.

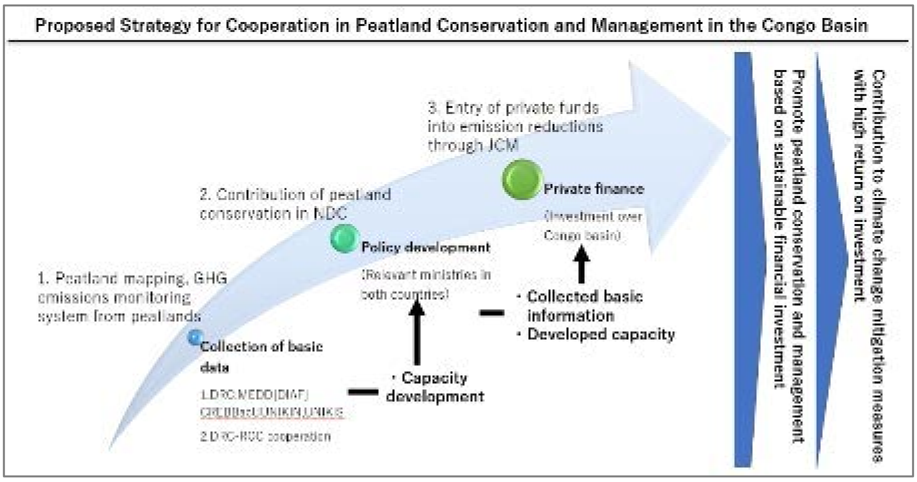


Figure5.3 1 Draft strategy for peat cooperation in the Congo Basin

(2) Implementation system

DDD and DIAF of the Congolese Ministry of the Environment (MEDD) will take the lead, but will also consider a cooperative framework by establishing a technical committee with the Congo Basin Water Resources Research Institute (CRRREBaC) of the University of Kinshasa, and a team of peat researchers from Kisangani University. Also, a technical committee will be established together with the Republic of the Congo on peat in the Congo Basin to consider a cooperative framework.

5.3.2 Status of methodology for estimating peat-derived greenhouse gas emission reductions

Specific studies have not yet begun.

5.3.3 Considerations for applying groundwater level estimation models

It is assumed that support for additional observation points will also be needed, as there is little actual data on groundwater levels in peatlands.

5.4 Orientation of peatland management and conservation projects utilizing external funding (draft)

JICA has been entrusted by CAFI to implement the Integrated REDD+(PIREDD) program in Kwilu Province under LOI1, and is currently seeking letter of interest for the program in the Congo under CAFI LOI2, which will be announced in May 2022. When considering the direction of peatland management and conservation projects utilizing CAFI funds, it is important to keep the movements of other donors related to LOI2 in mind.

CHAPTER 6. RECOMMENDATIONS FOR FUTURE COOPERATION STRATEGY ON PEATLAND MANAGEMENT AND CONSERVATION

6.1 The agenda of the international community and the position of peatlands

In making recommendations on future cooperation strategy on peatland management and conservation, the following is an overview of the status of peatlands in relation to the agenda being discussed by the international community.

■ Discussions in the United Nations Environment Program

The United Nations Environment Programme (UNEP) held its 4th United Nations Environment Assembly in Nairobi in March 2019, during which it adopted 16 resolutions, and the fourth resolution, *"Conservation and sustainable management of peatlands"*, was adopted.

This resolution stated:

“Recognizing also that degraded peatlands resulting from multiple activities contribute to biodiversity loss and environmental degradation and are a substantial source of greenhouse gas emissions globally, Considering the benefit and value of peatlands, which include but are not limited to providing vital ecosystem functions and services that reduce the scale and mitigate the impact of flooding and drought, preserve biodiversity, and supply food and water that maintain ecological systems and improve human livelihoods, and Recognizing the value of improving the management of peatlands in order to improve their carbon storage capacity on degraded sites, strengthen resilience, improve the socioeconomic livelihoods of populations around peatlands, and increase biodiversity, it is noted that such actions can contribute to the implementation of the United Nations Framework Convention on Climate Change and the Paris Agreement thereunder, and the Convention on Wetlands of International Importance, especially the Waterfowl Habitat (Ramsar Convention), the Convention on Biological Diversity and its Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets, the 2030 Agenda for SGDs."

Looking specifically at climate change mitigation functions, since degraded *peatlands* are thought to be responsible for 5% of current anthropogenic GHG emissions, emission reductions through rewetting and restoration could lead to considerable emission reductions, especially in Northern Europe and subarctic regions, where most peatlands remain untouched. Protection of peatlands from future development is also considered as an important peatland management pathway. According to the latest research, climate change mitigation using natural peatlands could amount to 1.1-2.6 Gt CO2e/year globally by 2030[78].

In terms of flood regulating functions, peatlands can influence water regulation by slowing the runoff of water from hillsides, thereby reducing flood peaks associated with increased rainfall due to climate change impacts. In addition, the water storage capacity of peatlands helps maintain baseflow during droughts[79], and by restoring *peatlands* to good condition and maintaining species diversity, peatland wildlife will be better able to adapt to climate change and are more likely to experience changes in species richness and distribution than in damaged peatlands. In other words, peatlands are not just greenhouse gas storage sites, but are co-beneficial landscapes, playing a variety of roles including biodiversity, disaster prevention functions, and food and water supply that was featured in COP26[80].

---

78 Maria Strack, Scott J. Davidson, Takashi Hirano & Christian Dunn, 2022
79 Gao & Holden, 2016
80 https://www.unep.org/news-and-stories/story/peatlands-spotlight-cop26

A further important resolution states the need for an accurate inventory of peatlands.

"The Executive Director of the United Nations Environment Programme, within the scope of existing resources and in consultation with the secretariat of the Ramsar Convention, is requested to coordinate *efforts to create a comprehensive and accurate inventory of global peatlands, which will be crucial as a basis for identifying the extent of peatlands globally, determining appropriate interventions, understanding the value and potential of carbon sequestration, and planning for sustainable peatlands management;"*

This resolution implies that the most accurate inventory data possible is essential for the international community to take any action (intervention) on peatland management, suggesting the importance of efforts from the research field.

As mentioned above, peatlands can be understood as co-beneficial landscapes that provide a variety of ecosystem services, but they can also be understood as nature-based solutions (NbS) to social problems. NbS are defined thus: *"Nature-based solutions are actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits"*[81]. And as mentioned earlier, the protection and management of the ecosystem of peatlands is itself an activity that contributes to social issues such as climate change mitigation functions, flood control functions, and food supply functions.

Based on this recognition, the Fifth United Nations Environment Assembly held in Nairobi in 2022 adopted a resolution on the importance of NbS and the promotion of these activities by each country. Specifically, the resolution states, *"They are among the actions that play an essential role in the overall global effort to achieve the Sustainable Development Goals, including by effectively and efficiently addressing major social, economic and environmental challenges, such as biodiversity loss, climate change, land degradation, desertification, food security, disaster risks, urban development, water availability, poverty eradication, inequality and unemployment, as well as social development, sustainable economic development, human health and a broad range of ecosystem services;"* and it is evident that the importance of ecosystem conservation, including peatland conservation, is strongly recognized.

In addition, it is noteworthy that the statement at the 4th UN Environment Assembly pertaining to this work is that *"Nature-based solutions are* efficient *and effective when planned for the situation to achieve multiple benefits and applied according to the best available science. This is linked to the "need for inventory data".* It was clearly stated that NbS including peatland management promotion plans can only be efficient and effective if there is a scientific basis, methodology, etc.

■ **Discussions at the UN Framework Convention on Climate Change**

At the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow in November 2021, attention was focused on "methane emission reduction", which is highly effective in reducing greenhouse gas emissions, based on the recognition that immediate action is needed to achieve the 1.5°C target. Methane is known to have a significant impact, with a global warming potential 28 times greater than CO2 over a 100-year period and approximately 84 times greater over a 20-year period, and methane in the current atmosphere is estimated to be responsible for 23% of global warming. While its global warming potential is higher than that of CO2, it remains in the atmosphere for only about 10 years, which is shorter than that of CO2, so it is expected to be effective in curbing the progress of global warming if measures are taken early on.

[81] IUCN 2016

Against this background, the Global Methane Pledge (GMP)[82] was jointly proposed by the United States and the European Commission at COP26. This pledges to reduce methane emissions by at least 30% by 2030 compared to 2020 levels, and if this goal is achieved, global warming by 2040 will be reduced by 0.3 degrees Celsius. Although Russia, China, and India, which are particularly high emitters did not participate in this goal, as of November 2021, more than 100 countries had endorsed it.

While no sectoral breakdown of the 30% reduction is given, it is clear that the reduction of methane emissions from peatlands is the most important initiative in the land sector in terms of GHG reductions.it is clear that reducing methane emissions from peatlands is the most important effort in the land sector.

■ **Discussions at the 15th Conference of the Parties to the Convention on Biological Diversity (CBD-COP15)**

At the above CBD-COP15 held in Montreal, Canada in December 2022, the main agenda item dealt with the formulation of a "Post-2020 Biodiversity Framework" to replace the "Aichi Targets" that had been the global target until 2020.

As a result, the "Kunming-Montreal Global Biodiversity Framework" was adopted, and the 2030 Mission towards the 2050 Vision and the 2030 Targets with 23 specific goals were presented. The report states that 2030 targets are “To take urgent action to halt and reverse biodiversity loss to put nature on a path to recovery for the benefit of people and planet by conserving and sustainably using biodiversity, and ensuring the fair and equitable sharing of benefits from the use of genetic resources, while providing the necessary means of implementation”.

Of the 23 specific goals, Target 11, "Maintain, restore, and enhance ecosystem regulating functions and services through natural or ecosystem-based approaches", is the resolution most relevant to peatlands.

It states, *"Restore, maintain and enhance nature's contributions to people, including ecosystem functions and services, such as regulation of air, water, and climate, soil health, pollination and reduction of disease risk, as well as protection from natural hazards and disasters, through nature-based solutions and/or ecosystem-based approaches for the benefit of all people and nature"* . These goals are indicated to be addressed through the NbS.

Target 15 also states that *“Take legal, administrative or policy* measures *to encourage and enable business, and in particular to ensure that large and transnational companies and financial institutions: (a) Regularly monitor, assess, and transparently disclose their risks, dependencies and impacts on biodiversity, including requirements for all large as well as transnational companies and financial institutions regarding their operations, supply and value chains and portfolios; (b) Provide information needed to consumers to promote sustainable consumption patterns; and (c) Report on compliance with access and benefit-sharing regulations and measures, as applicable, to provide consumers with the information they need to promote sustainable consumption patterns”.* This clearly indicates that private companies must be aware of the risks and impacts on natural resources when conducting their activities.

■ **Other International Organizations (FAO and GPI)**

Various international organizations and research institutes are developing activities on peatlands, but here we will touch on FAO and GPI in particular.

[82] https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_21_5206

FAO has projects in tropical peatlands in the same three regions as this study (South America, Asia, and Africa), and its support activities are based on three pillars: 1) knowledge sharing and capacity building; 2) policy and governance, including integration of peatlands into national planning and reporting; and 3) technical support at regional, national, and field levels. In particular with technical support, it includes mapping, monitoring, and integrating these activities into existing frameworks and institutions.

In particular, the "Peatland mapping and monitoring- Recommendations and technical overview-" published in 2020[83] describes the methodology for mapping and monitoring peatlands. In addition, in the chapter on recommendations for the future, three issues are identified: estimating groundwater levels, identifying reliable soil wetness, and estimating greenhouse gas emissions.

The GPI is an initiative established under the UNDP umbrella with the support of 52 international aid agencies, universities, NGOs, and other organizations to carry out peatland management and conservation activities. Like the FAO, GPI works mainly in three regions, but its main focus is on peatland conservation from a scientific perspective and takes a global and regional level approach.

The global approach provides an up-to-date, comprehensive assessment of the state of peatlands and their importance in the global carbon cycle and national economies, highlighting their role in enabling the fulfillment of global commitments to mitigate climate change as outlined in the Paris Agreement. As a specific outcome, the "Gobal peatland assessments" were published in November 2022[84]. This document was written to encourage urgent action by countries and decision makers to advance sustainable peatland management through improved mapping, monitoring, and reporting efforts, and to integrate peatlands into national climate strategies. It also launched "The Virtual Peatland Pavilion"[85] at COP26 to help advance the international debate on peatland conservation.

Although there are other international organizations such as Wetland International and The International Peatland Society, FAO and GPI are the two organizations that are most easily linked to JICA's activities, especially peatland monitoring and management. Many of the researchers working at these organizations are involved in the preparation of IPCC guidelines, and they are considered important partners for JICA's efforts to disseminate its activities internationally.

6.2 Trends in Japan, and the position of peatland management

The previous section outlined the position of peatlands in the international community's agenda, and now we turn our attention to domestic trends and how the private sector is involved in peatland management.

■ Greenhouse gas reduction targets and corporate initiatives (GX League)

Japan has submitted a target to the United Nations to reduce greenhouse gas emissions by 26% by 2030, and as a longer-term goal, the Fourth Basic Environment Plan calls for an 80% reduction by 2050. In conjunction with this, the private sector is accelerating its efforts to reduce emissions, and in particular, initiatives such as carbon pricing and the GX League are being launched.

[83] https://www.fao.org/3/CA8200EN/CA8200EN.pdf
[84] https://globalpeatlands.org/resource-library/global-peatlands-assessment-state-worlds-peatlands-main-report
[85] https://globalpeatlands.org/node/219

The GX League is an abbreviation for "Green Transformation", and its purpose is to promote the transformation of the entire economic and social system to achieve emission reductions and improve industrial competitiveness, by viewing efforts to achieve carbon neutrality by 2050 and national greenhouse gas emission reduction targets by 2030 as opportunities for economic growth. The GX League aims to "formulate policies through dialogue among businesses that are leading pioneering initiatives" through (1) the Future Society Dialogue, (2) market rule formation, and (3) voluntary emissions trading. In particular, in (3) the voluntary emissions trading arena, demand for emission reduction credits is expected to increase as companies voluntarily set high emission reduction targets, promote and disclose their efforts to achieve these targets, and conduct voluntary emissions trading through the carbon credit market.

As mentioned earlier, greenhouse gas emission reductions resulting from peatland management are recognized by the international community as an extremely effective initiative, and the project is expected to play an important role in meeting the demand for emission reduction credits needed by the private sector.

■ **Nature-related financial disclosure task force**

The World Economic Forum estimates that more than half of the world's economy is moderately or highly dependent on nature, and there is concern about the loss of biodiversity due to this dependence, and therefore, the Taskforce on Nature-related Financial Disclosures (TNFD) was conceived at the World Economic Forum Annual Meeting in Davos in January 2019 to direct the flow of funds toward conservation and restoration activities. It is positioned as one of the sustainability-related disclosure frameworks that many companies are already working on amidst the growing importance of non-financial information such as ESG (Environmental, Social and Governance) information, and is also closely related to ESG investment.

The TNFD released a beta version of the framework v0.3 on November 4, 2022, which provides guidance for information disclosure. The guidance recommends four types of disclosure: "governance", "strategy", "risk and impact management", and "indicators and targets. Of these, when it comes to "risk and impact management", the guidance calls for disclosure of how the organization identifies, assesses, and manages nature-related dependencies, impacts, risks, and opportunities.

Peatlands are used as a site for economic activities by various companies, such as palm oil production and afforestation activities, and are a landscape with extremely high interdependence between corporate activities and natural resources. Therefore, companies that are engaged in such activities are required to identify and assess peatlands in accordance with the disclosure requirements of the TNFD, which is expected to become an important activity for obtaining ESG investments, and quantitative assessment methods for peatland management and conservation are needed as indicated in the draft TNFD Guidance.

6.3 Points to keep in mind when considering future cooperation strategy on peatland management and conservation

As summarized above, the international community has developed a common understanding of peatlands as a function of climate change mitigation, as a nature-based solution (NbS) to social problems for the realization of a sustainable society, and as a site for providing multifaceted ecosystem services. In particular, the need for scientific methods and inventory data has been cited in promoting peatland management, and great expectations are placed on the efforts of various international cooperative organizations and research institutes.

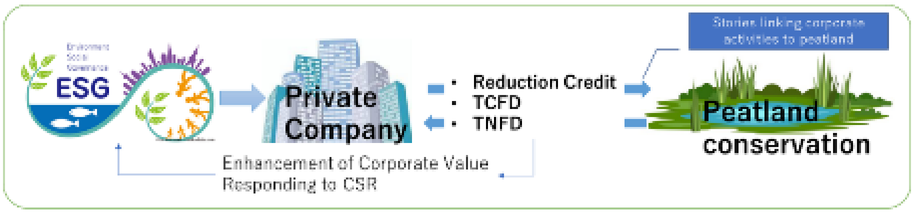


Figure6.3 1 Window for private companies to engage in peat management and conservation

However, although the international community is strongly aware of the importance of peatland management, mobilization of private funds is essential for sustainable activities, and it is expected that private funds will flow into peatlands, encouraged by domestic trends.

In terms of domestic trends, from the perspective of private companies, peatlands can be seen as a place to create highly effective GHG emission reduction credits, and as an opportunity to promote ESG investment while utilizing the peatlands as a place for economic activities.

Here are some points to keep in mind when private financing is introduced.

・ **Creation of credits with high credibility**

Although there are high expectations for greenhouse gas emission reduction credits, it is important to pay sufficient attention to their credibility, which may be subject to criticism through “greenwashing” in recent years. The term "greenwashing" was coined by American environmental activists in the 1980s by combining the English words "whitewashing" and "green", meaning "environmentally friendly. It is called "fake environmental friendliness", which is the pretense of making a product or service that is not really environmentally-friendly look good. In the case of emission reduction credits, the uncertainty of non-standardized evaluation methods and high uncertainty in quantification may fall under this category, and therefore, the basic data and evaluation methods necessary for peatland management must be addressed in a robust manner using the latest available knowledge, while ensuring transparency as far as possible. In this sense, it would be most desirable for the IPCC guidelines to clearly specify the various methods and data to be used.

・ **Efforts in line with the speed of private-sector studies**

As discussed in the "Trends in Japan", demand for GHG emission reduction credits from the private sector is increasing at an accelerating pace. On the other hand, as mentioned above, it is necessary for international organizations to establish guidelines for peatland management methods so that environmental considerations are not merely a facade, but the development and agreement of guidelines by the IPCC will require a considerable amount of time based on past experience. In order to fill the time gap required for this effort, it is important to take a stepwise approach in which results and findings obtained through projects are gradually published, rather than waiting until all methodologies and basic data have been completed. Specific examples include the registration of project results in the emissions factor database[86] which was maintained by the IPCC, and it should be noted that it is essential to publish the results in a scientific paper or other work.

[86] https://www.ipcc-nggip.iges.or.jp/EFDB/main.php

・ **The justification of addressing nature positive trends and peatlands**

The G7 2030 Nature Compact, agreed at the G7 Summit held in the UK in June 2021, set a goal of halting and reversing biodiversity loss by 2030. In response, CBD-COP15 adopted a goal of effectively conserving at least 30% of land and sea as healthy ecosystems by 2030 (30 by 30), with the goal of halting and reversing biodiversity loss by 2030 (Nature Positive). As mentioned earlier, peatlands are a unique landscape that provides a variety of ecosystem services, and at the same time, they are an area with high climate change mitigation function effectiveness, making them worth focusing on.

6.4 Future cooperation strategy on peatland management, and conservation based on the results of the basic information collection survey

As mentioned above, peatland management attracted the attention of the international community at COP26 (GMP), and peatland conservation and utilization were cited as a representative example of a nature-based solution at UNEP and CBD-COP15. On the other hand, domestic trends include the launch of nature-related financial information disclosure through TFND against the backdrop of ESG investment, and an increase in demand for emission reduction credits against the backdrop of the GX League.

Again, as described above, momentum for peatland management and conservation is growing, but in order to develop sustainable activities, it is essential to utilize not only public funds but also private funds. To this end, it is essential to collect a variety of basic data on peatlands (distribution area and greenhouse gas absorption emissions per unit area), and to improve the reliability of such data. Conversely, it is clear from the viewpoint of responding to greenwashing criticisms that highly uncertain information cannot be used to foster common understanding and encourage the participation of a wide range of stakeholders in peatland management.

In this study, we estimated peatland distribution using satellite data and estimated greenhouse gas (CO2, CH4) absorption emissions from peatlands using a meteorological model, and developed techniques for refining the basic information. These efforts have made a significant contribution to the methodology and basic information required by the international community, and in terms of standardization of peat assessment to encourage private sector participation.

While taking this into consideration above, we have taken into account that tropical peatlands have regional characteristics, such as those that form peat domes and cases where there is a mineral supply from rivers, we recommend two pathways of policies for future peatland management and conservation using each seed technology.

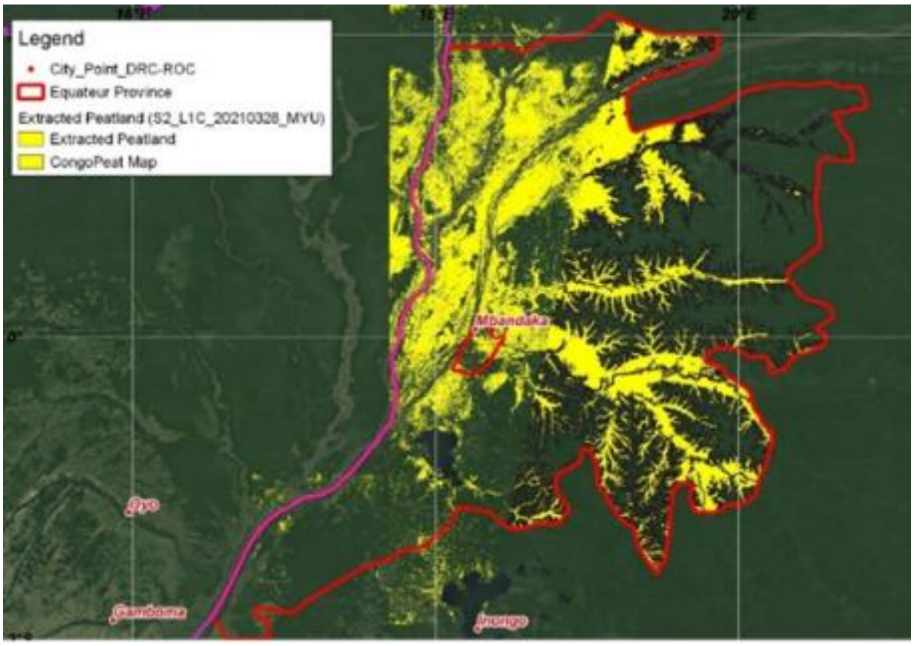


Figure6.4 1 Distribution map of peat in the Congo Basin prototyped in this study

(1) Refinement of absorption emissions from peatlands, and internationalization of methodologies by combining satellite data and flux towers.

In the area around the Congo Basin, we have worked on the estimation of peatland distribution using satellite technology, and clarified the peatland distribution of the DRC (Equatorial Province) and the Republic of the Congo (Gamboma area). Following these results, the Japanese government has decided to implement the installation of flux towers in the DRC from 2023 using a non-professional grant scheme. Through this activity, it is expected that the CO2 and CH4 absorption emissions from peatlands will be determined by combining the peatland distribution map and detailed parameters obtained from the flux tower. In some cases, complementary data from the ISS onboard hyperspectral sensor (HISUI) may also be used in an effort to contribute to improving accuracy.

In order to make the most of the results of these activities and contribute to the international community, it is important to collaborate with various stakeholders. Specifically, information and methodology-sharing with internationally active organizations such as the Global Peatland Initiative (GPI) is an efficient and effective way to internationalize the technology developed by JICA.

From the viewpoint of technology internationalization, it is ideal that the methodology developed will be included in the IPCC guidelines and its utilization in other countries will be promoted, so collaboration with prominent international organizations such as those mentioned above is also important here.

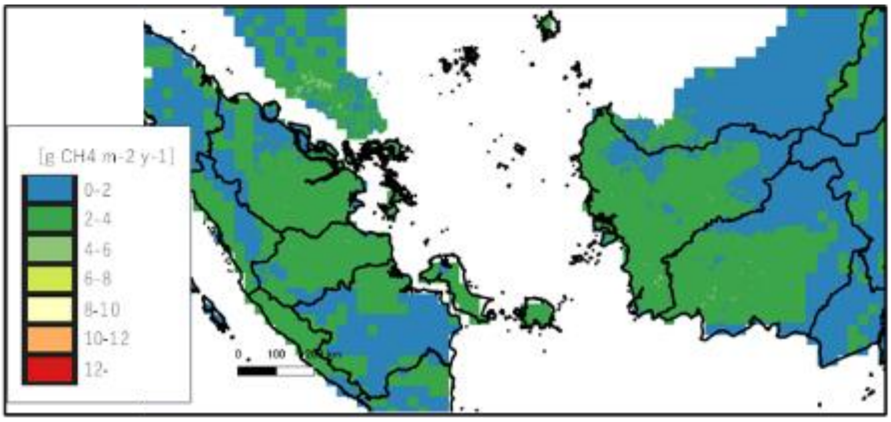


Figure6.4 2 Methane emissions in Indonesia estimated in this study

(2) Social implementation of the calculation of CO2 and CH4 absorption emissions in peatlands using the WRF model

In Indonesia, we worked on the estimation of soil moisture and groundwater level using the WRF model, and were able to estimate CO2 and CH4 absorption and emissions in peatlands using these parameters. As the next step, it is important to encourage Indonesian government officials to maintain and improve the development model, and estimate CO2 and CH4 absorption emissions from peatlands over time. In this process, it is essential to further refine the WRF model while obtaining basic information from borehole surveys and flux towers for field verification.

The ultimate goal is to increase the recognition and credibility of the WRF model within the Indonesian government, and to incorporate the model into the GHG inventory and contribute to the revision of the NDC.

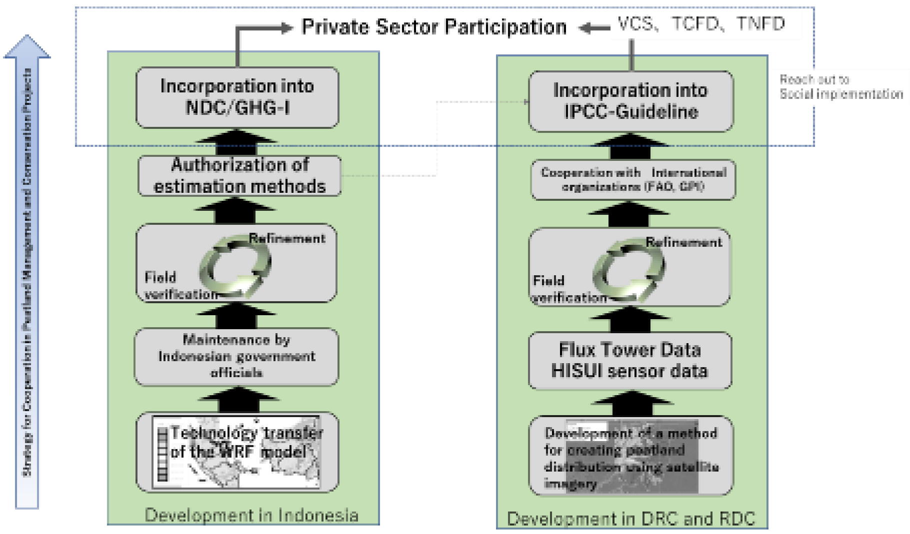


Figure6.4 3 Proposed pathway for future cooperation strategy on peatland management and conservation in Indonesia and the Congo Basin

Endnote: COP26 Information Dissemination

COP26 Peat Pavilion JICA Side Event
Technology and data collection for peatland management
November 9, 2021, 11:00 a.m. - 12:30 p.m.

Report of the event

1 What led to the side event

JICA has been continuously supporting peat conservation and management efforts due to the significant impact peat has on climate change, and has a proven track record in Indonesia and Peru. Against this background, JICA launched a study to collect and organize basic information on peat in three regions of the world where peat is distributed (Peru, Indonesia, and the Congo Basin).

This study, which began in the spring of 2021, has yielded results, particularly in new efforts to map peat distribution in the Congo Basin, and in peat borehole surveys in areas where no information was available before.

JICA has been seeking opportunities to widely disseminate and share these results with the international community, to contribute to peat conservation and management in various countries, and to demonstrate JICA's presence.

On the other hand, the Global Peatland Initiative (GPI), launched under the umbrella of UNEP, provides a forum for the exchange of information on peat-related activities being conducted around the world, consolidates research activities, and assesses peat conditions, and is recognized as an important international initiative in the field of peat.

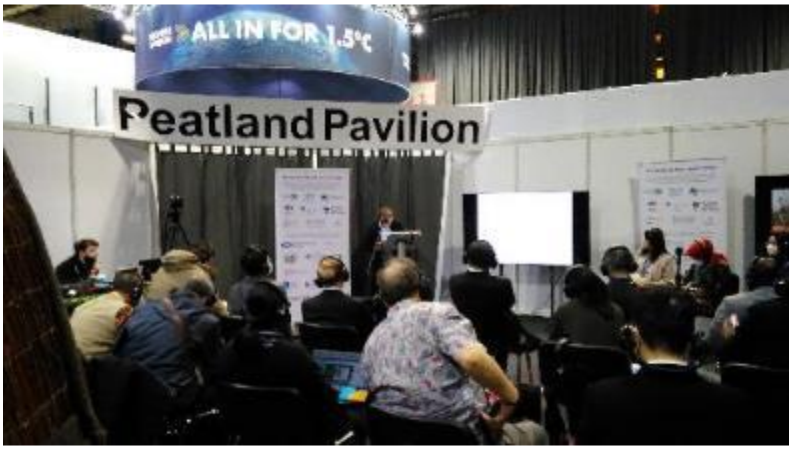
GPI has now been approved by the UNFCCC to have a permanent peat pavilion at COP26, which will host a wide variety of peat-related side events.

Within this framework, JICA was approached by GPI to host a 90-minute side event to effectively disseminate the results of the basic information survey (Appendix-1 Side Event Application Form).

The purpose of the basic information collection survey is to develop data collection and monitorzevents of the Peat Pavilion will be held under the concept of "Science and Data".

2 Side event management

The Peat Pavilion operated as a permanent installation during the COP, but due to COVID-19, all side events were a hybrid of on-site and online participation. This was not only the case for the participants, but also for the speakers, making this a highly unusual side event. An area was set up in the venue of COP26 where all the side events were integrated, and the Peat Pavilion was permanently set up in one corner of the area. (Next paget: The entire Peat Pavilion)



3 Side Event Program Structure

As mentioned above, the speakers were selected based on the following considerations, given that the event was held under the concept of "Science and Data", and that the results of the basic information survey were in line with this concept.

- Sharing opinions from developing countries, as well as JICA's efforts
- While covering technical topics such as data collection, we also give consideration to clarifying the position of the data, including the need for the data and where the data will be used.
- In relation to the above, as a necessary element for peat management, "data collection contributes to the development of higher level policies", with a view to understanding the current situation based on data collection and reflecting it in appropriate planning, we include a slot for reports from policy makers in developing countries related to this.
- In addition, it is essential to strengthen the capacity of data collection and monitoring rigs so that the developed technologies can take root, and we include a report slot on this point.

The above considerations were taken into account in planning the program for the side event.

The program consisted of seven slots (eight speakers), with the exception of the opening remarks, and covered a wide range of areas including policy, technology, data collection, and capacity building. Four of the eight speakers were from developing countries, one was from an international organization, and two were Japanese, creating an international flavor to the list of speakers.

Agenda		
Time	Particulars/Speakers	Comments/Key messages
3min	Takashi Nishimura	Welcome speech
10min	Osaki Mitsuru	Keynote speech
10min	Jean Jacques Bambuta	PEATLAND GOVERNANCE AND KNOWLEDGE DEVELOPMENT
10min	Jose Alvares Alonso	Peatlands management in Peru
15min	Hirose Kazuyo	Peatland mapping by latest remote sensing data in Congo Basin
10min	Corneille E.N. Ewango	Field data collection of peatlands in the DRC.
10min	Tsuyoshi Kato& Niken Andika Putri	Peatland monitoring and new satellite technology
10min	Maria Nuutinen	Peatlands and high-carbon ecosystems, technical lead on peatlands, National Forest
10min	Q/A	
2min	Summary	Summary of the side event

4 Side Event (Summary of speakers' presentations)

The following is a brief summary of each speaker's presentation.

Speaker	Report summary
Jean Jacques Bambuta (DRC)	• Introduction of the various activities being developed in the DRC • National peat strategy to be developed in January 2022. • Promoting understanding of peat is essential for strategy development • For this reason, peat research is essential to collect basic information

Speaker	Report summary
Jose Alvares Alonso (Peru)	• Implications for peat management in Peru • Need to accelerate study on definition of peat, etc. • Quantification of mitigation potential is urgently needed in conjunction with revision of the NDC, and data development is extremely important.
Hirose Kazuyo (JICA)	• Horizontal expansion of mapping methods using aguaje vegetation in Peru to the Congo Basin. • The effectiveness of mapping by combining Sentinel satellite (optical sensor) and SAR (Synthetic Aperture Radar) observations is reported. We will continue to validate the results using existing maps and ground surveys.
Corneille E.N. Ewango (DRC)	• Field survey confirmed peat distribution in the DRC (Nioki). • New findings were obtained that the number of emergent tree species was smaller than initially expected, and that palm tree species were dominant. • Laboratory analysis of the core samples collected was performed to determine carbon content per unit volume, etc.
Tsuyoshi Kato& Niken Andika Putri (Sumitomo)	• Proposal for an Integrated Monitoring, Reporting, and Verifying System (iMRV) in Indonesia combining Ground Survey, UAV Survey, and Satellite Analysis • The above methods are simple, inexpensive, and of high quality, and are proposed to work effectively for the preservation of natural capital.
Maria Nuutinen (FAO)	• Reported that there are three stages for successful capacity building: The initial stage, the planning and implementation stage, and the finalization and sustaining stage, each with its own key points • Stated that in the initial stage, there is a need for capacity-building, in the next stage, a training plan with a long-term perspective is required, and in the last stage, there is a need to strengthen the local population, along with monitoring and evaluation

5 Questions

Due to the limited time for questions, one question was taken from the audience site, and one from the online chat.

① If we were to apply your proposed method to the entire Congo Basin, would the peat area extend beyond what we have currently identified?

« We are currently verifying the comparison with the existing Congopeat map, and cannot answer whether or not the existing distribution area is exceeded at this time.

② Maps of peat and other information are being completed, and based on this, one would think that the value of peat will become clearer and that conservation and management of peat will advance. When will people recognize and understand the value of peat?

« Expect the process of interpreting and valuing the peat distribution map to take longer than the time it takes to create it.

QA sessions in a hybrid online and on-site format

6 Outcomes of the event and suggestions for the future

According to GPI, the JICA-hosted side event was the most successful among the many that had been held, in terms of the number of local participants and the number of questions asked online. When asked about the reason for this, it became clear that the number of prominent experts invited from a wide range of fields, the number of speakers from developing countries as well as developed countries and international organizations, and the topics on advanced remote sensing technologies were the main factors that attracted the largest number of visitors. In this sense, the objectives of effectively disseminating the results of basic information collection and enhancing JICA's presence were achieved. The side event is scheduled to be publicized on the GPI's Youtube site, which is expected to continue to have a positive effect.

On the other hand, the challenges recognized by the organization of this side event and the future direction required for peat conservation and management can be summarized as follows.

i. Not only is peat monitoring important for national policy-making, but private sector participation is also crucial at the community level.
ii. Data preparation and monitoring are important elements of the activity, as quantitative data through regular monitoring can clearly demonstrate the results of peat management and conservation to the outside world.
iii. The importance of peat conservation and management as a climate change mitigation measure is indisputable.
iv. On the other hand, "policy", "science and technology and monitoring", and "capacity building", which are important for peat conservation and management, are not discussed in an integrated manner, and further collaboration is needed.
v. Global partnerships and knowledge-sharing are central to peat conservation and management efforts, and JICA needs to promote collaboration with various stakeholders and levels to address this important issue.