Summary

Forest Research Centre (FRC)

Research Programmes & Activities

2020-2025

Sabah Forestry Department

Contents

Compiled by Arthur Y.C. Chung (**updated – 9 March 2023**)
Cover designed by Alviana Damit

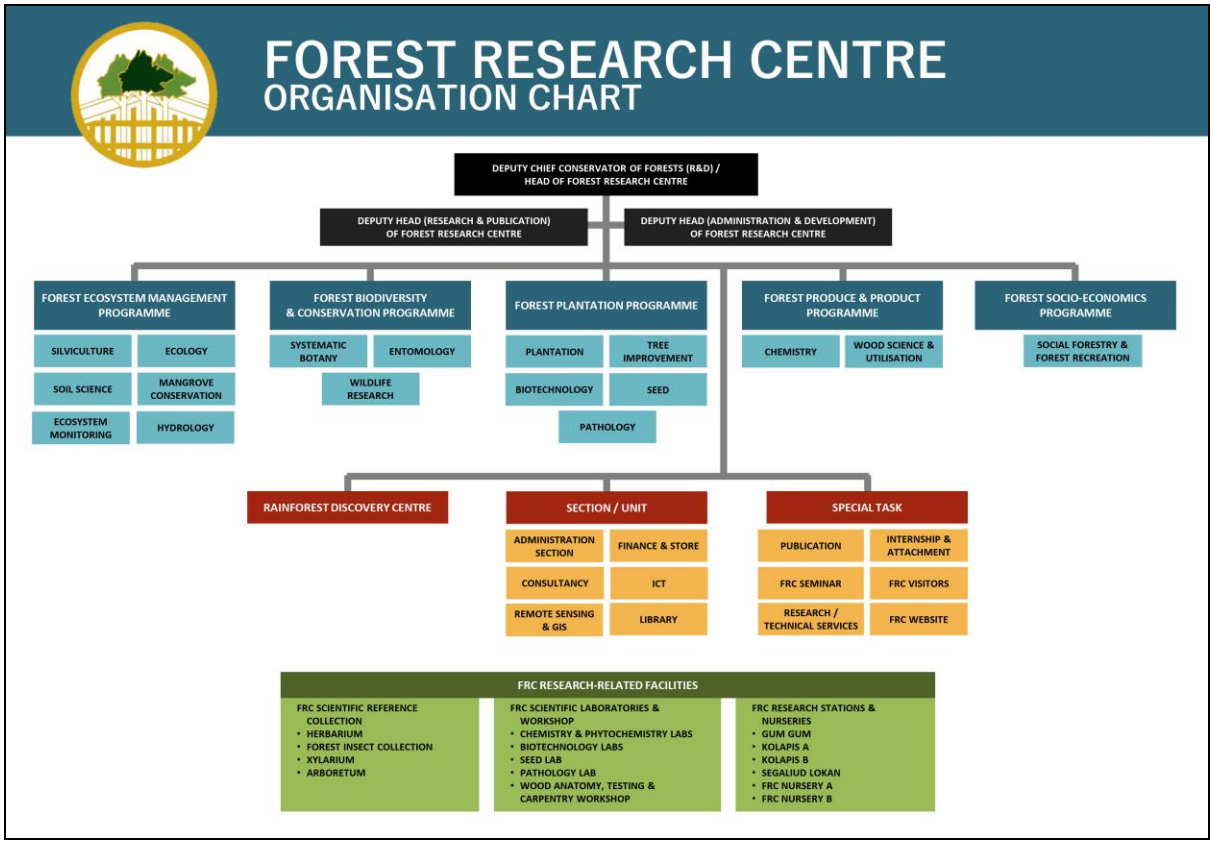
Forest Research Centre (FRC),
Sabah Forestry Department

Vision

To be a centre of excellence in forestry research providing the best service to its clients

Mission

To generate knowledge and technology to support the conservation, management, development and sustainable utilisation of the forest resources of Sabah through scientific research


FOREST RESEARCH CENTRE
ORGANISATION CHART
DEPUTY CHIEF CONSERVATOR OF FORESTS (R&D) / HEAD OF FOREST RESEARCH CENTRE
DEPUTY HEAD (RESEARCH & PUBLICATION) OF FOREST RESEARCH CENTRE
DEPUTY HEAD (ADMINISTRATION & DEVELOPMENT) OF FOREST RESEARCH CENTRE
FOREST ECOSYSTEM MANAGEMENT PROGRAMME
SILVICULTURE
ECOLOGY
SOIL SCIENCE
MANGROVE CONSERVATION
ECOSYSTEM MONITORING
HYDROLOGY
FOREST BIODIVERSITY & CONSERVATION PROGRAMME
SYSTEMATIC BOTANY
ENTOMOLOGY
WILDLIFE RESEARCH
FOREST PLANTATION PROGRAMME
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TREE IMPROVEMENT
BIOTECHNOLOGY
SEED
PATHOLOGY
FOREST PRODUCE & PRODUCT PROGRAMME
CHEMISTRY
WOOD SCIENCE & UTILISATION
FOREST SOCIO-ECONOMICS PROGRAMME
SOCIAL FORESTRY & FOREST RECREATION
RAINFOREST DISCOVERY CENTRE
SECTION / UNIT
ADMINISTRATION SECTION
FINANCE & STORE
CONSULTANCY
ICT
REMOTE SENSING & GIS
LIBRARY
SPECIAL TASK
PUBLICATION
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FRC SCIENTIFIC REFERENCE COLLECTION
HERBARIUM
FOREST INSECT COLLECTION
XYLARIUM
ARBORETUM
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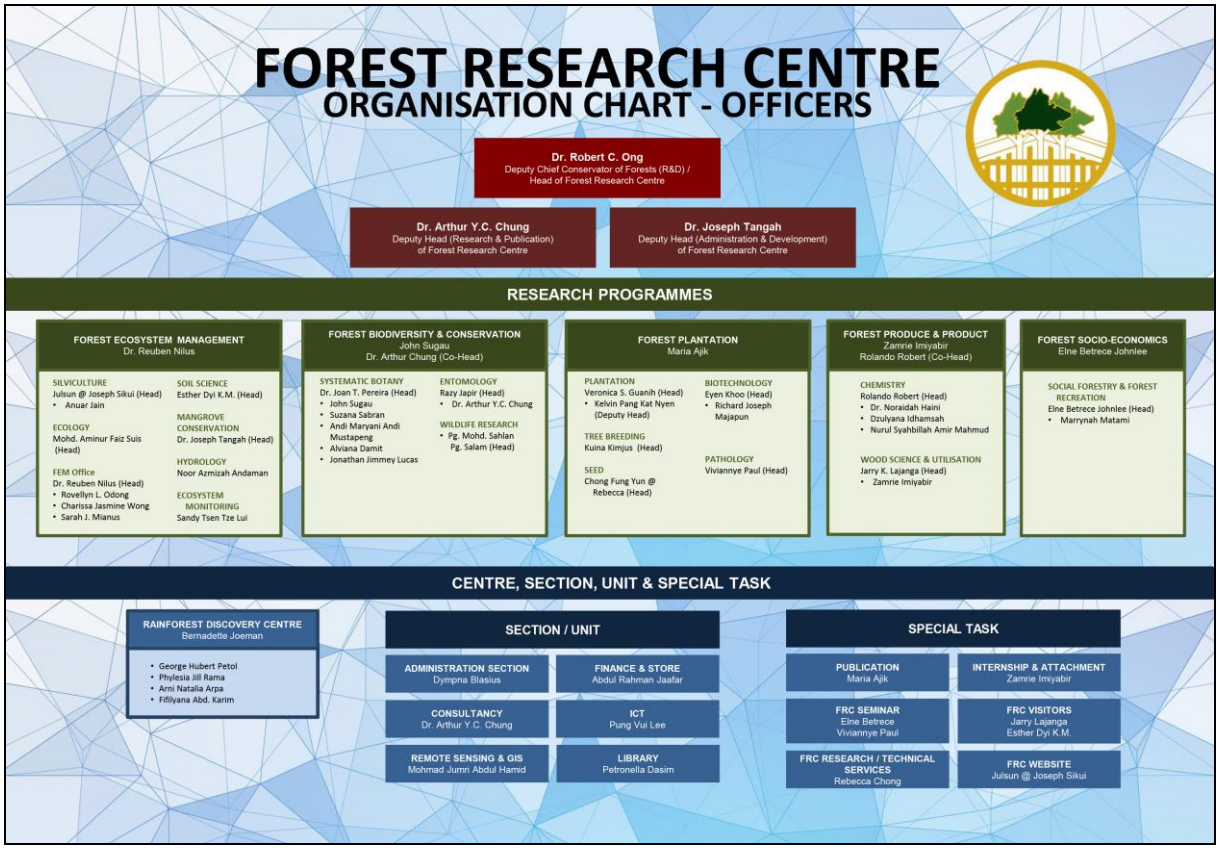
CHEMISTRY & PHYTOCHEMISTRY LABS
BIOTECHNOLOGY LABS
SEED LAB
PATHOLOGY LAB
WOOD ANATOMY, TESTING & CARPENTRY WORKSHOP
FRC RESEARCH STATIONS & NURSERIES
GUM GUM
KOLAPIS A
KOLAPIS B
SEGALIUD LOKAN
FRC NURSERY A
FRC NURSERY B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Deputy Head (Research & Publication) of Forest Research Centre
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SOCIAL FORESTRY & FOREST RECREATION
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FRC Research Programmes 2020

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Deputy Head (Research & Publication): Dr Arthur Y.C. Chung
Deputy Head (Administration & Development): Dr Joseph Tangah

No.	Programme	Head	Sub-Programme	Subject / Topic
1	Forest Ecosystem Management	Dr Reuben Nilus	• Terrestrial Ecosystems • Tidal Ecosystems • Physical Environment • Ecosystem services • Conservation Monitoring Systems	Multiple landuse management, forest ecosystem services, mangrove conservation & forest ecosystem health
2	Forest Biodiversity & Conservation	John Baptist Sugau Co-Head: Dr Arthur Chung	• Plant & Fungal Diversity • Wildlife Diversity	Plant diversity, including fungi and plant population genetics. Sabah Red List. Wildlife diversity – mammals, reptiles, amphibians, birds, fish & insects
3	Forest Plantations	Maria Ajik	• Plantations • Tree Breeding	Plantation silviculture, tree breeding, seed procurement, non-timber plantation, agroforestry, insect pests & diseases, Improvement of plantation species (biotech), nutritional studies
4	Forest Produce and Products	Zamrie Imiyabir Co-Head: Rolando Robert	• Science & Utilisation of Wood and Woody Biomass • Viability of Forest-based Industries • R&D of Non-Timber Forest Products • Method Development	Wood & non-wood science & utilisation, herbal & medicinal plants, carbon & climate change (under collaborative projects)
5	Forest Socio-economics	Elne Betrece Johnlee	• Forest Socio-Economics • Nature Tourism	Forest socio-economics, nature tourism, forest recreation, urban forestry

*Research projects /studies are grouped according the research programme. This does not include collaborative research with outside researchers.

1. FOREST ECOSYSTEM MANAGEMENT

SUB-PROGRAMME 1.1 - TERRESTRIAL ECOSYSTEMS

Rationale:
The Rain Forests of Borneo are some of the oldest and most biologically diverse forests on this planet. Sabah's terrestrial landscape comprised diverse forest ecosystems, from the highlands to the coast, driven by distinct underlying edaphic conditions, with unique community assemblages. However, over the past century, these forests have been pressured by logging and converted for agricultural use, mining, and urbanization, leaving fragmented patches of forests in varying degrees of degradation. Changes to the floristic assemblages of such perturbed forest systems have been poorly documented and pose potential challenges to effectively managing these forests. Observing and tracking (monitoring) the dynamics of these forests could help identify appropriate management options across a range of Sabah's Forest ecosystems. Whilst long-term monitoring of these forests would also facilitate periodic assessments of the conservation status of our forests, which is an essential basis for developing strategic forest conservation policies for the state.

Objectives:
1. To document the forest structure and its floristic assemblages across terrestrial forest ecosystems.
2. To monitor floristic turnover, forest growth and biomass change across terrestrial forest ecosystems.
3. To assess the conservation status of terrestrial forest ecosystems periodically in Sabah.

A. Ecological Integrity Component

Project 1.1.1: Assessment of diverse terrestrial forest ecosystems

Study 1.1.1.1 Document various terrestrial forest ecosystems in Sabah (PI: Mohd Aminur Faiz bin Suis & Reuben Nilus)
Notes Compilation of findings throughout various forest ecosystems assessment.
Output: Documentations on the floristics of various forest ecosystem.
Timeline 2020-2024

Funding
- State Funding
- Federal Funding – Partially RMK 12 (Heart of Borneo)

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.1.2: Monitoring of various forest ecosystems changes in floristic composition and structure

Study 1.1.2.1 Forest ecosystems health and climate change (PI: Mohd Aminur Faiz bin Suis & Dr Reuben Nilus)
Notes Monitoring trends and changes in forest composition assemblages, forest dynamics**,** above-ground biomass and carbon pool.

Output Periodic reports on trends in forest health turnover to key stakeholders.
Timeline Long-term (25 years)

Funding

- State Funding
- Federal Funding – Partially RMK 12
- International Funding-Aberdeen University, Bristol University, and Cambridge University

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.1.3: Inventory of forest cover and land use

(PI: Dr Robert Ong, Mohd Aminur Faiz bin Suis, Dr Reuben Nilus, Julsun Sikui, Charissa J Wong & Sarah J Mianus)

Study 1.1.3.1 Rapid assessment of forest cover and land use
Notes Assessment of gazette inventory points of 10.2 km grid for statewide and 5.1 km for landscape, using satellite imagery.
Output Periodic reports on trends in forest cover and other land use to key stakeholders.
Timeline Long-term (50 years)

Study 1.1.3.2 Pilot project: Tabin Landscape inventory
Notes Assessment and permanent establishment of gazette inventory points of 10.2 km grid for statewide and 5.1 km grid for landscape, using remote sense and ground survey data.
Output Periodic reports on trends in forest cover and other land use to key stakeholders.
Timeline Long-term (50 years)

Study 1.1.3.3 Pilot project: Ulu Kalumpang-Wullersdorf wildlife corridor vegetation cover
Notes Monitoring of vegetation cover using remote sense and ground survey data.
Output Periodic reports on trends in vegetation cover to key stakeholders.
Timeline 10 years

Funding

- State Funding
- RMK 12 Funding
- World Wildlife Fund for Nature

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

B. **Assessment of forest ecosystem conservation status (Forest ecosystem red list)**

Project 1.1.4: Forest Ecosystem red list

(PI: Sandy Tsen, Dr Reuben Nilus, Charissa J Wong & Sarah J Mianus)

Study 1.1.4.1 The natural vegetation of Sabah
Notes Update current vegetation cover of Sabah.
Output Periodic reports on trends in vegetation cover to key stakeholders.
Timeline Long-term (50 years)

Study 1.1.4.2 The pristine vegetation of Sabah
Notes Monitoring of pristine vegetation cover using remote sense and ground survey data.
Output Periodic reports on the pristine forest ecosystem in Sabah.
Timeline Long-term (50 years)

Study 1.1.4.3 The conservation status forest ecosystems of Sabah
Notes Monitoring of vegetation cover using remote sense and ground survey data.
Output Reports on the conservation status of the terrestrial forest ecosystem in Sabah.
Timeline 5 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:

This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

C. **Ecosystem management**

Project 1.1.5 Management of timber resources

(PI: Julsun Sikui, Dr Reuben Nilus & Charissa J Wong)

Study 1.1.5.1 Natural forest management
Notes Resource assessment for advanced growth and secondary growth forests.
Output Periodic reports on the resource assessment in natural forest management in Sabah.
Timeline 5 years

Study 1.1.5.2 Industrial tree plantation
Notes Resource assessment for industrial tree plantation.
Output Periodic reports on the resource assessment in natural forest management in Sabah.
Timeline 5 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 2) & Thrust 3 (Objective 1 & 2); 18th Malaysian Forestry Conference Resolutions 2.3, 3.4 & 5.2.

SUB-PROGRAMME 1.2 – TIDAL ECOSYSTEMS

Rationale:
Mangroves and the adjacent intertidal vegetation are important fishery areas as nursing and harvesting grounds for fish, prawns and shellfish. Mangrove systems are essential in abating shoreline erosion and are sites of land expansion. However, exploitative extraction of its timber and other non-wood products has altered these forests' composition and underlying dynamics. These changes have been poorly described and studied. The long-term monitoring of the forest condition shall provide valuable insights into the appropriate management requirements of these forests, whilst periodic assessments on the conservation status of these forests will support the government's long-term goals in conserving and promoting the sustainable utilization of this valuable biological resource.

Objectives:
1. To determine mangrove forest composition and structure
2. To determine mangrove forest changes in species, turnover and growth
3. To determine mangrove forest biomass changes

A. Ecological Integrity

Project 1.2.1: Assessment of Mangrove Ecosystems in Sabah

(PI: Dr Joseph Tangah & Marrynah Matami)

Study 1.2.1.1	Set-up and monitor long-term Mangrove LTER site in Sepilok FR & Sulaman Lake FR
Notes	Monitoring trends and changes in forest composition assemblages, forest dynamics**,** above-ground biomass and carbon pool.
Output	Periodic reports on trends in forest health turnover to key stakeholders.
Timeline	Long-term (25 years)

Funding
- State Funding
- Federal Funding – Partially RMK 12
- ISME

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

B. Conservation assessment of the Mangrove ecosystem

Project 1.2.2: Assessment of Mangrove Ecosystems conservation status in Sabah

Study 1.2.2.1	Mapping of the extent and zonation of mangrove ecosystems in Sabah (PI: Charissa J Wong)
Notes	Monitoring of mangrove cover using remote sense and ground survey data.
Output	Reports on the conservation status of the tidal ecosystem in Sabah.
Timeline	5 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

C. Mangrove ecosystem management

Rationale:
There is a general lack of information in Sabah on the potential commercial value, silvicultural regimes for many important mangrove species. Investigational studies are needed to enhance the potential future sustainable use of these resources for the benefit of communities, and industries that are reliant on these resources. For example; the tannin from the bark of Ceriops tagal (Tengar) is used as a natural dye for batik in Indonesia, and a preservative for the fermentation of toddy (coconut wine) in the Philippines. The wood is also used for boiling shrimp and fish in Madagascar. Phytochemical constituents from the bark of Tengar could also lead to the development of new drugs.

Objectives:

1. To determine growth and performance of selected mangrove species
2. Commercialization and regulate the use of selected mangrove species
3. To identify edible insects and pest from mangrove

Project 1.2.3: Silvics and ecology of some threatened mangrove species and economically valuable mangrove coastal species in Sabah

Study 1.2.3.1	Silvics and ecology of Nibung laut (PI: Dr Joseph Tangah & Marrynah Matami)
Notes	Procurement of planting material, nursery techniques and planting trial on site.
Output	Reports on the growth performance of Nibung Laut.
Timeline	10 years
Study 1.2.3.2	Silvics and ecology of Tengar (PI: Joseph Tangah & Marrynah Matami)

Notes	Procurement of planting material, nursery techniques and planting trial on site.
Output	Reports on the growth performance of Tengar.
Timeline	10 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

SUB-PROGRAMME 1.3 – PHYSICAL ENVIRONMENT

A. Ecological integrity

Project 1.3.1: Soil Productivity Assessment in Forested Area

Rationale:
Forest soils are fundamental resources on which our forests can provide various benefits. Soil productivity is reflected in its capacity to produce plants in regeneration, survival and long-term desired natural or plantation forest vegetation, as well as for habitat conservation and biodiversity. It is important to assess such capacity as a decrease in soil productivity could affect these forest ecosystem values. In short, soil productivity is a key to sustainable forest management.

Objectives

1. To assess and evaluate the soil conditions in a particular forested area
2. To identify any limiting factors affecting soil productivity
3. To monitor changes in soil properties due to forest activities

Study 1.3.1.1	Soil productivity of various land use (PI: Esther Dyi Ka Mei)
Notes	Compilation of findings of various soil productivity assessments.
Output	Periodic reports on trends in soil productivity across various land use to key stakeholders.
Timeline	10 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.3.2: Carbon stock Assessment of Forested Land in Sabah

Rationale:

Malaysia has taken part in mitigating the carbon emission issue by signing the United Nations Framework Convention on Climate Change (UNFCCC). It is committed to developing, periodically updating, publishing, and making available to the Conference of Parties (COP) its national emissions inventories by sources and removals by sinks of all GHGs. Carbon stock assessment is important for a wide range of forest management and sustainable forest planning in relation to low carbon emissions. Using suitable and rigorous methods to estimate forest biomass is required. Therefore, updating the trend of research and findings on carbon stock is important to assess the magnitude of uncertainty and error in biomass estimation. Forest carbon has been gazetted under the Forest Enactment through an amendment of section 2 in 2013.

Objectives

1. To estimate carbon stock value in the different forests (inland forest, mangrove forest and peat swamp forest) in Sabah.
2. To determine the magnitude of forest carbon changes

Study 1.3.2.1	Updating trend of research and findings on carbon stock (PI: Esther Dyi Ka Mei)
Notes	Compilation of findings of various research and findings on carbon stock.
Output	Periodic reports on trends in carbon stock across various land use to key stakeholders.
Timeline	10 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:

This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.3.3: Water quality of rivers

Rationale:

Monitoring river water quality can assist land managers in taking proactive measures to prevent environmental degradation and ensure that these resources are protected to support aquatic wildlife and human well-being. Furthermore, the important benefit of river monitoring is that it provides valuable data that can be used to inform management decisions

Objectives

1. To assist in the assessment of river water quality manage by the department.

Study 1.3.3.1	Assessment of river water quality in SFD managed forest management unit. (PI: Noor Azmizah bte Andaman & Reuben Nilus)
Notes	Compilation of water quality assessment findings in SFD managed forest management unit.
Output	Periodic reports on trends in carbon stock across various land use to critical stakeholders.
Timeline	10 years

Funding

- State Funding

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

B. Climate

Project 1.3.4: Changes in rainfall and temperature in Sabah

Rationale:
Monitoring changes in rainfall is vital for the sustainable management and protection of forest resources. Consistent and accurate rainfall measurement is necessary to understand the water cycle and precipitation's environmental impact. Moreover, air temperature affects the growth and reproduction of plants and animals, with warmer temperatures promoting biological growth.

Objectives
1. To procure rainfall and temperature data from relevant agencies.
2. To summarise data annually and disseminate it for public reference.

Study 1.3.4.1		Changes in rainfall pattern in Sabah (PI: Sarah J Mianus & Noor Azmizah bte Andamans)
	Notes	Procure, analyse and publish rainfall information.
	Output	Establishment of rainfall portal in Conservation Monitoring System website.
	Timeline	2 years
Study 1.3.4.2		Changes in temperature pattern in Sabah (PI: Sarah J Mianus & Noor Azmizah bte Andaman)
	Notes	Procure, analyse and publish air temperature information.
	Output	Establishment of air temperature portal in Conservation Monitoring System website.
	Timeline	2 years

Funding
- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

C. Sensitive sites

Project 1.3.5: Mapping of sensitive area

Study 1.3.5.1		Soil, slope & fault line (earthquake-prone area)
	Notes	Procure, analyse and publish sensitive soil, slope & fault line information.

Output Establishment of sensitive soil, slope & fault line portal in Conservation Monitoring System website.
Timeline 2 years

Funding:
- State Funding
- Federal Funding: RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 3 (Objective 1 & 2), and 18th Malaysian Forestry Conference Resolutions 2.3 & 4.4.

SUB-PROGRAMME 1.4 – ECOSYSTEM SERVICES

A. Mapping ecosystem services

Project 1.4.1: Mapping Forest ecosystem services to support the maintenance of species diversity in Sabah

Study 1.4.1.1 Critical Watershed Area of Sabah (PI: Julsun Sikui & Noor Azmizah bte Andaman)
Notes Procure, analyse and publish the critical watershed area of Sabah.
Output Map publishes on the Conservation Monitoring System website.
Timeline 2 years

Study 1.4.1.2 Land-use change analysis (PI: Julsun Sikui)
Notes Procure, analyse and publish the critical watershed area of Sabah.
Output Map publishes on the Conservation Monitoring System website.
Timeline 2 years

Study 1.4.1.3 Above-ground carbon of Sabah (PI: Esther Dyi Ka Mei)
Notes Procure, analyse and publish the above-ground carbon of Sabah.
Output Map publishes on the Conservation Monitoring System website.
Timeline 2 years

Funding
- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.4.2: Evaluating forest ecosystem services in Sabah

Study 1.4.2.1 Catchment area (PI: Rovellyn L. Odong, Esther Dyi Ka Mei, Sarah J Mianus & Charissa J Wong)

Notes	Assessment of land-use cover, ecological integrity and ecosystem services perceptions of various stakeholders. Production of ecosystem services map of the catchment area.
Output	Map publishes on the Conservation Monitoring System website.
Timeline	2 years

Study 1.4.2.2	Totally protected area (PI: Rovellyn L. Odong, Esther Dyi Ka Mei, Sarah J Mianus & Charissa J Wong)
Notes	Assessment of land-use cover, ecological integrity and ecosystem services perceptions of various stakeholders. Production of ecosystem services map of the protected area. (PI: Rovellyn L. Odong, Esther Dyi Ka Mei, Sarah J Mianus & Charissa J Wong)
Output	Map publishes on the Conservation Monitoring System website.
Timeline	2 years

Study 1.4.2.3	To quantify water use and consumption by users in the selected area. (PI: Esther Dyi Ka Mei, Sarah J Mianus & Charissa J Wong)
Notes	Procure, analyse and publish water use and consumption by users in the selected area.
Output	Information publishes on the Conservation Monitoring System website.
Timeline	2 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

B. Enhancement of forest ecosystem services

Project 1.4.3: Forest rehabilitation

Rationale:
The Rain Forests of Sabah are some of Earth's most biologically diverse forests, driven by the underlying edaphic conditions forming ubiquitous floristic communities. These forests are the primary habitat for many unique and highly threatened species. However, over the past century, these forests have been pressured by industrial timber extraction and converted to other non-forest land use, leaving a patchwork of forests with degrees of degradation and fragmentation. Forest fragments and habitat edges pose considerable negative impacts on both the biotic and physical environment. Spatial attributes adversely impacting these forest ecosystems' biological components include fragment size and shape, degree of isolation, the matrix surrounding the fragment, founding population and diversity. Due to dynamic processes, localised extinction within fragmented habitats is not immediately due to a time lag. Habitat restoration or rehabilitation enhances species persistence through potentially increasing population sizes, expanding available habitats, and establishing connectivity, thus allowing inter-fragment dispersal.

Objectives:

1. To design effective forest rehabilitation and afforestation techniques (silviculture, site species matching, etc., soil productivity change) for degraded and previously non-forest sites.
2. To establish rehabilitation demo plots on selected critical ecosystems or habitats.
3. Identify and prioritise key ecological restoration sites within selected critical ecosystems or habitats.

Study 1.4.3.1		Spatial prioritization of critical ecosystems for restoration and afforestation in Sabah (PI: Dr Reuben Nilus, Sarah J Mianus & Sandy Tsen)
	Notes	Using remote sensing tools to prioritization ecosystems for restoration and afforestation in Sabah.
	Output	Information publishes on the Conservation Monitoring System website.
	Timeline	2 years
Study 1.4.3.2		Preferential species for restoration (PI: Dr Reuben Nilus, Mohd Aminur Faiz bin Suis & Sandy Tsen)
	Notes	Listing of species for restoration based on ecological preferences
	Output	List of species according to site preference.
	Timeline	2 years
Study 1.4.3.4		Forest restoration on previously non-forest land use. (PI: Dr Reuben Nilus, Mohd Aminur Faiz bin Suis & Sandy Tsen)
	Notes	Collaborate in procuring planting materials, designing restoration plans, and operating and monitoring the development of restoration activities.
	Output	Periodic reports on collaboration.
	Timeline	10 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:

This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.4.4: Rehabilitation of mangrove and coastal beach ecosystems

Rationale:

About 60% of Malaysia's mangrove vegetation is found along the coast-line of Sabah, forming about 4.5% of the State of Sabah's total forest cover. Covering about 365,000 hectares, these mangrove forests face increasing pressure due to socio-economic development, such as converting mangrove areas into aquaculture, agriculture and urbanization. Yet the mangrove systems of the State are an important resource, contributing to the State's fishery and tourism industry. However, an estimated

1% of Sabah's mangrove vegetation is highly degraded and requires rehabilitation. Through a collaborative project with the International Society for Mangrove Ecosystems (ISME), and with support from Federal and State funds, annual planting of between 40-50 hectares is targeted in Sabah.

Objectives:

1. To select suitable species (site specific) for the mangrove/coastal beach rehabilitation project in Sabah
2. To improve rehabilitation techniques and cost-effective methods for mangrove restoration in Sabah
3. To establish rehabilitation demo plots for mangroves and associate mangrove species
4. To enhance capacity building on mangrove rehabilitation and related activities

Study 1.4.4.1	Long-term mangrove and coastal beach ecosystem rehabilitation site in Sabah (PI: Dr Joseph Tangah & Marrynah Matami)
Notes	Monitoring of 428 ha: Beaufort District - Pulau ISME (Islet 2) & Weston FR (Ext.) Class I; Semporna District - Opposite Timbun Mata island, (Tinggol-Tinggol & Gading-Gading) Semporna FR Class V; Kota Kinabalu District - Sulaman Lake FR (Class V), Sulaman Wetlands, Tuaran; Kota Belud District - Abai FR (Ext.) Class V; Sandakan District– Labuk Bay Proboscis Monkey Sanctuary; Beluran District – Sg Matanggar at Kuala Bonggaya & Kuala Labuk (Class V)
Output	Periodic reports on the mangrove and coastal beach ecosystem rehabilitation in Sabah.
Timeline	Long-term (25 years)

Funding

- State Funding
- ISME

Remarks:

This project aligns with Sabah Forest Policy Thrust 1 (Objective 4), Thrust 2 (Objective 2), Thrust 3 (Objective 1 & 2), and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.4.5: Wildlife research on enhancing food resources in forest area

Rationale:

Over the recent past, anthropogenic activities have accelerated the fragmentation and degradation of the forest ecosystems across Sabah. Yet much of the remaining forested lands are key habitats for the many threatened faunal species in Sabah and the region. Forest restoration or rehabilitation is a central management tool employed by the Sabah Forestry Department to enhance the ecological function of such degraded sites and provide connectivity between forest patches. Figs are a keystone resource, an essential fall-back food source for many wildlife species. Including fig species in restoration or rehabilitation planting programs could serve a crucial role in providing food for many forest-dwelling frugivores and is hoped to raise the carrying capacity of such restored or rehabilitated forest patches for wildlife. However, there is often a lack of information on the distribution of fig species across the forest ecosystems of Sabah, as well as its phenological patterns, site selection, propagative techniques, and the appropriate silvicultural management regimes at out-

planting. This study aims to answer some basic silvicultural questions for successfully introducing fig species for restoration and rehabilitation planting in Sabah.

Objective:

1. To identify forest fruit plants eaten by wildlife (frugivores)
2. To determine the best propagation techniques for selected forest fruit plants
3. To determine appropriate field planting techniques for selected forest fruit plants

Study 1.4.5.1 Documenting feeding habits of wildlife on selected forest fruit plants. (PI: Pg Mohd Sahlan bin Salam)
Output Periodic reports on the feeding habits of wildlife on selected forest fruit plants.
Timeline 5 years

Study 1.4.5.2 Propagation of selected Ficus species. (PI: Pg Mohd Sahlan bin Salam)
Output Periodic reports on the propagation of selected Ficus species.
Timeline 5 years

Study 1.4.5.3 Re-introduction of selected Ficus species in degraded forest. (PI: Pg Mohd Sahlan bin Salam)
Output Periodic reports on the re-introduction of selected Ficus species in degraded forests.
Timeline 5 years

Study 1.4.5.4 Development of fig garden in Rainforest Discovery Park. (PI: Pg Mohd Sahlan bin Salam)
Output Establishment of fig garden.
Timeline 5 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:

- This project aligns with Sabah Forest Policy Thrust 1 (Objective 4), Thrust 2 (Objective 2), Thrust 3 (Objective 1 & 2), and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.4.6: Wildlife research on providing alternative nesting sites for selected arboreal wildlife

Rationale:

Natural tree cavities are an important habitat for several bird and mammal species. Tree cavities are often found at higher densities in natural forests than in managed or disturbed forests. Forest management is thought to affect this decay process by suggesting that the incidence of heart rots in trees could largely reflect tree cavities. Changes in the floristic composition and structure of the forests (size and age classes) are also factors that potentially reduce the number of tree cavities in managed or disturbed forests. The limited occurrence of tree cavities in managed or disturbed forests would affect the availability of suitable nesting sites for many secondary cavity dwellers. It may have a cascading effect on the diversity and abundance of forest-dwelling wildlife species reliant on these keystone resources. Artificial nest boxes are a potential tool for conserving cavity-

dwelling wildlife species in forests by providing alternative nesting sites. However, much is unknown, from the materials suitable for constructing such nest boxes to the design (size of box and size) and placement of these nest boxes in the forest (tree size and height of attachment).

Objectives:

1. To design customized artificial nest boxes suited to selected arboreal wildlife.
2. To determine the appropriate placement of artificial nest boxes in the field.
3. To observe the impact of artificial nest boxes on wildlife behaviour.

Study 1.4.6.1 The efficacy of using artificial nest box to in providing alternative nesting sites for selected arboreal wildlife (PI: Pg Mohd Sahlan bin Salam)
Output Viable artificial nest boxes for selected arboreal wildlife
Timeline 5 years

Funding

- State Funding
- Federal Funding – Partially RMK 12

Remarks:
This project aligns with Sabah Forest Policy Thrust 2 (Objective 3) & Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 5.1.

Project 1.4.7: Wildlife corridor

(PI: Annuar Jain)

Rationale:
Infrastructure development and human expansion have caused habitat fragmentation that limits wildlife mobility. Wide-ranging wildlife struggles to move between habitat patches, which can lead to inbreeding and a loss of genetic diversity. If this occurs, the long-term health of a population will be greatly reduced and it is susceptible and vulnerable to disease, hence the risk of extinction. One ecological measure to reduce the impact of fragmentation is to improve connectivity or corridor linking nearby habitats through restoration that eventually will form a network of protected areas. This will enable wildlife to disperse amongst these protected areas to find food and shelter and ensure cross-breeding with other populations.

Objectives

1. To select suitable species according to site characteristics for the rehabilitation project
2. To conduct maintenance of planted trees periodically

Study 1.4.7.1 Tabin-Kulamba wildlife corridor
Output Viable artificial nest boxes for selected arboreal wildlife
Timeline 5 years

Study 1.4.7.2 Silabukan-Tabin wildlife corridor
Output Viable artificial nest boxes for selected arboreal wildlife
Timeline 5 years

Study 1.4.7.3 Silvicultural treatment in Bukit Piton (Compartment 103 & 104)
Output Viable artificial nest boxes for selected arboreal wildlife

Timeline 5 years

Funding

- State Funding
- Rhino and Forest Fund

Remarks:
This project aligns with Sabah Forest Policy Thrust 3 (Objective 1 & 2); and 18th Malaysian Forestry Conference Resolutions 2.3 & 3.5.

SUB-PROGRAMME 1.5 – CONSERVATION MONITORING SYSTEMS

Rationale:
A sustainable living landscape requires healthy ecosystems that support intact ecological integrity and provide multitudes of benefits to human well-being. Ecosystems can be easily stressed by climate and even more by human activities that result in the risk of loss of natural capital, erosion, air and water pollution and many other factors. Ecosystem monitoring, including the physical environment, biodiversity, ecosystem services, and human landscape, is fundamental to understanding how ecosystem change impacts our natural resources and is vital for developing evidence-based policy and management.

Objectives

1. To maintain and update the Conservation Areas Information & Monitoring System's portal
2. To develop Conservation Monitoring System's portal

Project 1.5.1: Conservation Areas Information & Monitoring System (CAIMS)

Study 1.5.1.1 Establish CAIMS website.
Notes Collate and publish protected area information.
Output Information publishes on the Conservation Monitoring System website.
Timeline 2 years

Funding:

- State Funding
- RMK 12 Funding

Remarks:
This project aligns with Sabah Forest Policy Thrust 1 (Objective 2 & 4) & Thrust 2 (Objective 2); and 18th Malaysian Forestry Conference Resolutions 2.2.

Project 1.5.2: Development of Conservation Monitoring System (CMS) Studies: Data acquisition and upload to the system

Study 1.5.2.1 Biodiversity component
Notes Collate and publish biodiversity components in Sabah.
Output Information publishes on the Conservation Monitoring System website.
Timeline 2 years

Study 1.5.2.2 Physical environment component

Notes Collate and publish physical environment components in Sabah.

Output Information publishes on the Conservation Monitoring System website.

Timeline 2 years

Study 1.5.2.3 Ecosystem services component

Notes Collate and publish ecosystem services component in Sabah.

Output Information publishes on the Conservation Monitoring System website.

Timeline 2 years

Study 1.5.2.4 Human landscapes component

Notes Collate and publish the human landscape component in Sabah.

Output Information publishes on the Conservation Monitoring System website.

Timeline 2 years

Funding:

- State Funding
- RMK 12 Funding

Remarks:

This project aligns with Sabah Forest Policy Thrust 1 (Objective 2 & 4) & Thrust 2 (Objective 2); and 18th Malaysian Forestry Conference Resolutions 2.2.

2. FOREST BIODIVERSITY & CONSERVATION

SUB-PROGRAMME 2.1 – PLANT & FUNGAL DIVERSITY

Project 2.1.1: Plant diversity

Investigators: John B. Sugau, Dr Joan T. Pereira, Suzana Sabran & Andi Maryani

Rationale: Through plant taxonomy and revision by plant experts, plant names are obtained and are constantly being updated. It forms the basis for conducting forestry-related studies. Specific studies on plant groups (lower plant flora & *Ficus*) with scarce information but important for wildlife and have economical values are essential.

Objectives

1. To document and provide detailed and up-to-date botanical and ecological information on the tree flora of Sabah & Sarawak with dbh > 10 cm as it is an important reference for foresters, botanists and all those involved in the timber and wood-based industries.
2. To document and provide detailed and up-to-date botanical and ecological information on the flora of Peninsular Malaysia.
3. To document and provide detailed and up-to-date botanical information of the ferns, lycophyte and bryo-flora of Malaysian, Borneo.
4. To produce plant checklists for Sabah.

Studies:

1. Tree Flora of Sabah and Sarawak (Pentaphylacaceae, Rubiaceae (*Ridsdalea*) and Theaceae
2. Flora of Peninsular Malaysia (Sapotaceae – *Payena* and *Sarcosperma*)
3. Lower Plant Flora: ferns, bryophytes and lycophytes (implication of the study, to benefit the people or forestry)
4. *Ficus* of Sabah (Moraceae)

Output:

1. An account of Theaceae/Pentaphyllaceae and *Ridsdalea* (Rubiaceae) for Tree Flora of Sabah and Sarawak project
2. An account of *Payena* and *Sarcosperma* (Sapotaceae) for Flora of Peninsular Malaysia project
3. An updated checklist and current status of Ferns and Lycophytes in Sabah and Borneo
4. New addition of mosses and liverworts (bryoflora) for Sabah and Borneo (via specimen collection, herbarium and lab work, revision and collaboration studies).
5. An updated revision / checklist for *Ficus* in Sabah
6. A checklist of plant species in Sabah
7. A checklist of tree species in Sabah
8. A checklist of endemic plant species in Sabah

Timeline: 2020-2025

Remarks: MFC Resolution 3.7 - Skilled human resources be made available to intensify assessments and documentations of flora and fauna

Project 2.1.2: Sabah Plant Red List

Investigators: Dr Joan T. Pereira, John B. Sugau, Sandy Tsen, Alviana Damit, Reuben Nilus, Eyen Khoo, Andi Maryani & Richard Majapun

Rationale: Meet the global, national and state commitments. Along with MFC Resolution 3.5: Conservation status of rare, threatened and endangered flora and fauna be continuously monitored and updated.

Objectives: To assess the conservation status of endemic tree species and also species that are most at risk in Sabah

Study: Conservation status assessment of endemic tree species in Sabah

Output:
1. Species assessments published in the IUCN Red List of Threatened Species website https://www.iucnredlist.org/
2. A compilation of Sabah Plant Red List: Sabah Endemic Trees - KPI output
3. Production of Red List assessment for Dipterocarpaceae in Sabah
4. Information disseminated in presentations (oral and poster) and publications
5. Contribute to the generation of the statewide High Conservation Value(HCV) maps for the state

Timeline: 2020-2021

Remarks: MFC Resolution 3.5-Conservation status of rare, threatened and endangered flora and fauna be continuously monitored and updated

Project 2.1.3: Conservation plan for threatened plant species

Investigators: Dr Joan T. Pereira, Alviana Damit, Eyen Khoo, Sandy Tsen & John B. Sugau

Rationale: Malaysia is the fifth country with greatest number of endemic *Rhododendron* taxa (54 species), of which 22 are threatened by extinction. Along with MFC Resolution 3.5: Conservation status of rare, threatened and endangered flora and fauna be continuously monitored and updated.

Objectives:
1. To carry out conservation programme for the threatened plant species
2. To develop and implement a comprehensive conservation plan for *Rhododendron monkoboense (CR) and Rhododendron tuhanensis (CR D)* that encompasses *in situ* and *ex situ* conservation in Sabah (might need to reword/ change the word CCP)

Study: The conservation of high mountain *Rhododendron*, particularly on *R. monkoboense* and *R. tuhanensis* in Sabah, Malaysia

Output: Establishment of *ex situ* living collections and propagation techniques and protocol for preserving the genetic diversity of *Rhododendron monkoboense* (CR) and *Rhododendron tuhanensis.*

Timeline: 2020-2021

Remarks: MFC Resolution 3.5-Conservation status of rare, threatened and endangered flora and fauna be continuously monitored and updated

Project 2.1.4: Dipterocarpaceae diversity in Sabah

Investigators: Richard Majapun & Eyen Khoo

Rationale: For the last decade, much work has been carried out in the updating of distribution range and conservation assessment of the Dipterocarpaceae family. While most published studies have been looking on widely distributed species, studies on species of small population/ restricted range to understand species that are rare, threatened and endangered (RTEs) are still scarce.

Objectives:
1. To document the update distribution range
2. To identify those that falls in the rare and threatened category at the State level.
3. To provide recommendations/take action for conservation

Method: Conduct transects survey/plot establishment/genetic sampling in different forest types under the HoB Initiative/Sectional survey/Cross Departmental to institutional's collaboration. For species that falls under the high threat categories, phenology surveys and seed collections will be conducted for subsequent *ex situ* conservation purposes.

Output:
1. Generation of species data and recommendations for dissemination/use in Forest Management Plans (FMPs), High Conservation Value Reports (HCVs), IUCN Red Listing (Global and State), publications and presentations.
2. Establishment of *ex situ* collections at selected sites RDC Dipterocarp Arboretum, IPS, Lok Kawi Botanical Garden and others for conservation and education purposes.

Timeline: 2020-2025

Remarks: In line with Sabah Forest Policy 2018 Thrust 2 & 3 and 18th MFC Resolution 3

Project 2.1.5: Fagaceae conservation assessment and diversity study in Sabah

Investigators: Eyen Khoo & Robert Ong

Rationale: For Borneo island, Sabah to date holds the highest recorded species for the family, such as phenology, germination, plant animal interaction (food source), distribution and regeneration. The project aims to address the mentioned gaps.

Objectives:
1. To document and update the distribution and ecological range.
2. To conduct conservation assessment (State and Global).
3. To document wildlife and plant interaction.

Method: 1.Conduct transects survey/plot establishment/observations in different forest types. (HoB Initiatives/Sectional survey/Inter-deparmental/Institutions' collaborations).
2. Modelling, phenology, germination and propagation.

Output: 1. Generation of species information and recommendations for dissemination/use in Forest Management Plans (FMPs), High Conservation Value Reports (HCVs), IUCN Red Listing (Global and State), publications and presentations.
2.Short listing of potential species for conservation, reintroduction, *ex situ* conservation at selected sites.

Timeline: 2020-2025

Remarks: In line with Sabah Forestry Policy 2018 Thrust 2 & 3 and 18th MFC Resolution 3

Project 2.1.6: Conventional and micropropagation of plants with conservation interest

Investigators: Eyen Khoo & Veronica Guanih

Rationale: Given the rich biodiversity on Borneo island, many of the forest plants have great potentials to be utilised as horticultural plants or as breeding parents in the generation of new plant varieties. Of particular interests would be those listed as rare, threatened and endangered category within families that are popular in the ornamental market.

Objective: To propagate plants of interests for the purpose of *ex situ* conservation or education

Study: Propagation of rare, threatened and endangered (RTEs) plants, such as Begoniaceae, Orchidaceae, Ericaceae and Araceae either using tissue culture or conventional propagation technique

Output: 1.Generation of species data and recommendations for dissemination/use in Publications and presentations
2.Establishment of *ex situ* collections at selected sites for *ex situ* conservation
3.Annual schools/colleges/universities students' visits for internship/short term Training and education purposes

Timeline: 2020-2025

Remarks: In line with Sabah Forest Policy 2018 Thrust 2 & 3 and 18th MFC Resolution 3

Project 2.1.7: Fungal diversity in selected forest reserves in Sabah

Investigator: Viviannye Paul

Rationales: Fungi are studied under a separate branch of Botany called Mycology. This is one of the main thrusts in the Sabah Forest Policy. Research on fungi in Borneo is still

scarce and relatively unknown. One of the reasons to conduct a study of fungi is to document the diversity of species in a particular area.

Objectives:
1. To identify areas of particular fungal interest (For example: detect the potential fungi that we can exploit fungi industrially/commercial value).
2. To make recommendations to conserve and promote further fungal interest, for consideration within the management plan of the site.
3. To promote awareness of ecological requirements of fungi.

Output:
1. Publications, presentations and reports on variety of conspicuous fungi in Sabah.
2. Attract visitors to visit the area of particular fungus interest: e.g. attracts nature photographers including those who are keen to capture close-up photographs of interesting fungi.

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 2, MFC-18 Resolutions 3.5 & 3.8

SUB-PROGRAMME 2.2 - WILDLIFE

Project 2.2.1: Diversity of mammals in selected forest reserves and conservation areas in Sabah

Investigators: Mohd. Aminur Faiz Suis & Dr Reuben Nilus

Rationale: The island of Borneo sheltered at least 247 terrestrial mammal species. However, these figures are not static as their diversities are influenced by natural causes and anthropogenic pressures. Hence, long-term studies on these taxonomic groups in Sabah are crucial. The findings are useful in monitoring Sabah rare, threatened and endemic species. Information on mammal can be integrated with other research disciplines (e.g. plant diversity, forest ecosystem and social science) to formulate a comprehensive management plan. This in turn will widen the research capacity of Forest Research Centre. These projects are in line with Sabah Forest Policy Thrust 2, and Malaysian Forestry Conference 2018 Resolutions 3.5 and 3.8.

Objectives:
1. To inventory terrestrial mammal species
2. To assess species richness of mammals, and their conservation status
3. To assess the issues and threats detrimentally affecting the terrestrial mammals
4. To provide recommendations for conservation from the mammal perspective

Method:
1. Camera-trapping
2. Opportunistic and indirect sighting

Output:
1. Species richness of terrestrial mammal (preliminary checklist of terrestrial mammals)
2. Data on rare, threatened, endemic and outstanding conservation value species for FMP and HCV reports
3. Dissemination of information in publications, reports & presentations
4. Photographic data deposited in database for researchers & students

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 2, MFC-18 Resolutions 3.5 & 3.8.

Project 2.2.2: Diversity of birds in selected forest reserves and conservation areas in Sabah

Investigators: George Hubert Petol, Bernadette Joeman, Mohd. Aminur Faiz Suis & Dr. Reuben Nilus

Rationale: The island of Borneo sheltered at least 673 bird species. However, these figures are not static as their diversities are influenced by natural causes and anthropogenic pressures. Hence, long-term studies on these taxonomic groups in Sabah are crucial. The findings are useful in monitoring Sabah rare, threatened and endemic species. Information on bird can be integrated with other research disciplines (e.g. plant diversity, forest ecosystem and social science) to formulate a comprehensive management plan. This in turn will widen the research capacity of Forest Research

Centre. These projects are in line with Sabah Forest Policy Thrust 2, and Malaysian Forestry Conference 2018 Resolutions 3.5 and 3.8.

Objectives:
1. To inventory bird species
2. To assess species richness of birds, and their conservation status
3. To assess the issues and threats detrimentally affecting the terrestrial birds
4. To provide recommendations for conservation from the bird perspective
5. To train lay people in conducting bird survey from the perspective of bird ecology
6. To come up with a standardised methodology for rapid bird assessment
7. To promote birdwatching in Sabah

Method: Opportunistic and indirect sighting, MacKinnon List method in enumerating birds

Output:
1. Species richness of birds
2. Data on rare, threatened, endemic and outstanding conservation value species for FMP and HCV reports
3. Dissemination of information in publications, reports & presentations
4. More people trained in conducting bird surveys

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 2, MFC-18 Resolutions 3.5 & 3.8

Project 2.2.3: Mangrove fauna

Investigators: Dr. Joseph Tangah, Dr. Arthur Y.C. Chung, Razy Japir, Dauni Seligi, Dr. Henry Bernard, Dr. Tohru Naruse

Rationale: Mangrove is a unique ecosystem between the sea and inland forest. It is a breeding ground for marine life as well as a haven for some terrestrial wildlife. It is important to gain a better understanding on the ecology, distribution and behaviour of the animals inhabiting the mangrove forests, in relation to the livelihood of the communities living within and adjacent to the mangroves.

Objectives:
1. To survey mangrove wildlife of Sabah
2. To investigate their behavioural traits and ecological aspect
3. To study ways of promoting selected fauna (e.g. proboscis monkey, crocodile, etc) for nature eco-tourism in Sabah

Study: Study on selected and iconic groups of mangrove fauna

Output:
1. Data procured will be used for general information and talks
2. Publications, reports & presentations in conferences

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 2 & 4

Project 2.2.4: The inland freshwater fish research of selected forest reserves in Sabah

Investigator: Nur Syafiqah binti Shamsul Kamal

Rationale: Inland freshwater fishes are declining mainly due to habitat destruction from logging activities, pollution from extensive agricultural plantations, overfishing and illegal fishing. Among all vertebrates, freshwater fishes had the highest extinction rate. In Sabah, freshwater fish conservation and taxonomy study are still very much in discovery phase. Hence, the understanding of influence on freshwater fish can help in forest management and conservation of freshwater fish diversity.

Objectives:
1. To document the freshwater fish fauna.
2. To survey and assess the diversity and its conservation status.
3. To provide up-to-date information on inland freshwater fish diversity in Sabah.
4. To identify the issues and threats adversely affecting the inland fish fauna.
5. To expand the Forest Research Centre inland fish collection.

Study: The quantitative and qualitative of inland freshwater fish in Sabah

Output:
1. Technical reports, presentations, publications
2. Establishment of inland freshwater fish voucher specimens for future reference

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forestry Policy Thrust 2 and 18th MFC Resolution 3.5 & 3.8

Project 2.2.5: Anuran diversity and conservation of selected forest reserves in Sabah

Investigator: Pg. Mohd Sahlan bin Salam

Rationales: The global amphibian decline is a well-documented phenomenon, with up to 40% of species threatened with extinction. Whilst tropical regions such as Southeast Asia harbour high anuran diversity, they also contain the most threatened habitats. Due to their environmental and physiological limitations, tropical anurans are highly sensitive to changes in their environment, and are thus highly susceptible to habitat loss and degradation. The island of Borneo has high anuran diversity (over 180 species), but it is adversely affected by deforestation and habitat degradation. Furthermore, a lack of baseline diversity data, undermines potential conservation management of Southeast Asia's imperilled amphibians. Determining the anuran diversity of small forested areas, is paramount in ensuring the protection of forest patches which may not support large mammalian populations, but can serve as valuable sites of anuran diversity in disturbed landscapes.

Objectives:
1. To document Anuran diversity (frogs and toads)
2. To provide up-to-date information an anuran diversity in forest reserves in Sabah.
3. To expand the anuran collection in FRC.
4. To promote selected anurans in nature tourism.

Study: Anuran diversity and conservation of various forest reserves under the HoB Initiative

Output:
1. Established anuran scientific collection in FRC
2. Scientific publications, reports and presentations

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 2 & 4; and 18th Malaysian Forestry Conference Resolution 3.2.

Project 2.2.6: Insect diversity and conservation of selected forest reserves in Sabah

Investigators: Dr Arthur Y.C. Chung & Razy Japir

Rationale: Due to their high diversity and abundance, insects are utmost important in the functioning of the ecosystem, but much is still not known about the rainforest insects. Click this link for a comprehensive justification of this project: https://www.youtube.com/watch?v=TI0_8Pxx_5g

Objectives:
1. To document the insect fauna
2. To evaluate the diversity of insects and its status
3. To investigate the issues and threats adversely affecting the insect fauna
4. To provide recommendations for conservation from the insect perspective
5. To expand the FRC Insect Collection

Studies:
1. Nocturnal insect diversity (via light-trapping)
2. Butterfly diversity (via sweep-netting & fruit-baiting)
3. Dragonfly diversity (via sweep-netting)
4. Beetle diversity (via light-trapping & manual collecting)
5. Ant diversity (via manual collecting)
6. Grasshopper & cricket diversity (via manual collecting – day & night)
7. Stick insect diversity (via manual collecting – day & night)
8. Praying mantis diversity (via manual collecting & light-trapping)

Output:
1. Data on endemic species and other species of conservation interest for FMP & HCV reports
2. Dissemination of information in publications, reports & presentations
3. Insect specimens deposited in reference collection for researches and student

Timeline: 2020-2025

Gantt Chart

Task Name/ Month	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
PLANNING												
RESEARCH												
WRITING-UP												
SEMINAR												

Remarks: This project is in line with Sabah Forest Policy Thrust 2, MFC-18 Resolutions 3.5 & 3.8.

Project 2.2.7: Insect diversity in promoting nature tourism

Investigators: Dr Arthur Y.C. Chung & Razy Japir

Rationale: Like bird watching, insect watching, especially butterflies and dragonflies, is gaining momentum. These nature tourism related activities should be promoted as they can generate revenue for the state government and improve the livelihood of the local communities. This is one of the main thrusts in the Sabah Forest Policy. Research on insects in nature tourism is still scarce and relatively unknown. Therefore, it is timely for studies to be conducted to evaluate its potential in Sabah, as well as to document insects of nature tourism interest.

Objectives:
1. To document insects that contribute towards nature tourism
2. To investigate the life cycle, behavioural and ecological aspect of selected insects
3. To study ways of promoting selected insects in nature tourism

Study: Study will focus on selected groups, which include butterflies, beetles & dragonflies

Output:
1. Data procured will be used for talks for students, tourist guides and public in general
2. Scientific publications, reports & presentations in conferences
3. Layman publications for the general public

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 2 & 4, MFC-18 Resolution 3.2

Project 2.2.8: Insect diversity as a tool to monitor the ecological succession of selected mangrove sites in Sabah

Investigators: Dr Arthur Y.C. Chung, Dr Joseph Tangah, Razy Japir & Dr Maria Lourdes (UMS)

Rationale: Insects are often used in environmental studies as bioindicators due their diversity, abundance and close relationship with the biotic and abiotic factors in the environment. They can indicate the effects of habitat changes and fragmentation, and the effectiveness of management schemes designed to preserve or change individual species- or community-level patterns. Insect diversity has been used as a tool to indicate the status of the surveyed area, and to compare with other forested sites in Sabah. Mangrove insects, however, have remained a neglected field although Sabah accounts for about 60% of the mangroves in Malaysia. Hence, this project is being conducted.

Objectives:
1. To document insect fauna in selected mangrove site in Sabah
2. To investigate the status of mangroves based on insect diversity

Study: Study will focus on two sites, namely Sg. ISME in Sg Manila and LTER site in Sepilok Laut

Output:
1. Scientific publications, reports & presentations in conferences
2. Layman publications for the general public on insect fauna of mangroves
3. Enhance collaboration among ISME, UMS and SFD in research cooperation
4. Capacity building for interns and final year student projects from UMS

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 2 & 7, MFC-18 Resolution 3.1

Project 2.2.9: Insects causing damage to figs in Sabah

Investigators: Dr Arthur Y.C. Chung, Razy Japir, Dr Zainal Z.Z. (BORA) & Bryan Wong Haoen (BORA)

Rationale: This is a joint project with BORA (Bringing Back Our Rare Animals), based in Tabin. Initially, the Fig Germplasm Centre with about 100 species was established in Tabin as a source of food for the rhinos. With the extinction of rhino in Sabah now, the focus is on fig diversity in association with insects that are causing damage to figs, as well as other research projects.

Objectives:
1. To document insect fauna from the Ficus Germplasm Centre (Tabin) in Sabah
2. To investigate the damage caused by insects on figs

Study: Study will focus at the Ficus Germplasm Centre in Tabin, Sabah.

Output:
1. Scientific publications, reports & presentations in conferences
2. Layman publications for the general public on insects associated with figs
3. Enhance collaboration between SFD and BORA in research cooperation

Timeline: 2022-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 2 & 7, MFC-18 Resolution 3.1

Project 2.2.10: Papilionid butterfly conservation in Sepilok

Investigators: Dr Arthur Y.C. Chung & Razy Japir

Rationale: This is a conservation project, primarily focussing on the birdwing butterflies in Sepilok, such as *Troides amphrysus, T. helena* and *T. miranda*. The population of *T. miranda* has declined drastically within Sandakan areas over the years. Hostplant, *Aristolochia acuminata*, will be planted and monitored in Sepilok. The project will also contribute towards nature tourism in Sepilok.

Objectives: 1. To enhance the papilionid butterfly population in Sepilok
2. To study the propagation and growth of *Aristolochia* hostplant in Sepilok

Study: Study will focus on papilionid butterfly population and their hostplant in Sepilok.

Output: 1. Scientific publications, reports & presentations in conferences
2.Distribution of propagated hostplants to resorts in Sepilok and enhance awareness on butterfly conservation

Timeline: 2022-2024

Remarks: This project is in line with Sabah Forest Policy Thrust 2, MFC-18 Resolutions 3.5 & 3.8.

Outreach & extension

- Capacity building (courses & lectures) on plant and insect identification for rangers, students and the general public
- Plant and insect identification services to FMU holders, other forestry stakeholders and related agencies
- Internship programme for local university students, such as UMS, UPM, USM and UNIMAS.

Other related activities & technical services

- Biodiversity Exploration/Expedition
  The Forest Biodiversity & Conservation Programme conducts exploration to collect plant and fauna (insect, fish & frog) specimens around Sabah. Since the initiation of the Heart of Borneo (HoB) project in 2008, scientific expeditions were focused on selected areas for inventories, including identification of related corridor/buffer for conservation targets within the HoB area. This effort is to assess the plant & fauna diversity and their conservation status and also determine the vegetation and fauna quality in the various forest types.

- Botanical Research & Herbarium Management System (BRAHMS)
  The specimens stored at the Sandakan Herbarium are curated and the information are input into a database, i.e., BRAHMS to produce a networkable information system designed to assist botanists and others working with botanical data with the assembly, storage, processing and publication of data associated with their work. These data have been used for producing Checklist of plants, producing conservation assessments of plants and many more outputs.

- Maintenance and curation of Scientific Reference Collections: Sandakan Herbarium, Insect Museum, Fish & Frog Collection (see sub-heading on FRC Scientific Reference Collections).

3. FOREST PLANTATIONS

SUB-PROGRAMME 3.1 - PLANTATIONS

Project 3.1.1: Taxa trial of fast-growing selected potential plantation species

Investigators: Maria Ajik & Pang Kat Nyen Kelvin

Rationale: Forest plantation is in an arm's race against external factors, such as market demand and, pests and diseases to find a timber species which has the potential to be used for forest plantation. The epidemic caused by *Ceratocytis* on the Acacia plantation throughout the region is a good case study of what will happen if we were to be over-reliant on a certain species, such as Acacia for forest plantation development in Sabah. We will need to constantly find and explore new species which has the potential to be used as plantation species and then introduce it to the upstream and downstream wood industry.

Objectives: To quantify the growth and yield of the selected potential species in plantation condition
To evaluate the physical form of the species for solid wood utilization
To document the species performance and make recommendations of the species suitability for forest plantation development

Species:
1. Laran putih (*Neolamarckia cadamba*)
2. Talisai Paya (*Terminalia copelandii*)
3. Binuang (*Octomeles sumatrana*)
4. *Eucalyptus pellita*
5. Mahogany (*Swietenia macrophylla*)
6. *Acacia crassicarpa*
7. Batai (*Falcataria moluccana*)
8. Laran Merah (*Neolamarckia macrophylla*) *
9. Local batai (*Albizia kostermansii*)*
10. Sesenduk (*Endospermum diadenum*)*

(* To be undertaken when seeds and seedlings are available)

Output:
1. Data of growth and yield of the selected forest plantation species
2. Information on the physical form of the selected species for various utilization aspects
3. Dissemination of information in publications, reports & presentations
4. Advice and recommendations on potential species for forestry stakeholders

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolutions 4.1.

Timeline: 10-15 years from planted date with the assumption that a one full rotation is 10-15 years OR when DBH of planted tree is above 45cm average.

Project 3.1.2: Silvicultural trial (spacing, pruning & thinning) and herbivory predation prevention

Investigators: Maria Ajik & Pang Kat Nyen Kelvin

Rationale: This project is a continuation of the first project. After finding a potential timber species which can be used for forest plantation, we will need to find the best silvicultural treatment/practice which is the most suitable for the said species; from the nursery stage to the planting stage, and then the post-planting stage. This project will be able to answer questions, such as:
What is the best planting spacing for the species?
What weeding regiment needs to be carried out?
Is there a need to do pruning and thinning?
What type of animals associated to the herbivory on the selected species?
Is there any effective predation prevention for the said affected species?

Objectives:
1. To determine the most optimum planting density for solid wood production
2. To determine the need, appropriate timing and methodology for pruning and thinning of the selected species
3. To observe, record and conduct herbivory prevention method
4. Dissemination of information in publications, reports & presentations
5. Advice and recommendations on potential species for forestry stakeholders

Output:
1. Data on the optimum spacing and the need for pruning and thinning of the selected forest plantation species for saw log production
2. Information on the physical form of the selected species for various utilization aspects
3. Information on the herbivory behaviour related to the selected species
4. Dissemination of information in publications, reports & presentations
5. Advice and recommendations on potential species for forestry stakeholders

Timeline: 5 years with the assumption that most if not all silviculture practices need to be carried out in the initial years of the planting which will affect the growth of the planted trees.

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolutions 4.1.

Project 3.1.3: Study on Sesendok (*Endospermum diadenum*) growth in the wild and mother trees selection

Investigators: Rebecca Fung Yun Chong & Pang Kat Nyen Kelvin

Rationale: Sesendok is a fast-growing pioneer species. This species is widespread, and easily found in the dry and less fertile soil. Its timber is commonly used for minor timber products. This species has potential to be used for afforestation and even forest plantation but there is limited information on the growth and reproduction of the said species in Sabah, Malaysia.

Objectives: 1.To observe and record the growth according to diameter size in the

wild.
2.To select good mother trees as seed trees, and selection must be conducted with the dioecious nature of the species (produce single sex flowers).

Output:
1. Data on growth performance in the wild
2. Identification of mother trees for seed collection
3.Dissemination of information in publications, reports and presentations

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolution 4.1

Project 3.1.4: Insect pests of forest plantation trees and potentially important trees in Sabah

Investigators: Dr Arthur Y.C. Chung, Razy Japir, Viviannye Paul & Kelvin Pang

Rationale: In forest protection, integrated pest management rather than control is advocated. Constant and continuous pest monitoring will have to be developed and it forms an integral part of forest plantation management. An understanding of the biology of the pests and the damage that they caused, would help foresters in deciding what to plant, and how to avoid potential pest outbreak. It is always better, whenever possible, to prevent than to cure.

Objectives:
1. To document the insect pests of selected forest plantation trees
2. To evaluate the health status of the effected trees
3. To study the life cycle of the insect pests
4. To provide recommendations and advice on pest management

Study:
1. Laran Merah (*Neolamarckia macrophylla*)
2. Laran (*Neolamarckia cadamba*)
3. Talisai Paya (*Terminalia copelandii*)
4. Binuang (*Octomeles sumatrana*)
5. Eucalyptus (*Eucalyptus pellita* & other species)
6. Other tree species upon request from forestry stakeholders

Output:
1. Data on insect pests of selected tree species
2. Dissemination of information in publications, reports & presentations
3. Advice and recommendations on pest management for forestry stakeholders

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolutions 4.1.

Project 3.1.5: Insects associated with Dipterocarpaceae and Fagaceae

Investigators: Dr Arthur Y.C. Chung, Razy Japir & Eyen Khoo

Rationale: The dipterocarps are the most important commercial timber trees in the tropical forests. Borneo has a total of 267 dipterocarp species, which accounts for more than half of the world's dipterocarps. With no less than 155 species endemic to this island, Borneo is the centre of the world's diversity for Dipterocarpaceae. Hence, it is important to study the insect pests related to dipterocarps. Fagaceae are important forest trees providing source of food for wildlife, and they are preferred trees for migrating birds. Under the Sabah Forestry Department, Fagaceae trees are prohibited to be felled.

Objectives:
1. To document insects associated with dipterocarps and Fagaceae in Sabah
2. To investigate the life cycle, behavioural and ecological aspect of insects
3. To provide recommendations for pest management, especially in the nursery

Study: Insects associated with selected dipterocarpaceae and Fagaceae species in FRC

Output:
1. Data procured will be disseminated in scientific publications, reports & presentations in conferences
2. Recommendations for pest management

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.1

Project 3.1.6: Insects associated with urban forestry

Investigators: Dr Arthur Y.C. Chung, Razy Japir, Viviannye Paul & Eyen Khoo

Rationale: There is a huge demand for ornamental plants inside the country and abroad as well. Many of these plants originate from forests. Within the country, the ornamentals are widely used in urban landscaping, lining the avenues of towns and cities, decorating both public and private gardens. They provide shade, cool the atmosphere and beautify the environment. It is important to document the insects associated with urban forestry and also to monitor the status of pests in the urban areas, as well as to find solution to problems that occur. Beneficial insects, such as pollinators will be studied as well.

Objectives:
1. To document insects associated with ornamentals in Sabah
2. To investigate the life cycle, behavioural and ecological aspect of the insects
3. To provide recommendations for pest management in urban forestry

Study: Insects associated with selected ornamentals for urban forestry in Sabah

Output:
1. Data procured will be disseminated in scientific publications, reports & presentations in conferences

2. Recommendations for pest management and pollination in urban forestry

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.1

Project 3.1.7: Occurrence of diseases in forest plantations

Investigator: Viviannye Paul, Dr Arthur Y.C. Chung, Razy Japir & Kelvin Pang

Rationale: Forest Pathology is the study of tree diseases. Plant disease can be a dangerous phenomenon in the forestry sector if not detected or taken care at the right moment as the intensity of spreading increases in a forest due to its vulnerability, such as Ceratocystis Wilt Disease affecting Acacia and Gall Rust Disease on Albizia trees.

Objectives:
- To document diseases causing damage to forest trees in Sabah.
- To investigate the status of infestation & ecological aspects of diseases.
- To provide recommendations for plant disease management.

Outputs:
- Data procured will be disseminated in scientific publications, reports & presentations in conferences.
- Recommendations for plant disease management in FMUs & other forestry stakeholders.

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.1

Project 3.1.8: Encouraging tree planting by smallholders and local communities as an important timber source for the timber industry (Project under the 12th Malaysian Plan)

Investigators: Pang Kat Nyen Kelvin & Veronica S. Guanih

Rationale: The decreasing supply of timber from the natural resources is affecting the timber industry in Sabah. One of the ways to overcome this problem is to encourage planting of timber trees by smallholders and local communities in alienated or uncultivated lands. The timber produced from these lands will alleviate the demand of timber from the natural forest and at the same time feed the downstream processing industry.

Objectives:
- To identify areas outside the forest reserve that can be used for tree planting.
- To encourage the planting of timber trees by providing planting materials and free technical services.
- To develop a database on existing tree plantation by smallholders and local communities.
- To develop tree plantation outside of the forest reserve by supplying planting material (seedlings) to small farmers and local communities as many as 100,000

seedlings throughout the duration of the project.
- To develop a plantation demonstration plot in the land of smallholders or local communities.

Outputs: The volume of wood produced by the 100,000 trees can be harvested and fed to timber downstream industry within 7-10 years after planting. This project will also expose the public and private sector to the benefit and importance of smallholder tree plantation initiatives.

Timeline: Timeline: 2021-2025 (Throughout the duration of the 12th Malaysian Plan)

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-19th Resolutions 5.2.

SUB-PROGRAMME 3.2 – TREE BREEDING

Project 3.2.1: Provenance/progeny trial of selected plantation species

Investigators: Maria Ajik & Kuina Kimjus

Rationale: One of the prerequisites in a successful forest plantation program is the use of good, improved and high quality planting materials at the onset. Tree breeding/improvement caters to provide reliable and sufficient source of improved planting materials. Tree breeding/improvement activities include plus tree selection, provenance test, progeny/clonal test, establishment of seed production areas/orchards.

Note*Parent-tree selection, or phenotypic selection is based on physical appearance, an expression of genetic (in the tree) and environment. Testing is required to determine the genetic worth of each parent, that is, the ability to pass on its superiority to its progeny (the offspring). A progeny trial is done by growing seedlings of each parent and evaluating them, along with the progeny of other parents selected on several planting.

Objectives:
1. To evaluate performance/adaptability of provenances in different site conditions
2. To select best provenance/progeny for further breeding activities

Species:
1. Binuang (*Octomeles sumatrana*)
2. Laran (*Neolamarckia cadamba*)
3. *Eucalyptus pellita*
4. *Acacia mangium*

Output:
1. Determination of suitable provenance/progeny in different site conditions
2. Selection of best provenance/progeny for forest plantation activities
3. Findings to be disseminated in publications, reports and presentations

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolutions 4.1.

Project 3.2.2: Conversion of existing research trials into seed production areas & experimenting the use of chemicals/fertilizers to trigger flowering/fruiting

Investigators: Maria Ajik & Eyen Khoo

Rationale: Forest plantations require continuous supply of improved seed and this can be materialized by converting our existing trial plots that are no longer being assessed. The idea of this study was first prompted by the head of FP program following the issue of acquiring good and reliable seeds for taxa trial, a joint research project with BFC, and further discussed during Paul Warburton's visit to Kolapis A in February 2020. It is necessary to have our very own SPAs rather than to continue relying from wild collection sources. Sale of seed will generate income too.

Note* Challenges – dioecious nature in Binuang, male and female flowers on separate trees. Based on general observation, to date, no single tree has shown sign of flowering. On another note, planted Laran in Lungmanis as observed began to produce flower after 13 years.

Objectives:
1. To assess and conduct thinning on selected existing old trial plots, and to convert them into seed production areas
2. To enhance the production of improved seeds

Species:
1. Binuang (*Octomeles sumatrana*)
2. Laran (*Neolamarckia cadamba*)
3. *Eucalyptus pellita*
4. *Falcataria moluccana* (established in Segaliud Lokan in 1997)

Output: Improved seeds from seed stands

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & MFC-18 Resolutions 4.1.

Project 3.2.3: Seedlings growth and performances on selected potential forest plantation species in the nursery

Investigators: Kuina Kimjus , Maria Ajik & Kelvin Pang

Rationale: The information on how to produce high-quality seedlings for the selected forest plantation species is still lacking, hence this study is proposed.

Objectives:
1. To conduct study on the effect of using polybags and nursery containers grow on the seedlings growth and quality in the nursery.
2. To investigate the growth and performance of vigor vs non vigor seedlings in the nursery and to continue observing their performance in the field.

Species: 1. Laran (*Neolamarckia cadamba*)
2. Laran Merah (*Neolamarckia macrophylla*)
3. Sesendok (*Endospermum diadenum*)

Output: 1. Recommendations on seedling growth and performances in the nursery and in the field.
2. Dissemination of findings in scientific publications, reports & presentations.

Timeline: 2020 - 2025

Remarks: This project is in line with Taxa Trial/BFC project, Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.2, 4.3 and 4.5

Project 3.2.4: Growth performances of Laran Merah (*Neolamarckia macrophylla*) cutting materials in the field

Investigators: Kuina Kimjus & Maria Ajik

Rationale: Laran merah is considered a lesser-known species in Sabah but has become one of the potential forest plantation species following its introduction to Sabah in 2013. Currently, it is almost impossible to get sufficient seeds from oversea, hence stem cutting is being opted to produce planting materials of Laran Merah.

Objectives: To assess the growth and performance of Laran Merah cuttings in the field.

Timeline: 2020 – 2025

Output: 1. Plot establishment for Laran Merah (through stem cutting materials).
2. Data on growth performance of Laran Merah cuttings in the field.
3. Advice and recommendations on potential of Laran Merah cuttings for forestry stakeholders.
4. Research findings will be disseminated in scientific publications, reports & presentations in conferences.

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.2, 4.3 and 4.5

Project 3.2.5: Phenological study on the targeted plantation species

Investigators: Rebecca Fung Yun Chong & Pang Kat Nyen Kelvin

Rationale: A sufficient supply of planting materials and germplasm is necessary in any embarkation of large-scale forest plantation. However, seed supply has become one of the main constraints as occurrence of fruiting events is irregular and some of the target species may not fruit every year. A consistent and well-planned monitoring on phenological events will result in useful phenology information to the stakeholders on the next seed harvest.

Objectives: To quantify and summarize the phenological behavior of a population.

Study:
(1) *Endospermum diadenum* (Sesendok)
(2) *Macaranga* spp. (Sedaman Jari & Sedaman Daun Besar)
(3) *Neolamarckia macrophylla* (Laran Merah)

Output:
(1) Seed harvesting calendar of selected tree species
(2) Advice and recommendation on the seed collection plan for forestry stakeholders
(3) Research papers on phenological events of the studied species

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 (1) & MFC-18 Resolution 4.1

Project 3.2.6: Improved seed technology study to produce quality seeds

Investigators: Rebecca Fung Yun Chong

Rationale: Seed quality is most important for establishing tree plantation and there is no guarantee if self-collection was conducted on poor quality of the mother trees and using seeds without proper seed testing and health check. Hence, it is important to have a series of seed improvement studies related to ways of handling seeds, especially during seed processing, seed health check and seed storage. The project focuses on capacity-building relating to tree seed technologies and seed procurement.

Objectives:
1. To determine the best protocol/method to process the seeds from fleshy fruit so that it gain higher germination.
2. To study the germination rate and also analyse the nutrient leakages of the low vigour seeds.
3. To study the viability of seeds stored in dry-box (Desiccator) under ambient compared to the fridge storage.

Study:
1. Comparison of seed drying method
2. Seed health check and vigour testing
3. Seed storage trial

Output:
1. Technical reports
2. Research papers

Timeline: 2020-2025

Remarks: This project is in line with Sabah Forest Policy Thrusts 4 & MFC-18 Resolution 4.1

Project 3.2.7: Micropropagation of potential species of interests for plantation programme research purposes

Investigators: Veronica S. Guanih & Eyen Khoo

Objectives: To provide assistance in the micropropagation and assessment of tissue cultured materials of various life stages.

Rationale: Now and again, the plantation program would have identified local species that have potentials to be utilised as timber and devising the most economical ways to mass produce this source either through seeds, conventional means or alternatively micropropagation. Targeted species listed in the programme will be micropropagated, observed and based on data collected at various stages of the plant development (lab/nursery/plantation sites), analysis will be conducted.

Output:
1. Generate protocol for the micropropagation of species of interests (*Neolamarckia macrophylla*, *Terminalia coopelandii* and *Falcataria moluccana* subsequently published and disseminate to parties of interests.
2. Establishment of tissue cultured materials to be tested out in the field and data obtained for analysis.

Timeline: 2021-2024

Remarks: In line with Sabah Forest Policy 2018 Thrust 3 (Objective 1) and 18th MFC Resolution 4.

Project 3.2.8: Vegetative propagation & field testing of Eucalyptus Hybrid (ex SFI)

Investigators: Kuina Kimjus & Maria Ajik

Objectives:
1. To mass-propagate (via stem cutting) the 5 best clones of E. hybrid obtained from ex SFI.
2. To evaluate and to compare the growth performance of the 5 best clones of E. hybrid in the field as against their performance in ex SFI.

Rationale: The Eucalyptus hybrid was first introduced in Malaysia in the 2008 using clones selected from Southern China and was later planted in many parts including Sabah Softwood Berhad and some parts in Peninsular Malaysia (Ahmad Zuhaidi *et al.* 2020). At 5 years, the E. hybrid planted by FRIM in Bukit Sedanan F.R recorded a mean diameter at breast height (dbh over bark) ranging between 20 and 22 cm and clear bole height of 7 and 10 m (Ahmad Zuhaidi 2020). The 5 top performing E. hybrid collected from ex SFI Sipitang produced comparably good results at 5 years with a dbh and height ranging between 20 and 25 m and 16 and 20 cm, respectively (unpublished data SFI). Although it is too early to tell the full potential of the species, the results clearly show some indication of the potential of the species for

large scale planting in the country.

Output: Dissemination of findings in scientific publications, reports & presentations.

Timeline: 2022 – 2026

Remarks: This project is in line with Sabah Forest Policy Thrust 4 & 19th MFC Resolution 5

Technical Services

Training on nursery management for SFD staff and other stakeholders. This is to improve knowledge and skills on nursery management and to knowledge on vegetative propagation technique, focusing on nursery management of forest plantation species and natural forest species.

4. FOREST PRODUCE & PRODUCTS

There are 5 components—4 research and 1 core function—within FPP Research Programme based on current research and activities, either in-house or on a collaborative basis, undertaken by the Wood and Chemistry Sections. The activities under these components are in line with the thrusts and objectives underlined in the Sabah Forest Policy 2018, specifically Thrust 3 (Objectives 1, 4 & 6), Thrust 5 (Objective 2) and Thrust 7 (Objectives 1 & 2) (See Appendix for details).

SUB-PROGRAMME 4.1: SCIENCE & UTILISATION OF WOOD AND WOODY BIOMASS

Project 4.1.1: Wood quality of timber species in Sabah

Investigators: Jarry Lajanga & Zamrie Imiyabir

Rationale: The basic information on wood quality such as physical and mechanical properties of tree species is very important as the suitability of the timber for certain products and end-uses is largely determined by its wood properties. The quality of wood of trees (mostly exotic species) grown in Sabah may differ from those grown in other places, thus the wood properties and potential utilisation (for certain products) of the plantation species in Sabah should be determined directly.

Objective:
1. To determine the wood properties (physical and mechanical) of selected species
2. To determine the proportion of sapwood and heartwood of plantation species
3. To determine the potential timber utilization of the selected species

Studies:
1. Wood properties and wood characteristics of selected plantation species in Sabah
2. Wood properties of potential indigenous species in Sabah (such as local Batai)
3. Proportion of sapwood and heartwood of selected plantation species
4. Potential timber utilization (both plantation and naturally grown species)

Output:
1. Database of wood density and other wood properties of plantation species
2. Guidelines for future selection of species for plantation programmes
3. Technical reports, publications/presentations

Timeline: 2020 – 2025 (or beyond, with new species being introduced/planted for trials and as long as the wood samples can be obtained for the study)

Project 4.1.2: SAFE log decomposition experiment

Investigators: Rolando Robert & Dr. Terhi Riutta (Imperial College London)

Rationale: From a chemistry point of view, wood is a heterogeneous material whose chemical constituents vary within and between species and across spatial and temporal scales. In the context of wood and woody biomass utilisation, the dynamics of wood chemistry have huge implications on forest ecology and commercial value of the raw material. This research project comprises several field experiments conducted in parallel to evaluate how wood chemical properties change at different site

environments with emphasis on the biomass and wood chemistry. The information generated from this project may contribute to future research and development of value-added products from degraded wood resources or wood waste.

Objective:
1. To study the chemical properties of wood and leaf of selected timber species
2. To determine how chemical and physical properties of wood change during decomposition and degradation
3. To isolate and identify sap-staining fungi colonising logs in Kalabakan Forest Reserve

Studies:
1. Nutrient partitioning in trees of selected timber species
2. Decomposition of logs on the forest floor
3. Decomposition of logs at a simulated landing site
4. Survey of sap-staining fungi colonising logs at Kalabakan FR

Output:
1. Datasets on wood chemical properties
2. Research article on comparative analysis of nutrient storage and allocation in selected timber species
3. Research articles on the changes in chemical and physical properties of wood during decomposition and degradation
4. A technical note on sap-staining fungi in Kalabakan FR

Timeline: October 2018 – June 2021 for laboratory analyses. Analysis of data and writing up may take longer

Project 4.1.3: Evaluating yield of plantation logs

Investigators: Jarry K. Lajanga, Zamrie Imiyabir, Kelvin Pang, Inovwood Sdn. Bhd. (timber industry) and BFC Research & Development Sdn. Bhd.

Rationale: Currently, there is an increasing interest in the use of fast-growing plantation species to supplement/replace mix timber hardwood (MTH). There is not much concern if the target is for pulp. However, there are issues in the utilisation of plantation species for solid wood/veneer such as significant degrade due to end split, degradation of timber caused by delays to deliver logs to the mills (blue stain), and also concern over wood properties and suitability of plantation species for products.

Objective:
1. To survey the wood quality by age class of selected plantation species
2. To assess (width/length) of end splitting of logs over time (days) for selected plantation species
3. To assess the logs of selected plantation species for blue stain over time after being stored in water
4. To determine the volume recovery for products (example, veneer) at varying age-class and silvicultural treatments

Studies:
1. Survey of wood quality of selected species by age-class (resource assessment) where rapid non-destructive assessment technologies will be trialled along with the conventional methods
2. Effects of delay in log processing on plywood yield of selected plantation species

3. End split assessment over time of harvested logs of selected plantation species
4. Sawn and veneer recovery of the selected plantation species

Output:
1. Technical reports and peer-reviewed publications/presentations
2. Training of local researcher/staff in application of rapid non-destructive method to assess the wood properties of standing trees
3. Resource assessment (wood properties by age-class with particular emphasis on solid wood properties: density, stiffness, heartwood percentage)
4. Sawn and veneer recovery of the selected plantation species

Timeline: 2021 - 2025

Project 4.1.4: Fibre analysis of wood and woody biomass

Investigators: FRC & Inovwood Sdn. Bhd.

Rationale: Fibres notably cellulose, hemicellulose and lignin are becoming mainstream with uses ranging from wood-based to medical and security industries. Wood are increasingly thought to be viable sources for the fibres. Species are expected to differ in their contents of these fibres. Further, effects of age, localities and even parts of the tree would be expected. This type of information will figure quite strongly in the choice of species for plantations targeted as sources for these fibres. Baseline studies to generate and collate data on these parameters are therefore relevant.

Objective:
1. To figure out the method or methods for measurement of contents of cellulose, hemicellulose and lignin in woody material for routine analyses.
2. To study the fibre contents in wood and woody biomass of various trees species

Studies:
1. Optimisation and standardisation of methods to measure contents of cellulose, hemicellulose and lignin in woody material
2. Determine fibre contents in wood from tree species in Sabah
3. Significance of tree age, locality, provenances, etc. on fibre contents

Output:
1. Routine method for measurement of fibre content in wood and woody biomass
2. Database of fibre contents in wood or woody biomass from various tree species
3. Technical report, publications, presentations

Timeline: 2021 – 2025; Proposed (This is subject to whether or not there is the relevant equipment for the measurement, and the human capability and capacity to do so).

Project 4.1.5: Formaldehyde emission tests

Investigators: FRC & Inovwood Sdn. Bhd.

Rationale: Emission of formaldehyde from wood and wood products are becoming a major concern because formaldehyde is considered a carcinogen. Malaysia has planned to regulate formaldehyde emissions from wood-based panel products---particle/chipboards, fibreboard and plywood---with the restrictions coming under

the MTIB and to be enforced from 1 July 2020. The proposal was circulated via a WTO document No. 19-6067 in September 2019. To do the testing, the relevant lab must be accredited by APAC or ILAC. This will involve substantial input in staff and preparation of lab facilities; something FRC is not yet in the capacity to be. However, formaldehyde occurs naturally in the environment. Most living things including humans make small amounts as part of normal metabolic processes. It has been reported, although still largely anecdotal, that certain tree species emit naturally high levels of formaldehyde. A good baseline study screening species of trees in Sabah for formaldehyde emission would provide pertinent information for the local wood industry.

Objective:
1. To develop a small-scale method for routine testing of formaldehyde emission from wood-based panels
3. To develop a database of formaldehyde emission from wood-based panels according to tree species

Studies:
1. Optimisation and standardisation of formaldehyde emission testing methods
2. Study formaldehyde emission from tree species in Sabah

Output:
1. Technical note outlining an in-house protocol for testing formaldehyde emission
2. Database of species-specific formaldehyde emission from wood-based panels

Timeline: 2021 – 2025 (This is subject to whether or not there is the relevant equipment for the measurement, and the human capability and capacity to do so).

SUB-PROGRAMME 4.2: VIABILITY OF FOREST-BASED INDUSTRIES

Project 4.2.1: The role of smallholders in the wood industry

Investigators: Idea of project from DCCF/R&D; This is more toward socio-economic and suggested to be handled by the relevant programme. As commented by DCCF/R&D, the study will most probably be outsourced to private consultants but monitored by FRC.

Rationale: Several companies source their timber from private lands and/or smallholders and the contribution can be significant. Information on this contribution and capacity can help toward understanding the various streams of wood sources to the industry and how these might be optimised. Participation of community in the industry may become clearer.

Objective: To find out to what extent the contribution of smallholders and communities are to the wood industry and what the impacts are on their livelihoods

Studies: Survey of smallholders involved with the wood industry – capacity, what, how & wherefore

Output: Data; Information on contribution of smallholders to the timber resource; Technical reports, publications/presentations

Timeline: 2021 - 2025

SUB-PROGRAMME 4.3: RESEARCH & DEVELOPMENT OF NON-TIMBER FOREST PRODUCTS

Project 4.3.1: Medicinal plant research

Investigators: Dr. Noraidah Haini

Rationale: This is an on-going project documenting the medicinal plant species in Sabah and studying the ethnobotanical and phytochemical aspects of the plants. One of the important first line of investigation in looking at the potentials of a medicinal species is screening for the antioxidant properties. Information from the screening is very relevant in finding out whether or not to proceed to deeper and more complex levels of study. The project also serves as a training programme for junior researchers in developing their analytical and laboratory skills.

Objective:
1. To set up a screening protocol based on antioxidant studies
2. To establish a database on contents of phenolics and flavonoids, and antioxidant activities of selected plant species in Sabah

Studies: Total phenolic contents, total flavonoid contents and antioxidant activities of selected medicinal plant species in Sabah

Output:
1. Technical report and peer-reviewed publications/presentations;
2. Protocols for measuring contents of phenolics and flavonoids, and antioxidant activities

Timeline: 2019 - 2024

Project 4.3.2: Lianas of Sabah's forest reserves

Investigators: Zamrie Imiyabir & Jarry K. Lajanga

Rationale: The knowledge of lianas species in Sabah is lacking or hardly available. The basic information of lianas species such as distribution, morphological characteristics and anatomical features is necessary to determine their potential utilisation. In addition, morphological characteristics and anatomical features could support lianas biological aspects study and its identification purposes in the future.

Objective: To investigate the distribution, morphological characteristics and anatomical properties of lianas species in Sabah's forest reserves.

Studies:
1. Survey of Lianas species in Sabah's forest reserves
2. Morphology and anatomical features of Lianas species
3. Phenology of Lianas species
4. Potential utilisation of Lianas

Output: Scientific publications, reports and research papers for presentation in Conferences/Seminars, and Lianas samples collection (for FRC Xylarium)

Timeline: 2021 - 2025

Project 4.3.3: Non-Timber Forest Products (NTFPs) of Sabah in local tamu (open market)

Investigators: Zamrie Imiyabir, Jarry K. Lajanga & Dr. Noraidah Haini

Rationale: NTFPs have been recognised to play a major role in the livelihood of forest dependent community in Sabah. People especially local and rural communities utilised NTFPs and some also trade them in open market (tamu) throughout the state. Assessing the NTFPs which been collected and traded locally in the tamu, therefore, is important in determining other utilisation potentials and changes in availability of such resources.

Objective:
1. To determine the importance of NTFPs of Sabah.
2. To determine changes in NFTPs availability and resources

Studies:
1. Survey of NTFPs in Tamu of Sabah
2. Determine the current utilisation and other potentials of NTFPs in Sabah

Output:
1. Database of NTFPs of Sabah traded in local tamu
2. Technical reports, publications / presentations

Timeline: 2021 - 2024

Project 4.3.4: Wood anatomy and identification of medicinal plant and lesser known species in Sabah

Investigators: Jarry K. Lajanga & Zamrie Imiyabir

Rationale: For tropical forest with high species diversity, identification of the wood of the plants is very important. The high diversity of plants in Sabah means that there is an abundance of medicinal plants here, and other lesser known species. Nowadays, medicinal plants are gaining greater attention worldwide. The manufacturers of medicinal (and health supplements) need to properly identify the wood of plants that are used to make their products. Samples available for species identification are often in the form of wood components. Thus, precise identification of the wood is needed. This requires a systematic method of wood examination and identification. Ideally, a reliable features or keys should be developed which would allow identification of wood both through macroscopic and microscopic examination. Thus, anatomical features (macroscopic and microscopic) of the lesser-known species should be determined, measured and documented.

Objective:
1. To determine the wood anatomical features (macroscopic and microscopic) of medicinal plants and other tree species in Sabah.
2. To obtain the photomicrographs of wood anatomical features of medicinal plants

Study:
1. Wood anatomical features (macroscopic & microscopic) of medicinal plants in Sabah (focusing only on woody species)

2. Wood anatomical features (macroscopic & microscopic) of lesser known species

Output: 1. Technical reports, publications, posters
2. Collection of microscopic slides and photomicrographs of the medicinal plants and other tree species

Timeline: 2017 – 2025 (or, should be carried out as continuous projects subject to availability of plants that are identified or reported as having medicinal values)

Project 4.3.5: Research and conservation programme for wild gingers (tuhau) in Danum Valley, Maliau Basin, Imbak Canyon, and other forest reserves in Sabah (2021–2025)

Investigators: Dzulyana Idhamsah, Nurul Syahbillah A. Mahmud,Rolando Robert, Yayasan Sabah, & Universiti Malaysia Sabah

Rationale: *Etlingera coccinea*, known locally as Tuhau, is one of the local delicacies especially among the Kadazan-Dusun ethnics in Sabah. The locals harvest this wild ginger species from forests as a source of food and for medicinal uses. Despite claims of its medicinal properties, there is a paucity of information on the biologically active compounds responsible for its therapeutic attributes, highlighting the need for more research on aspects of its phytochemistry. Nonetheless, Tuhau is becoming increasingly popular in this region following the commercialization of several Tuhau-based food products in the market. Previously, Tuhau is harvested from the wild for subsistence; against the backdrop of higher commercial demands, there is a potential risk of overharvesting of natural populations that warrants conservation measures. Extirpation has even been reported in several sites in eastern Sabah (Dr. Noreen M./Dr. Yap SW, 2021—pers. comm.). To address current knowledge gaps in research and conservation status of Tuhau in Sabah, the overarching aim of this project is to characterise the intraspecific biodiversity of local Tuhau (*Etlingera coccinea*) with respect to its genetic make-up, biochemical phenotypes, and characteristics of their habitats.

Objective: 1. To establish reference DNA barcodes of wild gingers (family Zingiberaceae) in Sabah with emphasis on endemic taxa
2. To infer the population genetic structure of Tuhau (*Etlingera coccinea*) in Sabah and to identify distinct conservation units among the local population
3. To isolate and characterise the secondary metabolites and potentially bioactive compounds in wild Tuhau
4. To characterise the biological activity of Tuhau extracts in-vitro

Studies: 1. Molecular phylogenetics of wild gingers (family Zingiberaceae) and population genetic structure of Tuhau (*Etlingera coccinea*) in Sabah
2. Variability in secondary metabolites and bioactive compounds of wild Tuhau (*Etlingera coccinea*) in Sabah

Output: 1. Reference DNA barcoding sequences for wild gingers
2. Novel microsatellite markers for population genetic studies of Tuhau
3. Library of solvent extracts of Tuhau
4. Information on the biological properties of Tuhau extracts

Timeline 2021 – 2025

Project 4.3.6: Impacts of land-use change on the taxonomic and functional diversity of soil bacteria in lowland forests of Sabah

Investigators: Rolando Robert; Prof. Vijay Kumar, Dr. Cahyo Budiman (Universiti Malaysia Sabah)

Rationale: Phosphorus (P) is a limiting nutrient in most tropical forests and particularly in managed landscapes. Biological and biochemical transformation of P is the main process making P available to plants and these processes are mediated chiefly by soil microbes (i.e., fungi, bacteria, and archaea). The soil microbiome plays an important role in mobilising P by producing enzymes and other secretory products such as organic acids and siderophores that mineralise organic P and desorb P bound to aluminium and iron minerals. The molecular pathways for these secretory products is well characterised in bacteria than in other microbes. By using soil bacteria as the model organism, this study aims to investigate how disturbance and conversion of lowland forests in Sabah alter the biological and functional properties of the soil with emphasis on P cycling.

Objective:
1. To determine the changes in taxonomic and functional diversity of soil bacteria along a gradient of land use in the vicinity of Sungai Tangkulap, Sabah
2. To determine the ability of bacteria isolated from soils in Sungai Tangkulap to mobilise soil nutrient and improve plant nutrient uptake

Studies:
1. Impacts of land-use change on the taxonomic and functional diversity of soil bacteria in a lowland forest in Sabah
2. Screening of soil bacteria capable of utilising multiple sources of phosphorus and testing their viability as soil bioinoculants

Output:
1. Technical report and peer-reviewed publications/presentations;
2. Collection of bacterial isolates capable of mobilising phosphorus for further studies on biotechnological applications

Timeline 2020 – 2024

SUB-PROGRAMME 4.4: METHOD DEVELOPMENT

Project 4.4.1: Development and optimisation of laboratory methods

Investigators: Chemistry Section

Rationale: Analytical methods including instruments employed in the process evolve continuously to further improve the accuracy and precision of the results. The development of new methods or adaptation of current ones entails comparing the performance of the methods or verifying their reproducibility with independent replicates, extensive cross-contamination control, and rigorous statistical tests.

Objective: To adapt, optimize and standardize measurements to produce results with consistent precision and repeatability

Studies:
1. Effects of grinding method on the multi-element analysis of plant samples
2. Effects of sieving method on the soil texture analysis
3. Comparing methods of measurement of phosphorus with different instruments

Output:
1. Technical notes or short communications; Publications/presentations
2. Protocols to measure total contents of multi-element analysis of plant sample by using different grinding method, sieving method on the soil texture analysis and measurement methods of phosphorus analysis.
3. Research datasets of total contents of elements in plants and soil texture analysis classes.

Timeline: 2020 - 2023

Project 4.4.2: Investigation of other methods on evaluation of wood properties

Investigators: Jarry Lajanga & Zamrie Imiyabir

Rationale: Current method of determining wood properties (destructive method) is rather time consuming with the need to fell many trees to obtain wood samples for the tests. With the advancement in technology and equipment, it is potentially possible to identify other means to carry out these activities. With funding under the RMK11, a tree acoustic tomography has been proposed for non-destructive evaluation on wood strength of standing trees.

Objective: To determine the potential of non-destructive methods in evaluating wood properties of selected species

Studies: Non-destructive evaluation of the wood properties of selected plantation species (involving various techniques including vibration, acoustic, stress wave, ultrasonic and electromagnetic methods to assess the wood properties).

Output:
1. Alternative method or protocol for evaluation of wood quality
2. Technical report or research publication/presentation
3. Another means to enhance service to industries/public (rapid resource assessment)

Timeline: 2021 – 2025 or beyond, based on the related technology developments

Analytical & Technical Services

Activity 1: Reference Wood Collection (Xylarium)

Investigators: Wood Science Section

Description: The curated wood collection in the FRC Xylarium was established in the early 1940s and is continuously expanded since. The curated samples correspond to the SAN Herbarium accessions that together serve as one of the primary references for taxonomic identification of trees in Sabah. Maintaining the collection requires substantial effort in time and human resource.

Output: Physical collection of primary vouchers consisting wood samples and microslides as well as photomicrographs serving as secondary vouchers

Timeline: Continuous / On-going

Activity 2: Wood identification and preparation of authenticated wood samples

Investigators: Wood Science Section

Description: This service is provided for SFD District Forestry Officers, timber industries, and the public. A part of the service includes sales of authenticated wood samples prepared according to the standards stipulated by the International Association of Wood Anatomists (IAWA).

Output: Technical reports and provision of authenticated wood samples

Timeline: Continuous / On-going

Activity 3: Analysis of ecological samples

Investigators: Chemistry Section

Description: The service comprises analysis of chemical and physical properties of soil, plant, and water samples. The samples analysed are from researchers from within the Sabah Forestry Department and from those collaborating with the department.

Output: Data and technical reports from laboratory analyses

Timeline: Continuous / On-going

5. FOREST SOCIO-ECONOMICS

SUB-PROGRAMME 5.1 – FOREST SOCIO-ECONOMICS

Project 5.1.1: A socio-economic evaluation of Sabah's Permanent Forest Estate (PFE)

Investigators: Dr. Robert Ong, Jaffirin Lapongan, Jarry K. Lajanga & Elne Betrece Johnlee

Background: Sabah covers an area of about 7.4 million hectares, of which 3.8 million hectares are legally designated for forest use. These 3.8 million hectares are made up of forest reserves, state parks and wildlife sanctuaries, and are collectively referred to as Permanent Forest Estate (PFE). The PFE is principally managed by three government agencies, namely the Forestry Department, the Sabah Parks, and the Wildlife Department.

Apart from its crucial importance to biodiversity conservation and environmental protection, the PFE is also an important socio-economic resource for Sabah. It has been an important source of revenue for Sabah, generated largely from timber production and tourism related activities. In addition, it attracts external funding from various sources of projects and activities related to forest restoration and research, thus creating employment opportunities and livelihoods associated with a broad array of skills. Such projects also see the involvement of local and international NGOs, who depend largely on external funds to support their work.

Rationale: There are obviously shortcomings and knowledge gaps in the evaluation of forestry sector's contribution to Sabah's Gross Domestic Product (GDP), let alone the contribution of the PFE per se. The official data on the forestry sector is often lumped together in one category, namely Agriculture, Forestry and Fishing. Such highly aggregated data does not provide a clear picture on the role and importance on the forestry sector. For this reason, the economic contribution of the forestry sector is grossly undervalued, given that the existing national accounting method only accounts for activities in the formal forestry sector (e.g. logging, production and processing of timber and non-timber forest products); and their direct economic impacts on the state's economy.

The economic contribution of Sabah's PFE should be considerably higher if forest related tourism and recreational activities; provision of raw materials as input to the industry, transport, utilities (energy, water), professional services (accounting, auditing, certification, environment management, banking, insurance, consultancy and R&D); and informal employment and subsistence activities in the forest industries are taken into account.

To generate critical inputs to the strategic planning process for the forestry sector in Sabah, the economic importance of the sector must be properly ascertained. In order to protect and maintain the integrity of the PFE, as

matter of government policy, there is a need to quantify the value of PFE in a more comprehensive manner that more accurately reflects its socio-economic value.

Objectives:

1. To quantify the value of the PFE in a more comprehensive manner that more accurately reflects its socio-economic value.
2. To review the existing socio-economic data collection and compilation approaches and methods employed by the relevant government agencies.

Methodology: This study will include survey for the ecotourism industry players comprising of tour operators, lodgers, resorts and many more, key informant interviews and secondary data collection by referring to past reports and publications.

A consultant is appointed to carry out the following specific tasks:

a) Meet/interview with the relevant government agencies (Sabah Forestry Department, Wildlife Department, Sabah Parks) to discuss scope of study and data requirements;
b) Analyse the published and unpublished data provided by these agencies;
c) Map out the Forestry sector's supply chains and identify key stakeholders;
d) Interview key stakeholders;
e) Facilitate and act as resource person in stakeholder/focus group workshop;
f) Review the existing data collection and compilation approaches and method employed by relevant government agencies and Department of Statistics of Malaysia;
g) Identify gaps and weaknesses in the existing data collection and compilation approaches and methods and make recommendations to address those gaps/weaknesses;
h) Prepare and present the Inception, Interim and Final Reports.

Output:

1. Publications, presentations and reports on socio-economic evaluation of Sabah's Permanent Forest Estate.
2. Database of demographic status and socio-economic aspect of the local community and stakeholders in the Permanent Forest Estate.

Timeline: 2020-2021

Remarks: In line with Sabah Forest Policy Thrust 4 (objective 5) and 18th MFC Resolution 3.2 and 3.3

Project 5.1.2: Social Impact Assessment (SIA)

Study 1: A case study of the proposed development of the Sukau Bridge in Kinabatangan

Investigators: Elne Betrece Johnlee, Jaffirin Lapongan & Jarry Lajanga

Rationale: This study will help in identifying the positive and negative impacts of the

proposed project towards the surrounding community and stakeholders. And also find out the views of affected people, whether they agree or disagree on the development of the project. Impact assessment helps promotes community development and empowerment, builds capacity, and develops social network and trust. The goal is to bring about more ecologically, socio-culturally and economically equitable environment.

Objectives:

1. To develop a socio-economic profile characterizing the proposed development of Sukau Bridge
2. To identify and analyze socio-economic impact, risk and opportunities of the proposed development of Sukau Bridge on the surrounding community
3. To collect representative views of the surrounding community and stakeholders involved on the proposed development of Sukau Bridge

Output: Social Impact Assessment Study Report

Timeline: 2020 - 2021

Remarks: In line with Sabah Forest Policy Thrust 5 (Objective 1) and 18th MFC Resolution 3.2 and 3.3.

Project 5.1.3: Socio Economic Evaluation of Forest Adjacent Communities

Study 1: Socio-economic evaluation and community's views and perception on forest conservation in adjacent forest reserve in Sabah

Investigators: Elne Betrece Johnlee, Jaffirin Lapongan & Jarry Lajanga

Rationale: There are many stakeholders involved in the management of the forest, including local communities, government organisations, non-government organisations, researchers, regional and district councils and others. They have a significant role in forest management activities and economy development of the area. There is a need for further information on the current status of land, particularly related to the human population living in the area in which these areas have the potentials to be further protected. A participatory appraisal of community livelihoods and aspirations amongst the local communities is needed to evaluate their capacity and willingness to support environmental protection and their dependency on the resources and different perception of how the forests should be managed and utilised.

Objectives:

1. To study the socio-economic and livelihoods status of communities living within and adjacent to the forest reserve
2. To evaluate the local community capacity and willingness to support management regimes aimed at increased conservation of the target forest

Timeline: 2020 – 2021

Output: Research papers and study reports

Remarks: In line with Sabah Forest Policy Thrust 5 (Objective 1) and 18th MFC Resolution 3.2 and 3.3.

Study 2: Socio-economic evaluation and contribution of mangrove forest towards the surrounding local communities in Sabah

Investigators: Elne Betrece Johnlee, Jaffirin Lapongan & Jarry Lajanga

Rationale: Contribution of mangroves to the livelihood of coastal communities is often ignored and receives little recognition from the policy makers and practitioners. There is lack of information available on the mangrove goods and quantity extracted, processed or sold (Narendran et al., 2001; Delang, 2006). Mangrove ecosystem provides goods and services that contribute to the human well-being, directly and indirectly (Vo et al., 2012). The findings of this study can serve as proof that the forest including mangrove helps to generate income for the local community and also contribute to the country's economy.

Objectives:
1. To study the socio-economic and livelihoods status of communities living near mangrove forest
2. To identify goods and services obtained from the mangrove forest and determine its value based on income derived by the local community

Timeline: 2020 – 2022

Output: Research papers and study reports

Remarks: In line with Sabah Forest Policy Thrust 4 (objective 4) & 5 and 18th MFC Resolutions 3.2 and 3.3.

Project 5.1.4: The viability of planting rubber as a commercial crop in forest reserves in Sabah

Investigators: Dr. Robert Ong, Jarry K. Lajanga, Jaffirin Lapongan & Elne Betrece Johnlee

Rationale: Rubber trees have been planted in some of the Forest Management Units (FMUs) which are managed by the Sustainable Forest Management License Agreement (SFMLA) holders; and some alienated land planted by smallholders in Sabah. There is a need to study the social and economic impact of the planted rubber in order to determine the viability of rubber trees as a commercial crop in the class II Forest Reserve. The data gathered from this study will also be useful for the Sabah Forestry Department to determine the royalty that have to be paid by the SFMLA holders if they are planting rubber within their FMU.

Objectives:
1. To determine the socio-economic importance of rubber as a commercial agricultural crop in the Class II Forest Reserve; and
2. To determine the importance of rubber cultivation as a means of livelihood for smallholders.

Methodology:

- Compare latex yield of both SFMLA holders and small holders;
- Assess the influence of rainfall on yield;
- Identify areas most suitable for rubber cultivation at the state level;
- Determine the cost of latex production for selected SFMLA license holders;
- Carry out financial analyses to compare rubber, oil palm and timber tree plantation as commercial crops;
- Determine the effectiveness and importance of government subsidies in rubber cultivation;
- Determine factors influencing the local market pricing for rubber;
- Carry out a profile analyses of rubber smallholders in Sabah.

Timeline: 2022 -2024

Output: Research papers and reports on socio-economic evaluation of planted rubber by SFMLA holders and smallholders.

Remarks: In line with Sabah Forest Policy Thrust 4 and 18th MFC Resolutions 4.3 and 4.4

SUB-PROGRAMME 5.2 – NATURE TOURISM

Project 5.2.1: Evaluation of the ecotourism potential of selected forest reserves in Sabah

Investigators: Jarry K. Lajanga, Jaffirin Lapongan & Elne Betrece Johnlee

Rationale: The tourism sector has generated high economic return for Sabah where the tourist focus is mainly towards the ecotourism attractions in Sabah. The influx of tourists also provides economic opportunity for the local people to operate business related to tourism sector. To accommodate the increasing number of tourists to Sabah, new and potential tourism products should be introduced. Forest reserves in Sabah that have the potential as ecotourism attraction can be developed as tourism product and this in turn will increase the economic return in tourism sector for Sabah.

Objectives:
1. To survey, assess and document interesting spots / aspects in selected forest reserves in Sabah.
2. To provide data for forest management plan.

Timeline: 2020 – 2025

Output:
1. Ecotourism potential in selected forest reserves in Sabah have been identified.
2. Publications, presentations and reports on ecotourism potential in selected forest reserves in Sabah.

Remarks: In line with Sabah Forest Policy Thrust 4 (Objective e) and 18th MFC Resolutions 3.2 and 3.3.

Project 5.2.2: Survey on the interesting forest trails in Sabah

Investigators: Dr. Robert Ong, Jarry K. Lajanga, Jaffirin Lapongan & Elne Betrece Johnlee

Rationale: Hiking activity is gaining popularity among locals as well as the tourist. Forest trail development has been established in forestry area around Sabah. However, to date, there are no trail assessment studies have been conducted on the trails. With the trail assessment documentation generated through this study, it will make it easier for recreational goers to plan their trip, while at the same time, the trail documentation can help to promote the forest recreation site.

Objectives:
1. To survey, assess and record interesting forest trails in Sabah.
2. To promote interesting forest trail as a recreational area.

Timeline: 2021 – 2023

Output:
1. 20 interesting forest trails in Sabah have been surveyed.
2. Publications of a guide book on interesting forest trail in Sabah, including

the trail mapping and general information of the forest trail area.

Remarks: In line with Sabah Forest Policy Thrust 4 and 18th MFC Resolutions 3.2 and 3.3.

Project 5.2.3: Economy contribution from bird watching activity at the major bird watching locations in Sabah

Investigators: Dr. Robert Ong, Jarry K. Lajanga, Jaffirin Lapongan & Elne Betrece Johnlee

Rationale: Tourism economic data, usually presented as a general data, such as the arrival of tourists and the period of stay. Normally specific data of the tourist expenses, rarely can be found. There are need for more data for tourist expenses, as guideline in developing tourism infrastructure in a systematically way. By completing this study, hopefully it can be a supportive data for more precise development on the facilities needed in supporting the bird watching industry.

Objectives:

1. To get economy contribution data of the bird watching activity at the major bird watching locations in Sabah, namely Rainforest Discovery Centre, Deramakot Forest Reserve, Danum Valley Conservation Area, Tabin Wildlife Reserve, Kinabalu Park, Kinabatangan and Maliau Basin Conservation Area.
2. To promote bird watching area in Sabah.

Timeline: 2022 – 2025

Output:

1. Economy contribution data of bird watching activity at the major bird watching location in Sabah.
2. Publications, presentations and reports on economy contribution from bird watching activity at the major bird watching location in Sabah.

Remarks: In line with Sabah Forest Policy Thrust 4 and 18th MFC Resolutions 3.2 and 3.3.

COLLABORATION WITH FOREIGN RESEARCHERS / RESEARCHERS OUTSIDE SFD* FROM 2019 ONWARDS

(*not listed in the core research programmes)

No.	Local collaborator(s) / collaborator via MoU	Project title	Researchers (Institution)	Year
1	Alexander Hastie	Forecasting impacts of drought on human-modified tropical forest by integrating models with data	• Dr Tomasso Jucker (Bristol University, UK)	2019–2024
2	Alviana Damit	Systematic study of Araceae in Sabah	• Jyloerica Joling (Universiti Malaysia Sarawak)	2020
3	Anuar Mohammad Maria Ajik Kelvin Pang K.N. & other researchers of the Forest Plantation Programme	Forest plantation taxa trial	• Paul Warburton (Borneo Forestry Cooperative)	2020
4	Andi Maryani A.M.	Phylogeny, evolution and biogeography of genera *Oreogrammitis, Radiogrammitis* and *Themelium* (Polypodiaceae)	• Dr Nipuni Sirimalwatta (University of Hawaii)	2019
5	Andi Maryani A.M.	Genetic variability of Athyriaceae in Malaysia	• Nur Aliah mohd. Khaduwi (UKM)	2019
6	Andi Maryani A.M.	A taxonomic revision of Malaysian Lejeuneaceae (Marchantiophyta)	• Dr Lee Gaik Ee (Universiti Malaysia Terengganu)	2019
7	Andi Maryani A.M. Geofarry Gunsalam (Sabah Parks)	Contributing to the fern flora of Sabah, with special references to Grammitid and Vittarioid	• Cheng Wei Chen (Taiwan Forestry Research Institute) • Dr Kuo-Fang Chung (Biodiversity Research Center, Academia Sinica, Taiwan) • Dr. Yi-Shan Chao (School of Life Science, National Taiwan Normal University)	2020-2023
8	Andi Maryani A.M.	Restoration and enhancement of orangutan (*Pongo pygmaeus*) and Bornean banteng (*Bos javanicus lowi*) food plants	• Datuk Dr. John Payne • Dr Zainal Zahari Zainuddin • Mohamad Farqhan Bin Kelana • Mellinda Jenuit • Alvin Erut • James Bin Sandiyang • Ronald Jummy @	2021-2023

			Kuramat • Hassan Bin Sani • Davidson Kuntil • Eddy Masel • Mohamad Soprih Bin Amdan • Maslin Bin Mohiddin (BORA: Bringing Back Our Rare Animals / Borneo Rhino Alliance Bhd)	
9	Andi Maryani A.M.	Diversity and taxonomy of rainforest herbaceous plants in Sabah	• Dr Martin Dancak • Dr Michal Hrones • Alena Uvirova (Palacky University in Olomouc, Czech Republic)	2023
10	Dr Arthur Chung	SAFE Project - Invertebrate communities: the effect of rainforest modification on invertebrate diversity and function	• Prof Rob Ewers (Leader) • Ross Gray • Nichar Gregory • Emma Mackintosh • Maisie Vollans • Catherine MacLean • Frederica Poznansky • Calvin Leung Tsz Kin (Imperial College London, UK)	2019-2025 2019 2019 2019 2019 2019 2019 2020-2021
11	Dr Arthur Chung	Effects of tropical forest modification on above-below ground interactions and invertebrate food webs	• Dr Eleanor Slade (Nanyang Technological University, Singapore)	2019-2021
12	Dr Arthur Chung	A guide to dung beetles from lowland Sabah, Borneo	• Dr Jonathan Parrett (Oxford University, UK)	2019-2020
13	Dr Arthur Chung	The impacts of tropical forest degradation and fragmentation on ant-plant mutualisms, and consequences for plant community dynamics	• Dr Mickal Houadria • Dan Lestina • Nichola Sarah Plowman (Biology Centre of the Czech Academy of Sciences, Czech Republic)	2019
14	Dr Arthur Chung	Study on stick insect diversity and taxonomy in Sabah	• Prof Francis Seow-Choen (LKC-Natural History Museum, Singapore)	2019
15	Dr Arthur Chung	Research on forest insects in Sabah	• Dr Steven Bosuang (Kipandi Park, Sabah)	2019
16	Dr Arthur Chung	Community assembly in old-growth tropical forest	• Dr Hannah Griffith • Dr Kate Parr (Uni. of Liverpool, UK) • Dr Paul Eggleton (Natural History Museum, London)	2019-2021 2019 2019
17	Dr Arthur Chung	How does the relationship	• Josie Phillips	2019

		between biodiversity and ecosystem function change as rainforest is converted to oil palm?	• Dr Farnon Ellewood (University of the West of England, UK)	
18	Dr Arthur Chung Andi Maryani A.M.	Systematics of *Bactrocera* fruit flies	• Prof Dr Daniel Rubinoff • Dr Camiel Doorenweerd (University of Hawaii, USA)	2019
19	Elne Betrece Johnlee	Sabah Social Forestry and Climate Change	• Gordon John Thomas (PACOS Trust) • Dr. Daisuke Naito (Kyoto University, Japan) • Dr. Moira Moeliono (Center for International Forestry Research, Indonesia) • Dr. Walter Lintangah (Universiti Malaysia Sabah) • Hardawaty Yahya (Universiti Malaysia Sabah)	2018 - 2022
20	Eyen Khoo	Evaluation of loss of large animals on large seeded-plants and figs in Sabah	• Dr Miyabi Nakabayashi (Hiroshima University, Japan)	2019-2021
21	Dr Joan Pereira	Phylogenomics of Moraceae, and convergent evolution of biotic pollination in wind-pollinated angiosperm linages: a functional and genomic exploration of a rare transition	• Dr Elliot Gardner • Shuai Liao (The Morton Arboretum, USA)	2019-2020
22	Dr Joan Pereira	Taxonomic studies on the family Acanthaceae from Sabah	• Prof Deng Yun Fei • Prof Ge Xuejun • Sunan Huang • Assoc Prof Zheli Lin • Assoc Prof Shixiao Luo • Asst Prof Pu Zuo (South China Botanical Garden, Chinese Academy of Sciences)	2019-2020
23	Dr Joan Pereira	Taxonomic accounts for Flora Malesiana-Malvaceae subfamily Dombeyoideae and flora of Sabah – follow up investigation on putative new species of *Garcinia* growing on ultramafic substrate	• Dr S.K. Ganesan (Singapore Botanical Garden)	2019
24	John Sugau Dr Joan Pereira Eyen Khoo	Research on ornamental plants & other plants of conservation interest in Sabah	• Dr Steven Bosuang (Kipandi Park, Sabah)	2019

25	John Sugau Matsain Mohd. Buang (Sabah Parks)	The phylogeny and distribution patterns of the Nepenthaceae in Sabah	• Hoo Pui Kiat (Universiti Malaysia Sabah)	2019-2020
26	John Sugau Dr Elia Godoong (UMS)	Taxonomy and phylogeny of the Sterculiaceae in Sabah	• Muhd. Ali Zulhazim Rosli • Dr Elia Godoong • Dr Berhaman Ahmad • Dr Colin Maycock (Universiti Malaysia Sabah) • Rimi Repin (Sabah Parks)	2020
27	John Sugau Rimi Repin (Sabah Parks)	Diversity, systematics and conservation strategies for orchids from disturbed and undisturbed forests in Sabah	• Edward Entalai Besi • Dr Rusea Go (Universiti Putra Malaysia)	2020
28	John Sugau	Long-term vegetation dynamic of tropical rainforests in Deramakot in relation to forest management	• Dr Nubuo Imai (Tokyo Uni. of Agriculture) • Dr Ryota Aoyagi (Forestry & Forest Products Research Institute) • Prof Kanehiro Kitayama (Kyoto University)	2020-2021
29	Dr Joseph Tangah	Tropical rainforests in human-modified landscapes: biodiversity, forest regeneration and carbon storage at forest edge	• Jacob A. Anderson (University of York, UK)	2019
30	Dr Joseph Tangah	Effects of forest fragmentation and habitat quality on the conservation of primates in Lower Kinabatangan	• Dr Ikki Matsuda • Prof. Hiromichi Fukui (Chubu University, Japan) • Dr Shin Watanabe (Ryukus University, Japan)	2020
31	Julsun Sikui	Amphibian and leaf litter arthropod community responses to logging in production forests	• Dr Sami Asad (Leibniz Institute for Evolution & Biodiversity Science, Germany)	2019
32	Julsun Sikui	Plant community dynamics across a forest disturbance gradient in Sabah, Malaysia	• Dr Martin Svatek (Mendel University, Czech Republic)	2019–2021
33	Julsun Sikui	The view from below: the technical capabilities and social implications of drones for forest conservation and monitoring	• Benjamin R. Newport (University of Bristol, UK)	2020
34	Julsun Sikui Dr Kalsum M. Yusah (UMS)	Impacts of liana cutting on logged forest structure, diversity and composition	• Patrick G. Cannon • Robert w. Davies • Daniel Simonsen • Lucy B. Watson (University of Sheffield, UK)	2020
35	Mohd. Aminur Faiz S.	The vulnerability of large	• Dr Paulo Bittencourt	2019

	Dr Reuben Nilus	tropical trees to water stress in a changing climate	(University of Exeter, UK)	
36	Mohd. Aminur Faiz S. Dr Reuben Nilus	Will environmental change affect plant hydraulic and carbon trade-offs in tropical forest trees?	• David C. Bartholomew • Dr Lucy M. Rowland (University of Exeter, UK) • Philip B. Nelson (Uni. of Arbedeen, UK)	2019-2021 2019-2020
37	Mohd. Aminur Faiz Suis	Using plant hydraulic scaling to predict the drought vulnerability of the world's tallest tropical trees	• Dr Paulo Bittencourt (University of Exeter, UK)	2022
38	Mohd. Aminur Faiz Suis	Monitoring wild cats and their prey in key forest reserves	• Roshan Guharajan • Thye Lim Tee (Panthera Malaysia)	2021 – 2022
39	Mohd. Aminur Faiz Suis	Using plant hydraulic scaling to predict the drought vulnerability of the world's tallest tropical trees	• Paulo Bittencourt (University of Exeter, UK)	2022-2023
40	Mohd. Aminur Faiz Suis	Monitoring wild cats and their prey in key forest reserves	• Roshan Guharajan • Thye Lim Tee (Panthera Malaysia)	2021 – 2023
41	Mohd. Aminur Faiz Suis	Wildlife responses to forest phenology assessed with remotely piloted aerial vehicles in Sabah, Borneo (Malaysia)	• Adi Shabrani bin Mohammad Ridzuan (University of Montana)	2022-2023
42	Mohd. Aminur Faiz Suis	ForestScan: new technology for characterising forest structure and biomass	• Amy Clare Bennett (University of Leeds)	2022-2023
43	Mohd. Aminur Faiz Suis	Tropical forest recovery along a land-use gradient in Malaysian Borneo	• Martin Svatek (Mendel University in Brno)	2022-2023
44	Mohd. Aminur Faiz Suis	Linking wood anatomical properties to drought tolerance in tropical trees across the edaphic gradient	• Palasiah Jotan (Czech University of Life Sciences Prague)	2022-2023
45	Dr Noreen Majalap Rolando Robert	Decomposition of deadwood debris left over from tropical rainforest logging operations	• Dr Terhi Riutta (Oxford University & Imperial College London, UK)	2019-2020
46	Dr Noreen Majalap	Biodiversity and land-use impacts on tropical ecosystem function (BALI): quantifying biogeochemistry across forest disturbance gradients in Sabah	• Dr Terhi Riutta (Oxford University & Imperial College London, UK)	2019-2020

47	Dr Noreen Majalap Rolando Robert	The importance of soil nitrogen in the functioning of tropical heath forests	• Giacomo Sellan • Dr Francis Brearley (Manchester Metropolitan University)	2019-2020
48	Dr Noreen Majalap	El Nino Southern Oscillation (ENSO) effects on water use efficiency and tree ecophysiology	• Nara Vogado • Alex Cheesman (James Cook University)	2019-2020
49	Dr Noreen Majalap	Weighing trees with lasers: reducing uncertainty in tropical forest biomass and allometry	• Alex Shenkin (University of Oxford) • Phil Wilkes • Andrew Burt (University College London)	2019-2020
50	Dr Noreen Majalap	A 3D perspective on the effects of topography and wind on forest height and dynamics	• Tobias Jackson (University of Cambridge)	2019-2020
51	Nur Syafiqah S.K. Pg. M. Sahlan P.S. Razy Japir	Baseline survey of aquatic and terrestrial fauna in Deramakot & Kabili-Sepilok Forest Reserves, Sabah, East Malaysia	• Dr Tan Heok Hui • Dr Chan Kin Onn • Dr Wendy Wang Yanling • Dr Ng Ting Hui • Dr Ang Yuchen • Dr Hwang Wei Song • Tan Siong Kiat • Dr Wan Faridah Akmal W.J. • Foo Maosheng • Muhd. Dzaki Safaruan • Iffah Lesa • Siti Maimon Hussin • Ruzaini Ghazali • Dr Jose Christopher E.M. (LKC-Natural History Museum, Singapore)	2020-2021
52	Pg. M. Sahlan P.S.	The Bornean carnivore programme: application of landscape genetics to measure population structure and connectivity of Sunda clouded leopards and sympatric threatened carnivores in Sabah	• Dr Andrew Hearn • Chrishen R. Gomez (Oxford University, UK) • Dr Vijay Kumar (Universiti Malaysia Sabah)	2019-2020
53	Pg. M. Sahlan P.S.	The Bornean carnivore programme: exploring animal health in a human dominated landscape	• Dr Andrew J. Hearn • Dr Paloma E. Alcazar (Oxford University, UK) • Dr Noor Haliza Hasan (Universiti Malaysia Sabah)	2019-2020
54	Razy Japir Dr Arthur Chung	Contribution to the taxonomy and ecology of	• Dr Tan Ming Kai (Institut de Systématique,	2019-2021

		Orthoptera in eastern Sabah	Evolution et Biodiversité (ISYEB), Paris, France)	
55	Razy Japir Dr Arthur Chung	Riparian protection versus pest and disease control in oil palm plantations	• Dr Chiew Li Yuen (SEARRP) • Dr Eleanor Slade (Nanyang Technological University, Singapore)	2021-2022
56	Razy Japir Dr Arthur Chung	Diversity and distribution of mantids, phasmids and cockroaches of Borneo	Dr Philip Edward Bragg (Independent researcher)	2022-2023
57	Razy Japir Dr Arthur Chung	The distribution of species along elevation gradients: the impact of traits, phylogeny and climate change	• Dr Eleanor Slade (Nanyang Technological University, Singapore)	2022 -2023
58	Razy Japir Dr Arthur Chung	Effects of habitat modification and fragmentation: a re-survey of sung beetles at the SAFE sites	• Dr Chiew Li Yuen (SEARRP) • Dr Eleanor Slade • Yim Wen Han Marx (Nanyang Technological University, Singapore)	2022-2023
59	Razy Japir Dr Arthur Chung	The status of *Pteroptyx* (Coleoptera: Lampyridae) firefly in Sabah	• Vickly Mobilim • Dr Mahadimenakbar Dawood • Dr Liew Thor Seng (Universiti Malaysia Sabah) • Dr Wan Faridah Akmal Jusoh (LKC-NHM, Singapore)	2023
60	Dr Reuben Nilus	A comparative study of tropical forest dynamics considering variation in elevation, forest type and human disturbances	• Dr Kazuki Miyamoto (Forestry & Forest Products Research Institute, Japan) • Prof Shinichiro Aiba (Kagoshima University, Japan) • Prof Kanehiro Kitayama (Kyoto University, Japan) • Dr Ryota Aoyagi (Forestry & Forest Products Research Institute, Japan)	2019
61	Dr Reuben Nilus	Plant community composition across life-stages in logged tropical forests: implications for long-term recovery	• Robin Hayward (University of Stirling, UK)	2020
62	Dr Reuben Nilus	SAFE Project – tree communities: the effect of rainforest fragmentation and above ground vegetation	• Dr Robert Ewers • Dr Lan Qie • Ross Gray • Emma-Lee L. Peterson	2019-2025 2019 2019 2020-2021

		structure and composition	• Maria B. Mills (Imperial College London, UK)	2020-2021
63	Dr Reuben Nilus	Three-dimensional structure of the world's old-growth forests	• Dr Martin Ehbrecht (University of Goettingen, Germany)	2019-2020
64	Dr Robert Ong	Monitoring fruit-vertebrate interactions	• Dr Jedediah Brodie (University of Montana, USA)	2020
65	Dr Robert Ong	Exploring intra-specific functional trait diversity and community stability under drought	• Dr Michael O'Brien (Southeast Asia Rainforest Research Partnership - SEARRP)	2019-2020
66	Dr Robert Ong	Terrestrial vertebrate responses to resource dynamics	• Peter J. Williams (University of Montana, USA)	2019-2020
67	Dr Robert Ong Johnny Kissing	The direct effects of logging on large terrestrial mammals in Deramakot Forest Reserve	• Seth Wong (Leibniz Insttute for Zoo and Wildlife Research)	2019
68	Rolando Robert	The importance of soil nitrogen in the functioning of tropical heath forests	• Dr. Giacomo Sellan (Laboratoire Ecologie, Evolution, Interactions des Systèmes Amazoniens) • Dr. Francis Q. Brearley (Manchester Metropolitan University)	2021 – 2022
69	Rolando Robert	Investigating the accuracy of stem respiration estimates: scaling methods, and vertical and diurnal variation	• Maria B. Mills (University of Leicester) • Dr. Terhi Riutta (University of Oxford)	2023 – 2024
70	Suzana Sabran	Ensuring the future of perennial crops in S.E. Asia in a context of global change: case of *Garcinia* fruit tree species	• Yao Tze Leong (Universiti Putra Malaysia)	2020
71	Suzana Sabran	Systematics of the genus *Erycibe* Roxb. (Convolvulaceae)	• Pongsakorn Kopchaiphat (Mahidol University)	2020

FRC SCIENTIFIC REFERENCE COLLECTIONS

Scientific reference collections (e.g. herbarium, insect collection, xylarium) are fundamental supporting facilities for forestry related research. The collections themselves are ways of promoting *ex-situ* conservation of biodiversity. The herbarium which currently houses about 11,000 plant species from more than 276,000 specimens, is among the largest collections in this region. The insect collection has more than 180,000 mounted specimens of over 18,000 species, is the largest in Sabah. The xylarium houses more than 5,630 wood samples from over 1,070 species. FRC has just started the scientific collection of fishes (some 76 species from more than 100 specimens) and frogs (over 50 species from 70 specimens). All these facilities contribute significantly to the on-going research not only at the Forest Research Centre but throughout the world. Many visiting scientists and university students use the collections for their research work.

Facility 1: Plant Collection (Herbarium)

Section-in-charge: Systematic Botany
Objectives: To curate plant specimens collected from the forests of Sabah
Status: On-going
Results: The herbarium is the centre of botanical reference for various researchers and students. At the moment, the herbarium houses about 11,000 plant species from more than 276,000 specimens.

Facility 2: Insect Collection (FRC Insect Museum)

Section-in-charge: Entomology
Objectives: To curate insect specimens collected from the forests in Sabah
Status: On-going
Results: The museum is the centre of reference for various entomologists and students, either from local or foreign institutions. The insect museum currently houses more than 180,000 mounted specimens with more than 18,000 identified species. It is divided into two parts, namely the insect exhibition at the main FRC Complex and the main insect collection in a compactor system at the former Institut Perhutanan Sabah (IPS) building.

Facility 3: Wood Collection (Xylarium)

Section-in-charge: Wood Science
Objectives: To store wood samples from various timber species in Sabah. The collection (established 1940s) serves as a reference for researchers and students.
Status: On-going
Results: A reference collection of wood samples and microslides, as well as photomicrographs. At this stage, the collection houses more than 1,074 species from 5,556 samples.

Facility 4: Fish & Frog Collection

Persons-in-charge: Nur Syafiqah S. Kamal & Pg. Sahlan Pg. Salam
Objectives: To store fish and frog specimens from various forest reserves in Sabah. The collection will serve as a reference for researchers and students.
Status: recently established
Results: A reference collection of fishes and frogs.

RAINFOREST DISCOVERY CENTRE

Activity 1: Rainforest Discovery Centre as a centre for excellence in environmental education

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To maintain RDC as a centre for excellence in environmental education
Rationale: RDC is currently one of the most active and prominent EE centres in Malaysia. RDC is also a reference on EE to other departments.
Status: On going
Time schedule: 2020-2025
Expected results: All EE programmes continue to attract students, teachers and the general public.

Activity 2: Environmental Education Race (EERace)

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To expand RDC's training course for educators throughout Malaysia
Rationale: EERace is RDC's signature course on EE for teachers. However, we have also opened the course for other educators from Sarawak, Peninsula Malaysia and even international educators. Hence, we have the capacity to expand this course further to all educators, apart from teachers.
Status: On going
Time schedule: 2021-2025
Expected results: More environmental educators who are not teachers will have the opportunity to participate in EERace.

Activity 3: Enhancing the capacity of environmental educators in Sabah

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To conduct capacity building in promoting conservation and awareness efforts to interested parties.
Rationale: Upon invitation and requests, the RDC has provided numerous training courses in EE and nature interpretation to various organisations. We expect more requests to come every year.
Status: On going
Time schedule: 2020-2025
Expected results: Produce more trained environmental educators to implement conservation and awareness programmes in Sabah.

Activity 4: To conduct seminars, workshops and/or conferences in environmental education

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To be a platform for Malaysian environmental educators to share experiences, skills and knowledge.
Rationale: The RDC has conducted three national conferences and 1 international conference in EE. We have also conducted numerous seminars and workshops in EE. We would continue to organise such events the years to come.
Status: On going
Time schedule: 2020-2025
Expected results: More collaborative work amongst environmental educators in Sabah and possibly within Malaysia.

Activity 5: Enhance the promotion of RDC

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To increase annual visitation rates, so as to support the sustainability of RDC's workforce.
Rationale: The RDC currently has 31 staff. Proceeds from the ticket collection currently pay for 9 RDC and 4 FRC contract staff. To sustain them, we need to generate about RM35,000 each month.
Status: On going
Time schedule: 2020-2025
Expected results: Increased in monthly income to sustain all contract staff.

Activity 6: Support the HoB Initiative through environmental education outreach programmes

Person in charge: Bernadette D. Joeman & George Hubert Petol
Objective: To create better rapport between forestry officers at the district levels and the communities living adjacent to Forest Reserves, through environmental education outreach programmes.
Rationale: Sabah Forestry Department has always been regarded as an enforcement authority by communities living near forest reserves. Hence, many members of the communities are reluctant to cooperate with forestry officers who are performing their duties in forest reserves. We believe that environmental education programmes could create better rapport between SFD and communities.
Status: On going
Time schedule: 2020-2025
Expected results: With better rapport, there will be better cooperation between SFD and communities in conserving forest reserves.

APPENDICES

SABAH FOREST POLICY 2018
(THRUSTS & OBJECTIVES)

1. **Objectives for Thrust 1 (Sustainability of Forest Resources)**:
   a. To maintain at least 50% of Sabah's land mass under forest reserves and tree cover for long term multiple forest use;
   b. To ensure the systematic and transparent administration and management of forest reserves;
   c. To strengthen forest enforcement and laws; and
   d. To create public awareness on the importance of sustainable forest resource management.

2. **Objectives for Thrust 2 (Protection of Biodiversity and Environmental Services):**
   a. To allocate adequate areas under Totally Protected Areas (TPAs) for environmental services;
   b. To ensure all forest types, ecosystems and their biodiversity are adequately represented and protected;
   c. To ensure all degraded forests are restored to enhance their ecological functions; and
   d. To minimize the impact of forest management activities on environmental services.

3. **Objectives for Thrust 3 (Research, Development, Commercialisation and Innovation)**:
   a. To strengthen research, development, commercialisation and innovation (RDC&I) programmes in support of forest management; and
   b. To explore and apply the use of new technologies and innovation.

4. **Objectives for Thrust 4 (Economic Well-being)**:
   a. To ensure the sustainability and viability of the wood-based industry;
   b. To optimise forest rent captured from natural forests and forest plantations;
   c. To explore the potential of Payment for Ecosystems Services (PES) for generating revenues;
   d. To explore alternative revenue sources from Non-Timber Forest Produce (NTFP);
   e. To promote forest recreation and nature-based tourism; and
   f. To advance Sabah towards receiving carbon and climate change related payments.

5. **Objectives for Thrust 5 (Social Well-being)**:
   a. To strengthen the participation of local communities in the implementation of forest management activities.

6. **Objectives for Thrust 6 (Human Resources Development)**:
   a. To strengthen skills and competency of human resources at all levels through continuous capacity building; and
   b. To strengthen organisational structure to support efficiency and innovation in all core administration and management activities.

7. **Objectives for Thrust 7 (State, National and International Cooperation and Obligation)**:
   a. To observe compliance to all state laws, federal laws and binding international convention; and
   b. To encourage collaboration at the state, national and international level for long term mutual benefits.

18th MALAYSIAN FORESTRY CONFERENCE (31st July – 2nd August 2018) RESOLUTIONS

Resolutions 1 ***Recognizing the importance of good forest governance in implementing sustainable forest management, the conference resolved that:***	
1.1	Forest Policies be widely accepted to ensure their long-term relevance.
1.2	Legislation be periodically reviewed to ensure effectiveness in managing forest.
1.3	Latest and appropriate technologies be used to enhance the effectiveness of forest law enforcement.
1.4	Cross-sectoral efforts includingsharing of information between three regions be enhanced to curb forest offences.
1.5	Skilled human resources in investigation and prosecution of forest offences be made available and strengthened.
Resolutions 2 ***Recognizing the importance of technology, innovation and good practices in Sustainable Forest Management, the conference resolved that:***	
2.1	Adequate skilled manpower be made available and capacity building be continuously implemented for sustainable forest management.
2.2	The use of latest and appropriate technology in managing forest resources be explored and embraced.
2.3	Research, development and innovation to support decision making in sustainable forest management be intensified.
2.4	Forest management certification be vigorously pursued to ensure highest management standards.
2.5	Sufficient and sustainable financial support be made available for sustainable forest management.
2.6	Stakeholder education and awareness to influence mindsets towards effective management of forests be given special emphasis.
Resolutions 3 ***Recognizing the importance of conserving forest biodiversity for maintaining healthy ecosystems, the conference resolved that:***	
3.1	Restoration and rehabilitation of degraded forest areas be intensified.
3.2	Nature-based tourism activities to support forest conservation be regulated and promoted.
3.3	Landscape approach be adopted in conservation and eco-tourism planning.
3.4	Identification and management of unique ecosystem ofthe forest for the purpose of conservation be intensified .
Resolutions 4 ***Recognizing the importance of forest plantation to sustain wood production and wood based industry, the conference resolved that:***	
4.1	Research and development on pestsand diseases, high quality planting materials and suitable trees with emphasis given to indigenous species be intensified.
4.2	Application of latest and appropriate technologies and innovations in forest plantation nurseries be intensifiedto produce high quality planting materials.
4.3	Private sector and small holders participation in forest plantations be encouraged.
4.4	Best management practices in forest plantations be actively pursued and implemented.
4.5	Sharing of R&D findings and germplasms exchange among planters be encouraged.

4.6	Sufficient and sustainable financing for forest plantation programmes be made available.
4.7	Special attention be given to enhance downstream processing to support forest plantation industries.
Resolutions 5 ***Recognizing the importance of forest ecosystem services for the benefit of present and future generations, the conference resolved that:***	
5.1	Landscape approach to forest restoration and rehabilitation to improve forest ecosystem qualityand mitigate climate change be intensified.
5.2	Long-term management and continuous monitoring on forest quality and services using effective approaches be encouraged.
5.3	Mechanisms for Payment for Ecosystem Services (PES) in generating new wealth be further explored.
5.4	The establishment of forest parks in all urban environments be further encouraged.
5.5	Knowledge sharing among the three regions on management of ecosystem services be further intensified.
Resolutions 6 ***Recognizing the importance of forest and its produce to local communities or affected local public, the conference resolved that:***	
6.1	Social Forestry programmes be designed to uplift community livelihoods andreducing forest encroachment.
6.2	Appropriate participatory approaches (Grievance Mechanism, Social Impact Assessment and Free Prior Informed Consent) in managing forests and forest resources be given due attention.
6.3	Building partnership with local communities in forest monitoring and ecotourism be encouraged.
Resolutions 7 ***Recognizing the importance of good leadership and professionalism in forest management, the conference resolved that:***	
7.1	Special attention be given to succession planning and mentoring.
7.2	Forestry training at all levels be intensified and supported by the three regions.
7.3	Staff exchange programme between the three regions be revived.
Resolutions 8 ***Recognizing the importance of regulating and providing legal recognition to the forestry profession in Malaysia, the Conference resolved that;***	
8.1	The proposed Foresters Bill by Institut Rimbawan Malaysia (IRIM) to be studied and reviewed by three regions.
8.2	State governments' views and jurisdictions over forestry matters be given due consideration, including their prerogative to enact their own respective statutes and regulations.
8.3	All qualified and eligible forestry practitioners be encouraged to join as IRIM members.

19th MALAYSIAN FORESTRY CONFERENCE (12th – 16th June 2022) RESOLUTIONS

RESOLUTION 1 **Recognizing the importance of good forest governance in implementing policy, legislation, enforcement and certification, the conference resolved that:**	
1.1	Law enforcement strategies to protect and conserve flora and fauna be integrated
1.2	Innovative technologies and approaches be employed to curb forest crimes
1.3	Inter-agency collaboration in forest law enforcement be strengthened
1.4	Rewards and/or incentives mechanism to forest officers or informants be introduced or reviewed
1.5	Involvement of women in enforcement activities be encouraged
1.6	Forest management certification for both natural forest and plantation forest be intensified
RESOLUTION 2 **Recognizing the importance of technology, innovation and practices towards SFM implementation, the conference resolved that:**	
2.1	Forest fire team be established and strengthened including the involvement of local communities and other stakeholders
2.2	Reduce Impact Logging (RIL) practices be reviewed and enhanced, when necessary
2.3	Implementation of Big Data Analytics (BDA) and Internet of Things (IoT) be encouraged and intensified
2.4	Research and Development (R&D) to support forest management and conservation efforts be enhanced
RESOLUTION 3 **Recognizing the importance forest ecosystem services for food, water, energy and climate change, the conference resolved that:**	
3.1	Forest carbon initiatives and Payment for Ecosystem Services (PES) mechanism for new wealth be regulated and/or intensified
RESOLUTION 4 **Recognizing the importance of conservation, restoration and protection of forest biodiversity, the conference resolved that:**	
4.1	Long term financing for the establishment and maintenance of ecological corridors be made

	available
4.2	Local communities and other stakeholders' participation in restoration activities be enhanced
4.3	Potential high-risk areas prone to natural disaster within PRF/PF/FR be identified and mapped out.
4.4	Biodiversity conservation program to be intensified
RESOLUTION 5 **Recognizing the importance of forest economic and commodity, forest plantation, wood-based industry and non-timber forest product, the conference resolved that:**	
5.1	Transformation of forest plantation development be explored and implemented
5.2	Smallholder participation in tree farming to support timber production be encouraged
5.3	Monitoring mechanism in forest plantation be enhanced to achieve planting target
5.4	Issues related to forest plantation certification be addressed
RESOLUTION 6 **Recognizing the importance of forest livelihood, social forestry, ecotourism and CEPA, the conference resolved that:**	
6.1	Sufficient and sustainable financial support be made available for social forestry program.
6.2	The Model of "Malim Gunung Perhutanan" be explored and introduced as a new approach in nature-based recreation activity in PRF/PF/FR
6.3	Assessment of socio-economic contribution from forest products and services be determined and periodically monitored
6.4	Individual, public, private sector and NGOs participation in greening program be intensified
6.5	Appropriate agroforestry model with the application of the latest technology be established
6.6	Local community-based ecotourism be encouraged