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Concept Note on "Responsible Management of Tropical Peatland"

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Preference

Tropical peatland is a high-carbon and water reservoir ecosystem, closely related to global warming and climate change. This is due to huge amount of carbon emitted by fire and oxidation of peat during El Niño season which contribute to the acceleration of global warming.

Tropical peatlands found in the Indonesia and Malaysia, the Amazon lowlands, and the Central African lowlands are amount to around 42 Mha and are thought to store approximately 148 Gt of carbon. Tropical peatland comprises more than 12% of land in Indonesia (Miles et al., 2017).

Japan and Indonesia have been collaborating in key the study of the ecosystem of tropical peatland in Indonesia for more than 30 years. The concept Note on "Responsible Tropical Peatland Management" is based mainly on Japan-Indonesia Research Projects listed in Collaborator.

Besides the Japan-Indonesia projects, many other projects have been done and are still in progress. However, only very few succeeded in managing tropical peatland. The key points are water management and water supply during dry season. This is because, in dry season, the peatland is devoid of water supply.

As water is stored in the peatland, instead of in ponds or canal, to manage water supply during dry season requires a large-scale peatland management design, which focuses on comprehensive Water Reservoir system as proposed in this Concept Note on Responsible Management of Tropical Peatland.

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JICA-JPS & BRG Program
Kyoto University-Hokkaido University-RINH & BRG Program
FOERDIA-PT. WSL/PT. MTI Pilot Project
JICA IJ-REDD Project
JICA-JST Project (SATREPS)
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Abbreviation:

BMKG	Meteorological, Climatological, and Geophysical Agency, Indonesia
BPPT	Agency for the Assessment and Application, Technology, Indonesia
BRG	Peatland Restoration Agency, Indonesia
DOC	Dissolved Organic Carbon
ESG	Earth Resilience Goals
GOSAT	Greenhouse Gases Observing Satellite
GWT	Groundwater Table
GWL	Groundwater Level
ICALRRD	Indonesian Center for Agricultural Land Resources Research and Development
IRIBB	Indonesian Research Institute for Biotechnology and Bioindustry
JASTIP	Japan-ASEAN Science, Technology and Innovation Platform
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency, Japan
JPS	Japan Peatland Society, Japan
JSS	Japan Space Systems
LAPAN	National Institute of Aeronautics and Space, Indonesia
LCTF	Liquid Crystal Tunable Filter
LIPI	Indonesian Institute of Sciences
LULUCF	Land Use, Land-Use Change and Forestry
MoEF	Ministry of Environment and Forestry, Indonesia
MRV	Monitoring, Reporting, Verifying
MTI	PT Mayangkara Tanaman Industri
NEE	Net Ecosystem Exchange
PHU	Peatland Hydrological Unit
RIHN	Research Institute for Humanity and Nature, Japan
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SATREPS	Science and Technology Research Partnership for Sustainable Development
SDG	Sustainable Development Goals
SRI	Socially Responsible Investment
UF	Un-drained Forest
WSL	PT Wana Subur Lestari

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I. Summary of Key Concept

Key Concept on "Responsible Management of Tropical Peatland" focuses on large scale (more than 10,000 ha) peatland ecosystem with high groundwater table (GWT) and cheapest investment, maintaining high Water/Carbon Reservoir Ecosystem

I-1. Model for Large Scale Water Management System

Tropical peatland ecosystems consider as a key role not only in the storage of carbon in forest and peat, but also controlling water resources and preserving bio-resources and biodiversity (Osaki et al., 2016). This can only be managed effectively with a landscape approach with considering its zone determination from the upper area (peat dome) until the local community's area on the in the lower area (peat dome edges). The zonation for model of large-scale water management system are as follows:

Water Reservoir Zone: natural forest/primary forest zone in upstream area, maintaining 0~20 cm groundwater table (GWT) [Plant species: native/endemic trees species]

Buffer Zone: the zone has a role in maintaining high GWT in the water reservoir zone and prevent ecological impacts of plantation activities on the water reservoir zone, maintaining 0~20 cm GWT [Plant species: local tree species with high GWT tolerance]

Plantation Zone: acacia, oil palm and other plants, maintaining 20~40 cm GWT [Plant species: acacia, oil palm, rubber, local tree species for wood processing]

Satoyama (Human-nature coexistence) Zone: mix-cropping and agroforestry system including animal husbandry and fishing, maintaining 0~40 cm GWT [Plant species: vegetable, fruits, charcoal trees, economic plants (coffee, cacao, etc.)]

Coastal Zone: Conservation and part of Satoyama Zone, depending on sea water level [Plant species: mangrove trees, coconuts palm, sago palm, nipa palm]

Key Points:

1. Water in peatland is supplied mainly by rain, indicating water from precipitation must be absorbed by the peatland itself (Fig.1 and Fig.2).
2. Peatland is a high-water reservoir [weak water retention function in peatland by "Intermolecular Force (van der Waals force)"]
3. Thoughtless canals and pond accelerate water flow from peatland [strong water drainage function from peatland by "Gravity Force" and "Cohesive Force"]

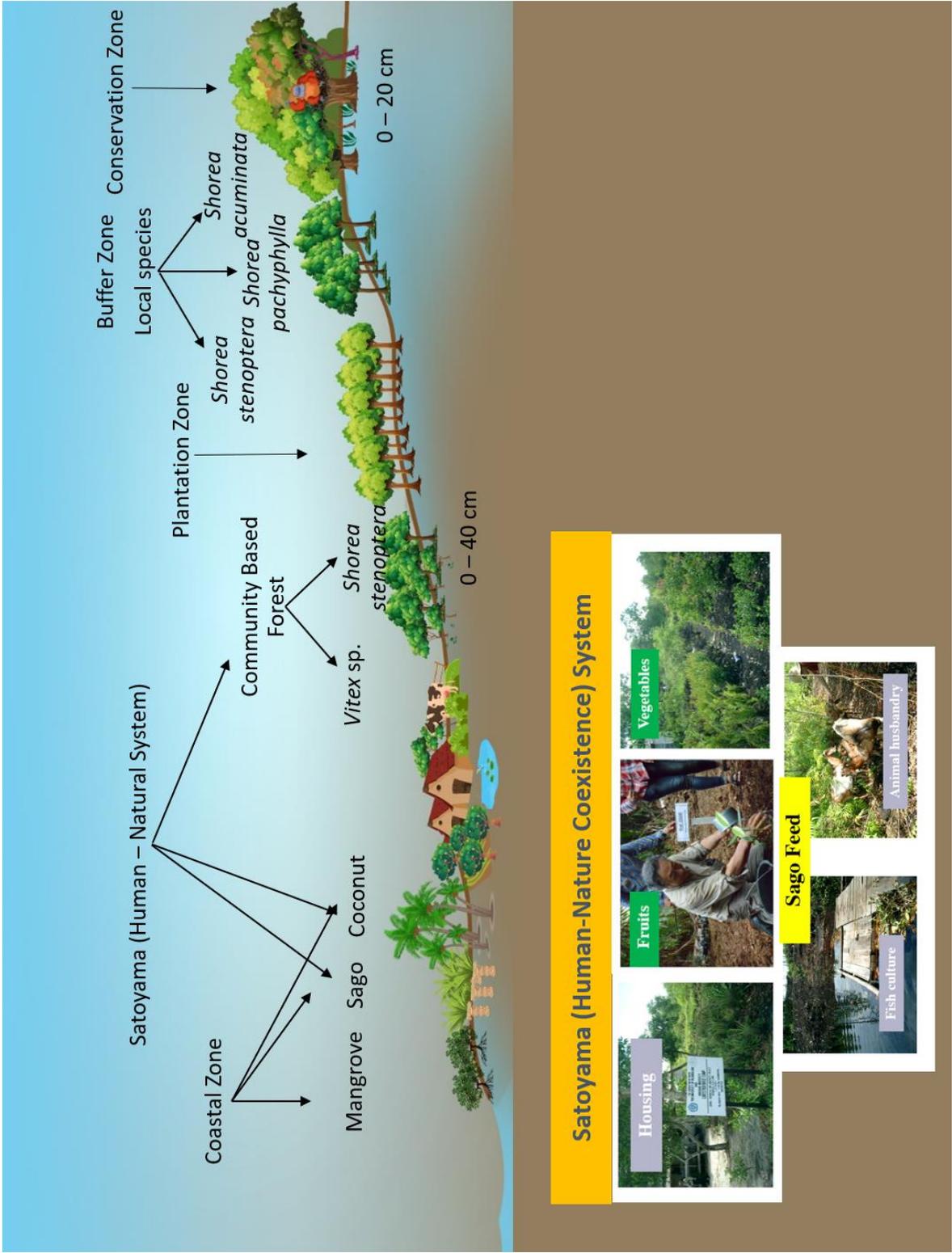


Fig. 1. Large scale profile of an innovative **Water Reservoir Ecosystem** in tropical peatland

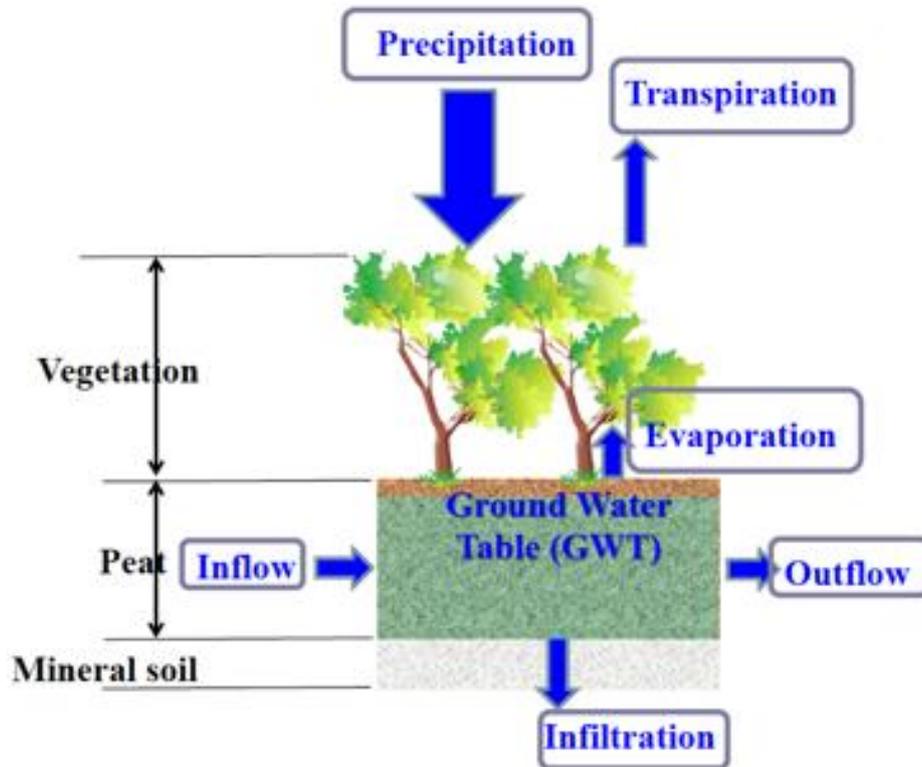


Fig. 2. Water balance in tropical peatland

Therefore, it requires 1) "**Water Reservoir**" in upstream area and on top of the peat dome, and 2) "**Water Pool**" in big canal in downstream area to prevent water leakage, 3) "**Canal Blocking**" to keep high water table, and 4) "**Infrastructures**" for adjusting optimal water level and supplying water throughout the area during the dry period.

In "Responsible Management of Tropical Peatland", high "Groundwater Table (GWT)" should be maintained at less than 40 cm (0-40 cm) below ground surface to prevent forest/peat fire, for which "AeroHydro Culture" methodology, supplying nutrients and oxygen to peatland surface, should be applied (Fig. 17).

In the plantation and Satoyama (Human-nature coexistence) zones, AeroHydro culture methodology by which "nutrients" and "oxygen", most limiting elements in high water table peatland, are applied from land surface.

I-2. Large-scale MRV System

The term "Measurement, Reporting and Verifying (MRV)" first appeared in the Bali Action Plan at COP13 in 2007. It introduced the principle of action for developed countries and developing countries in the context of improving climate change mitigation actions at the national level and international. Measurement to monitor, calculate and track development; Reporting to record and disclose developments publicly to communicate and give transparency; and Verification to confirm progress and test its accuracy impartial.

The Government of Indonesia is committed to reducing greenhouse gas (GHG) emissions. To achieve that goal, a monitoring system to measure GHG emissions needs to be developed continuously and needs to be supported by various parties. Deforestation, degradation and forest fires contribute to greenhouse gas emissions. An accurate monitoring system is needed to form the basis of the Measurement, Reporting and Verifying (MRV) system. This needs to be accompanied by actions of nature conservation and forest protection initiatives.

To achieve that goals, an integrated MRV system should be established in a big scale. There are three components (minimum) consists of monitoring system on the ground, using drone or microsatellite, and satellite. By combining all measurement using GOSAT, Flux Tower, Hisui, MODIS Landsat, PALSAR, and GPM (Global Precipitation Measurement), monitoring system to calculate parameters such as CO₂ concentration and haze; CO₂ and CH₄; forest degradation and deforestation (species mapping and biomass); peat fire and peat loss; topography; Groundwater Level; peat subsidence; water soluble organic carbon; and animal species can be measured.

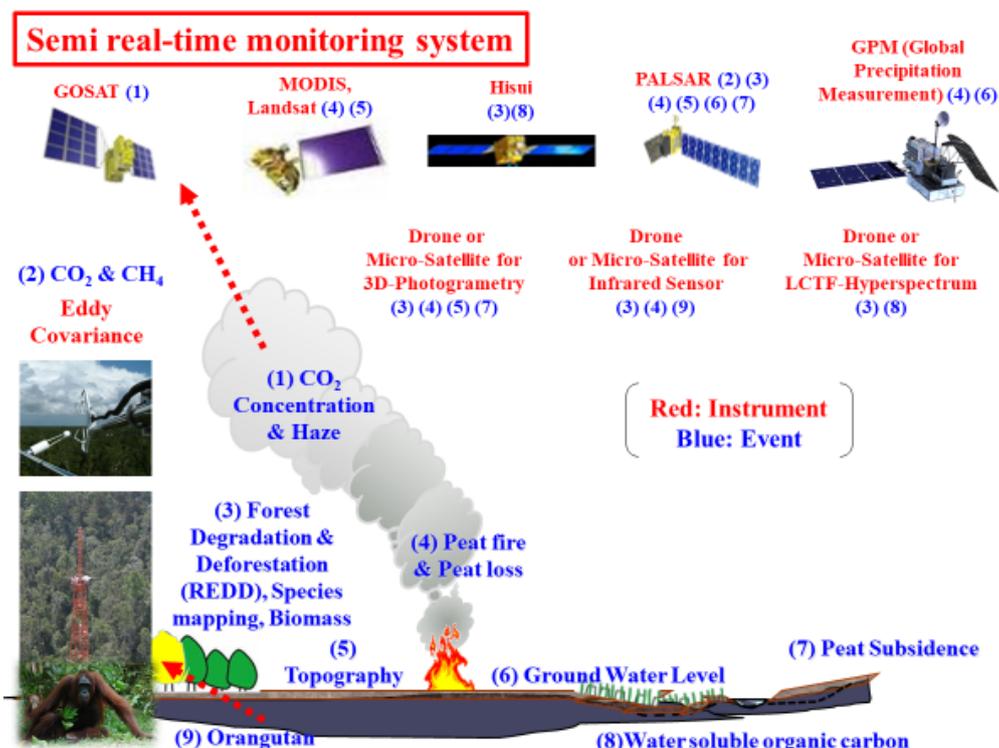


Fig. 3. Semi real-time monitoring system - Minimum components for integrated MRV (Measuring, Reporting, Verifying) System, composing three layers; 1) Monitoring on ground, 2) Drone or Microsatellite, and 3) Satellite

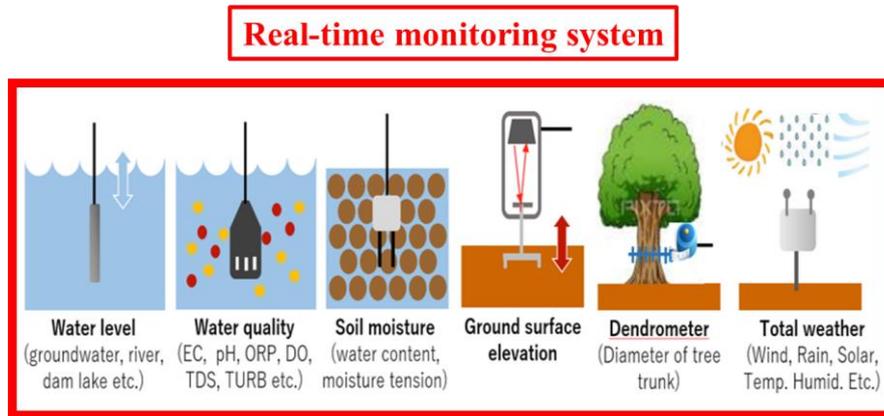


Fig. 4. Real-time monitoring system – Using some sensors (water level, water quality, soil moisture, ground surface elevation, dendrometer, and total weather station) in several points every 10 minutes, and could be monitored from a website

Key Points:

Integrated MRV (Measuring, Reporting, Verifying) System provided in semi-real time for 1) water table mapping, 2) soil moisture mapping, 3) carbon emission mapping, 4) land subsidence mapping, 5) wild fire mapping (surface fire and peatland fire, separating), 6) peatland loss mapping by fire, 7) peat fire prediction mapping, 8) fire scar mapping, 9) accumulative hotspot mapping (against peat areas) 10) vegetation and plant diversity mapping, 11) animal nest and behavior mapping (Fig. 3 and Fig. 4).

I-3. Observation and Training Station

Collecting data obtained from remote sensing monitoring equipment that will provide information that corresponds to the use of specific tools (Gosat, Modis, Hisui, PALSAR and GPM). All monitoring integrations are estimates, due to low resolution, and errors in detection. Hence, to determine each appropriate monitoring, such as hydrological monitoring, measurements are carried out on the spot with real-time transmissions, using data loggers sent to the server via a mobile network, such as groundwater level measurements, rainfall as a validation measurement that has accurate data high.

Peatland monitoring stations have been installed in six provinces in Indonesia, with the aim of mapping peatland protection and management plans (water control, fire control, vegetation management, carbon accounting and so on). To support operational activities in several observation stations, local training needs to be carried out with the support of local governments, international partners and civil society groups. For smoothness including the selection of measurement point procedures, measuring and frequency tools, carrying out measurements, reporting and verification as well as technical guidance on management/utilization and maintenance of monitoring equipment, equipment installed will be managed by the local government and the community.



Fig. 5. Observation Station Networks. The observation stations to be established in 1) Riau, 2) Jambi, 3) West Kalimantan, 4) Central Kalimantan, 5) Sulawesi, and 6) Papua

Key Points:

As several models should be validated by actual monitoring and sensing data, observation station network covering elements in Fig. 5 should be established. These observation stations provide capacity building especially for training for the application of several models (mapping) into local/regional peatland management (water control, fire control, vegetation management, carbon accounting, so on).

I-4. Real Time Observation Networks by Microsatellite



Fig. 6. Equator Orbiter Micro-Satellite Network. As microsatellite in Equator Orbiter observe several times a day, spots scene in cloud free space can synthesize as one belt scene even in optical sensor

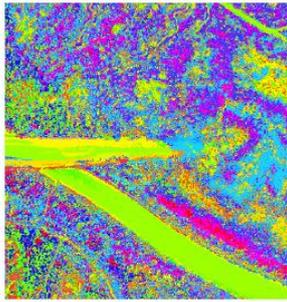
Key points:

1. Sensors Composition in Equator Microsatellite such as:

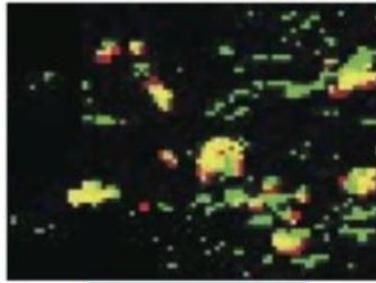
- a) LCTF (Liquid Crystal Tunable Filter) Hyperspectral Sensor
- b) Infrared Sensor
- c) Two angle sensors for 3D-Photogrametry

- d) High resolution in all, 50cm x 50cm
2. Real time information necessary in tropics for:
- a) Dynamics of "High Carbon/Water Reservoir Ecosystem"
 - b) El Nino and La Nina effect
 - c) High Biomass Productivity
 - d) High resolution for Fire Spots
 - e) Animal distribution
 - f) Deforestation monitoring
3. Cost performance:
- a) Extremely cheap (less than 10 Million US dollar/ one micro-satellite) comparing with such as LiDAR (several 10 Million US dollar for only peat dome survey for only once a time: impossible real-time monitoring)
 - b) Extremely Cheap because of covering all ecosystem and geography in Indonesia
 - c) Increase information volume in more than 10~100 times
 - d) Protect disaster (fire, land sliding, illegal logging, so on)
 - e) Increase Agriculture/Plantation Income by checking i) nutrients disorder or unbalance, ii) disease, iii) water management, iv) GHGs emission, v) subsidence
4. LCTF-Hyperspectral Sensor Function:
- a) Biodiversity Mapping (one tree mapping)
 - b) Forest Degradation Mapping
 - c) Biomass Mapping
 - d) Leaf Water Potential Mapping
 - e) Land Cover and Land Cover Changing
 - f) Fishery and Coastal Ecosystem
 - g) Dissolved Organic Carbon (DOC) Mapping
 - h) Peat Depth Mapping applied by Plant Phenology
 - i) Rice Growth Stage Mapping
 - j) Crop Yield Mapping
 - k) Leaf Protein Content of Rice at Flowering Stage
 - l) Disease Mapping (Early detection of rice blast)

Information on real time management, natural resources, environmental and weather are as follows: (1) Agriculture, monitoring of agricultural land and production estimates; (2) Forestry, including forest inventory and monitoring; (3) Land Use; (4) Disaster including mitigation needs; (5) Geology/Volcanology; (6) Environment; (7) Marine and Coastal; (8) Weather and Climate. Microsatellite is considered the most efficient, effective and very well operated. Satellite-based monitoring systems are the primary tools for providing near real-time (NRT) information on newly deforested areas in vast and inaccessible tropical forest (Reiche, 2017). Global imperative to address deforestation to achieve international forest, biodiversity, and climate goals. Near real-time monitoring can now play a large role in those efforts.

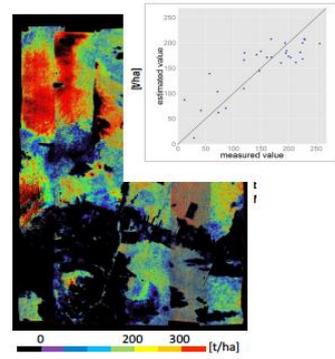


**Biodiversity Mapping
(one tree mapping)
(Y. Takahashi et al)**

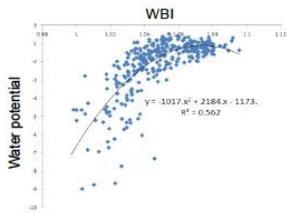


Red : Dead trees
Green-Yellow : Water stressed trees

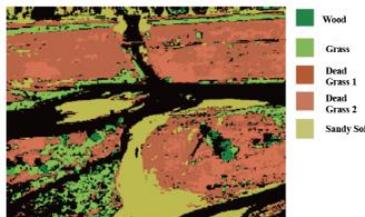
**Forest Degradation
Mapping (JSS & JAXA)**



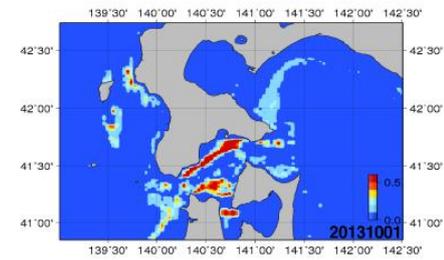
Biomass Mapping (JSS & JAXA)



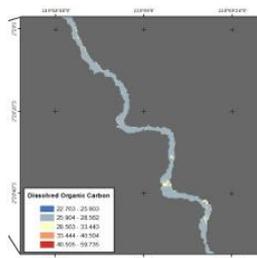
**Leaf Water
Potential Mapping
(JSS & JAXA)**



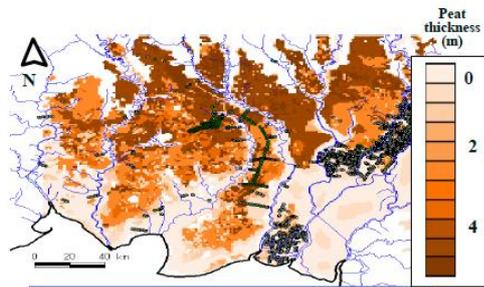
**Land Cover and Land
Cover Changing (Shin
Satori)**



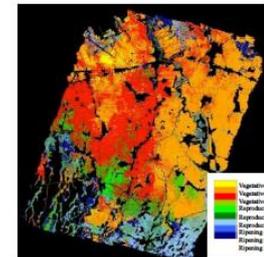
Fishery



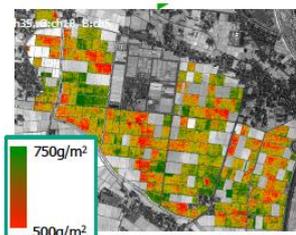
**Dissolved Organic Carbon
(DOC) Mapping (JSS & JAXA)**



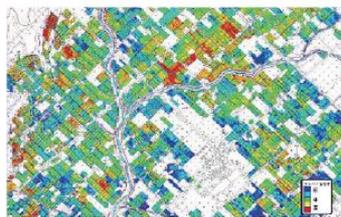
**Peat Depth Mapping applied by Plant Phenology
(Sawahiko Shimada)**



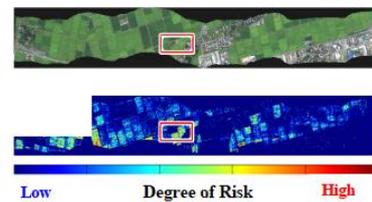
**Rice Growth Stage
Mapping (JSS & JAXA)**



**Crop Yield Mapping
(JSS & JAXA)**



**Leaf Protein Content of
Rice at Flowering Stage
(Shin Satori from Fujitsu
Hokkaido systems)**



**Disease Mapping
(Early detection of rice blast)
(JSS & JAXA)**

Fig. 7. Hyperspectral Sensor Function (partly from Hirose et al., 2016)

II. Background

Tropical peatland is amount to 170 Mha (Gumbricht et al., 2017), which is more than threefold the current estimates (Page et al., 2011). The world's three major regions of lowland tropical peat are the Cuvette Centrale (Congo Basin), Western Amazonia (Amazon Basin) and the tropical island of Asia (mostly Indonesia). Latest published research estimates that the area of peat in Cuvette Centrale to be approximately 14.55 Mha, making the Cuvette Centrale the most extensive peatland complex in the tropics with store approximately 30.6 Gt of carbon belowground (Dargie et al., 2017). Meanwhile, latest study in model for tropical wetlands and peatlands mapping reveals that South America has the largest tropical peatland with Brazil amasses 31.23 Mha (Gumbricht et al., 2017). The peatlands of Southeast Asia lie within inter-tropical convergence zone that experiences a wet tropical climate with annual rainfall generally in excess of 2,500 mm (Riley and Page 2005). Indonesia is a major tropical peatland area in this region with estimated area up to 14.91 Mha, spreads across the islands of Sumatera (6.44 Mha), Kalimantan (4.78 Mha), and Papua (3.69 Mha) (Wahyunto et al., 2014).

Peatland degradation has long been a problem before the 2014-2015 fires occurred. Approximate 3.74 million ha or 25.1% of the total area of peat in Indonesia, has been heavily degraded and has become very critical land issue (Wahyunto et al., 2014). Hereof, the Indonesian government enacted Government Regulation Number 71 of 2014, which was later revised in Number 57 of 2016 for the Protection and Management of Peat Ecosystem. To define peat ecosystem, the areas are defined as that spatially formed into Peatland Hydrology Units (PHUs). Peatland hydrological unit as mentioned in Article 1 Section (4) of the Government Regulation number 57 of 2016, is a peat ecosystem located between 2 (two) rivers, between a river and a sea, and/or at a swamp. PHU is a unit that can be used as a peatland ecosystem management unit. In 2017, the Ministry of Environment and Forestry (MoEF) issued a Ministerial Decree number SK.129/MenLHK/Setjen/PKL.0/2/2017 concerning Determination of National Peat Hydrology Units Map. The decree states that there was 865 PHU in total throughout Indonesia, with the following details: 207 PHU in Sumatera; 190 PHU in Kalimantan; 3 PHU in Sulawesi; 465 PHU in Papua (Fig.8).

Afterwards, the procedure for determining the peat ecosystem function as mentioned in Article 9 section (2) of the Ministerial Regulation Number P.14/2017 includes the Peat Ecosystem Protection and the Peat Ecosystem Cultivation Function. Article 9 section (2) explains that the Peat Ecosystem area with a protected function that covers at least 30% of all PHU, located in one or more peat domes. Protected area of peat dome is established to maintain the function of peatland ecosystem protection.

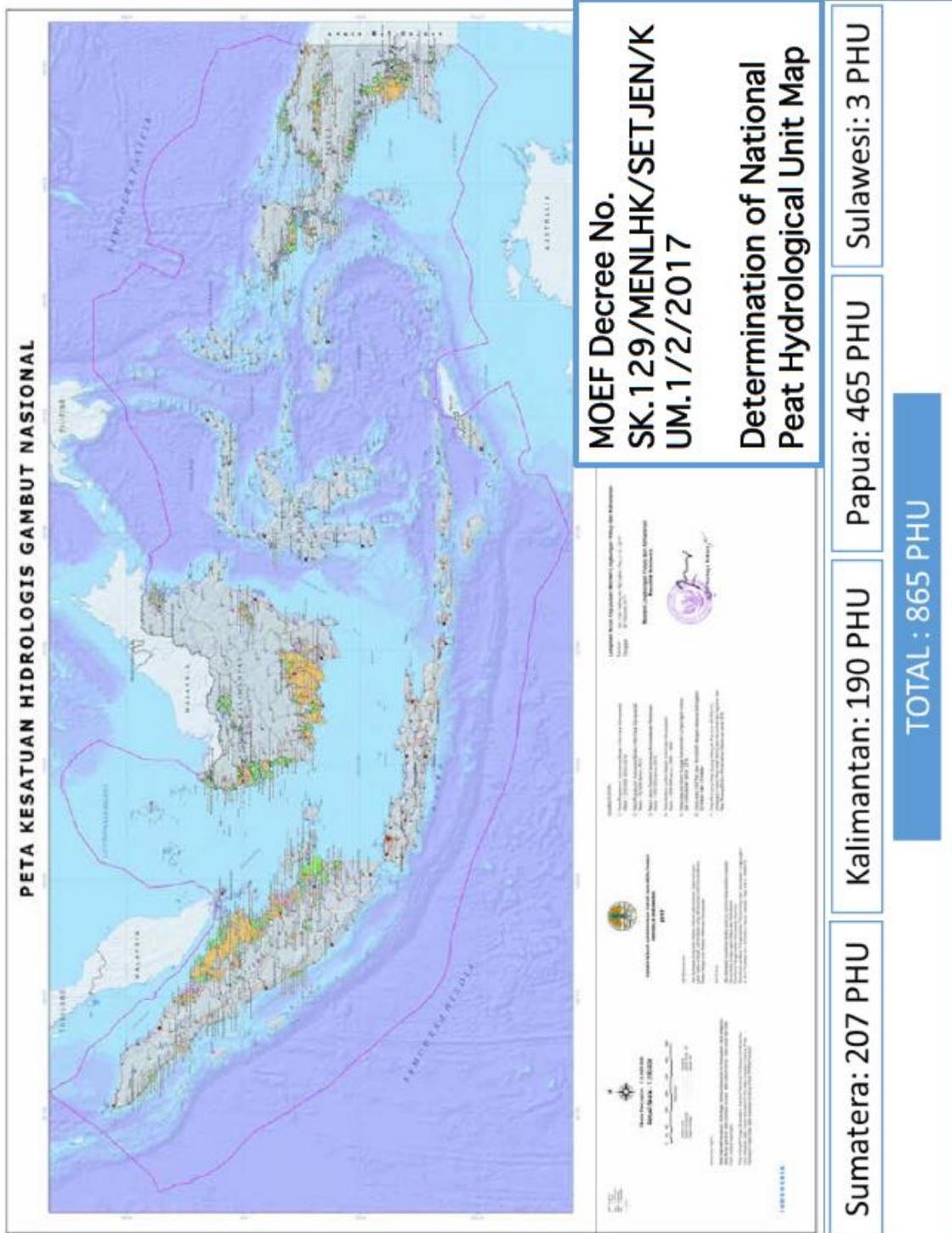


Fig. 8. National Peatlands Hydrological Map

Peat domes are an important part of peat ecosystems. The convex land that is higher than the surrounding area functions as a water balance regulator. Based on the data from MoEF and ICRAD (2011) the total extent of peat dome in Indonesia is approximated 8.9 million hectares. Conservation of native peatland should be implemented. The Government Regulation Number 57 of 2016 (Article 9; Section 4) states that "Peat ecosystem located in a protected area, protected forest area, and conservation forest area as defined in the spatial plan, the Minister shall be determined it as functions of the peat ecosystem". Lesson learned from peatland management of past decades, is that most of the canal-built were cut through the peat domes, which lead to over drained conditions and fire haze. The most important part of the Responsible Management of tropical Peatland is water management, monitoring system, nutrient cycle and value chain. Water management is an important aspect for hydrological restoration in tropical peatland because available water to be distributed in dry and rainy seasons. According to the Government Regulation Number 57 of 2016 (Article 23; Section 3), "A peat ecosystem with cultivation functions shall be declared damaged if it meets the damage criteria as follows: The groundwater level at the peatland is more than 0.4 (zero point four) meters beneath the peat surface at the compliance point."

Key Points:

Based on the regulation for "Responsible Management of Tropical Peatland" design:

1. 0.4 m Groundwater Level (The Government Regulation Number 57 of 2016; Article 23; Section 3)
2. 30% Top Dome Conservation (The Government Regulation Number 57 of 2016; Article 9; Section 3)
3. Conservation of Native Peatland (The Government Regulation Number 57 of 2016; Article 9; Section 4)

III. Water Management

In general, peat dome has a function of keeping ecosystem sustainability and substantial water reserves for the entire area even though during the dry season. Peatland management with the correct water management system can store an exceptional amount of water reserved in the peat dome. Most importantly, the groundwater table and soil humidity balance should be kept in the entire area throughout the year. This proper water management can increase plantation productivity at the same time.

WSL-MTI Model:

WSL and MTI have utilized peat dome in the conservation area as water reservoirs. To support this, WSL/MTI has determined the hydro-buffer area as a buffer between conservation and planting areas to minimize water flow from conservation to the planting area. The water reservoirs in the conservation area help balance and stable of the groundwater level in the entire area during the dry season. The buffer area serves as a barrier between conservation and planting areas to prevent the negative effects on the ecosystem of the conservation area. Several local species, such as dipterocarp species dominated in the conservation area, have been planted in the hydro-buffer area.

The water zones used for canal network design, where the main canals are aligned across the contour and secondary canals, are aligned along the contours. Water control structures such as peat dams and spillways have been built between the water zone to avoid excessive drainage and maintain high groundwater levels (during low rainfall periods and dry seasons).



Fig. 9. Peat dam with “comb bypass” design: Spillways structure (a) and Peat dam (b)

WSL/MTI also have been developing some innovative technologies to maintain commercial economics and dynamic regulatory, one of which is flap gate. It is made by simple design, low cost, and easy to maintain. The technology is not only can be used by the company but also widely used, especially by the community and other companies around the concession.



Fig. 10. Flap gates: MTI plantation area (a) and community own land (b)

By implementing proper water management, WSL/MTI maintained a high groundwater level at 20-40 cm across the landscape during El Niño dry period in 2015, as a result there was no peat fires in our planting area.

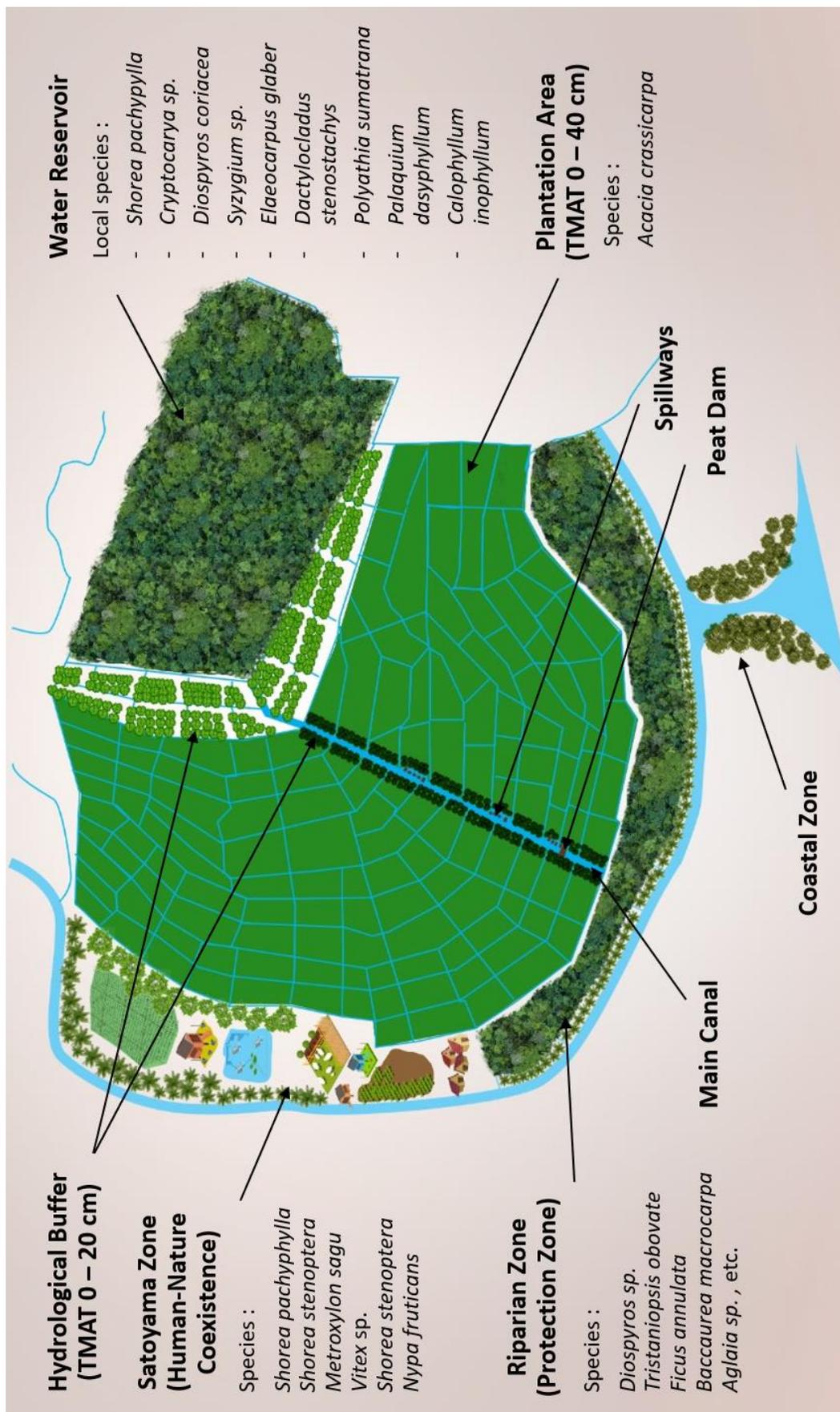


Fig. 11. Water Management Diagram based on WSL-MTI Model

For peat fire and peat degradation (Oxidation) protection, two strategies are essential that are: 1) high groundwater table and 2) high soil (peat) moisture. Thus, the proposed Water Management system is based on WSL-MTI Model (Yusup et al., 2016).

Key points:

1. Water reservoir: keeping a high Groundwater Table (0-20 cm) throughout the year in Water Reservoir Zone and Buffer zone.
2. Canal Blocking: keeping a high Groundwater Table.
3. Infrastructures: adjust targeted Groundwater Table and maintain it at a constant level throughout the year.
4. Canopy Coverage: keeping High Soil (Peat) Moisture.

Infrastructures should be **“Simple, low cost, and easy to maintain”**. It is not because only one company needs to achieve proper peat management, but it is meaningless if these technologies are not widely used by national, local governments, and communities.

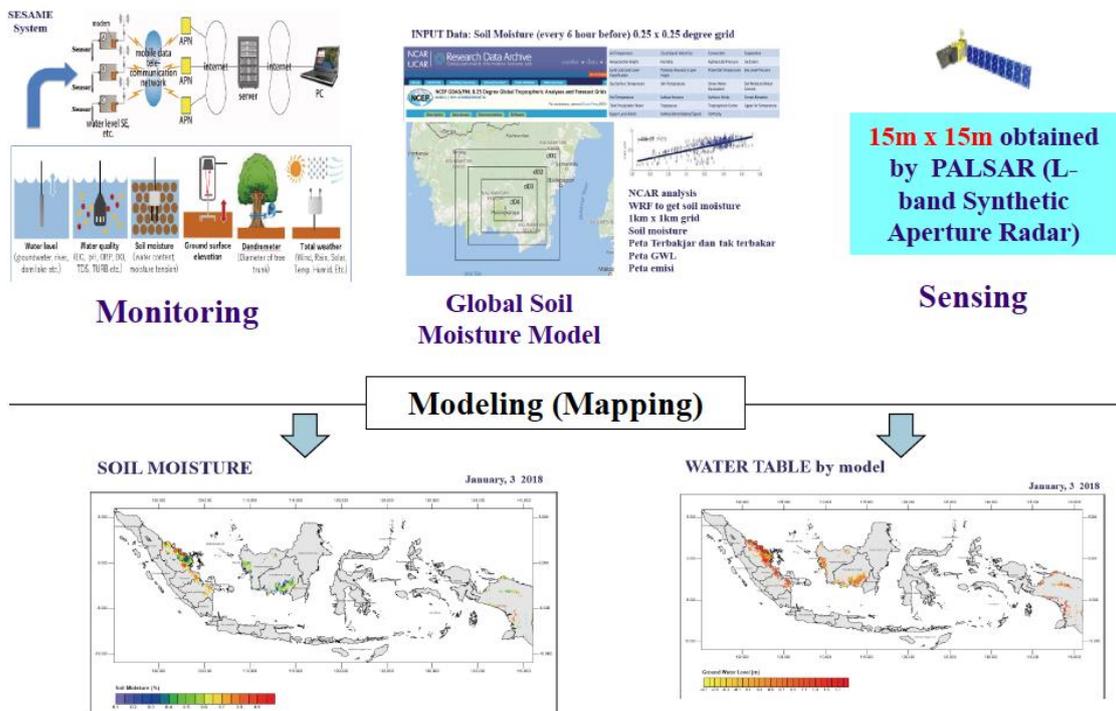


Fig. 12. Monitoring, Sensing and Modeling of Water in Peatland

IV. Carbon Management

Carbon emission model from peat decomposition uses Eddy Covariance flux tower to estimate Net Ecosystem Exchange/NEE. Data recorded from Eddy Covariance flux tower are used to calculate physical parameters such as wind velocity, air/soil temperature and CO₂.

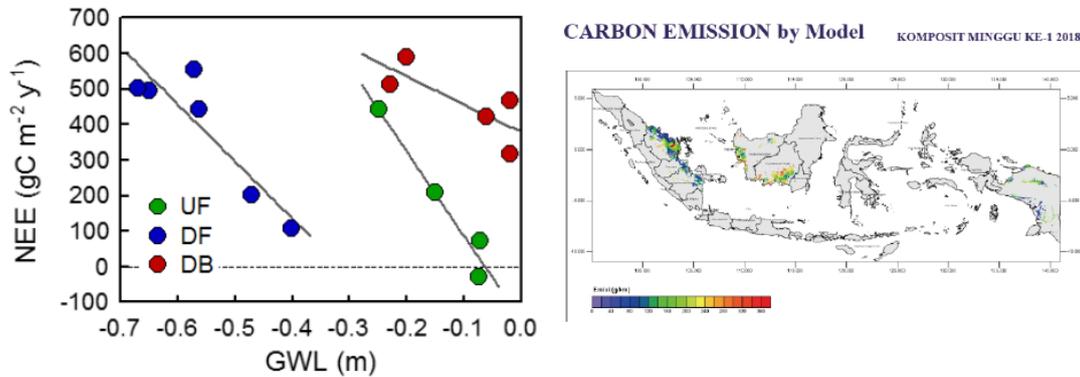


Fig. 13. Carbon Emission Modeling in Peatland (Hirano et al., 2013)

Carbon emission model from peat decomposition is based on the assumption that there is a linear relationship between NEE and GWL. Based on this relationship, the model allows us to estimate an annual NEE by using the lowest monthly average GWL. NEE means the difference between CO₂ amount which is emitted by ecosystem respiration and absorbed by photosynthesis (gross primary production/GPP). Ecosystem respiration is found to increase with soil temperature and decrease as GWL or soil moisture rises. In forest ecosystems, CO₂ exchange between atmosphere usually occupies most of the carbon flow. If other carbon is negligible, the carbon balance of forest ecosystems can be determined by NEE.

The net ecosystem exchange (NEE) is negatively correlated with groundwater table; however, its correlation coefficient varies among the ecosystems, such as undrained forest peatland (native forest; UF), drained forest peatland, and drained and burned peatland. Real-time carbon emission map was developed from water table map and the coefficients of NEE-groundwater level (GWL) regression.

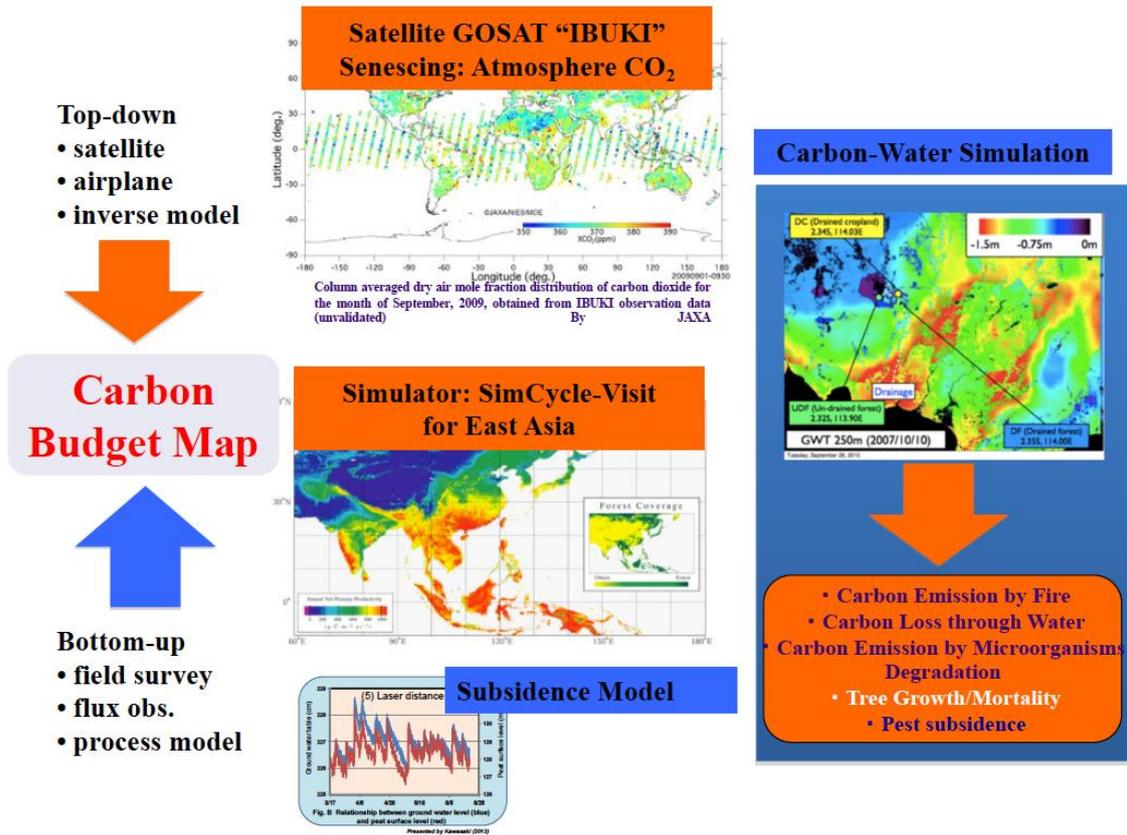


Fig. 14. Cross Check Diagram of CO₂ emission models in peatland (from Honma T, 2016 and Ito A, 2002, partially)

Key Points:

Carbon Emission is estimated through several models. Now it is possible to cross check models on CO₂ emission (Fig 14). Carbon Emission Models are as follows:

1. CO₂ emission by microorganism's degradation; NEE-Groundwater Table Model and Peat Subsidence-Water Table Model.
2. CO₂ emission by Peat fire: Peat Loss-Water Table Model and Peat Loss by iSAR.
3. Carbon Balance Simulator: SimCycle-Visit for East Asia.
4. Atmosphere CO₂ by Satellite GOSAT "IBUKI" Senescing: Inversion Model.

V. Landscape Management and Conservation Network

WSL/MTI has developed the concept of conservation network to make a balance between tree production and ecosystem conservation. The network consists of core areas with high conservation valued forest and green corridors for providing natural habitat and movement of animals.

To prevent the habitat from being left behind in the form of islands, WSL/MTI has also been consulting with neighboring companies to build a conservation network that sets the green corridor in a mesh pattern. Although management at the landscape level is attracting attention worldwide, these efforts will be a rare case.

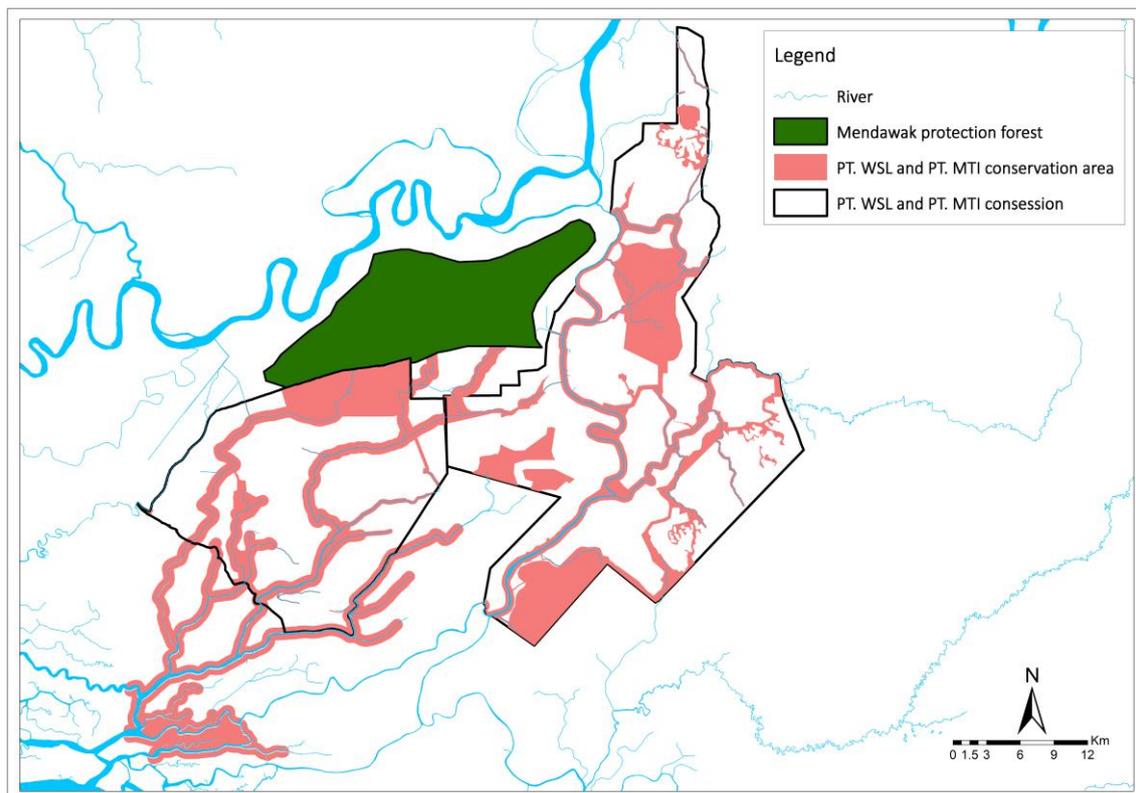


Fig. 15. Conservation Network for biodiversity corridor

Protection Forest: Forest designated for protecting soil and hydrology, and nationally managed.

Conservation Forest: Forest designated primarily for conservation of biological diversity, and natural and associated cultural resources. In general, the concept of High Conservation Value Forest (HCVF) has been applied for the delineation of the Conservation Forest.

Conservation Network: Consisting of core conservation area (Conservation Forest) and riparian zones to provide natural habitat and green corridors for movement of animals.

Case study

The boundaries of concession area set by the government do not match the edges of ecosystems. Therefore, the scope of WSL/MTI's survey should be expanded to outside of the concession area in order to study landscape process as an end management. As a result, in addition to the concession area of 115,000 ha, the nationally managed protection forest of 20,000 ha is also covered. The national protection

forest forms a large elevated dome of water in damaged peat and plays an important role in the region.

Also, after thorough fauna and flora research, the areas to be protected were decided. Periodic surveys of animals and plants are conducted in areas to be protected, and for orangutans and proboscis monkeys, which are rare animals, not only monitoring the number of individuals but also investigating suitability of habitats for its living including food source and resting area.

Key Points:

1. Achieve balance between tree production and ecosystem conservation.
2. Biodiversity Preservation by the concept of the Conservation Network.
3. Contribution on water reservoir, because Protection and Conservation Forest play an important function in water stocking, and protection water leaking along canal or river side.
4. Collaboration with neighboring private sectors, local communities, and governments to ensure connectivity of the forested area and high conservation value area for biodiversity conservation and protection.



Fig. 16. *Buceros rhinoceros* (left) and *Nasalis larvatus* (right)

VI. Land Surface Management

In recent decades, utilization of peatland is not well managed and leads to degradation. While, tropical peatland is a huge ecosystem for carbon and water storage (Osaki and Tsuji 2016), many peatlands were changed into cultivation areas and followed by drainage. According to The Government Regulation, Number 57 of 2016 (Article 23; Section 3), "A peat ecosystem with cultivation functions shall be declared damaged if it meets the damage criteria as follows: The groundwater level at the Peatland is more than 0.4 (zero point four) meters beneath the peat surface at the compliance point." Many stakeholders (mostly palm oil companies) couldn't agree to keep water at high level. If the ecosystems are destroyed, huge carbon emission changes the water balance and will give a serious negative impact on global environments (Osaki and Tsuji 2016), such as increased GHG emissions, greater frequency of fires and loss of biodiversity including endangered species (FAO 2016) and those actions will lead to climate change. Peatland management is complex not only because of the presence of multiple stakeholders but also due to the natural characteristics of peatland ecosystem.

There are multiple elements that should be considered in managing peatland, such as 1) groundwater level; 2) nutrient status of peat soil and water, also 3) oxygen availability. Main reason of plant growth restriction in high water table are lack of oxygen supply and nutrients. One of new innovated on plant culture system called "AeroHydro Culture" is plant culture at high water table and oxygen/nutrient supply from land surface. This action is an effort to convince many stakeholders to accept the regulation. If this cultivation system come out well, it will have a huge impact in terms of responsible management of tropical peatland. AeroHydro Culture can be applied on a different ecosystem also to many food/cultivation crops.

VI-1. Aero-Hydro Culture

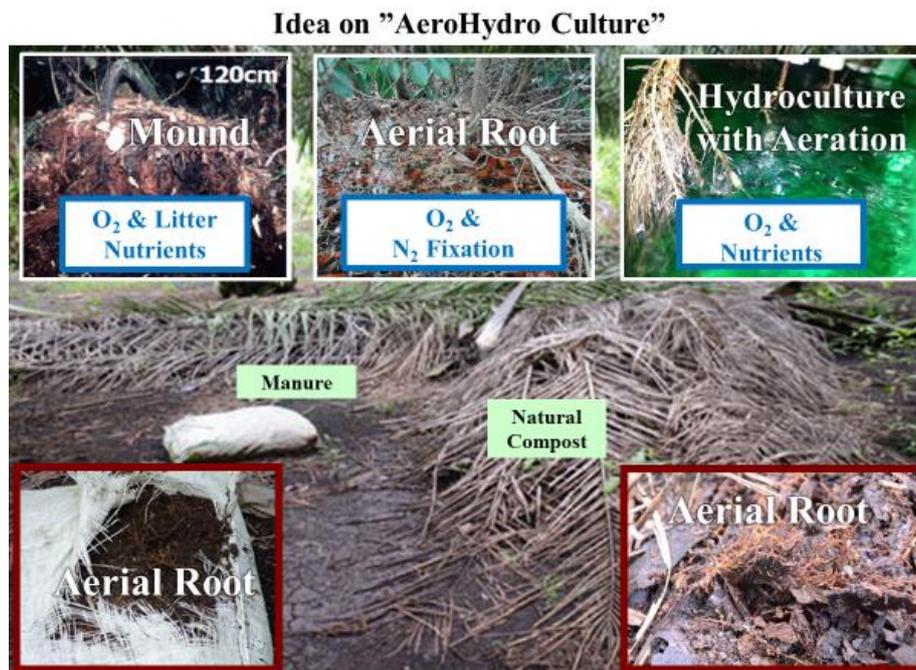


Fig. 17. Concept on AeroHydro culture, based on 1) native plant strategies under high water table; aerial root formation and mound root formation, 2) good practice of oxygen and nutrients supplying from land surface, and 3) hydroculture with aeration

Key Points:

1. In water, O₂ solubilization is very low, therefore O₂ is a serious limiting factor in peatland.
2. In peat of pH less than 4.0, all essential nutrients are not absorbed by peat, and quickly leaks, especially K⁺ nutrients.
3. AeroHydro Culture System is designed to a) keep High Water Table (higher than 40 cm, targeting 20~30 cm water table, b) keep High Soil Moisture, c) supply Oxygen/Nutrients from land surface, and d) promote Plant/Root Growth by Microorganisms symbiosis and Hormone like natural compounds.

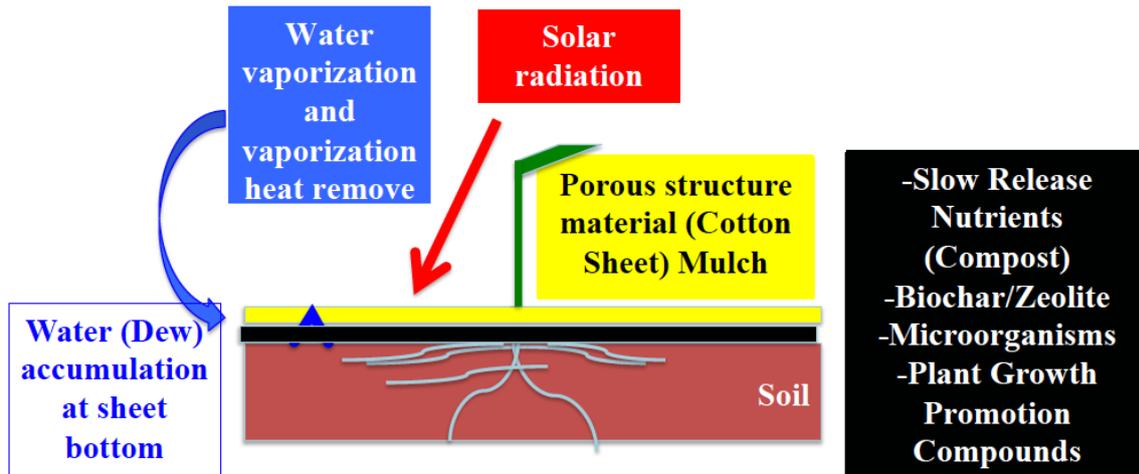
VI-2. HydroCycle Culture

Fig. 18. Concept on HydroCycle Culture, based on removing vaporization heat (latent heat) from porous material by solar energy, then cooling down the bottom of porous structure material

Key Point:

1. Solar energy radiation to porous structure materials (cotton sheet in case)
2. Vaporization of water inside porous structure
3. Removing Vaporization heat
4. Cooling down at the bottom of porous structure materials (cotton sheet in case)
5. Making a dew at the bottom of porous structure materials, and keeping wetness of land surface
6. Growing root well on land surface even in dry condition

VI-3. NutrientCycle Culture

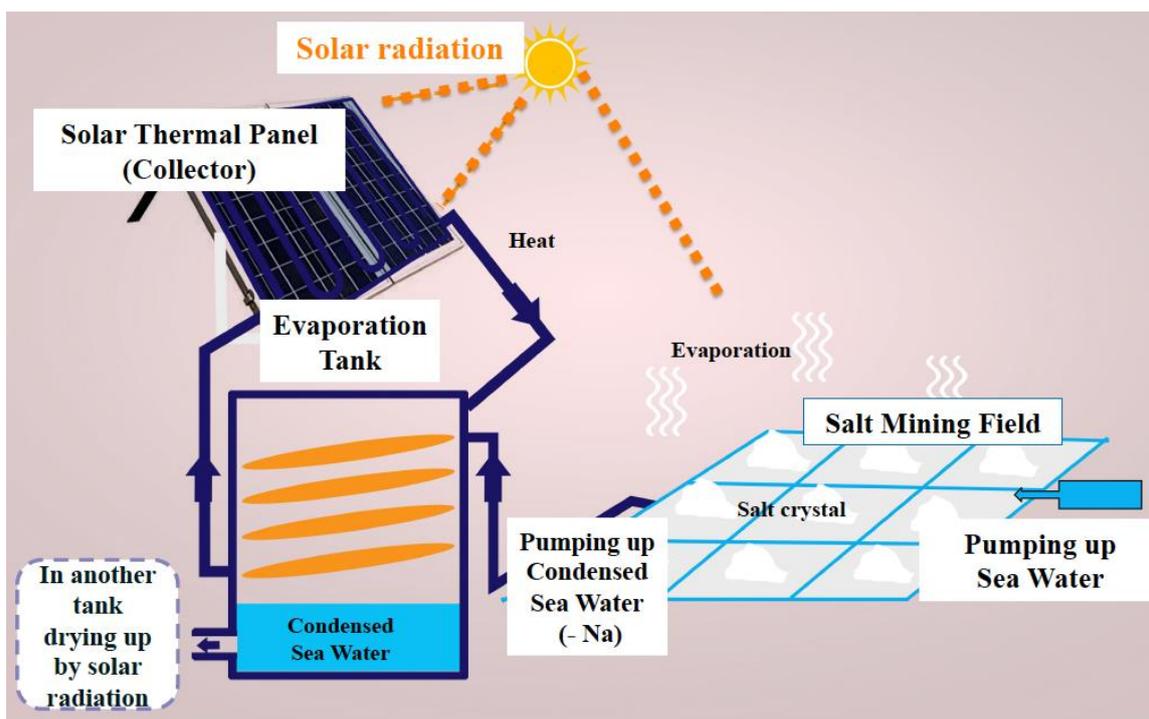


Fig. 19. Concept on NutrientCycle Culture, based on sea water condensation and removal of Na^+ by solar energy in coastal area

Key Points:

1. Nutrients are limited in peatland because it's not supplied by rain and no absorption of nutrients by peat in low pH (less than 4.5).
2. Nutrients in sea water are condensed by solar energy, and remove only Na^+ .

VII. Value Chains Construction

Peatland management needs innovation in every aspect of operations upstream to downstream. Industrial forests on peatlands, especially in Kalimantan and Sumatra has come under domestic and international spotlight because their negative effects on the environment, such as land subsidence, CO₂ emissions, fires, floods, and loss of biodiversity. This is due to a relatively weak governance, which only focuses on economic aspects without regard to sustainable social and environmental aspects. To meet these challenges, the Indonesian government has recently undertaken efforts and invested billions of dollars to improve management and conservation, eradicate fires, and restore degraded peatlands. This effort has a large-scale positive impact on sustainable forest management and has advantages in every business process activity that is reflected in a value chain, such as increased productivity, per-capita income, and increased competitive advantage of industrial forests.

The value chain in the peatland industrial area is one of the efforts for sustainable peatland management in determining the competitive advantage of companies/actors. Increase added value and efficiency of processing raw materials for greater production capacity through innovation in Information Technology (IT) and the Internet of Things (IoT), providing a balance between economic and social benefits for the community. The smart value chain in Peatlands composed of two processes, i.e: (1) sequential process upgrading into high quality (production-process-transportation-marketing); (2) efficient usage of by-products and waste materials. There are 6 (six) parts of the value chain from various raw materials to be processed into high-quality products (Fig. 20).

Key points:

1. Materials for a) consumer products in markets, b) land conservation (Biochar and Fiber mulching, organic farming), and c) Biomass Energy.
2. To increase local benefit, Bioenergy must process local materials.
3. IoT program should be introduced to high school and regional University, recommending 3D-CAD (computer-aided design) program learning: Design, Caving, 3D-printing & DDM (Direct Digital Manufacturing), and 3D-phoptogramatry.
4. Branding and Certification.

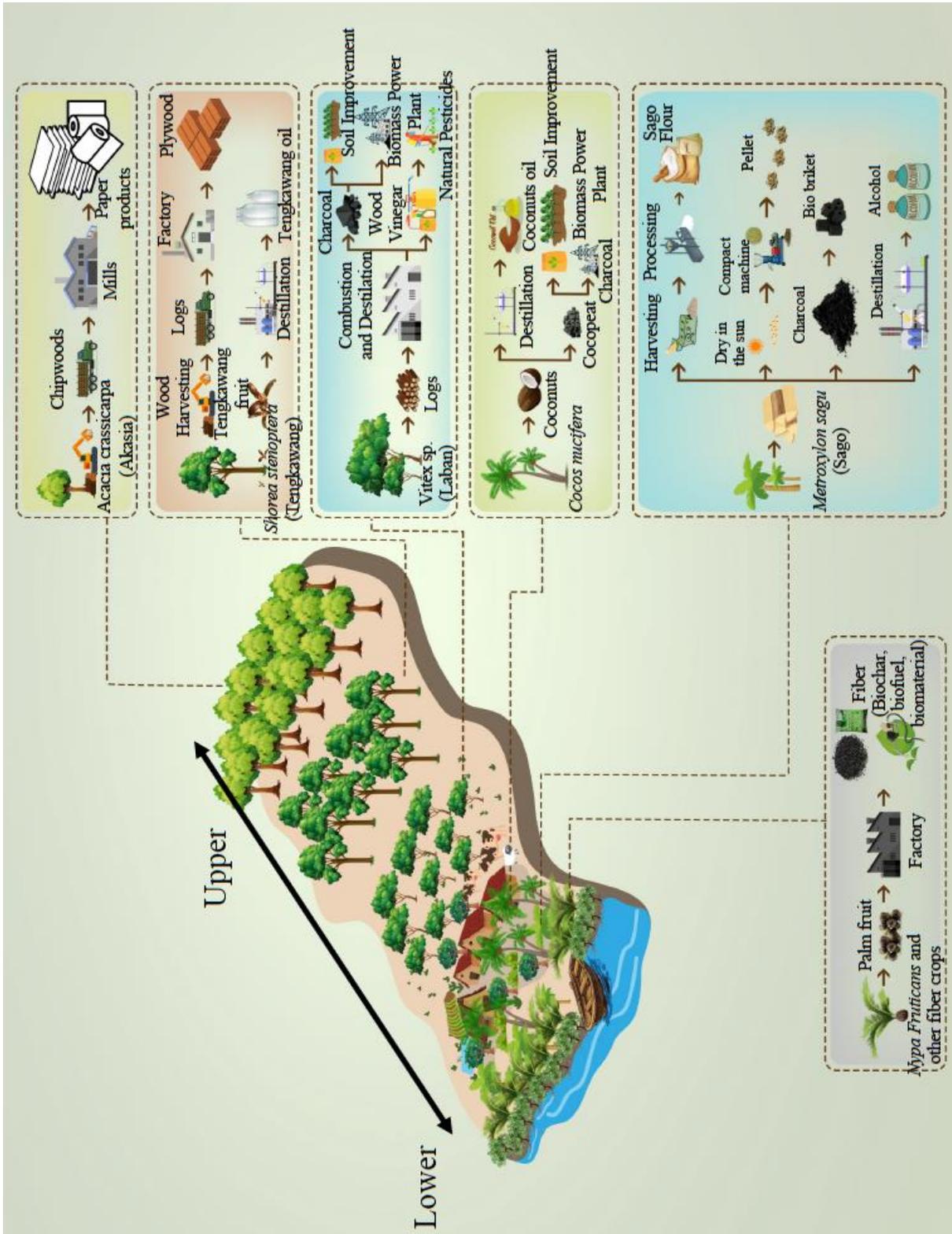


Fig. 20. Smart Value Chain Diagram of Products in Peatland

VII-1. Case Study of Rice Husk Charcoal

Most peatlands established by the government for rice production in Kalimantan have been abandoned because current low rice productivity. Unfortunately, it is problem because they become a source of CO₂ emissions. At present, migrants or farmers conduct illegal logging and agricultural slash and burn in or around the concession area. Meanwhile, WSL/MTI has developed peatland management techniques based on best practices in science and low-tech efficient methods for industrial tree plantations. WSL/MTI have been able to prevent peat fires during the long dry season in the planting areas by applying "simple, inexpensive and easy maintenance" technology to manage the degraded peatlands.

Rice husk charcoal: improve soil conditions and enhance microorganism activities to absorb nitrogen from the air.



Fig. 21. Local Economy Enhancement by Value Chain Mechanisms

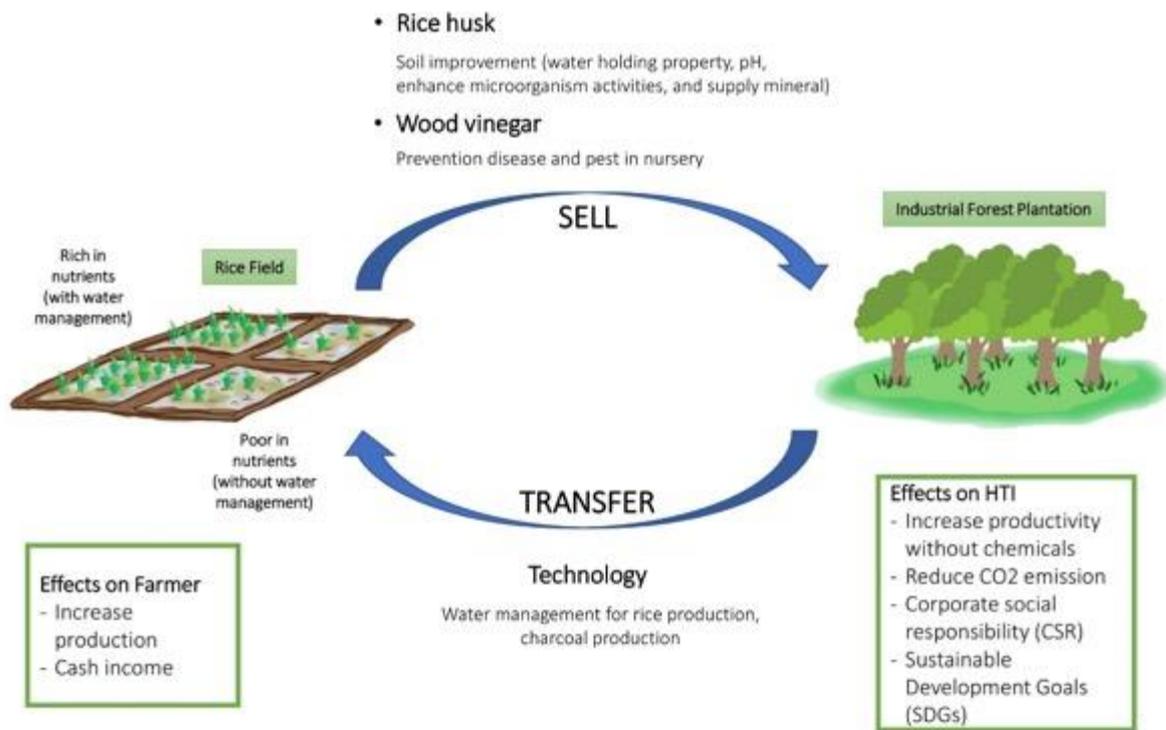


Fig. 22. Cyclic mechanisms on enhancement of Local Economy and Natural Capital by Value Chain Mechanisms

Based on WSL/MTI experience in managing peatlands, the water level management that has been adopted for rice fields can increase rice production even in an abandoned area. WSL/MTI can provide some technology for water management to expand the use of peatlands for farmers and also to prevent further destruction of peatland forests.

In addition, WSL/MTI will share and teach farmers how to make charcoal from rice husk. WSL/MTI has interest to supply rice husk charcoal to produce healthy acacia tree seeds for plantations.

This activity will benefit both parties because the company can easily get rice husk charcoal from the farmers while high rice productivity that is transformed into rice husk charcoal creates income for the farmers.

Key points:

1. Simple, low cost, and easy maintenance technology transfer to the farmers.
2. Prevent slash and burn practices.
3. Rice husk charcoal production to increase farmer's income.
4. Rice husk charcoal to produce healthy seedlings of acacia tree for plantations.

VII-2. IT and IoT innovation for Supply Chain

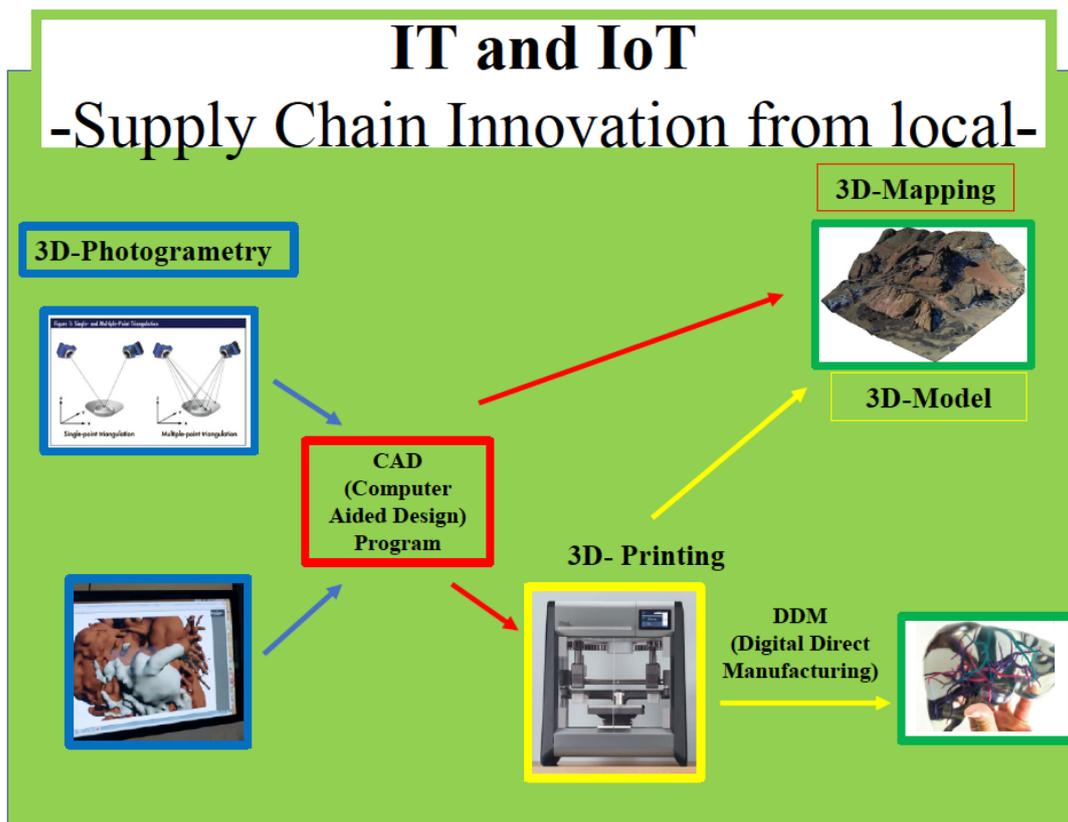


Fig. 23. Scheme of Local Supply Chain Innovation through IT and IoT (from Terayama M and Hasegawa H privately)

Since peatland is a dynamic ecosystem with high carbon content and water reservoir, it must be managed on a landscape scale and monitored regularly. One of the most important activities of peatland management is the mapping of peat dome because it reserves water for the lower area. Irresponsible management of peat dome can damage the ecosystem, making peatlands dry and flammable, which will release a lot of carbon into the air.

At present, most of the peat mapping is done using LiDAR technology. Unfortunately, large-scale mapping is very costly. However, peatland management must be carried out in a landscape, which makes the use of LiDAR in peat dome mapping ineffective. In this case, Information Technology (IT) and Internet of Things (IoT) can provide effective and efficient answer for peat dome areas mapping. The supply chain scheme, an IT and IoT innovation in peat dome mapping, is a technology that combines 3D-Photogrammetry, microsatellite, and 3D design programs. Because this system is applied to 3D-mapping, its use will be significantly cheaper than LiDAR technology to map peat domes.

VIII. Agrarian Reform in Peatland

Majority of peatland are state forest. Many of them have been conceded to companies through HTI, or HGU. (Once HGU is given on a designated location the status changes from state forest to state land). As exploitation of peat swamp forest by companies commenced, people come into the area and start working the land illegally. Local farmers from neighboring land with customary land rights expand their cultivation land into the peatland, especially to establish palm oil plantation.

Here we find issues regarding confusion of land title, overlapping, contestation, conflicts, and unsecure titles, with the companies' concession, customary laws, land cultivated illegally by immigrants, on the state forest/state land. These confusions become some of the reasons for the peatland degradations and fire.

The government intends to promote the agrarian reform to bring about justice and legal security in Indonesia. Recent regulations in the scheme of agrarian reform can extend the coverage to the peatland. Those regulations include Presidential Regulation (Peraturan Presiden) Number 88, Year 2017 concerning the Settlement of Land Control at the State Forest (Penyelesaian Penguasaan Tanah dalam Kawasan Hutan) ("**Perpres 88/2017**"), and Legislation of the Minister of the Environment and Forestry of the Republic of Indonesia No **P.17/MENLHK/SETJEN/KUM.1/5/2018** concerning the change of legal status from the State Forest and the Change of the Boundary between the State Forest to Become the Object of the Agrarian Reform.

The agrarian reforms on peatland are to be implemented gradually. It would cover the entire peatland, integrating the peatland restoration programs with the participatory mapping of land title on the peatland area. This agrarian reform on peatland will bring justice and secured land title as well as an integrated peatland restoration of all peatland in Indonesia.

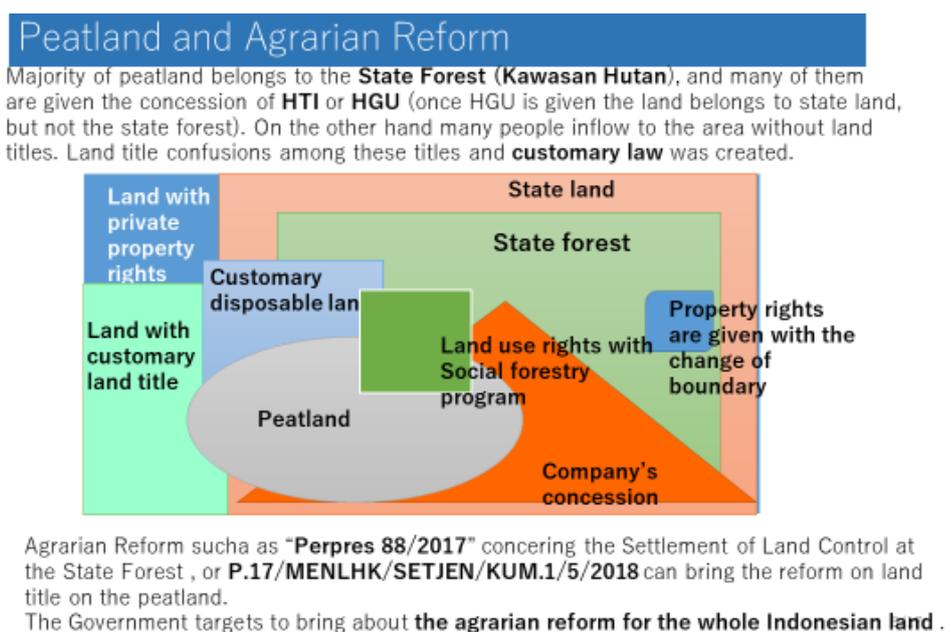


Fig. 24. Model for Agrarian Reform on Peatland

IX. Forest Functions as Natural Capital

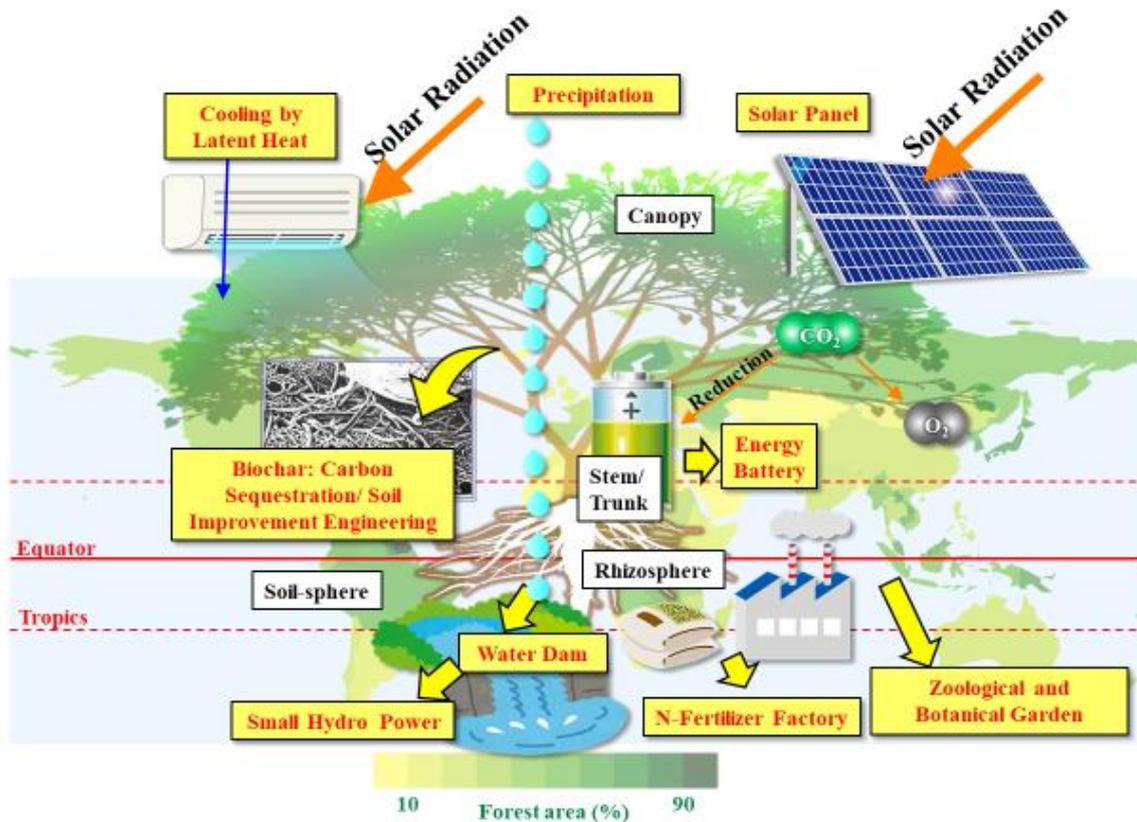


Fig. 25. Tree Functions as Natural Capital

Forest are simultaneously part of the biosphere, ecosystems of their own account, the source of material essentials to human survival, and finally, the origin of deep human symbols and meanings. In tropical zone, forest cover is still very high (63%) or 120.6 Mha (MoEF 2018) (Fig. 25), before forest biomass and biomass productivity which are also high. Forest and trees have multiple functions for ecosystem and environment, which contribute to carbon neutral and carbon negative. Indonesia's forest capital wealth is one of the most valuable in the world and yet the people living in and on the edges of forest are the poorest in Indonesia. According to Indonesia's share total wealth and natural capital composition in 2014, natural capital composition from forest and protected areas are 18%. Restoring forest natural capital leads to an improved economy and quality of life for all. Ecosystem goods and services in nature are closely interrelated and focus on the socio-economic benefits derived from ecosystem functions and services while maintaining their geographical dimensions.

Key Points:

1. Forest and trees have multiple functions defined as "Natural Capital". Forest and Trees "Natural Capital" is evaluated by alternative methods of industrial and civil engineering cost such as:

Leaf: Solar Panel

Leaf: Cooling Machine by Latent Heat

Stem/Trunk: Energy Battery

Stem/Trunk: Biochar

Rhizosphere: N₂ Fixing Factory

Soil sphere in forest: Water Dum and barrier against debris-slide and soil erosion

Water reservoir: Water Dum, small Hydro Power, and Water Cycle

Biodiversity: Zoological and Botanical Specimen Garden

2. In tropical zone, renewable energy should, therefore, focus on biomass energy and waterpower, not solar cell and window, because:

Window energy: unstable wind speed (very weak or very strong).

Solar Cell Energy: cloud (low efficiency), rainy (rotting, then waste disposition), rain (soil erosion and water runoff, no water stock causing soil dryness), and only one panel (more than 10 leaf panel because of more than 10 Leaf Area Index of tree).

X. Earth Resilience Goals (ERGs)

Resilience is the capacity to deal with change and continue to develop. Deal with disturbances like a financial crisis or climate change to spur renewal and innovative thinking. Resilience starts with humans and nature relationship as one social-ecological system. Resilience is strengthening the capacity to deal with the stresses caused by environmental change. It is about finding ways to deal with unexpected events and crises and identifying sustainable ways for humans to live within the Earth's boundaries.

Development is no longer only about the local perspective. Local development is linked to global change, and local events have global consequences: biodiversity loss, climate change, etc. Without forests, air, waterways and rich biodiversity, humanity will not survive, let alone thrive. Development must be good for the Earth's life support system, and help a growing population to weather future storms. Development actions should support people to thrive within changing circumstances.

Survival rate depends on the services provided by nature. Nature has provided numerous goods and services free of charge up to now. They also include biodiversity, a sufficient supply of food and a life-sustaining climate. In many cases we do not understand how nature produces these ecosystem services. However, we do know that our survival and well-being depend on these services.

IX-1. "Carbon Negative Society"

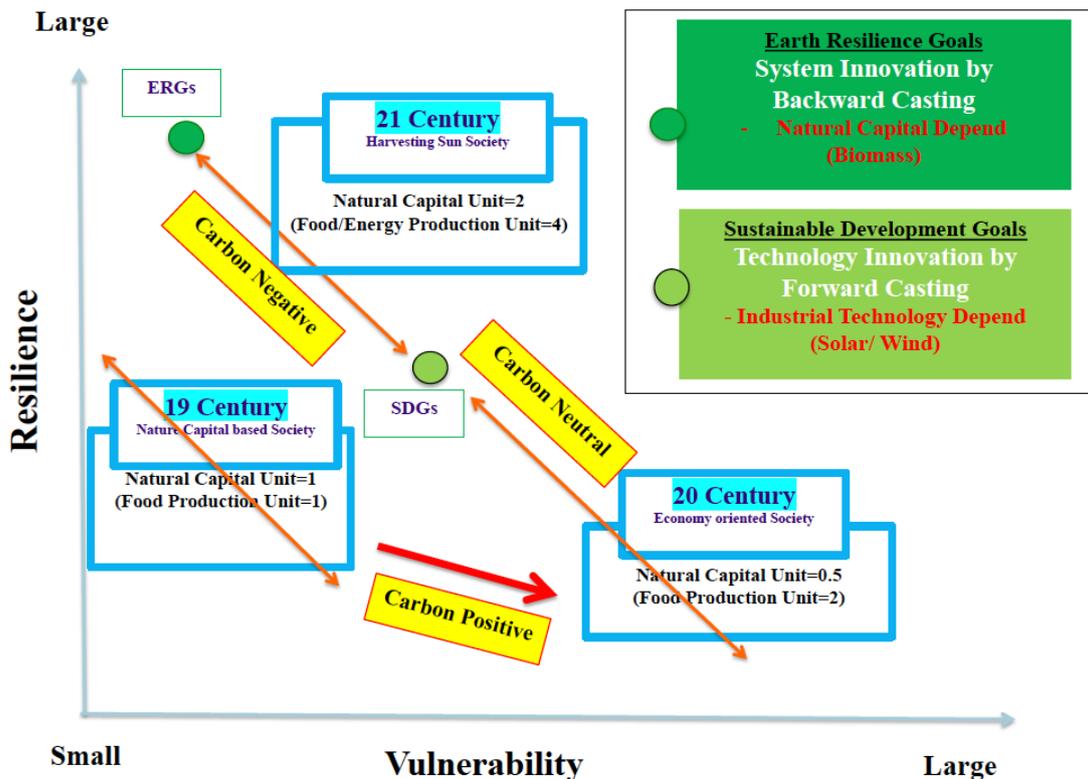


Fig. 26. Diagram of "Carbon Negative Society"

Based on Forest (representative indicator of natural capital=Resilience Element) and Arable Land (representative indicator of LULUCF= Vulnerability Element), 19, 20, and 21 Century are classified as relationship (balance) between Resilience Element and Vulnerability Element (Fig.26).

Key Points:

1. From the 19th Century to the 20th Century, the society was transformed into a Carbon Positive (carbon emission) Society, targeting increasing food and feed productions.
2. From the 20th Century to early 21st Century, the society was transformed into a Carbon Neutral (carbon cycling) Society, targeting SDGs (Sustainable Development Goals) by REDD+ and Natural Capital Conservation.
3. From early the 21st Century to late 21st Century, the society should be transformed into a Carbon Negative (carbon sequestration) Society, targeting ERGs (Earth Resilience Goals) by mainly Biochar (carbon sequestration) Biomass Energy, Cooling and Wetting (potent heat) by Solar-Porous material, Nutrients Cycling by Solar-Sea Water Evaporation.

IX-2. "Harvesting Sun Society"

The Social System Innovation is urgently required as the base of SDGs. In the past, the society mainly depended on the **harvested sun energy** (fossil fuels such as oil, coal, and natural gases) and harvested sun-energy materials (high carbon reservoirs ecosystem and peatland/costal ecosystem/permafrost), together referred to as the "**Harvested Sun Society**" (Fig. 26). In the future, we desire that the society depend mainly on "**harvesting sun energy**" (renewable energy sources such as wind, water, solar power, and biomass and **natural capital** such as water cycle by solar energy), together referred to as the "**Harvesting Sun Society**" (Fig. 27).

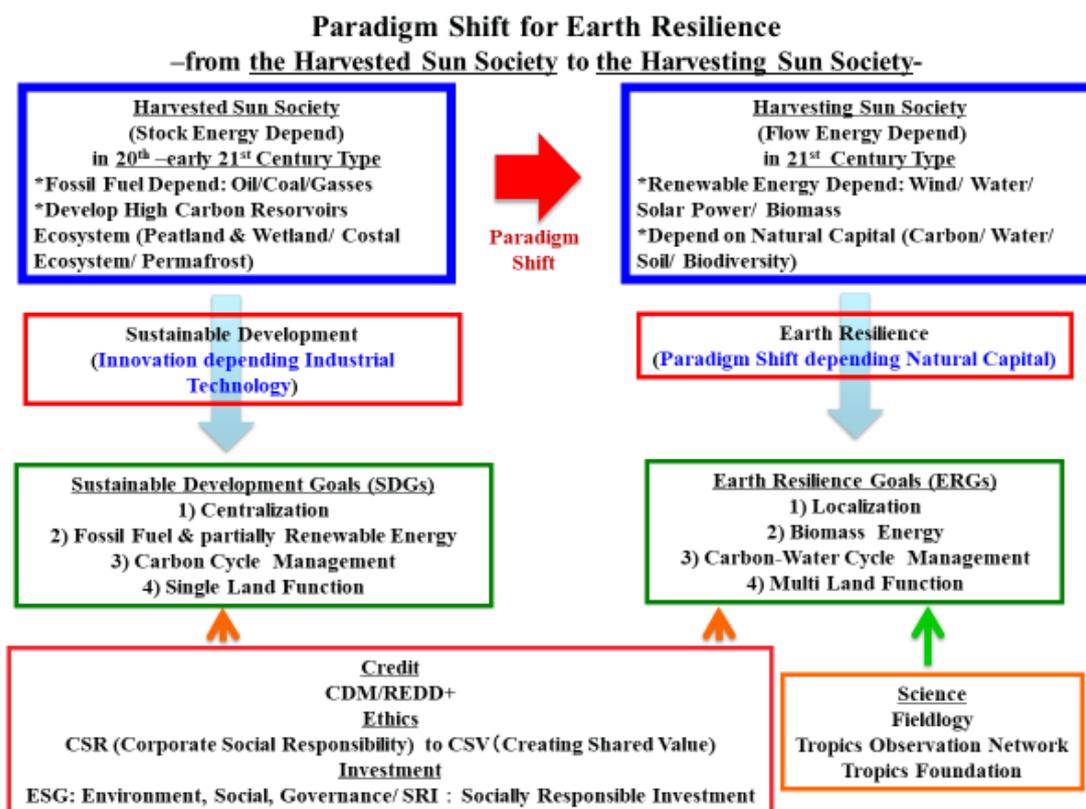


Fig. 27. Diagram of "Harvesting Sun Society"

Therefore, it is proposed that a national concept be established about how the **“Harvested Sun Society”** should transform into the **“Harvesting Sun Society.”** In the **“Harvested Sun Society,”** climate change strategy mainly includes mitigation (conservation) to climate change, supported by credits such as clean development mechanism, reducing emissions from deforestation and forest degradation (REDD+), and Ethics Investment, such as corporate social responsibility, in creating shared value such as social and economic values. In addition, in the **“Harvesting Sun Society,”** climate change strategy mainly includes adaptation (innovation) to climate change, supported by investment systems such as environment, social, governance (ESG), socially responsible investment (SRI), and green bond (carbon bond and water bond). **“Harvesting Sun Society”** in humid tropical regions should focus on Biomass Production and Usage because of the abundance of solar energy (photosynthesis) and through water cycle powered by the solar energy (one of the key elements of biosphere and human).

Reference

Dargie GC, Lewis SL, Lawson IT, Mitchard ETA, Page SE, Bocko YE, Ifo SA. 2017. Age, extent and carbon storage of the central Congo Basin peatland complex. *Nature* 542(7639):86–90.

[FAO] Food and Agriculture Organization of the United Nations. 2016a. FAOSTAT. Accessed 15 May 2016. <http://faostat3.fao.org/download/Q/QC/E>

Government Regulation. 2016. Government Regulation Number 71 in 2014 and revised in 57 in 2017 for the Peat Ecosystem Protection and Management.

Gumbrecht T, Roman-Cuesta RM, Verchot L, et al. 2017. An expert system model for mapping tropical wetlands and peatlands reveals South America as the largest contributor. *Glob Change Biol.* 23:3581–3599.

Hirano T, Segah H, Kusin K, Limin S, Takahashi H and Osaki M. 2013. Effects of disturbances on the carbon balance of tropical peat swamp forests. *Global Change Biology* 18: 3410-3422.

Hirose K, Osaki M, Takeda T, Kashimura O, Ohki T, Segah H, Gao Y, and Evri M. 2016. Contribution of Hyperspectral Applications to Tropical Peatland Ecosystem Monitoring. In "Tropical Peatland Ecosystems", Eds. by Osaki M and Tsuji N, Springer Japan, Springer Tokyo, Heidelberg, New York, Dordrecht and London.

Honma T, Kaku K, Usup A and Hidayat A. 2016. Detection and Prediction System of Peat-Forest Fires in Central Kalimantan. In "Tropical Peatland Ecosystems", Eds. by Mitsuru Osaki and Nobuyuki Tsuji, Springer Japan, Springer Tokyo, Heidelberg, New York, Dordrecht and London (ISBN 978-4-431-55680-0, ISBN 978-4-431-55681-7 (eBook), DOI 10.1007/978-4-431-55681-7), p397-406

Ito A and Oikawa T. 2002. A simulation model of the carbon cycle in land ecosystems (Sim-CYCLE): A description based on dry-matter production theory and plot-scale validation, *Ecological Modelling*, 151, 147–179.

Miles L, Ravilious C, García-Rangel S, Lamo X. d, Dargie G, and Lewis S. 2017. Carbon, biodiversity and land-use in the Central Congo Basin Peatlands, Cambridge, UK: United Nations Environment Programme.

Ministry of Environment and Forestry. 2017. Ministerial Regulation Number P.14/2017 includes the Peat Ecosystem Protection and the Peat Ecosystem Cultivation Function.

Ministry of Environment and Forestry. 2018. Managing Peatlands to Cope with Climate Change: Indonesia's Experience. Jakarta.

Ministry of Environment and Forestry. 2018. The State of Indonesia's Forest. Jakarta.

Osaki M, Hirose K, Segah H, and Helmy F. 2016. Tropical Peatland Ecosystem: Chapter 9 Tropical Peat and Peatland Definition in Indonesia. Springer Japan, Tokyo, 137-147.

Osaki M and Tsuji N (eds). 2016. Tropical Peatland Ecosystem. Springer Japan, Tokyo, 3-29.

Page SE, Rieley JO, Banks CJ. 2011. Global and regional importance of the tropical peatland carbon pool. *Glob Chang Biol* 17:798-818.

Rieley JO, Page SE (eds). 2005. Wise use tropical peatlands – focus on Southeast Asia. Alterra, Wageningen.

Presidential Regulation. 2013. Presidential Regulation Number 62 in 2013 Concerning on Agency for Reduction of Green House Gas Emissions from Deforestation, Forest Degradation and Peatland.

Reiche J, Hamunyela E, Verbesselt J, Hoekman D, Herold M. 2018. Improving near-real time deforestation monitoring in tropical dry forests by combining dense Sentinel-1 time series with Landsat and ALOS-2 PALSAR-2. *Remote Sens. Environ* 204:147-161.

Wahyunto and Dariah A. 2014. Indonesian Degraded Peatland: Existing Condition, Its Characteristics and Standardized Definition to Support One Map Policy Movement. *Indonesian Journal of Land Resources*, 8, 2, p81-93.

Wahyunto KN, Ritung S, and Sulaeman Y. 2014. Indonesian peatland map: method, certainty and uses. *Proceeding Lokakarya Kajian dan Sebaran Gambut di Indonesia*, 81-96.

Yusup AA, Kato T, Suhandi B, Suparna N, Brady MA. 2016. Water Management Approaches in Peatlands Based on Comprehensive Field Surveys and Analysis in West Kalimantan. *International PEAT Congress Proceeding 5.1: A-368*.