Enhancing Tropical Forest Resilience and Production through Tree Breeding Technology

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Dr. TANI Naoki is currently a Senior Researcher in the Forestry Division of the Japan International Research Center for Agricultural Sciences (JIRCAS). He also holds a professor position at the University of Tsukuba and serves as Pproject Leader of a SATREPS project on tropical forest resilience. His area of study includes forest genetics and molecular ecology in tropical forests, and he has extensive experience in international collaborations with research institutes in Malaysia, Indonesia, and Thailand. He received his Ph.D. in Agricultural Sciences from the University of Tsukuba in 1998. He joined JIRCAS in 2008 after 10 years' service at the Forestry and Forest Products Research Institute and 1 year as a visiting scientist at the Institut National de la Recherche Agronomique (INRA).

ABSTRACT

Tropical forests play a pivotal role in mitigating climate change, conserving biodiversity, and supporting local livelihoods. However, these invaluable ecosystems are increasingly vulnerable to the impacts of climate change, including extreme weather events and shifting environmental conditions. To address these challenges, our research focuses on improving the resilience of tropical forest tree species utilized for timber production.

In this symposium, I would like to discuss our innovative approach that utilizes tropical forest genetic resources, physiological trait evaluation, and genomic selection technology to identify and propagate individuals with enhanced resilience to climate change and economic values. Traits encompass various factors, including drought tolerance, growth rate, timber quality, and adaptability to climate change.

Genomic selection represents a revolutionary contribution to tree breeding. Conventional tree breeding methods necessitate lengthy evaluation periods, waiting for the growth of progenies to assess their phenotype for focal traits. In contrast, genomic selection allows us to evaluate the phenotype of seedlings in the early stages of the progeny, significantly accelerating the breeding cycle. This speedier approach not only increases the efficiency of breeding programs but also reduces resource requirements and expedites the development of resilient tree populations in tropical forests.

Ultimately, this research contributes to the broader discussion on tropical forest conservation, climate change mitigation, and sustainable resource management. By combining conventional tree breeding techniques with genomic technology, we strive to enhance the resilience of tropical forest species, contributing to global ecological stability and livelihood improvement.

[1] Sawitri, Tani et al. (2020) Potential of genome-wide association studies and genomic selection to improve productivity and quality of commercial timber species in tropical rainforest, a case study of *Shorea platyclados*. Forests, **11 (2)**, 239.

[2] Akutsu, Tani et al (2023). Comparing modeling methods of genomic prediction for growth traits of a tropical timber species, *Shorea macrophylla*. Frontiers in Plant Science, *in press*


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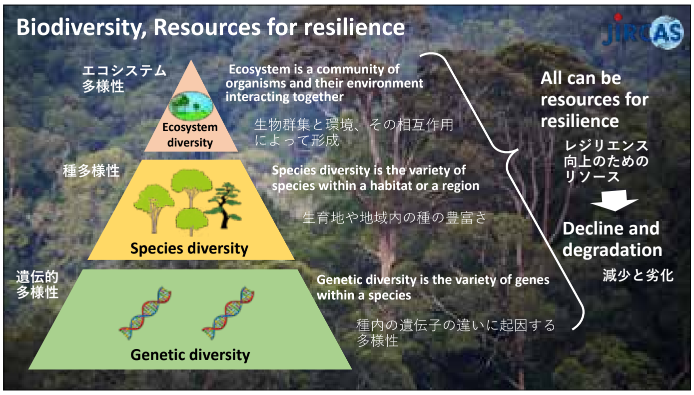
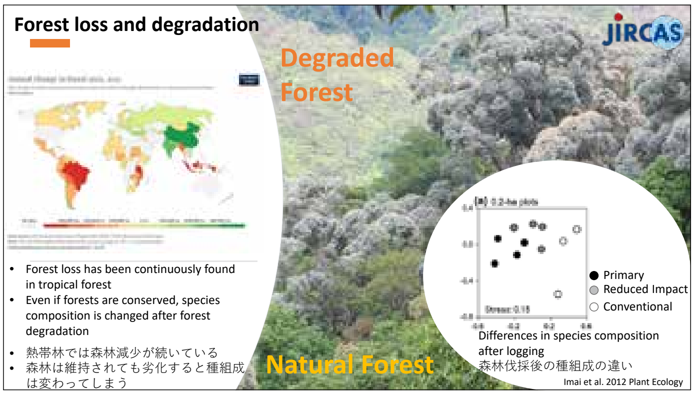
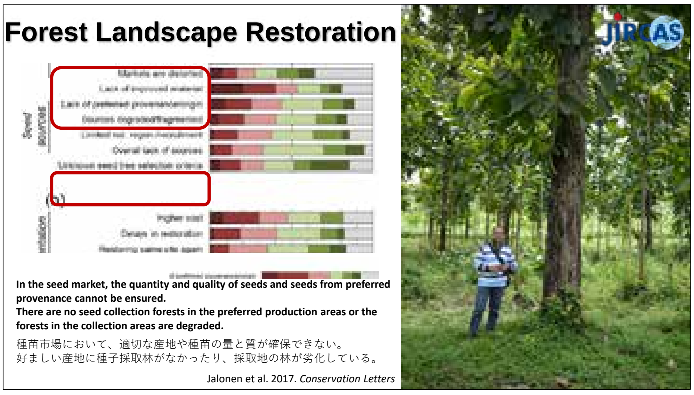
育種技術による熱帯林の強靭化と生産の向上
JIRCAS International Symposium 2023
Innovations to enhance the resilience of tropical forests and sustainability of the forest industry
JIRCAS
Naoki TANI
Japan International Research Center for Agricultural Sciences


Biodiversity, Resources for resilience
JIRCAS
エコシステム多様性
Ecosystem diversity
Ecosystem is a community of organisms and their environment interacting together
生物群集と環境、その相互作用によって形成
種多様性
Species diversity
Species diversity is the variety of species within a habitat or a region
生育地や地域内の種の豊富さ
遺伝的多様性
Genetic diversity
Genetic diversity is the variety of genes within a species
種内の遺伝子の違いに起因する多様性
All can be resources for resilience
レジリエンス向上のためのリソース
Decline and degradation
減少と劣化


Forest loss and degradation
JIRCAS
Degraded Forest
Natural Forest
Forest loss has been continuously found in tropical forest
Even if forests are conserved, species composition is changed after forest degradation
熱帯林では森林減少が続いている
森林は維持されても劣化すると種組成は変わってしまう
(a) 0.2-ha plots
Primary
Reduced Impact
Conventional
Differences in species composition after logging
森林伐採後の種組成の違い
Imai et al. 2012 Plant Ecology


Forest Landscape Restoration
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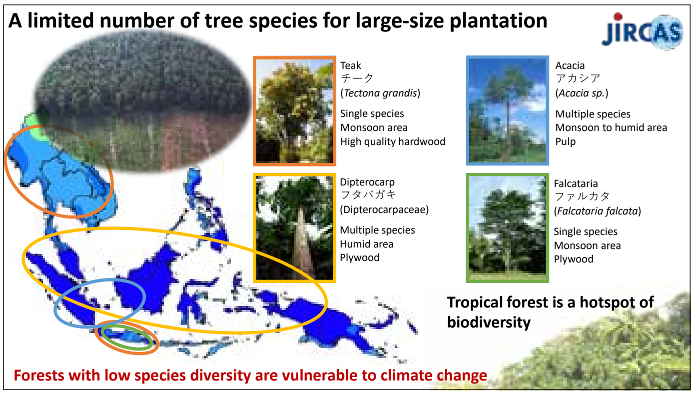
In the seed market, the quantity and quality of seeds and seeds from preferred provenance cannot be ensured.
There are no seed collection forests in the preferred production areas or the forests in the collection areas are degraded.
種苗市場において、適切な産地や種苗の量と質が確保できない。
好ましい産地に種子採取林がなかったり、採取地の林が劣化している。
Jalonen et al. 2017. Conservation Letters


A limited number of tree species for large-size plantation
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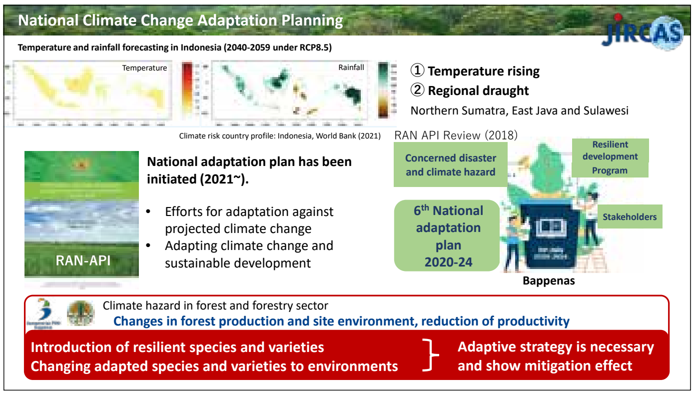
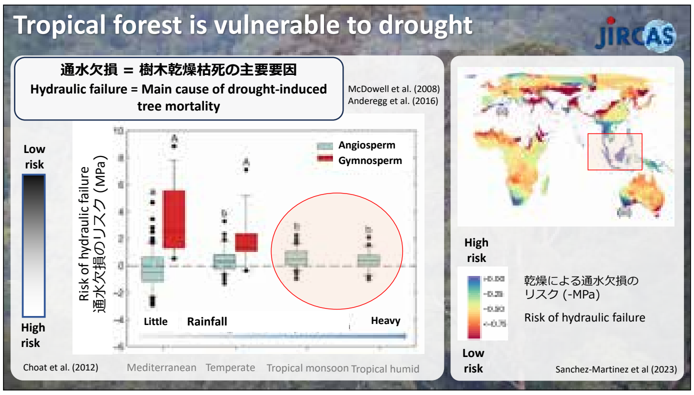
Teak
チーク
(Tectona grandis)
Single species
Monsoon area
High quality hardwood
Acacia
アカシア
(Acacia sp.)
Multiple species
Monsoon to humid area
Pulp
Dipterocarp
フタバガキ
(Dipterocarpaceae)
Multiple species
Humid area
Plywood
Falcataria
ファルカタ
(Falcataria falcata)
Single species
Monsoon area
Plywood
Tropical forest is a hotspot of biodiversity
Forests with low species diversity are vulnerable to climate change


National Climate Change Adaptation Planning
JIRCAS
Temperature and rainfall forecasting in Indonesia (2040-2059 under RCP8.5)
Temperature
Rainfall
Climate risk country profile: Indonesia, World Bank (2021)
① Temperature rising
② Regional draught
Northern Sumatra, East Java and Sulawesi
RAN API Review (2018)
National adaptation plan has been initiated (2021~).
Efforts for adaptation against projected climate change
Adapting climate change and sustainable development
RAN-API
Concerned disaster and climate hazard
Resilient development Program
6th National adaptation plan 2020-24
Stakeholders
Bappenas
Climate hazard in forest and forestry sector
Changes in forest production and site environment, reduction of productivity
Introduction of resilient species and varieties
Changing adapted species and varieties to environments
Adaptive strategy is necessary and show mitigation effect


Tropical forest is vulnerable to drought
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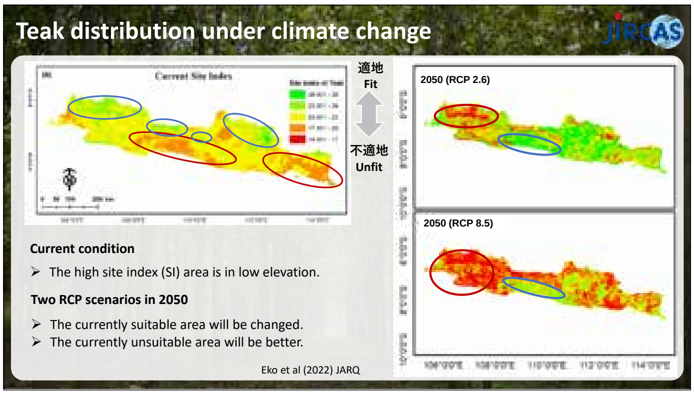
通水欠損 ＝ 樹木乾燥枯死の主要要因
Hydraulic failure = Main cause of drought-induced tree mortality
McDowell et al. (2008)
Anderegg et al. (2016)
Low risk
High risk
Risk of hydraulic failure
通水欠損のリスク (MPa)
Angiosperm
Gymnosperm
Little
Rainfall
Heavy
Choat et al. (2012)
Mediterranean
Temperate
Tropical monsoon
Tropical humid
High risk
Low risk
乾燥による通水欠損の
リスク (-MPa)
Risk of hydraulic failure
Sanchez-Martinez et al (2023)


Teak distribution under climate change
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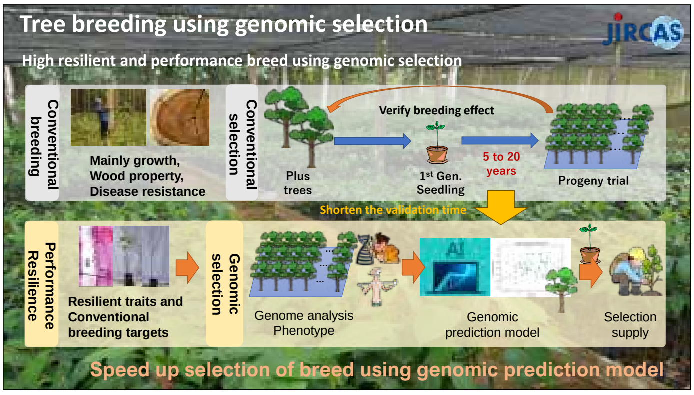
Current Site Index
適地
Fit
不適地
Unfit
2050 (RCP 2.6)
2050 (RCP 8.5)
Current condition
➢ The high site index (SI) area is in low elevation.
Two RCP scenarios in 2050
➢ The currently suitable area will be changed.
➢ The currently unsuitable area will be better.
Eko et al (2022) JARQ


Tree breeding using genomic selection
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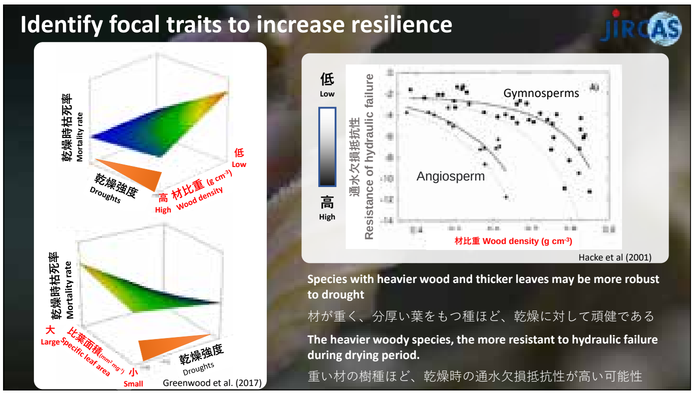
High resilient and performance breed using genomic selection
Conventional breeding
Mainly growth, Wood property, Disease resistance
Conventional selection
Verify breeding effect
Plus trees
1st Gen. Seedling
5 to 20 years
Progeny trial
Shorten the validation time
Performance Resilience
Resilient traits and Conventional breeding targets
Genomic selection
Genome analysis
Phenotype
AI
Genomic prediction model
Selection supply
Speed up selection of breed using genomic prediction model


Identify focal traits to increase resilience
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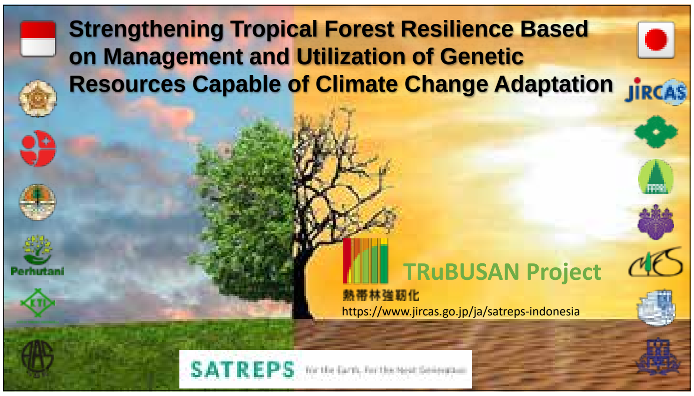
乾燥時枯死率
Mortality rate
乾燥強度
Droughts
高 材比重 (g cm-3)
High Wood density
低
Low
大 比葉面積
Large Specific leaf area
小
Small
Greenwood et al. (2017)
低
Low
高
High
通水欠損抵抗性
Resistance of hydraulic failure
Gymnosperms
Angiosperm
材比重 Wood density (g cm-3)
Hacke et al (2001)
Species with heavier wood and thicker leaves may be more robust to drought
材が重く、分厚い葉をもつ種ほど、乾燥に対して頑健である
The heavier woody species, the more resistant to hydraulic failure during drying period.
重い材の樹種ほど、乾燥時の通水欠損抵抗性が高い可能性


Strengthening Tropical Forest Resilience Based on Management and Utilization of Genetic Resources Capable of Climate Change Adaptation
JIRCAS
Perhutani
TRuBUSAN Project
熱帯林強靱化
https://www.jircas.go.jp/ja/satreps-indonesia
SATREPS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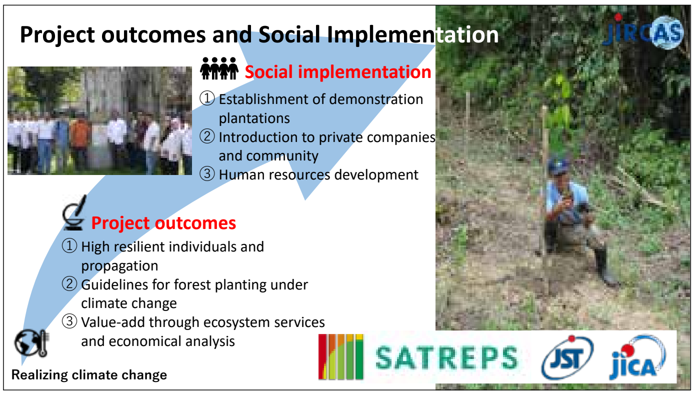
Sampling activities at training population
Perhutani


Project outcomes and Social Implementation
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Social implementation
① Establishment of demonstration plantations
② Introduction to private companies and community
③ Human resources development
Project outcomes
① High resilient individuals and propagation
② Guidelines for forest planting under climate change
③ Value-add through ecosystem services and economical analysis
Realizing climate change
SATREPS
JST
jica